* VIII. NOMOGRAM SOLUTION OF NUCLEAR DEFENSE DECAY PROBLEMS.

A. Purpose. Under certain conditions a nuclear attack may create a radiological hazard to personnel. Under such conditions, responsible authority will have need for a rapid method of determining such factors as radiological dosages, dose rates, and lengths of time personnel may remain in the affected area without exceeding specified dosage limits. The mathematical solution of these quantities is not simple and is very time consuming. The following two nomograms are sufficient to solve these problems that may arise relating to radiological contamination.

B. Instructions. These nomograms are used in the same manner as other nomograms, i.e., connecting two different values with a straight line will give a third value. The Standard Intensity, which is the dose rate in roentgens per hour one hour after the detonation, is used as the connecting link between the two nomograms. The Pivot, a mathematical relationship (D/R), is used on the Dose Nomogram, only to relate dose and times.

Note: 1. Radiacs are not highly accurate instruments; 2. these nomograms are based on an average decay rate; 3. various individuals will read the nomograms differently; therefore, rounding off answers on the safe side is a wise procedure.

C. Related Information.

1. Nomograms are of use only after the peak intensity has been reached and the decay period has started. The dose during the build-up period may be calculated by the use of the following formula: D=IT

D - Dose received in roentgens.
T - Time in hours from arrival of fallout to peak intensity.
I - Average intensity in roentgens per hour; which will be the initial intensity added to the peak intensity and divided by 2.

This formula may also be used for any time period before or after the peak intensity.

2. Intensity of radiation will decrease with an increase in shielding. This difference in radiation may be calculated with the aid of the following formula: R=I/Io

R - Residual Number; a ratio of intensities.
I - Intensity inside ship in roentgens per hour.
Io- Intensity outside ship in roentgens per hour.

Typical figures for R would be: wheel house 0.7; deep in the house structure 0.5; deep in the hull 0.3. Using these values for R, and knowing the intensity inside the ship, the outside intensity may be calculated.

D. Sample Nomogram Problems.

1. To use the Intensity Nomogram (Figure #1), connect a known dose rate in the "Intensity at time T" column with the corresponding time in the "Time" column. Note the reading on the "Standard Intensity" column. Connect this reading with the time of the unknown dose rate on the "Time" column and read the answer from the "Intensity at time T" column.

2. The dose rate 12 hours after a detonation is 50 r/hr. Find the dose rate at 18 hours. Using a straight edge, connect 50 r/hr on the "Intensity" column with 12 hours on the "Time" column and read 970 r/hr on the "Standard Intensity" column. Holding the 970 r/hr on the "Standard Intensity" column, move the straight edge to 18 hours on the "Time" column and read the answer (31 r/hr) from the "Intensity" column.

3. To use the Dose Nomogram (Figure #2), connect two known quantities with a straight edge and locate the point on the "Pivot" column where the straight edge crosses it. Connect this point with a third known quantity and read the answer from the appropriate column.

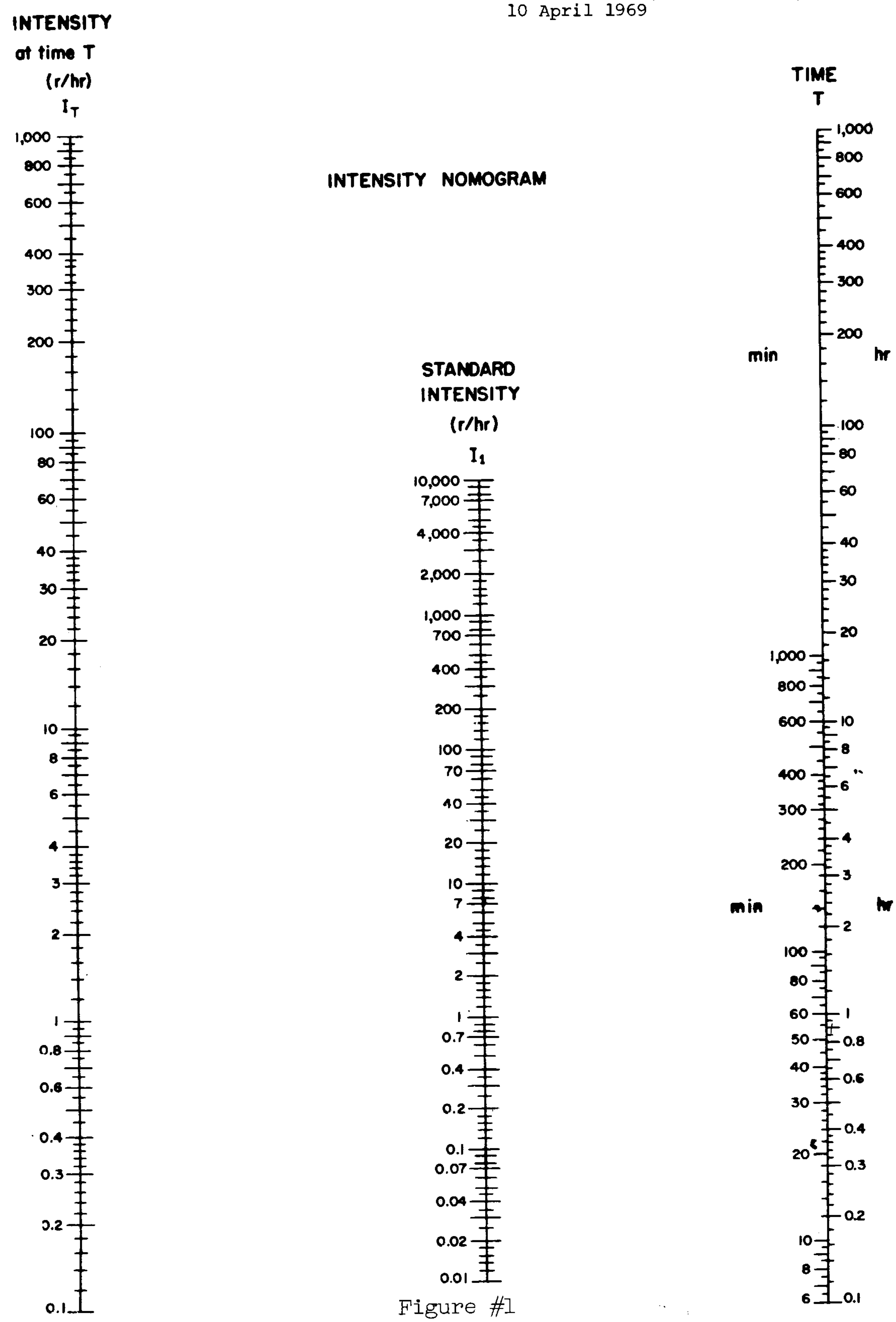

INTENSITY NOMOGRAM
INTENSITY
at time T
(r/hr)
I_T
STANDARD
INTENSITY
(r/hr)
I_1
TIME
T
min
hr

Figure #1

4. The dose rate 8 hours after an explosion is 10 r/hr. Find the total dose received by a person entering the area at 10 hours and staying for 4 hours. Find the "Standard Intensity" (120 r/hr) as described in D. 1 and 2. Using a straight edge, connect 4 hours on the "stay time" column with 10 hours on the "Entry Time" column. Find the point on the "Pivot" column. Connect this point on the "Pivot" column with the 120 r/hr on the "Standard Intensity" column. Read the answer (25 r) from the "Dose" column.

5. Dose rate is 12 r/hr at 10 hours. Stay time is 8 hours and MPE is established at 50 r. Find the earliest entry time into the area. Find the "Standard Intensity" (190 r/hr). Connect 50 r on the "Dose" column with 190 r/hr on the "Standard Intensity" column. Find the point on the "Pivot" column. Connect this point on the "Pivot" column with 8 hours on the "Stay Time" column. Read the answer (14 hours) from the "Entry Time" column.

6. A nuclear weapon was detonated on the surface of the ground. The dose rate in a nearby area was 100 r/hr at H+1. What will be the dose rate at H+7?
Answer: 10 r/hr.

7. At 0700 a nuclear bomb exploded. Four hours later the dose rate at a nearby location was 175 r/hr. What will the dose rate be at 0600 the next day?
Answer: 22 r/hr.

8. The dose rate 30 minutes after a nuclear burst was reported as 100 r/hr. What is the dose rate 2 hours after the explosion?
Answer: 20 r/hr.

9. One hour after a nuclear detonation the dose rate is 50 r/hr in a shipyard. A monitor team is to enter the area 4 hours after the explosion. The MPE is fixed at 25 for the mission. How long can the team remain without exceeding the MPE?
Answer: 3.5 hrs.

10. Command decision has set 20 r as the MPE. A decon team enters an area contaminated by fallout 5 hours after the explosion. If the dose rate at the time of entry is 6 r/hr, how long can the detachment remain without exeeeding the MPE?
Answer: 5 hrs.

11. A rapid survey reports that 3 hours following a nuclear explosion the intensity is 25 r/hr. If a decon team enters the area 1 hour later, and the estimated time to complete a job is 2 hours, what dosage will they receive on the job?
Answer: 27 r.

12. Six hours after a nuclear attack, a monitor enters the contaminated area and reads his radiac at 10 r/hr. If he stays 8 hours in the area, what dosage will the monitor receive?
Answer: 44 r.

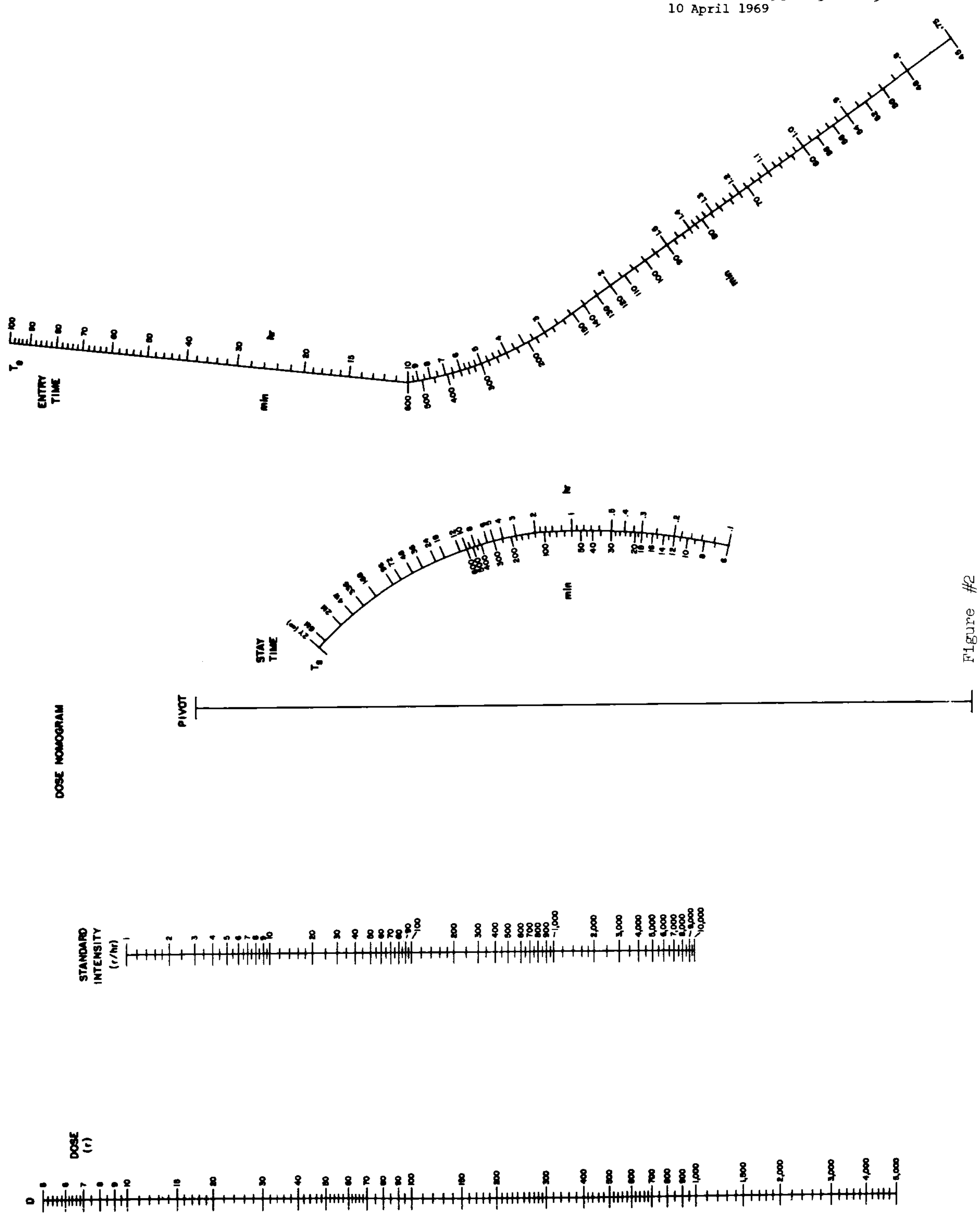

DOSE NOMOGRAM
ENTRY TIME
STAY TIME
PIVOT
STANDARD INTENSITY (r/hr)
DOSE (r)

Figure #2

CHAPTER 3

ADVANCED DAMAGE CONTROL For Deck and Engine Personnel (Lesson Plans)

Section 3.13

MONITORING PROCEDURES

I	Objectives	IV	Presentation
II	Material	V	Summary
III	Introduction	VI	Test and Application

I. OBJECTIVES.

A. To acquaint radiological monitoring teams with the procedures and techniques in monitoring, reporting and plotting.

B. To instruct monitoring teams in the safety precautions necessary to prevent excessive exposure to radiation.

II. MATERIAL.

A. Training Aids.

1. Films MN 6949A&B, Industrial Radiological Decontamination of Ships:

Part A - Introduction (20 minutes)

Part B - Contaminated Ship Handling (16 minutes)

2. Film MN 8923, Radiological Defense in Civilian-Manned Ships, (25 minutes).

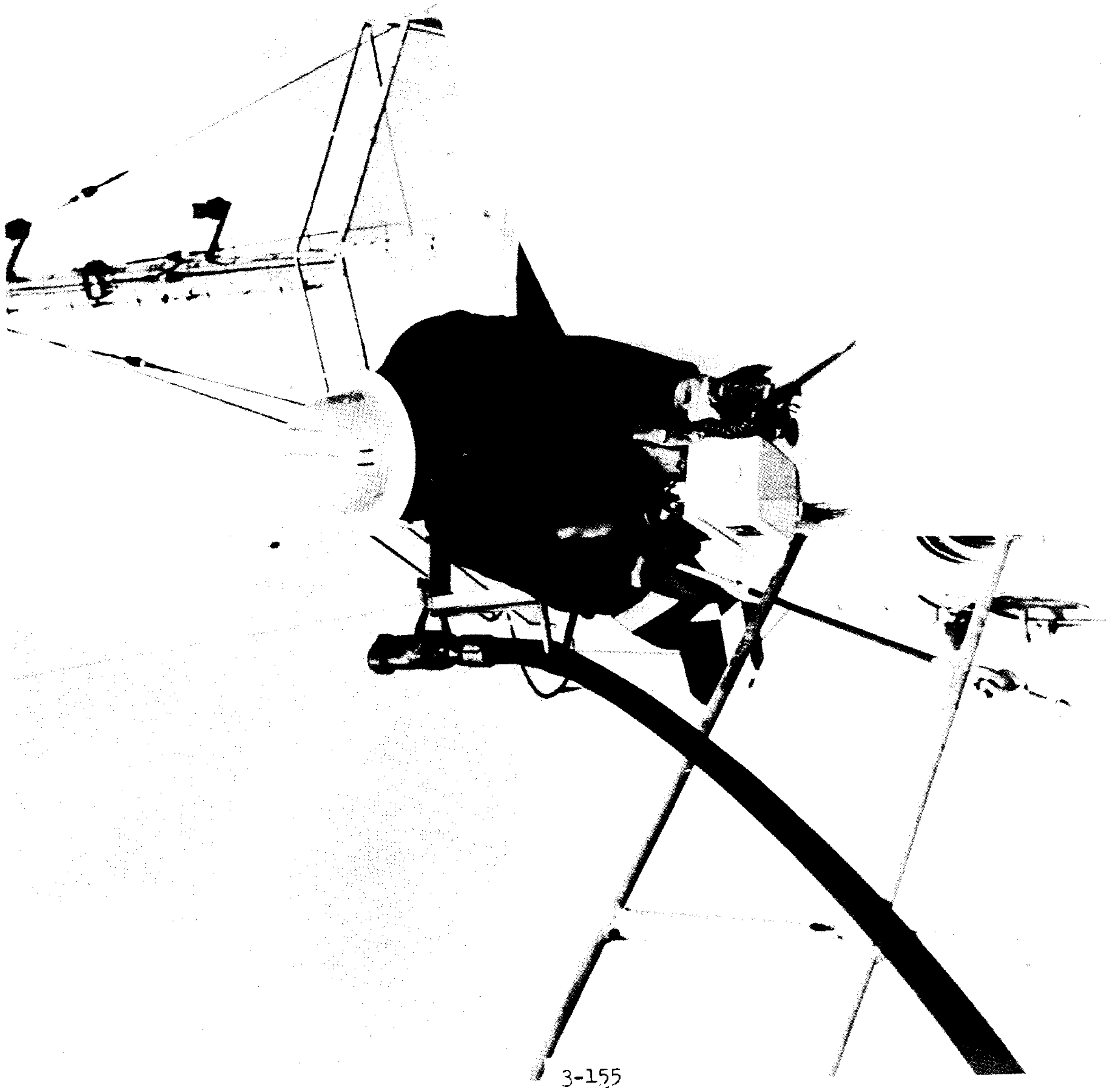
3. Ship's radiac equipment.

4. Ship's protective clothing.

5. Ship's damage control display plans.

6. Film, MN-8968, Nuclear Defense at Sea, color, sound, 35 minutes.

B. References.



1. ABC Warfare Defense, NAVPERS 10099.

2. Diaster Control (Ashore & Afloat), NAVPERS 10899.

3. BUSHIPS Technical Manual, Chapter 9900 (90).

III. INTRODUCTION.

A. Introduce self and subject (Monitoring Procedures).

B. Contamination. Radiological contamination is the presence of radioactive material over an area, article or individual. This may consist of any combination of alpha, beta or gamma emitters which constitute a hazard to personnel. Radiation from these emitters cannot be seen or felt, nor can it be detected by any of the five natural senses.

C. Purpose of Monitoring. Monitoring is conducted for the following purposes:

1. To determine and mark off contaminated areas and/or objects.

2. To establish an exposure rate or "stay time."

3. To detect contamination of personnel.

4. To establish "clean" routes for operating personnel.

5. To prevent the spread of contamination.

IV. PRESENTATION.

A. Ship's ABC Defense Organization. (See Section 1.5, NBC Defense Bill).

1. ABC Defense Officer (First Assistant Engineer).

a. Coordinate with the Damage Control Officer in organizing for ABC defense.

b. In charge of directing monitoring and decontamination teams from repair locker control point.

c. Is responsible for calculating and recommending to the Master the "MPE" (maximum permissible exposure) and "stay time" for personnel required to work in contaminated areas.

2. Master.

a. Based on calculations and recommendations of the ABC Defense Officer, establishes the "MPE" and "stay time". This is a command decision and may not be delegated.

b. The Atomic Energy Commission (AEC) has set a normal, peacetime "MPE" in any 13 consecutive weeks as $1\frac{1}{4}$ REM (biological dose or roentgens) per quarter or five REMs (or roentgens) per year. (For all practical purposes, a REM can be considered equivalent to a roentgen.)

c. In wartime, the Master would have to decide the "MPE" based on the tactical situation. For guidance, the following medical effects are listed:

Exposure	
0 to 150 R	25% of personnel will be sick for one day.
150 to 200 R	50% of personnel will be sick for one day.
200 to 300 R	100% will be sick for one day, with possibly 20% dead.

3. Repair Party Officer.

a. Trains personnel assigned to monitor teams.

b. Assures that the monitor team has a set of plans or charts, pencils, chalk, markers, survey meters, DT-60/PD dosimeters, and pocket dosimeters.

c. Assures that protective clothing and gas masks are properly worn including:

(1) Gloves - cloth and rubber, with sleeves taped closed around them.

(2) Coveralls - rubber, with pants legs taped closed at ankles.

(3) Rubber boots.

(4) Head covering.

(5) Protective masks or respirators.

d. Reports to ABC Defense Officer at repair locker control point.

4. Monitor Team. Each team consists of two or three men; generally a monitor, a recorder, and a messenger if necessary. Monitoring is performed quite some time after a burst if the radiation is severe. One man may first make a rapid rough survey to determine the extent of radiation intensity and also to avoid exposing additional personnel.

a. The senior man, the monitor, carrying a survey meter, reports the current dose, intensity, time and location to the recorder and later to the ABC defense officer.

b. The recorder plots the key intensities and type of radiation on plans provided, noting time of the survey. In addition, he logs readings of pocket dosimeters at start of the survey, and again on completion.

c. The messenger marks off "hot areas" by means of chalk or markers, showing the details of intensity and time.

B. Human Tolerances. The peacetime "MPE" (maximum permissible exposure) is established by AEC via the Federal Register. The latest allowance for AEC-licensed industrial workers was established by the Federal Register of 7 Sep 1960 as $1\frac{1}{4}$ REM (or roentgens) per quarter or 5 REM per year as a dose over the whole body or to the gonads, active blood-forming organs, head and trunk, the lens of the eye.

1. Accumulated Exposure. The maximum permissible accumulated exposure, at any age, is five times the number of years beyond 18, provided no annual part of this accumulated dose exceeds 12 roentgens. For example, at age 28, the MPE (accumulated) is 28 minus 18 or 10 years times 5 equals 50 roentgens.

2. Emergency Exposure. In an emergency, an exposure of 25 roentgens to the whole body (or an accidental exposure in peacetime) occurring only once in a person's lifetime, is assumed to have no effect on the radiation tolerance status of that person (National Bureau of Standards Handbook #59).

3. Medical Exposure. Radiation exposures resulting from medical and dental procedures are assumed to have no effect on the radiation tolerance status of individuals.

C. Monitoring Techniques. There are two basic techniques for taking survey readings with radiac instruments. These are: waist-high readings taken with instrument held constantly at waist level, and near-contact readings taken with the probe or instrument held about one inch from the contaminated surface.

1. Rapid or Rough Survey. The rapid survey is made in operational and weatherdeck areas as soon after the blast as safety and the situation dictate. It is taken by the waist-high technique and always using a Hi-Range survey meter. The initial survey is completed as rapidly as possible and may initially be made by just one man.

2. Detailed Survey. This is first taken by the waist-high method as above. If readings are low, it will be followed by a re-check with a Lo-Range survey meter, using the near-contact technique, and paying particular attention to vital areas.

3. Personnel Monitoring. This is always done by the near-contact technique, with a Lo-Range instrument if possible.

4. "Stay Time". After the rapid rough survey, the ABC Defense Officer will determine the command exposure rate, which is essentially the permissible "stay time" for decontamination teams. He will also plan safe routes and additional monitoring procedures. All readings on radiacs are plotted and reported to the ABC Defense Officer. Specified survey routes with designated spots at which readings are to be taken should be set up in advance for each individual ship depending on the priorities of operational areas and use requirements.

5. Re-surveys. Re-surveys follow all decontamination measures.

6. Survey Techniques.

a. Utilize the carrying harness on radiac survey instruments. This keeps the set from touching the deck and becoming contaminated and it also facilitates rough surveys in which readings are taken waist high.

b. For computing progress of decay, readings should be taken at the same distance from the surface monitored in both the rough and detailed surveys, followed by a second detailed survey by the near-contact method.

c. Take several readings of the same area if time and exposure permit.

d. There will be variations in readings after an interval due to decay and/or decontamination.

e. Take readings in all directions. Your body may shield the detection chamber.

f. Observe all safety precautions peculiar to radiation hazards.

7. Marking of "Hot Areas".

a. Use standard "atom" marker. (Radiological Defense, Volume II, Figure 9.36). Secure the markers to a manila line to keep personnel out of "hot areas" and to show safe access routes.

b. Write the intensity, time and date on the markers.

c. Intensities of areas may also be indicated by chalk.

d. Safe access routes should be clearly marked.

e. When the area has been decontaminated change to a "Safe" marker or remove the "Atom" marker.

8. Supplementary Monitoring. This will be conducted to:

a. Check food and water supplies.

b. Dispose of unpackaged water, food and particularly meat which is outside of reefer boxes.

c. Monitor personnel at decontamination stations before and after showering in order to record their exposures.

d. Monitor ventilation intakes and outlets.

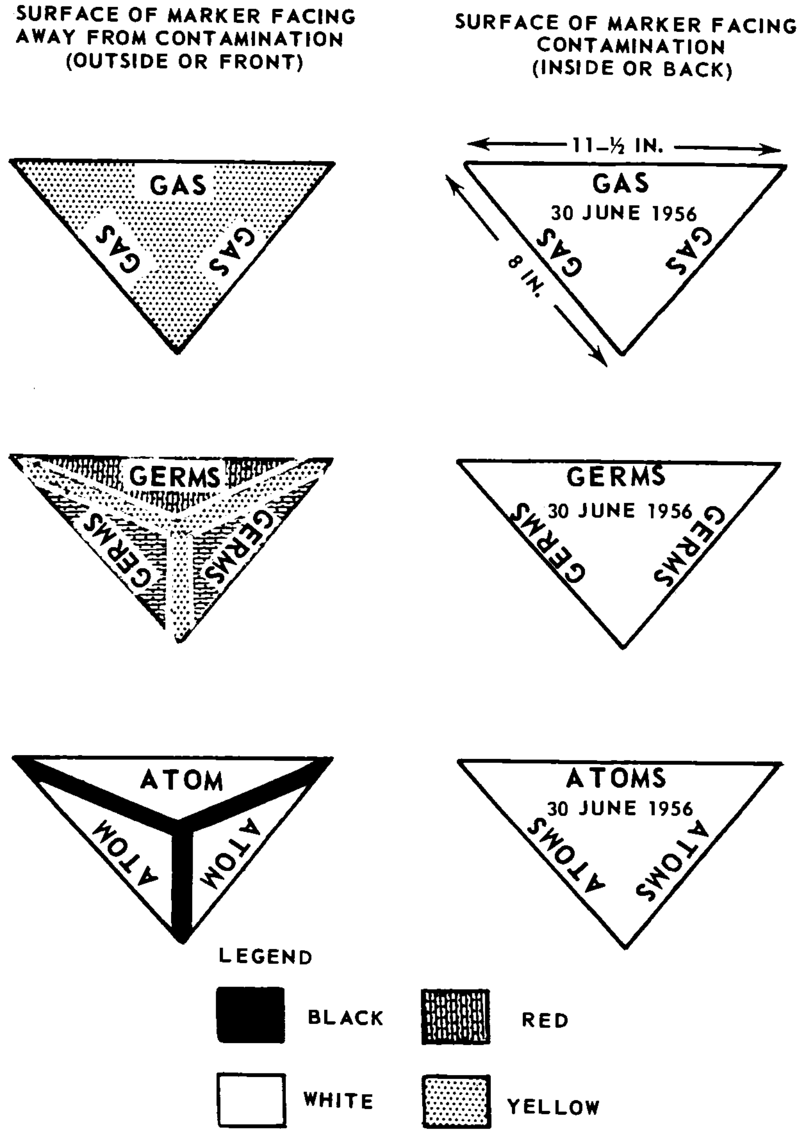
e. Monitor openings to weather deck areas.

V. SUMMARY.

A. Explain the duties and procedures of monitor teams in ABC defense.

B. Stress the importance of protective clothing.

C. Discuss possible decontamination routes to take on own ship.



ABC CONTAMINATION MARKERS

D. Review the meaning of dosage rate and explain why the MPD is a flexible one which may vary according to situations (particularly emergency situations).

E. Review various techniques in monitoring, the importance of reporting, and the value of accurate plotting.

F. Introduce and show one of the films listed as training aids.

VI. TEST AND APPLICATION.

A. Test. Use these and additional questions as an oral quiz:

1. Q. Who is the ABC defense officer in any MSTS ship?
A. The first assistant engineer is in all cases the ABC defense officer.

2. Q. What protective clothing and other protective devices do monitoring teams wear?
A. They wear rubber coveralls, rubber gloves, boots, head covering, respirators, DT-60/PD dosimeters, and pocket dosimeters.

3. Q. A monitor team consists of three men. Name them and briefly state their duties.
A. The senior man, the monitor, carries the radiac meter and calls off intensities and types of radiation. The recorder plots these readings on the plans. The messenger marks off "hot areas".

4. Q. What is meant by a dosage rate?
A. A dosage rate is the amount of radiation being emitted per unit of time, i.e., roentgen per hour.

5. Q. What is the main reason for the initial rough survey?
A. To determine the command dosage rate and the "stay" time for decontamination teams.

6. Q. Why should the radiac meter be carried in its harness and not be allowed to touch the ground?
A. The instrument itself must not become contaminated and all readings can readily be taken waist high during the rough survey.

7. Q. What do you do with slightly contaminated food and drink?
A. "Deep six" them; contaminated food or drink must not be used.

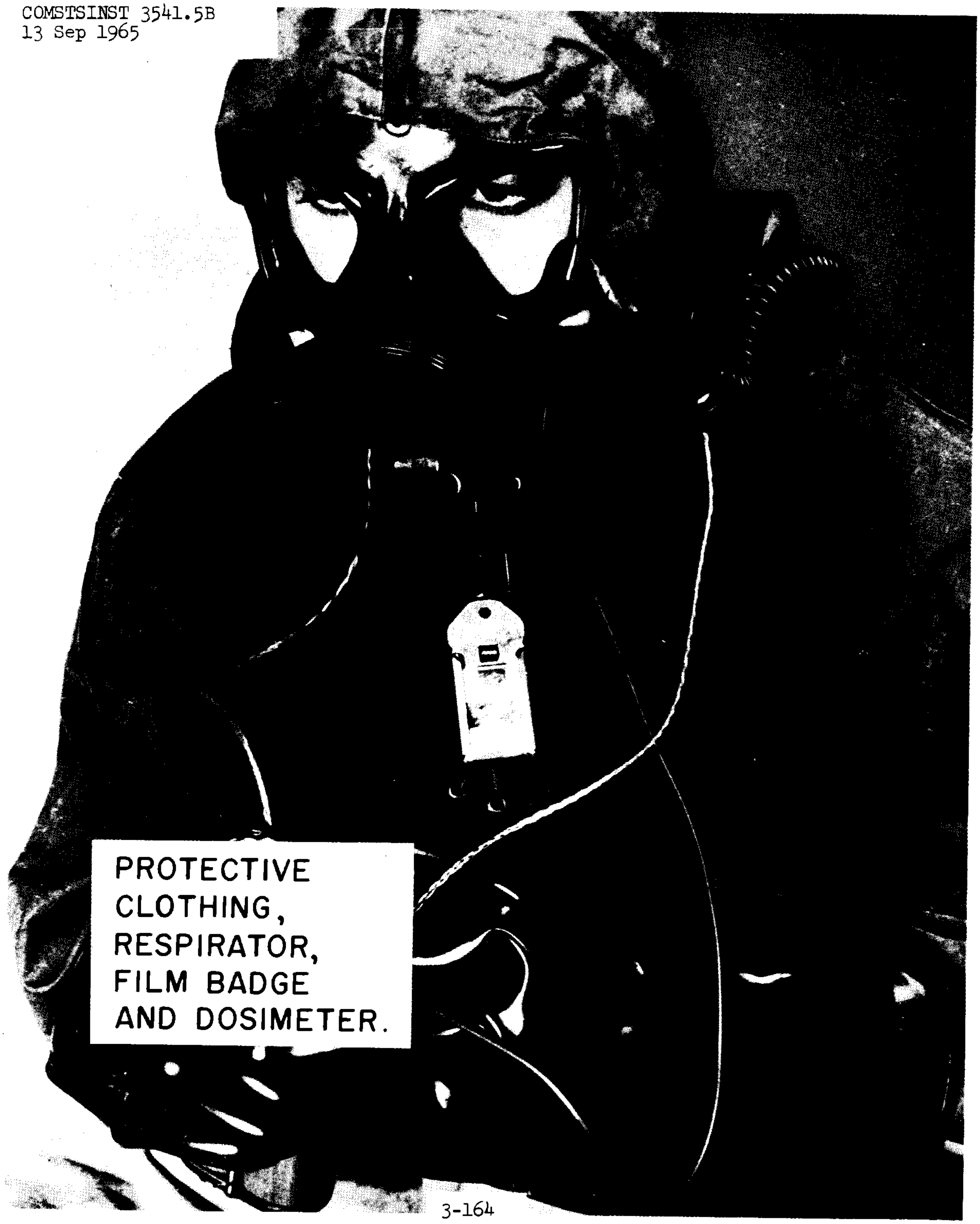
8. Q. After contaminated personnel have taken a hot shower with several soapings and rinses, what is the next step in the decontamination process?
A. Monitor them thoroughly and re-shower if necessary.

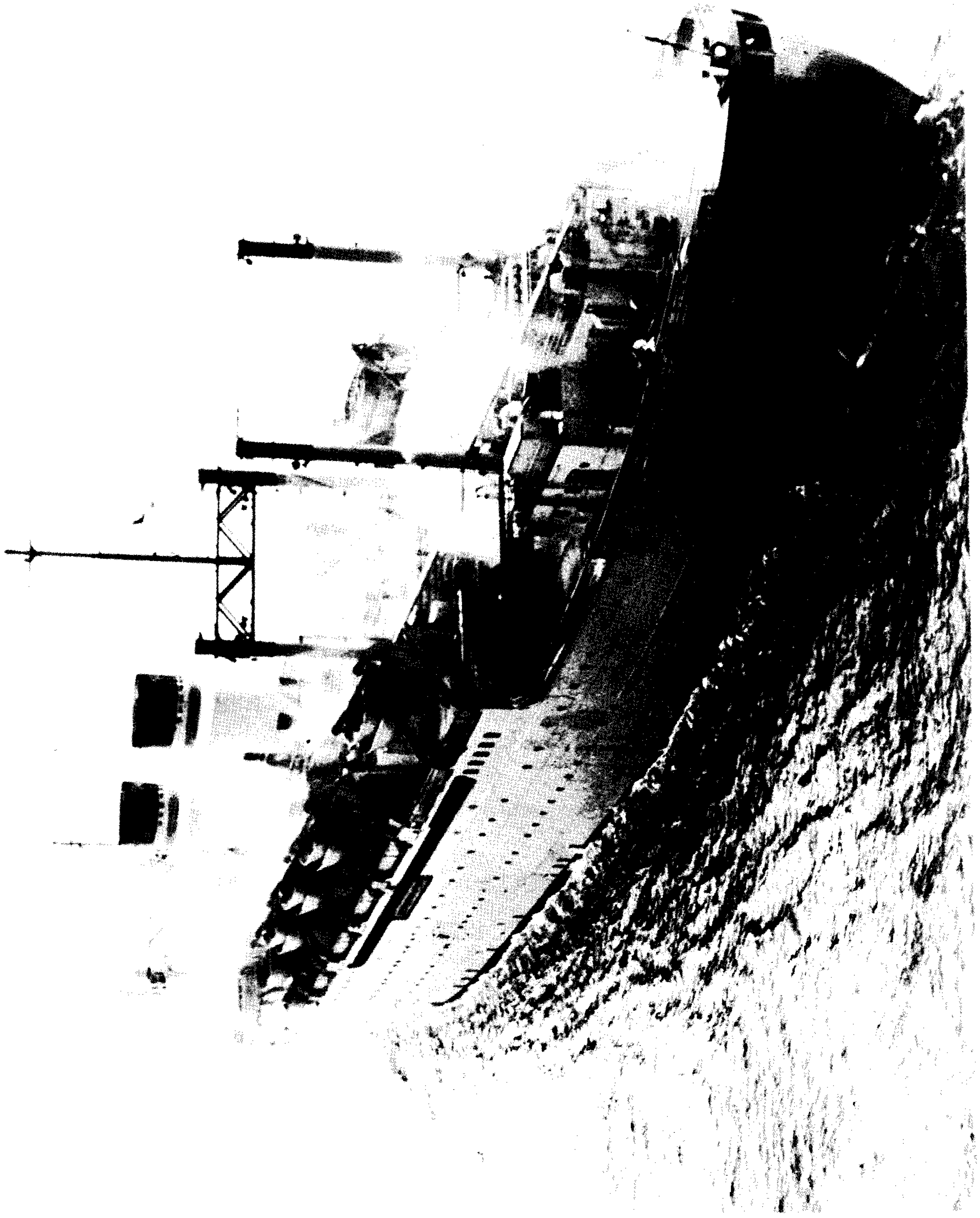
9. Q. What technique of monitoring is used in personnel monitoring?
A. The near-contact technique.

10. Q. What details should be noted on markers used to show "hot" areas and safe access routes?

A. Markers should show the intensity, time and date for "hot" areas, and should be changed to "Safe" markers after decontamination.

B. Application. Organize the group into monitor teams of three and have them demonstrate proper rough and detailed survey techniques, recording and markings.


PROTECTIVE
CLOTHING,
RESPIRATOR,
FILM BADGE
AND DOSIMETER.



CHAPTER 3

ADVANCED DAMAGE CONTROL - For Deck and Engine Personnel (Lesson Plans)

Section 3.14

DECONTAMINATION PROCEDURES

I Objectives
II Material
III Introduction
IV Presentation
V Summary
VI Test and Application
VII MSTS Magazine Article

I. OBJECTIVES.

A. To familiarize personnel with shipboard decontamination procedures.

B. To plan for the reduction of contamination hazards and the restoration of normal operations aboard ship in event of ABC attack.

C. To stress the need for personnel decontamination.

II. MATERIAL.

A. Training Aids.

1. Film MN 9221, The Washdown Countermeasures, Preventing Radiological Contamination of Ships Exposed to Underwater Atomic Attack, (20 minutes).

2. Film MN 6949C, Industrial Radiological Decontamination of Ships, Ship Decontamination Methods (16 minutes).

3. Ship's protective clothing.

4. Ship's damage control display plans.

B. References.

1. Radiological Defense - Volume II, Chapter 11.

2. Shipyard Industrial Radiological Manual - NAVSHIPS 250-348.

3. Instruction Guide for Shipboard Atomic Defense, NAVPERS 10886.

4. Atomic Warfare Defense, NAVPERS 10097.

5. Principles of Radiation and Contamination Control, NAVSHIPS 250-341-3, Volume I on physics of radiation; Volume II covers nuclear weapons effects; and Volume III contains needed data to conduct training courses, using Volume II as a text.

6. BUSHIPS Technical Manual, Chapter 9900 (90).

7. Disaster Control, NAVPERS 10899.

III. INTRODUCTION.

A. Introduce self and subject (Decontamination Procedures).

B. In World War II, damage control measures following ocean warfare attacks involved chiefly the clearing away of wreckage and restoring ships to normal operations.

C. Atomic, biological and chemical (ABC) warfare defense will require a preliminary job before clearing away wreckage and repairing damage, that is - "decontamination".

D. Radiological contamination may result from an underwater explosion, a surface burst, or from fallout as a result of an air burst explosion hundreds of miles away.

E. After a contaminating attack, restoration of undamaged equipment may be achieved either by waiting, to permit the radioactivity to decay, or by decontamination, which reduces the activity to a level at which it is no longer a significant hazard to operating personnel.

F. This session will be limited to radiological decontamination, although many of the same techniques, if all precautions are taken, will serve for biological and chemical decontamination.

IV. PRESENTATION.

A. Washdown Countermeasure. The washdown countermeasure establishes a water curtain or umbrella over the weather decks of the ship, wets the ship's superstructure down so that contamination will not stick readily and washes away much of the contamination which may fall. Thus it affords a continuous rough preventative and decontamination process. The washdown procedure consists of the following:

1. Set condition "Emergency" (Buttoned-Up). (See NBC Defense Bill, Section 1.5.)

2. Rig weather deck hoses to their respective washdown clips and take cover at designated repair locker or other interior location.

3. In ships equipped with the fixed-pipe spray system, rig hose jumpers and take cover at designated repair lockers or other interior location.

4. Start all fire pumps will full fire main pressure, check for good washdown coverage, and maneuver as necessary to assure best coverage.

Continue the washdown until conditions are determined to be safe and the fall-out has ceased.

5. This rough decontamination (washdown countermeasure) will reduce radiation intensity as quickly as possible to a point where personnel can use necessary gear or remain in the contaminated area for a limited time.

B. Monitoring. Monitoring teams then make a rapid rough survey for remaining "hot areas." Safe access routes for the operation of the ship will be roped off and marked.

C. Decontamination. Where the washdown or sprinkler system does not reduce radio-activity sufficiently, decontamination teams can hose down "hot areas" with sea water under pressure. Hosing down is most effective while metal or painted surfaces are still wet.

1. Decontamination teams are organized as follows:

a. Personnel will be assigned from Repair I and will be fully equipped with protective clothing, gas masks and DT-60/PD dosimeters, plus pocket dosimeters, if available.

b. Each team will consist of two men.

c. Each team will be told their dosage rate or "stay" time permissible to decontaminate.

2. After hosing down, a detailed survey is conducted for possible remaining contamination.

3. The ABC defense officer (the first assistant engineer) will:

a. Determine "hot areas" requiring further decontamination as a result of monitor team reports.

b. Determine the dosage rate or "stay" time for decontamination teams. The radiation dosage calculator described under Radiac Instruments can be used for this purpose.

c. Establish safe decontamination routes for the operation of the ship and will assign zone area personnel to guard decontamination routes and stations.

4. The O in C, monitoring teams will:

a. Assure that men assigned to monitor and decontamination teams are properly dressed and equipped.

b. Log men out and record the respective readings of their dosimeters, the phosphor-glass dosimeter, DT-60/PD, and the pocket dosimeter IM-9/PD, if available.

c. Notify decontamination teams of "hot areas" as designated by the ABC officer.

5. Isolation of "remote areas" may be accomplished by roping or marking off these areas for later shipyard decontamination.

6. Disposal operations. Contaminated debris and articles badly damaged, or articles which cannot be decontaminated, such as porous materials (canvas, line, etc.) should be disposed of over the side.

7. Washdown. Hose down weather deck surfaces and/or repeat the washdown countermeasure to remove any remaining contamination.

8. Other possible methods of rough decontamination by ship's force are by:

a. Steam.

b. Caustic solution - lye or boiler compound.

c. Sealing with a coat of paint.

9. Shipyard and repair base methods of detailed decontamination include:

a. Surface decontamination.

(1) Vacuum cleaning.

(2) Flame cleaning.

(3) Abrasion (scraping, grinding, sandblasting, etc.).

b. Aging and sealing.

c. Disposal.

D. Personnel Decontamination. Personnel decontamination will be accomplished as follows:

1. Exposed personnel will follow designated routes to decontamination stations.

2. They will strip their clothes off in designated spaces and will place them in the containers provided.

3. They will turn in their phosphor-glass dosimeters (DT-60/PD) for reading.

4. They will shower. This includes thorough soap scrubbing of

hair, armpits and pubic regions, rinsing and rescrubbing.

5. Personnel will be monitored immediately after leaving the showers and will repeat showering and scrubbing if necessary, until all contamination has been removed.

6. They will then enter the clean dressing rooms and be given clean clothing.

V. SUMMARY.

A. Summarize the use of the washdown countermeasure, introduce, and show film MN 9221 - The Washdown Countermeasure.

B. Review key points of preliminary and secondary decontamination methods.

VI. TEST AND APPLICATION.

A. Test. Use these and additional questions as an oral quiz:

1. Q. What is the main purpose of radiological decontamination aboard ship?
A. To get rid of radiological contamination and to resume normal activities as soon as possible after contamination.

2. Q. What are some of the primary causes of radiological contamination?
A. Surface, air or underwater nuclear bomb burst, or fallout as a result of a distant nuclear bomb explosion.

3. Q. How long should the washdown countermeasure, or water curtain, be maintained over the ship's exposed surfaces?
A. The washdown countermeasure should be continued until danger from fallout has passed.

4. Q. After the washdown countermeasure has been secured and the detailed monitoring survey has been completed, what is the procedure for decontaminating "hot areas"?
A "Hot areas" are then decontaminated by hosing down the areas with sea water under pressure.

5. Q. How many men comprise each decontamination team and from where are they assigned?
A. Each decontamination team consists of two men provided from repair party I.

6. Q What important information must the decontamination team have before starting to hose down "hot areas"?
A. They must have an established dosage rate or "stay" time in the "hot area". This is designated by the NBC officer, BASED ON THE COMMAND DECISION REGARDING THE MAXIMUM DOSAGE RATE

7. Q Name some of the methods used in decontaminating ships, other than by washing down with sea water under pressure, which can be accomplished by ship's force.

A. Use of steam, caustic solutions, or by sealing with a coat of paint.

8. Q. Name some of the shipyard methods used in decontaminating ships.

A. Shipyard decontamination methods consist of vacuum cleaning, flame cleaning, use of caustic solutions, and abrasion methods (scraping, grinding, sandblasting).

9. Q. What should personnel do if exposed to contamination?

A. Personnel exposed to contamination should immediately follow designated routes to decontamination stations, where the established decontamination procedure will be followed.

10. Q. What is the purpose of "rough decontamination" of "hot areas"?

A. Its purpose is to reduce the contamination sufficiently to permit personnel to work with or close to necessary equipment for limited periods.

11. Q. What is "detailed contamination"? State the three main procedures used.

A. Detailed contamination, in which the emphasis is on thoroughness, will be carried out in rear areas and repair bases. The three main procedures used are: (1) surface decontamination, (2) aging and sealing, and (3) disposal.

B. Application. Have the groups rig a portion of the ship for the washdown countermeasure and organize them into teams to demonstrate monitoring and decontamination procedures.

AGAIN—MSTS LEADS THE WAY

Maritime Administration Adopts ABC Washdown Countermeasure

USNS *Darby* demonstrates her ABC washdown equipment.

ADD ANOTHER "FIRST" to MSTS achievements, which include such innovations as roll-on, roll-off ships; new ice navigation techniques; the *Polynya* system of keeping Arctic ports open longer; rerouting of ships to avoid storms; discovery of the Northwest Passage; new safety and training methods; and many others.

The addition to the list is the MSTS washdown system of countering radioactive contamination. Now in a state of readiness on all nucleus ships, it has been adopted by the Maritime Administration at the suggestion of C. P. Milne, Assistant Secretary of the Navy (Material), following tests by BuShips. The Navy is installing the system on all combat ships and on merchant ships undergoing conversion to troopships, but on a more permanent basis than the fog spray nozzle clips MSTS uses.

Adopted as an interim measure by MSTS—part of ABC (Atomic, Biological, Chemical) phase of damage control training—the present clip and bracket system of holding firehose and fog nozzles at strategic places in the ship's superstructure has proved so satisfactory that no change to permanent piping is planned by MSTS.

This easily installed method of providing a sea-spray umbrella to protect ship and personnel against radioactive "fallout" was proposed originally by Pac employee Delbert G. Richards as a Beneficial Suggestion (No. 1047). It was submitted June 2, 1955, and was placed in effect on all civil-service-manned ships in June 1956. (*MSTS Magazine*, August 1956.)

Meanwhile, at Lant, William A. Warren, then 1st Officer of the *LST 325*, now Master, was submitting an almost identical suggestion (No. 1966). His was adopted and put into effect independently by Lant even before the June 1956 date.

Of special interest is the fact that MARAD has requested MSTS assistance in designing an effective washdown system for the first nuclear-powered merchant ship, NS *Savannah*, using MSTS clips, firehose, and fog nozzles. The request was promptly acted upon.

Nozzles with clip attachments are bent to rail to drench nearby area and guard against fallout.

In his letter to MARAD Administrator Clarence G. Morse, Assistant Secretary Milne pointed up the importance of the washdown system in this way:

"Mobilization plans require the installation of a countermeasure washdown system on all merchant ships as a defensive equipping measure since it has been demonstrated that this is an effective means of protecting ships and personnel from the effects of radioactive contamination.

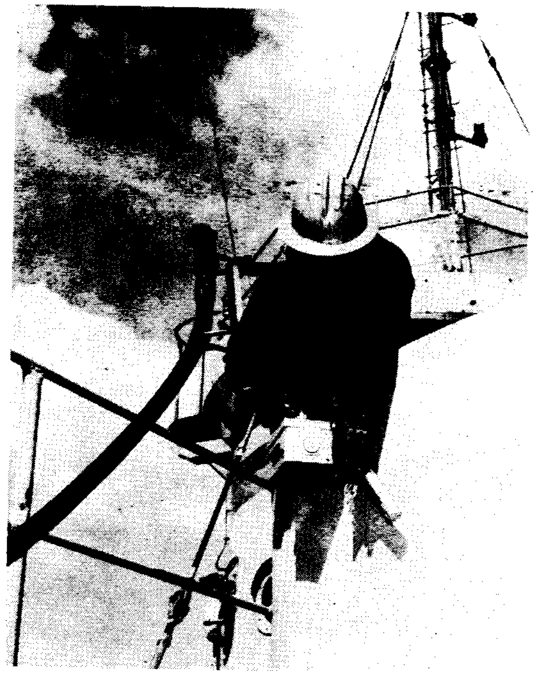
"The main function of the washdown countermeasure is to provide a free-flowing film of sea water on exposed decks and topside vertical areas when ships are in contaminated areas. A *permanent* system is installed where possible on all ships of the Navy and an *interim* washdown system when this is not practicable.

"To be readily available in the event of mobilization or surprise attack, the Department recommends that a method for washdown be provided on all merchant ships . . . installing clips similar to those now in use on ships in the Military Sea Transportation Service . . . .

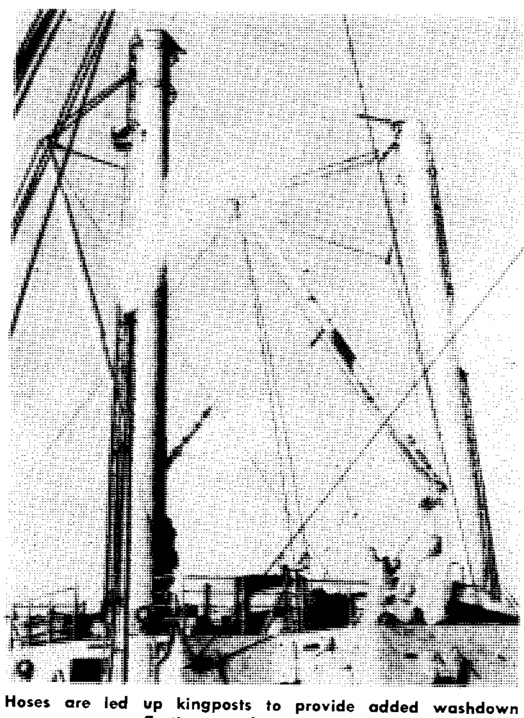
"Your cooperation in helping us to meet these requirements for ships that are under construction or conversion and also those that will be submitted under the provision of the Merchant Marine Act of 1936, as amended, will be appreciated."

Even wider application of the system, together with other damage control techniques created by MSTS, is in prospect. At recent NATO meetings of the Planning Board for Ocean Shipping, the joint MARAD–MSTS program of ABC defense and damage control, aimed at improving the readiness of the merchant marine, was discussed at length. As a result, the MARAD Secretariat to the Board received numerous requests from representatives of member nations for copies of the MSTS manual, "ABC Defense and Damage Control for Merchant Marine Personnel." Fifty copies were distributed.

The international interest thus shown in our techniques prompted Admiral Will to say: "COMSTS takes pleasure in this evidence of MSTS' leadership in promoting marine readiness and desires that the personnel responsible for the preparation of the Manual be commended." ⚓



Crewmember of USNS *LST 325* monitors superstructure as part of ABC drill. Note protective clothing, safety helmet, and clip attachment of firehose.



Hoses are led up kingposts to provide added washdown effectiveness along open decks.

CHAPTER 4

ADVANCED DAMAGE CONTROL - For Deck and Engine Personnel (Lesson Plans)

SECTION 4.1

FUNDAMENTALS OF SHIPS STABILITY

I. Objectives
II. Material
III. Introduction
IV. Presentation
V. Summary
VI. Test and Application

I. OBJECTIVES.

A. To provide the master and his officers with the basic elements of ship stability.

B. To stress the importance of stability and its affect on the safety of the ship, passengers, crew, and cargo.

II. MATERIAL.

A. Training Aids.

1. Film MN 61F, Damage Control - Elements of Stability in Ships, 37 minutes, B&W, sound.

2. Ship's Trim and Stability Booklet.

B. References.

1. BUSHIPS Technical Manual, Chapter 9880, Section I.

2. Stability and Trim for the Ship's Officer by Ladage and Van Gemert.

3. COMSTSPACAREA ABC Defense and Damage Control Manual for Merchant Marine Personnel (Rev. 1-60), pages 76-82.

III. INTRODUCTION.

A. Introduce self and subject (Fundamentals of Ships' Stability).

B. Definition.

The stability of a ship is its ability to right itself when displaced from its original position of equilibrium.

C. Importance of Stability.

Maintaining stability is the most important task in damage control. Although governed by the same fundamental principles, each ship has its own stability characteristics; the ship's officers must be familiar with these. The chances of survival in a casualty situation are greatly increased if the officers have this knowledge and are able to take immediate corrective action. The following are illustrations of the importance of stability:

1. The loss of the British-built SS TITANIC, with 1517 lives, after colliding with an iceberg on her maiden voyage in April 1912. The progressive flooding and loss of stability eliminated her reserve buoyancy and the ship sank in a comparatively short time. (See Section 7.2.)

2. The SS VESTRIS is a tragic case of a ship that had inadequate stability and freeboard. When the VESTRIS left New York, she was loaded a foot deeper than her winter loadline and with a slight list to port. Ten hours later it was reported that the ship had a list of three to five degrees to starboard. Due to her very low freeboard and list, water entered the ship through the starboard ash ejector and the half doors on the upper deck. The water ran down to the bilges by way of some upper deck hatches that were not battened down. This free water in the bilges reduced her stability further; the list increased and the scuppers on the upper deck became immersed, bringing in more water. Forty-two hours after her departure from New York the first S-O-S was sent out. One hour later, the Captain reported that the ship had a 32 degree list. Three hours after this report the VESTRIS went down. (See Section 7.9.)

3. The SS ANDREA DORIA, an Italian liner, was rammed in collision with the SS STOCKHOLM and sank in about 11 hours. It appears from the many conflicting statements that the lack of knowledge of the master and officers of the DORIA regarding the ship's stability features was the principal cause for the loss of this ship through progressive flooding. (See Section 7.4 and book "Collision Course" by Moscow.)

D. Coverage.

Learning to measure and ensure the self-righting ability or stability of a ship is the object of all stability studies. This lesson will examine the basic principles of stability, calculation of the center of gravity, and the stability of a ship.

IV. PRESENTATION.

A. Basic Principles.

1. Force. A force may be thought of as a push or pull. A force has direction as well as magnitude and is measured in pounds, tons, or similar units.

2. Moment. The moment of a force about an axis is equal to the product of the force and the perpendicular distance from its line of action to the axis. Figures 1 and 2 (in which the moment axis may be considered to be perpendicular to the paper through the point of rotation) illustrate moment. A moment is measured in foot-pounds, foot-tons, or similar units.

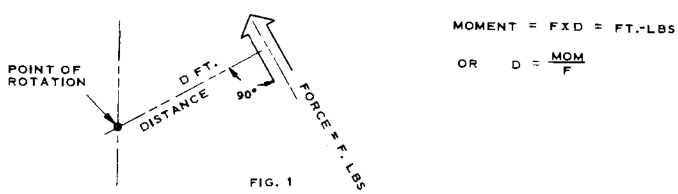


FIG. 1

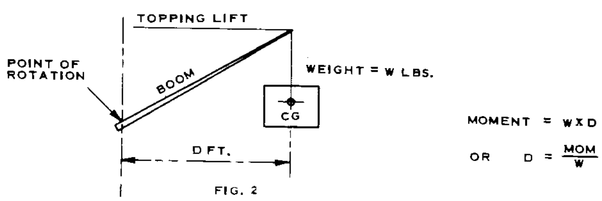


FIG. 2

3. Couple. A special case of moment is that where two equal but opposite parallel forces act in a plane to create a rotational moment. Figure 3 illustrates a couple. A little study will show that the rotational moment created is equal to the product of one of the forces and its perpendicular distance from the other force.

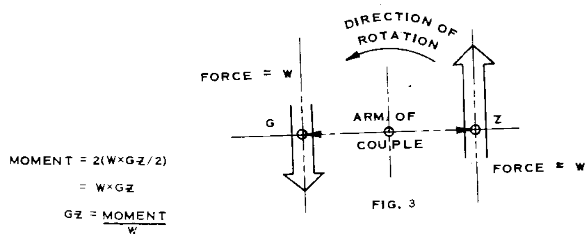


FIG. 3

4. Center of Gravity (CG). The center of gravity of an object is the point through which the total weight of the object may be considered to be acting.

5. Center of Buoyancy (CB). The center of buoyancy of a submerged object is the point through which the total buoyant force of the object may be considered to be acting.

6. Equilibrium. In order for a body to be in equilibrium there must be no unbalanced forces or moments acting on it. A good example of equilibrium is the see-saw in Figure 4. Here the upward supporting force of the see-saw balances the downward weight forces of the man and boy at the pivoting point. In addition the clockwise moment exerted by the man is balanced by the counter-clockwise moment exerted by the boy.

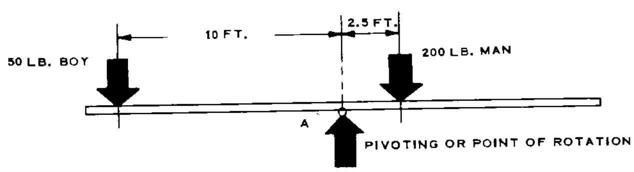


FIG. 4

7. Ship Stability. A ship which is inclined from its normal upright position and tends to return or right itself is said to be stable. A ship is said to be unstable when, after being inclined by a slight force, it continues to incline, possibly until it capsizes. The righting ability of a ship is determined by its underwater hull form, its built-in weight distribution, and by its variable weight (e.g., cargo, fuel or ballast) stowage. An initially unstable ship may sometimes incline until it reaches a point of stable equilibrium because of the change in underwater hull form as it inclines.

8. Effects of Weights. Any weight added, removed or shifted in a ship may affect its stability. The location of these weights has a definite relationship to the resultant stability. Furthermore, the addition of liquids, such as water from flooding or fire-fighting, may have a detrimental effect on stability separate from any weight effects. This is due to the virtual rise in a ship's center of gravity caused by large amounts of liquid free surface in the ship. (Free surface effects in slack tanks produce the same results and therefore, should be minimized.)

B. Calculation of Center of Gravity.

1. Example #1. In order to clarify the concepts of moment and center of gravity consider Figure 5 which shows several weights and their relation to a reference line or axis. The calculations tabulated below Figure 5 illustrate the procedure for determining the center of gravity of the group of weights with respect to the reference line.

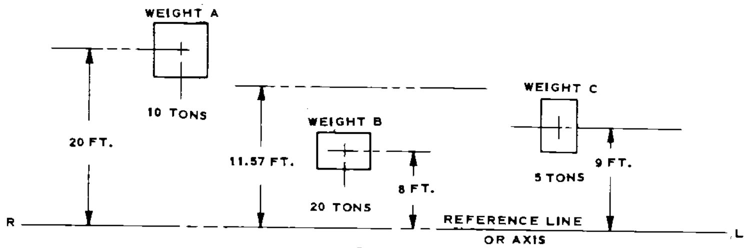


FIG. 5

	Weight		Vertical Distance Above Axis		Vertical Moment in Ft-Tons
A	10 tons	x	20 feet	equals	200 ft-tons
B	20 tons	x	8 feet	equals	160 ft-tons
C	5 tons	x	9 feet	equals	45 ft-tons
	35 tons				405 ft-tons

$$CG = \frac{405 \text{ ft-tons}}{35 \text{ tons}} = 11.57 \text{ ft}$$

These calculations indicate that if the total of weights A, B, and C (35 tons) was placed 11.57 ft. above the reference line, it would produce the same moment as that obtained by adding the individual moments produced by the separate weights. Therefore, this location of the CG of the system corresponds to the definition of CG as the point through which the total weight of the body acts.

2. Example #2. When dealing with weights and centers, it is important to recognize the overall effect caused by changing the magnitude and location of an individual weight. This is illustrated in Figure 6, which is similar to Figure 5 except that weight B has been increased to 30 tons and its distance from the reference line to 12 feet. The calculations below the figure indicate that, as a result of these changes, the center of gravity of the system has increased 1.87 ft. to 13.44 ft. above the axis.

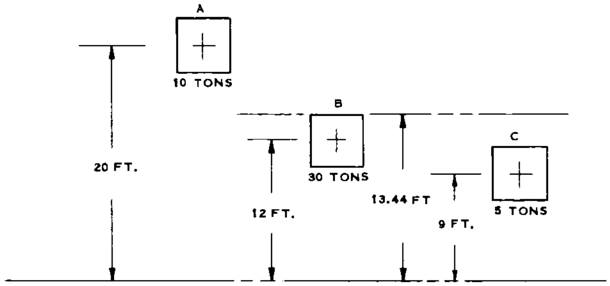


FIG. 6

		Weight		Vertical Distance Above Base Line		Vertical Mount
A	-	10 tons	x	20 feet	equals	200 ft-tons
B	-	30 tons	x	12 feet	equals	360 ft-tons
C	-	5 tons	x	9 feet	equals	45 ft-tons
		45 tons				605 ft-tons

$$CG = \frac{605 \text{ ft-tons}}{45 \text{ tons}} = 13.44 \text{ ft}$$

3. Determination of Center of Gravity in a Ship. As illustrated in the above calculations, the total moment divided by the total weight gives the distance of the center of gravity from the reference line. The center of gravity of a ship is determined by using the same principle. However, in this case it involves extensive work which requires a summation of all the weights and their moments in relation to a convenient reference line. The weight includes the hull, machinery, equipment and other material which go into the construction and operation of the ship, and also liquids and cargo added or deducted for various conditions of operation.

4. Vertical Center of Gravity. To determine the stability of a ship, it is necessary to calculate the vertical location of the ship's center of gravity. The keel is normally used as the reference line for this calculation. The vertical center of gravity is usually at some point in the centerline plane of the ship. Where there may be an unequal weight distribution between the port and starboard side so that the center of gravity does not lie in this plane, an additional calculation must be made to determine the horizontal position of the center of gravity relative to the ship's centerline.

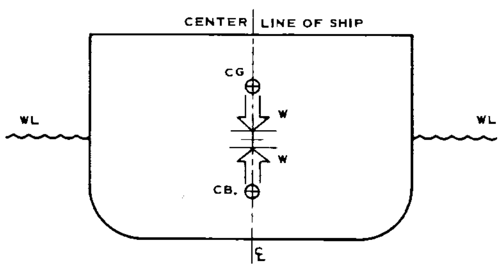


FIG. 7

C. The Stability of a Ship.

1. Ship Upright. In order for a ship to float, the weight of the ship (W) acting downward through its center of gravity must be balanced by the buoyant forces acting upward through the center of buoyancy of the hull. Furthermore, if no wind and wave forces are acting on the ship and the CG is directly above the CB (Figure 7) so that the weight and buoyant forces act in the same vertical line, the ship will float upright with no tendency to heel.

2. Ship Heeled, Righting Moment. Unless weight is added, removed or shifted in a ship when it heels, the location of its center of gravity does not change. However, its center of buoyancy shifts to a new position (Figure 8) away from the centerline in the direction of heel. Bearing in mind that the center of buoyancy is the center of gravity of the water displaced by the hull, its change in position is a result of the change in shape of the displaced water as the ship heels. In contrast to the ship when upright, as depicted in Figure 7, the weight of the heeled ship acting downward through the center of gravity and the equal upwards, buoyant force acting through the relocated center of buoyancy now form a couple with an arm, GZ, creating a righting moment. This righting moment equals W x GZ and tends to return the ship to its upright position.

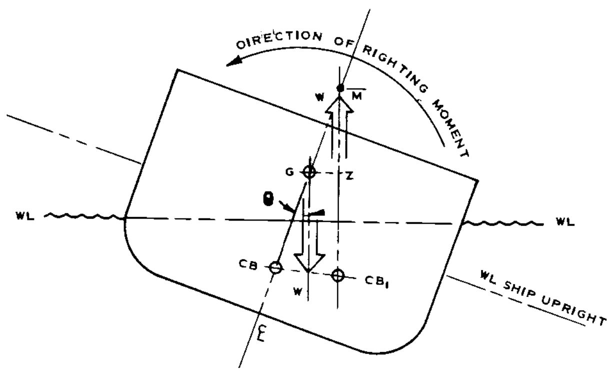


FIG. 8

3. Initial Stability, GM. Note that in Figure 8 the distance GM is a function of the righting arm GZ. Therefore, GM is also a measure of the ship's righting ability. The point M is the transverse metacenter of the ship and GM is known as the metacentric height. The length of the righting arm GZ, and therefore the metacentric height, is determined solely by the shape of the hull. Within a limited heel of up to 10 to 15 degrees, GM is a measure of the ship's initial stability and can be expressed as follows:

$$GM = \frac{GZ}{\sin \theta} \text{ (of heel)}$$

$$\text{where } GZ = GM \times \sin \theta$$

Now if the above value for GZ was substituted in the expression for righting moment, W x GZ, the ship's righting moment when initially heeled would become equal to W x GM x sin θ.

Example: Consider Figure 9 in which a 50 ton weight is added 20 feet to one side of the centerline of a ship initially floating upright. The heeling moment produced by this weight would be 50 x 20 = 1000 ft-tons. Under the action of this moment, the ship would heel until an equal righting moment was created and equilibrium again was established; therefore, the angle of heel (θ) can be calculated as follows:

$$1000 = M = W \times GM \times \sin \theta$$

Therefore $\sin \theta = \dfrac{M}{W \times GM}$

or $\sin \theta = \dfrac{1000}{12000 \times 3.5}$

$\sin \theta = 0.0238$

therefore θ, angle of heel $= 1^\circ - 22'$

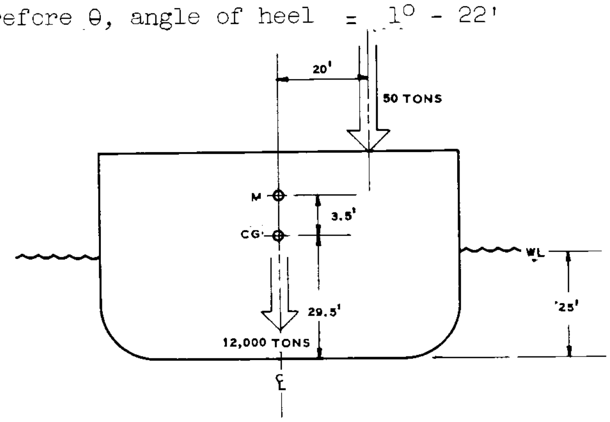


FIG. 9

4. Unstable Ship. So far we have considered a ship which will tend to right itself when heeled -- a stable ship. However, during normal operations, because of changes in the amount and/or location of variable weights aboard, a ship may lose this ability to right itself when heeled. Figure 10 shows the characteristics of an unstable ship. As indicated, the center of gravity is above the metacenter and the moment ($W \times GZ = W \times GM \sin \theta$) now tends to increase the heel rather than oppose it as in the stable ship of Figure 8. The addition of topside weight such as ice or deck cargo or the removal of weight low in the ship, by burning fuel oil or using fresh water, will raise the center of gravity and may result in an unstable condition.

Example: Again consider the ship represented by Figure 9. How will burning 1500 tons of fuel oil from the ship's double bottom affect its stability? Assume the center of gravity of the fuel was two feet above the keel.

New displacement = 12000 - 1500 = 10500 tons

New location of CG = $\dfrac{\text{Original moment - moment of fuel removed}}{\text{New displacement}}$

$= \dfrac{12000 \times 29.5 - 1500 \times 2}{10500}$

New CG = 33.4 ft..

This places the center of gravity 0.4 foot above the metacenter and results in the ship being unstable. In a ship of this size, such fuel consumption may readily be experienced in a voyage and must be compensated by ballast or other means. The problem of loss of stability will be further considered in the next lesson.

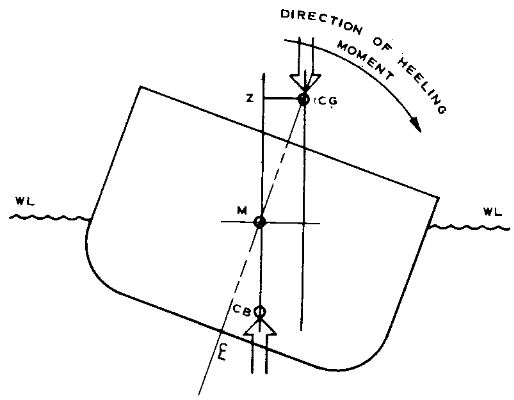


FIG. 10

V. SUMMARY.

In summary, the stability of a ship is determined by the weight distribution of the ship and by the buoyant forces acting on the hull which in turn are determined by the underwater shape of the hull. It is in controlling the weight distribution in the ship that the ship's officers control its stability. The stability problem which must be solved involves the ship's vertical center of gravity as determined by the various weights and their locations. The procedure for solving the stability problem is as follows:

A. Find a starting condition for which the displacement and locations of the centers of gravity and buoyancy can be determined.

B. Correct the starting condition by adding or subtracting weights as appropriate so that the actual or anticipated condition is reached.

C. Determine whether the new center of gravity is above or below the metacenter. The center of gravity must be below the metacenter for the ship to be stable.

D. If the ship is stable, determine whether the available GM is adequate for the anticipated voyage or applicable regulations. If it is not (or if the ship is not stable), action must be taken to lower the ship's center of gravity and thereby increase the GM.

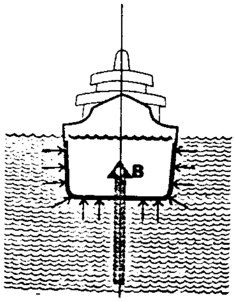
E. This material, excerpted from Ships, a volume in the Life Science Library, is considered one of the best explanations of the basics of ship stability. It is reproduced by permission of the Editors of TIME-LIFE BOOKS ©1965 Time Inc.

Every modern ship has a formal displacement curve plotted by her architects from the lines and dimensions of her hull. This graph is turned over to her officers on her delivery. To gauge the ship's weight or displacement at any time during loading or unloading, they simply take the average of the bow and stern drafts--the vertical distances between the water line and the keel. A glance at the graph tells them, in tons, the amount of water she is displacing. The figure is, of course, the precise equivalent of her own weight plus everything aboard. Conversely, the officers can learn from the graph what her draft will be under any given load.

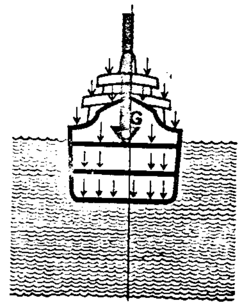
A modern oceangoing ship is basically a floating steel box, although a box of almost unimaginable complexity. But merely being certain that a ship will float is not enough; it must have the ability to remain afloat under all probable conditions. Therefore, the hull of a modern steel vessel is compartmented by watertight, transverse divisions, called bulkheads. If, through collision, shellfire or other circumstances, one section of the hull is flooded, the other compartments are designed to maintain sufficient buoyancy to keep the vessel from sinking. Highly compartmented ships, such as tankers, have even been sheared in two by collision, and the individual parts have remained aloat.

A ship must be designed for buoyancy, stability, and strength. Stability--the tendency of a ship rolling from side to side always to return to an upright position like a rocking chair or a weighted doll--is the second vital element which must be part of a vessel's design. Symmetry is an initial condition. The architect plans port and starboard sides of the hull as mirror images of each other. To know in advance the total weight of the ship and the exact distribution, designers tabulate everything that goes into the ship from the huge power plant to the crew's bunks.

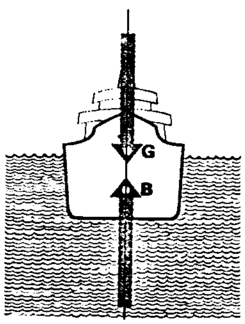
There are two forces, operating in opposite directions, which affect the stability of every ship. One is the summation of the entire weight of the ship--the downward force acting at the center of gravity. The other is the supporting force of the water, which acts upward through the center of buoyancy. When a ship is at anchor in a placid harbor, its center of gravity is located directly above its center of buoyancy on the vertical center line of the vessel.



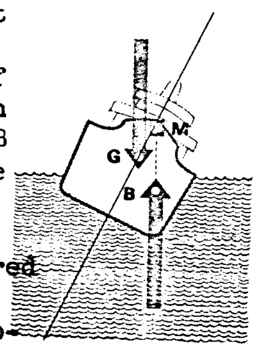
BUOYANCY AND GRAVITY are the two forces acting on a ship as it floats at rest. The water pushes all around on the submerged hull (small arrows, left). The total push acts as a single upward buoyant force, B, exerted at the center of the submerged part of the hull. The downward force of gravity is equal to the weight of the ship and everything in it (small arrows, right). The total force, G, is exerted at approximately the center of the ship.



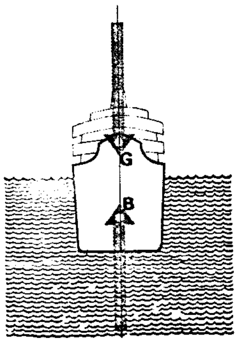
However, if a wave from a passing vessel causes her to heel momentarily, this positioning changes. If the tilt is to starboard, for example, the center of buoyancy is transferred laterally to the right. The relationship between the centers of buoyancy and gravity now becomes vital. If the center of gravity is sufficiently low, it will be to the left of the center of buoyancy, and the downward force of gravity and the upward force of buoyancy combine to push the vessel back to an upright position.



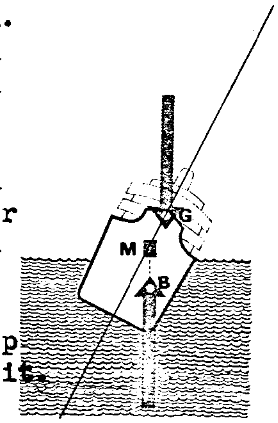
A STABLE SHIP is one that can right itself if it is heeled over. When it is upright, the ship's center of gravity, G, and buoyancy, B, are in line. When the vessel is tilted, B moves in the direction of the slope so that its upward push combines with G's downward force to right the ship. This stability is measured by the position of the metacenter, M, a theoretical point where the upward force B meets the ship's vertical midline. The position of M above G here indicates good stability.



However, if the center of gravity is too high it will be to the right of the center of buoyancy. Now the downward and upward forces are combined to aggravate the heel and the ship may capsize.



AN UNSTABLE SHIP cannot return to a normal upright position when tilted. Since the vessel is more narrow and top-heavy than a stable ship, B and G are located much farther apart (arrows, left). When the vessel tilts, the force of G shifts toward the direction of the slope; together the two opposing forces act to heel the ship even farther until it capsizes. The metacenter M, instead of being above G as in a stable ship (previous page) is here well below it.



About the mid-18th Century, Pierre Bouguer, a French mathematician and a founder of modern naval architecture, worked out a practical means, still in standard use, for evaluating the stability of a ship. Bouguer's concept was based on a point he called the metacenter, located at the intersection of the center line of the hull and a vertical line through the center of buoyancy of a listing ship. The distance between the metacenter, M, and the center of gravity, G, Bouguer proved, would measure a ship's stability. This distance, usually referred to as GM, is a matter of prime concern to the designer. If G is above M, there is danger of capsizing. If the GM is small, i.e., the center of gravity is below, but still too close to M, the ship will make long, slow rolls and may readily capsize in the event of a collision. However, if G is too far below M, the vessel will be "stiff" and jerk back to the upright, possible damaging the cargo and injuring the crew and passengers. A safe GM for the average fully loaded merchant ship is about 5 per cent of her beam--the breadth at her widest part.

The center of gravity is dependent upon distribution of weight in the ship and therefore shifts with each addition or unloading of cargo, with each fueling and with each hour's comsumption of fuel at sea. It is the job of the ship's architect to take all such factors into consideration, to calculate the position of M and then forecast the vessel's GM value under all foreseeable situations and conditions.

Before a ship goes to sea, she is put through an actual test to verify her calculated stability. First, tracks are installed across the ship's deck. A jumbo truck carrying several tons of weight is put on the tracks and rolled to one side of the ship or the other, thus causing the vessel to list. At various positions of the truck from the center of the ship, the designer measures the angle of inclination of the heeling ship by means of hanging pendulum bobs. A trigonometric equation gives him the result he seeks; confirmation of the architect's estimated value of GM and hence the precise location of G. With this information, the GM from minimum to maximum load conditions can be calculated. These data are given to the ship's officers for their guidance at sea.

In addition to buoyancy and stability, the designer of a ship must give her the pliant strength that will enable her to absorb and withstand a combination of mighty forces--the upward force of buoyancy, the downward force of gravity, and the powerful onslaught of ocean waves.

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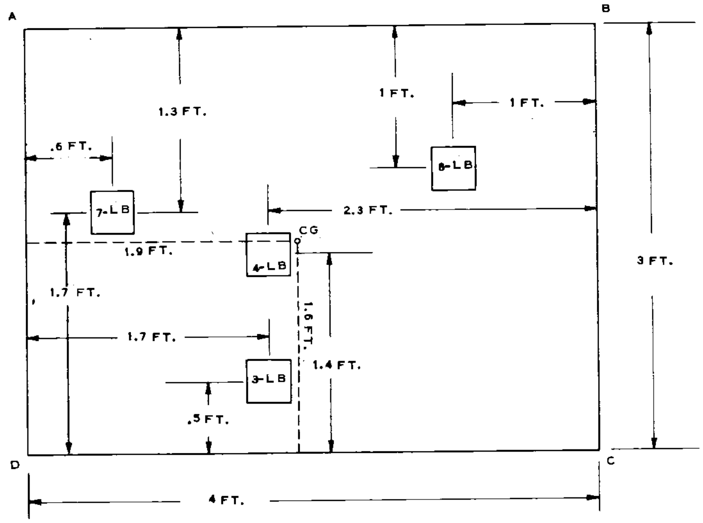
VI. TEST AND APPLICATION.

A. Problems.

1. The following weights are placed on a 6 lb. tray 3 ft. wide and 4 ft. long. Find the location of the center of gravity of the group.



SOLUTION: Take moments from one end AD and one side CD.

	Weight	Lever to End AD	L Mom.	Lever to Side CD	Side Mom.
	7 lbs	.6 foot	4.2	1.7 feet	11.9
	3 lbs	1.7 feet	5.1	.5 foot	1.5
	4 lbs	1.7 feet	6.8	1.4 feet	5.6
	8 lbs	3.0 feet	24.0	2.0 feet	16.0
Tray	6 lbs	2.0 feet	12.0	1.5 feet	9.0
Group	28 lbs	1.86 feet from AD	52.1 ft. lbs.	1.57 feet from CD	44.0 ft. lbs.

1.86 feet is obtained by dividing 52.1 by 28 lbs. 1.57 feet is obtained by dividing 44 by 28. These distances locate the CG as shown in the illustration.

2. Q. What is the righting couple of a ship?

A. The combination of buoyant force and gravity force multiplied by the righting lever or perpendicular line distance between the lines of action of these forces. (Displacement weight x righting lever.)

3. Q. Define the center of gravity of a ship.

A. That point at which all the vertically downward forces of weight are considered to be concentrated; the center of the mass of the vessel.

4. Q. Define the center of buoyance of a ship.

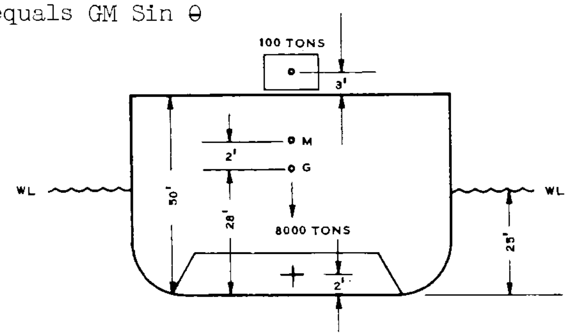
A. That point at which all the vertically upward forces of buoyancy are considered to be concentrated; the center of volume of the immersed portion of the vessel.

5. Q. What is the moment exerted on the mast by a 200# man on a yardarm 15 ft. away from the mast, assuming yardarm is fixed and at right angles to the mast.

A. Mom. equals 15 x 200 equals 3000 ft. lbs.

6. Q. Express the length of righting lever GZ of a ship in terms of angle of heel θ and metacentric height GM.

A. GZ equals GM Sin θ



7. Q. In the ship represented above, the 100 ton weight is shifted 20 ft. to port. What is the sine of the angle of heel? What is the angle of heel?

A. M equals W x GM x Sin θ
20 x 100 equals 8000 x 2 x Sin θ
Sin θ equals $\frac{2000}{8000 \times 2}$ equals .1250
θ equals 7° 11'

8. Q. Assume no change in location of M, what GM remains if 500 LT fuel are burned out of double bottoms at 2 ft. VCG?

A. 8000 x 28 equals 224,000
-500 x 2 equals -1,000
7500 223,000

VCG equals $\frac{223{,}000}{7500}$ equals 29.75 ft.

GM equals 30.0 - 29.75 equals 0.25 ft.

NOTE: This is a dangerously low GM and should be corrected by ballasting.

B. Application. Using your ship's current load condition, calculate its stability, assuming any practical change of weight, trim, stores, fuel, or flooding.

CHAPTER 4

ADVANCED DAMAGE CONTROL - For Deck and Engine Personnel (Lesson Plans)

SECTION 4.2

ELEMENTS AFFECTING THE STABILITY OF A SHIP

I. Objectives
II. Material
III. Introduction
IV. Presentation
V. Summary
VI. Test and Application

I. OBJECTIVES.

A. To provide an understanding of the changes in a ship's stability caused by forces of sea, wind, and damage which the ship's officer must control to keep the ship seaworthy.

B. To indicate characteristics built into a ship which provide stability and capacity to survive damage.

II. MATERIAL.

A. Training Aids.

1. Ship's Trim and Stability Booklet.

2. Films MN-61, Damage Control, Part L, Loose Water in Stability - In Intact Spaces, 13 minutes; Part M, Loose Water in Stability - In Spaces Open to the Sea, 13 minutes. Instructor may also refer to other films in the MN-61 series, Parts F through N.

B. References.

1. BUSHIPS Manual, Chapter 88, Section I, Parts 2, 3, and 4.

2. Stability and Trim for the Ship's Officer by Ladage and Van Gemert.

3. Principles of Naval Architecture, Volume I.

4. International Convention for Safety of Life at Sea, 1948 (CG 242).

III. INTRODUCTION.

A. Introduce self and subject (Elements Affecting the Stability of a Ship).

B. Definition. Stability is the ability of a ship to right itself when heeled over from the action of outside forces, such as wind and sea, and from internal forces, such as shifting of cargo or liquids or failure of ship's structure.

C. Arouse interest by referring to sea disasters such as the TITANIC, ANDREA DORIS, and VESTRIS as examples of the influence of the elements upon the stability of well-designed ships, causing them to sink. The TITANIC and ANDREA DORIA casualties are similar since since their loss was due to flooding resulting from collision, with an iceberg in the case of the TITANIC, and with the STOCKHOLM in the case of the ANDREA DORIA. The case of the VESTRIS is particularly significant since it is an example of the influence of wind and sea causing flooding through poorly secured hatches and hull openings which were exposed to the sea by cargo overloading. The NORMANDIE is an example of a ship lost due to addition of water from firefighting. The large amounts of water in the upper decks and on one side resulted in overcoming the ship's stability and causing it to capsize.

IV. PRESENTATION.

A. Mechanical Relationship between Center of Gravity and Center of Buoyancy.

1. Center of buoyancy depends upon the shape of the immersed watertight hull; it changes with:

a. Wave profile.

(1) Longitudinal differences cause pitching.

(2) Transverse differences cause rolling.

b. Damage to watertight shape of the hull which may flood:

(1) Compartments centered in the ship, causing no change in trim.

(2) Compartments on one side of the ship, causing off center shifting of the center of buoyancy, and change in trim.

c. Center of buoyancy is not controlled by ships' officers except indirectly.

(1) By changing the effect of waves through course and speed changes.

(2) By maintaining watertightness.

d. M & GM. At small angles of heel, the intersection of the vertical line through the center of buoyancy with the centerline plane of the ship is a point, designated as the metacenter or "M." The distance between the ship's center of gravity, CG, and M is the metacentric height, GM. As can be seen from the geometric relations, the righting arm, GZ, is proportional to the sine of the angle of heel.

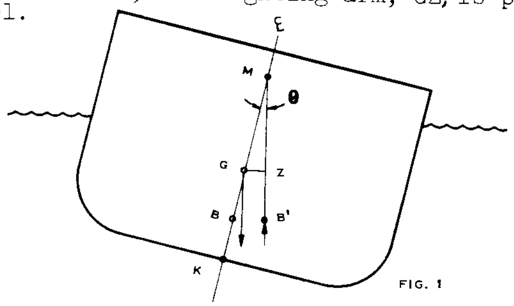


FIG. 1

e. Curves of Form. The designed characteristics of the ship which contribute to the ship's buoyancy and stability are described by a plan called the "Curves of Form" or "Hydrostatic Curves of Form." These curves indicate, for any draft: The ship's displacement; the tons per inch; the moment to trim 1"; the location of the center of buoyancy above reference point KB; the point at which the line of buoyancy intersects the centerline plane KM at small angles of heel (Metacenter) above reference point K. These locations are shown from both longitudinal and transverse axis, therefore, care must be taken to use the transverse centers when transverse stability is considered. These curves in tabular form are included in the Trim and Stability Booklet.

2. Center of gravity depends upon the distribution of weights in and on the ship. These include:

a. Cargo distribution.

(1) Shifts ship's CG vertically, transversely and longitudinally.

(2) Due to the weight of cargo, the influence of loading is usually a large and important factor.

(3) For a given leg of a voyage, the cargo is a weight that is not normally considered to be under control of ships' officers.

(4) Shifting of poorly stowed cargo while at sea may result in changing the ship's center of gravity, causing heel and a possibly dangerous condition in addition to internal damages.

b. Operating weights.

(1) As a result of operation, weights of fuel, water, and stores are consumed which, due to location and size, cause important changes in the center of gravity, usually raising it and therefore reducing the GM and subsequently the righting arm.

(2) Tanks emptied may be off center, giving the ship a heel to one side.

(3) If counterbalancing tanks are used, both may be slack, permitting liquid to move from side to side freely, causing changes in the virtual CG.

(a) Since for small angles of roll, the amount of liquid that can move depends primarily on its surface area, this effect upon the CG is called "free surface effect." The Trim and Stability Booklet contains tables showing the effect of liquid shifting in each of the ship's tanks.

(b) Free surface effect also depends upon the unfilled space which permits the movement of the liquid. Free surface effect can be reduced by pressing up the tank.

(c) Due to their location in the bottom of the ship, fuel tanks are particularly important. When they are emptied, the ship's resulting center of gravity rises, reducing the righting arm. Filling these tanks with salt water ballast results in maximum improvement in stability by:

Adding weight low in the ship.
Eliminating free surface by pressing the tanks up their fullest extent.

C. Special weight problems in cargo handling. Cargo being loaded with the ship's booms is a special problem, particularly heavy lifts. The lift is concentrated at the head of the boom as soon as the weight is supported by the gear, therefore it has an unusually high vertical lever. The large transverse lever has a corresponding effect on the ship's CG. The combined effect of vertical and transverse levers results in an unusually large shift in the ship's CG and lessening of available stability. Cargoes such as grain, coal, and ore may act like a fluid, shifting under the ship's roll and causing off-center weights. These must be secured against movement.

B. Grounding or Drydocking. These are special cases of ship stability since:

1. The weight of the ship is supported partially by the sea bottom, rocks, or drydock blocks instead of water.

2. The support, if off center, would cause a heeling moment, which may change as the water level changes with tide or drydock level.

3. Grounding must be considered as an individual problem. Unless the ship cannot be refloated quickly by lightening, grounding is a problem for the salvage teams. The ship must be kept from pounding if possible, by flooding if necessary.

4. Loss of stability due to faulty support by the drydock will be indicated by the ship taking a heel independently of the drydock attitude. The dockmaster should be notified as soon as heel is noted since the ship must be refloated to correct the support.

C. Ship Design and Damage Resistance.

1. A ship is designed and built so as to be able to survive the casualties that experience indicates may be encountered.

2. The two essential factors of survival are buoyancy (watertightness) and stability. A damaged ship may have enough buoyancy to float upside down, yet it cannot be considered to have survived the damage.

3. Buoyancy of a ship is built into the hull by providing, in addition to a watertight shell:

a. Transverse watertight bulkheads. The spacing of the watertight bulkheads is arranged so that the loaded ship, if damaged in one or two watertight compartments, would not sink beyond an arbitrary margin line located three inches below the bulkhead deck. If two adjacent watertight compartments may cause this sinkage, the ship is known as a two-compartment ship. If only one does, it is a one-compartment ship.

b. These bulkheads are joined longitudinally by one or more decks. The uppermost continuous deck to which the transverse watertight bulkheads extend is designated as the bulkhead deck. This deck may be either continuous or stepped in way of transverse bulkheads, extending above the deck such as in ships with forecastle, poop and well deck. The bulkhead deck, where covered by a house or where the shell extends above this deck as an enclosure, need not be watertight but requires protection by weathertight doors and coamings through the exposed bulkheads at the bulkhead deck level.

c. The maximum load line draft, if not exceeded, assures that sufficient reserve buoyancy is available in spite of the added weight of water due to damage by flooding, of one compartment in a one-compartment ship and two compartments in a two-compartment ship.

d. Ships over 200 feet long must be fitted with double bottoms.

4. MSTS transport ships are two-compartment ships in accordance with the International Convention for Safety of Life at Sea.

5. Stability of a ship as a function of metacentric height, GM, is determined by locating the center of gravity of the ship in light condition soon after it is built or undergoes any major changes affecting the ship's weight distribution. This is done by means of an inclining experiment.

6. Calculations are made under several loading and damaged conditions and wind forces to assure available stability, freeboard and safe operating condition in service.

7. Stability and trim of a ship is the responsibility of the ship's master. He in turn requires the first officer (and deck officers) to maintain the ship's stability through good cargo stowage and trim - and the chief engineer (and engineering officers) through proper ballasting.

D. Influence of Weather.

1. Wind force affects transverse stability by creating a heeling moment consisting of:

a. Wind force against the exposed side of the ship's hull and superstructure.

b. Reaction of the force of the water against the hull acting through the center of the underwater side profile of the ship.

c. A lever equal to the vertical separation between the two.

2. Wind heel is often the major factor in determining the requirements for minimum stability.

3. Ice and snow present a problem in direct proportion to the weight added and its location.

a. Due to difficulty in determining weights and levers of ice on board, the effect cannot be readily evaluated.

b. Any slowing in period of roll under icing conditions should be investigated and action taken to reduce the ice and snow loading.

4. Waves influence stability by:

a. Changing the shape of the underwater portion of the ship which changes the location of the center of buoyancy causing roll, pitch, and yawing.

b. Adding weight on deck.

(1) Major danger is the impact of waves, which may rupture watertight hatches and deckhouses and thus cause flooding.

(2) If watertightness is maintained, boarding seas will be drained off the decks by the ship's motion.

NOTE TO INSTRUCTOR: The above is a summary of material presented in detail in the references listed under IIB. These should be referred to for more detail in this presentation.

V. SUMMARY.

A. The problem of balancing the ship's weights and buoyancy may seem to have become complicated by curves of form, required compartmentation and floodable lengths, wind heel, free surface, and the effect of waves. It is emphasized that all these are tools used to measure the effects of ship weights and wind and water forces and to build characteristics into the ship which will assist in simplifying the stability problem under conditions of danger. In the use of these tools, the ship's officer must become a skilled craftsman. This can only be achieved by the old fashioned method of practice and continued exercise in solving the various problems which may be encountered. Napoleon took Paris with a minimum of apparent effort because he practiced a seige of the city when he was in the military school. In a smililar manner a ship's officer will be able to better cope with more difficult problems of stability if he studies assumed damage conditions beforehand and knows his ship's stability situation at all times, particularly in approaching coastal waters.

VI. TEST AND APPLICATION.

A. Test. Use these and additional questions as a review.

1. Q. Define the location of the metacenter at a small angle of heel.

A. The location of the metacenter is at the point at which the vertical line drawn through the center of buoyancy intersects the vertical centerline longitudinal plan of the ship.

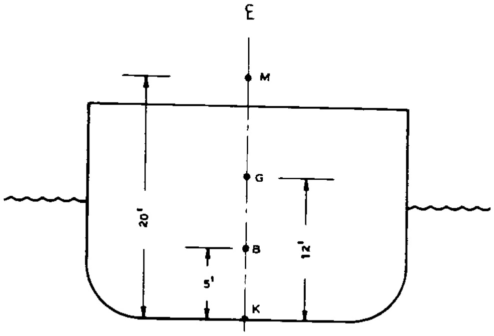
2. Q. What are the curves of form or hydrostatic curves?

A. They are curves showing the variation of the geometric characteristics of the ship corresponding to various drafts, such as volume of displacement, location of center of buoyancy, metacentric height, etc.

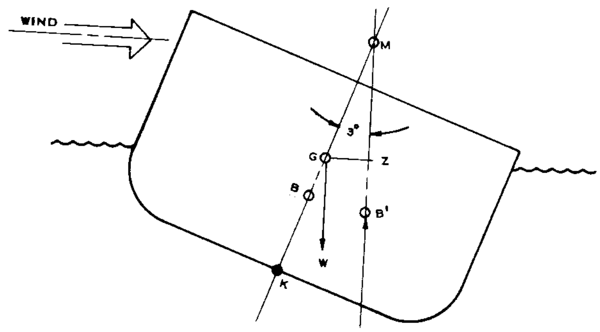
3. Q. What is meant by KM?

A. KM represents the distance of the metacenter, M, from the reference point, K (moulded baseline at centerline).

4. Q. Draw a diagram of transverse stability representing a ship with a KM of 20 feet, a center of gravity of 12 feet above moulded base line (K), a vertical center of buoyance 5 feet above K. Displacement is 5000 tons.



PROBLEM 4



PROBLEM 5

5. Q. In the above problem draw the diagram indicating the ship under the effect of a wind resulting in a heel to starboard of 3°. Assume no free liquids. (In the diagram exaggerate the heel.)

6. Q. What limits the heel to 3°?

A. The counter moment of the ship's weight times the horizontal distance between center of gravity and vertical line through the new center of buoyancy.

7. Q. What happened to the ship's center of gravity?

A. Nothing, no weight was added and since it was assumed no liquids could shift to the low side, no shifts in weight were made. In actual practice, liquids will shift, resulting in a proportionate shift in the ship's center of gravity.

8. Q. In the above problem, what is the horizontal shift of the center of buoyancy (sin 3° equals .05)?

A. Shift of B equals (KM - KB x sine θ
equals 20 - 5 x .05
equals 15 x .05 equals .75 ft.

9. Q. What is the righting arm?

A. GZ equals (KM - KG) x Sin θ
equals (20 - 12) x .05 equals 8 x .05 equals .4 ft.

10. Q. What is the righting moment?

A. M equals Weight of ship x righting arm equals 5000 x .4 equals 2000 ft. tons.

B. <u>Application</u>. Ship's officers should discuss the practical application of these principles in the ship's regular operations, solving similar practical problems.

CHAPTER 4

ADVANCED DAMAGE CONTROL - For Deck and Engine Personnel (Lesson Plans)

SECTION 4.3

THE TRIM AND STABILITY BOOKLET

I Objectives
II Material
III Introduction
IV Presentation
V Summary
VI Test & Application

I. OBJECTIVES.

A. To train personnel in the use of the Trim and Stability Booklet.

B. To assure that the ship has adequate stability for the desired compartmentation.

II. MATERIAL. Trim and Stability Booklets for the type ship, as: USNS GREENVILLE VICTORY (T-AK 237), USNS BARRETT (T-AP 196), or USNS AKL 17 (T-AKL 17).

III. INTRODUCTION.

A. Introduce self and subject (The Trim and Stability Booklet).

B. Establish scope of session and state objectives.

C. Arouse interest.

1. Coast Guard requirements (CG-256 and CG-257) state that:

a. Passenger vessels. "The master of the vessel shall be supplied with the data necessary to maintain sufficient intact stability under service conditions, to provide satisfactory operating stability, and also to enable the vessel to meet the damaged stability requirements."

b. Cargo vessels. "Information shall be furnished to the master which sets forth the stability data necessary to permit efficient handling of the vessel. In general, this information shall be such that the master can readily determine the metacentric height and determine the freeboard for any condition of loading."

2. MSTS requirements.

a. For cargo ships - a one-compartment standard.

b. For passenger ships - a two-compartment standard.

3. Master's responsibility. In accordance with the Coast Guard stability letter, "It shall be the master's responsibility to maintain proper stability at all times."

IV. PRESENTATION.

A. Types of Booklets. There are three basic types of trim and stability booklets. They cover the operation of passenger ships, cargo ships, and ships having virtually no restriction on the method of loading cargo, fuel, and water. The three types of trim and stability booklets thus are:

1. Passenger

2. Cargo

3. Unrestricted

B. Contents of Booklets. The trim and stability booklets are designed to inform the ship's officers with respect to how much stability is required and how the required stability may be obtained. All booklets contain the following basic information:

1. Information contained in all booklets.

a. Principal characteristics.

b. Hydrostatic properties.

c. Tank capacities, free surface corrections, and centers of gravity.

d. Cargo hold volumes and centers of gravity.

2. Special information in individual booklets.

a. Passenger ships. A loading table and loading diagram are given in the back of the booklet. In this table and diagram are entered the principal items of load according to height above the base line. These items are double bottom tankage, cargo and deep tankage, and passengers and stores. In general, additional double bottom tankage increases stability most per ton added. Cargo and deep tankage helps somewhat less. Addition of passengers and stores may decrease stability.

b. Cargo ships. A loading table and loading diagram are given in the back of the booklet. The principal items of load are double bottom tankage, cargo in holds, cargo in lower 'tween decks, cargo in upper 'tween decks, and deck cargo. Double bottom tankage and lower hold cargo increase stability. Lower 'tween deck cargo makes little difference. Upper 'tween deck and deck cargo decrease stability.

c. Unrestricted ships. Here the principal difference from passenger and cargo ship trim and stability booklets is that the ship has adequate stability for almost any condition of loading. As a result, the booklet indicates the stability, draft, and trim for widely different loadings, and omits examples or blank sheets for determining stability, draft, or trim.

3. Individual requirements. Since all passenger ships, or all cargo ships, are not the same, there are differences in the stability required after damage or the stability required in bad weather. The booklet provides that this amount of stability is available at all times so that the ship is always ready to sustain damage or heavy weather. One of the principal dangers when damaged is excessive listing due to water entering on one side only. This is commonly known as unsymmetrical flooding, and all possible means should be taken to reduct the list, by flooding to the other side (counterflooding) after a compartment to one side is damaged.

a. See general note #2 in operating instructions for the BARRETT--"When the No. 1 and No. 2 fresh water tanks in No. 3 hold are in use, the flooding equalizing valves, which are operated from 2nd deck, shall be kept closed and the blank flanges kept off. In case of damage involving one of these tanks, these valves shall be opened to equalize flooding. When these tanks are empty, the valves shall be open and the blank flanges off."

b. See general note #4 in operating instructions for GREENVILLE VICTORY-- "Ship shall be operated at no less than 14'-0" draft."

c. Refer to operating instructions for your ship to see if any particular condition such as the above has to be maintained. Note, in the case of the BARRETT, that cross-flooding is achieved by opening a valve in the interconnecting pipeline between port and starboard tanks, while in the GREENVILLE VICTORY the minimum required draft assures that cross-flooding will occur over the shaft alley if the ship is damaged in No. 4 or 5 holds. The danger of unsymmetrical damage water is demonstrated in the case of the ANDREA DORIA, under lessons from casualties.

C. Using the Booklet. No amount of reading and studying will instruct a ship's officer in the stability characteristics of his particular ship as well as will practical experience. Therefore, the ship's trim and stability booklet should be referred to. Its contents should be noted, the various sheets studied and sample loadings should be worked out. A good starting example would be to check the condition of the ship as she is at the moment. Refer to the instructions in the front of the booklet for developing the example, also check procedures against the example. Knowledge of the ship's stability can only be obtained by using the trim and stability booklet regularly:

1. Upon departure, to assure adequate stability for that condition.

2. For projected arrival condition.

3. For intermediate condition at which salt water ballasting will be required if the stability in the projected arrival condition is not adequate.

V. SUMMARY.

A. Coast Guard requirements.

B. MSTS requirements.

C. Types of Stability Booklets.

D. Information for passenger ships.

E. Information for cargo ships.

F. Discuss examples of departure and arrival conditions.

VI. TEST AND APPLICATION.

A. Test. Use these and additional questions as an oral quiz.

1. Q. What is meant by a "one-compartment ship?"

A two compartment ship?

A. A one-compartment ship is one that will remain afloat when flooded or open to the sea between any two main watertight bulkheads. A two-compartment ship will withstand the flooding of any two adjacent compartments.

2. Q. What is the required GM curve?

A. The required GM curve indicates, at various drafts, the minimum GM required before damage, in order to keep the ship afloat after damage.

3. Q. Explain the term and condition of a light ship.

A. Light ship is the ship complete in every respect, with water in the boilers at steaming level and liquids in machinery and piping, but with all fuel oil and fresh water tanks empty and no passengers, crew, cargo or consumable stores on board.

4. Q. What is the procedure when the GM available is less than the GM required?

A. This condition must be corrected by ballasting sufficient tanks so as to provide a positive margin of stability in the event of damage.

5. Q. Why does GM increase when tanks are ballasted?

A. Ballasting tanks adds weight low in the ship, thereby lowering the ship's center of gravity, "G", and moving it further away from "M."

6. Q. When both are available, is it more efficient to ballast double bottom tanks or deep tanks and why?

A. It is more efficient to ballast double bottom tanks since they have a lower center of gravity and will thereby have a greater effect in increasing the GM.

7. Q. What effect does free surface have on GM?

A. Free surface decreases the GM of a ship by raising the ship's center of gravity, "G," thereby moving it closer to "M."

8. Q. What is the trim table?

A. A trim table is a table of the change in inches to draft forward and aft for each 100 tons (or other fixed load) loaded or unloaded at any distance from amidship.

B. <u>Application</u>. Use the ship's trim and stability booklet to determine the ship's condition of stability for various loadings. Also, assuming various conditions of damage, determine the ship's stability, and the indicated action to improve it.

CHAPTER 4

OFFICERS' DAMAGE CONTROL - For Licensed Officers (Lesson Plan)

SECTION 4.4

PLASTIC PATCHING

I. Objectives
II. Material
III. Introduction
IV. Presentation
V. Summary
VI. Test and Application
VII. Handout

I. OBJECTIVES.

A. To familiarize personnel with the purpose of the plastic pipe patch and the method of application.

B. To familiarize personnel with the characteristics and adaptability of the plastic patch and the precautions to be followed in determining the amounts of material to use.

C. To acquaint personnel with the need for strict observance of safety precautions at all times.

II. MATERIAL.

A. Training Aids.

1. Ship's plastic pipe patching repair kit.

2. Split section of pipe patch.

3. Section of pipe with hole for demonstration.

4. Film, MN 9537C, Damage Control-Plastic Repairs, 20 minutes.

B. References.

1. Training Manual for Emergency Damage Control Metallic Pipe Patch, NAVPERS 91845 (1953).

2. MSTSPACAREA Emergency Pipe Repair Pamphlet, Volume No.1, Plastic Patching.

3. Training Manual for Damage Control Metallic Pipe and General Purpose Repair Kit, NAVSHIPS 250-638-2 (1959).

4. Manufacturers' Instruction Manual.

C. Handouts.

1. Types and Treatment of Ruptures.

2. Pre-cutting Patch Materials.

3. Preparing a Patch (D. C. Metallic Pipe Patch Kit).

4. Applying Patch (D. C. Metallic Pipe Patch Kit).

III. INTRODUCTION.

A. Introduce self and subject, Plastic Patching.