(2) Move the skillet to closed position marked CAL STD and with center knob adjust the needle to coincide with the RED pointer. This pointer is preset to the correct value of STANDARD in the skillet.

(3) Repeat (1) and (2) above till the needle settles on A and the RED pointer when the skillet handle is shifted between these two positions. When using the CP 95 computer-indicator, check needle in A and CAL STANDARD at frequent intervals (about every tenth DT 60 reading) for accuracy.

c. Reading the DT-60 Dosimeter.

(1) Open the DT 60 with wrenches or opening studs on top of CP 95 case under the handle. Take care not to touch the surface of the phosphor glass crystal.

(2) Log the serial number of the DT 60

(3) Place the crystal bearing half of the DT-60 in the receiver socket of the skillet.

(4) Read first on the 600R scale, then, if the reading is below 200R, read on the 200R scale.

(a) On the BLACK scale (o to 200R), the value of each division of the scale is 10R.

(b) On the GREEN scale (0 to 600R), the value of each division is 20R.

(5) Log the reading obtained on the lowest scale.

(6) Open the reader by moving the skillet handle all the way to the left. Remove the DT-60, reassemble with wrenches or studs on the CP-95 case, and return the dosimeter to the wearer.

D. Demonstration of Operation.

1. Using the radioactive source, demonstrate the operation of each radiac instrument to the group.

2. Then permit each trainee to operate the equipment himself.

E. Film. Briefly introduce and show training film MA 6730A, An Introduction to Radiation Detection Instruments, or appropriate films from the MN 8694 series, Radiac Equipment.

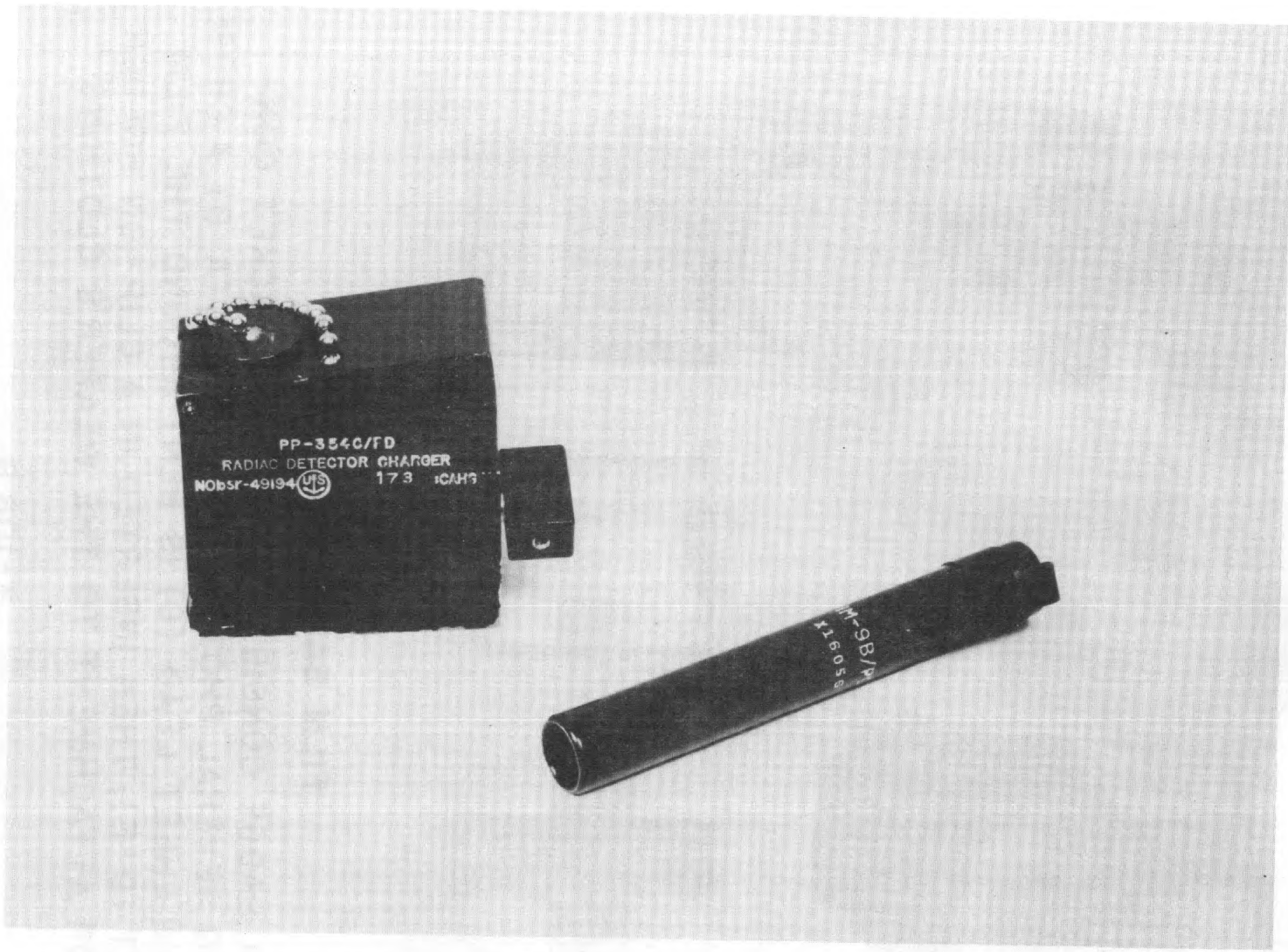
F. Radiac Allowance. Radiac equipment in MSTS ships includes some or all of the following allowances:

RADIAC EQUIPMENT IN MSTS SHIPS*

INSTRUMENT	PURPOSE	RANGE	POWER	REMARKS
RADIAC SET AN/PDR-18 Series (High Intensity Measurements)	Survey	0 to .5 R/HR 0 to 5.0 R/HR 0 to 50 R/HR 0 to 500 R/HR	Battery	Must be checked every six months by authorized radiac repair shop.
RADIAC SET AN/PDR-27 Series (Low Intensity Measurements)	Survey	0 to .5 MR/HR 0 to 5.0 MR/HR 0 to 50 MR/HR 0 to 500 MR/HR	Battery	Must be checked every six months by authorized radiac repair shop.
SURVEY METER ALPHA (Passenger ships only)	For Monitoring Food	0 to 10,000 DM	Battery	Must be checked every six months by authorized radiac repair shop.
PHOSPHOR-GLASS DOSIMETER DT-60/PD	Personnel protection	0 to 600 R	None required	Non-indicating. Must be read with a "Computer-Indicator" CP-95/PD.
POCKET DOSIMETER IM-9/PD	Personnel protection	0 to 200 MR	Set on zero by charger	Current pocket dosimeters are unreliable. New type being developed.
RADIAC DETECTOR CHARGER PP-354/PD	Charging Pocket Dosimeters		Self-contained electrostatic generator	Used in charging: AN/PDR-17, IM-8/PD, IM-9A/PD, IM-19/PD, IM-21/PD, and IM-22/PD
COMPUTER INDICATOR CP-95/PD	For use with DT-60/PD	0 to 200 R 0 to 600 R	120 Volt AC	Reading is total radiation dosage to which the DT-60/PD has been exposed.

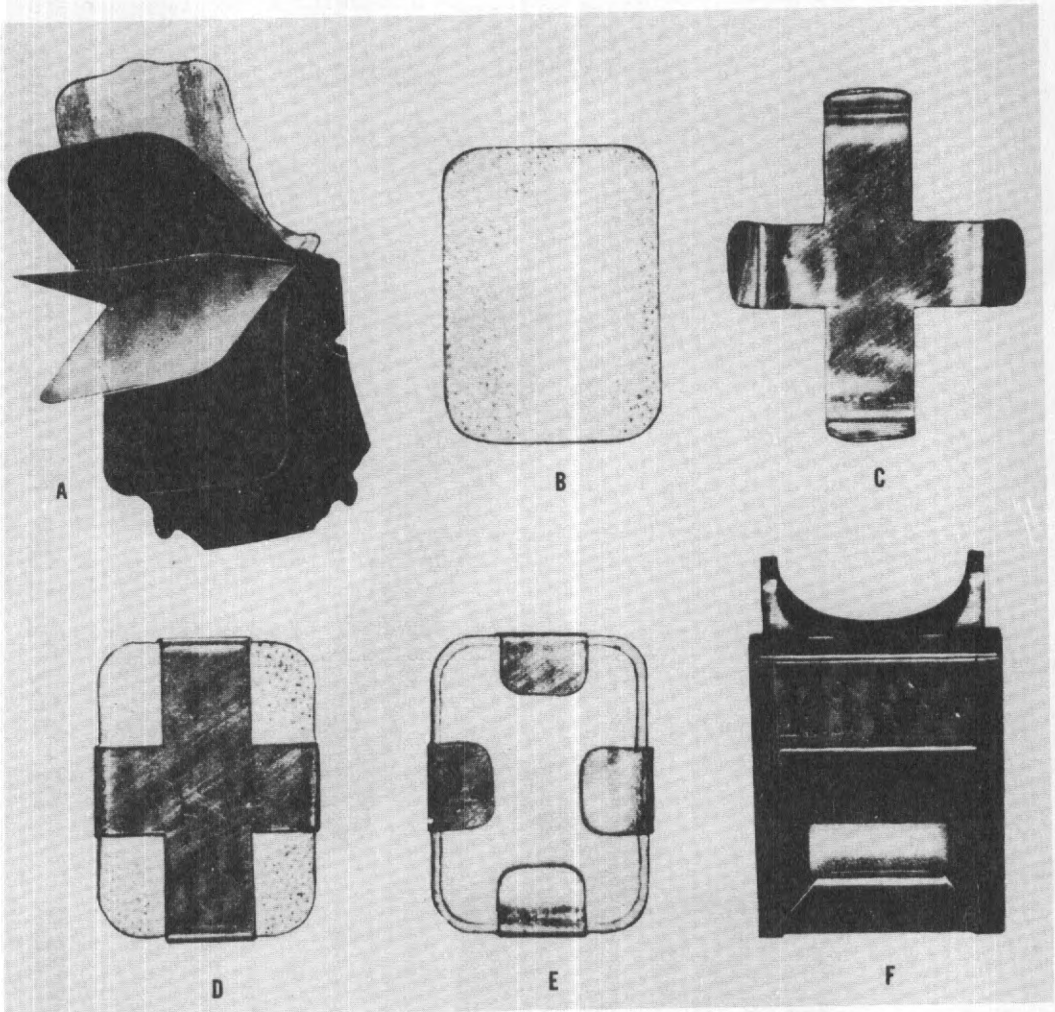
* Radiac equipment allowances for MSTS ships in-service are established by and contained in COMSTS INSTRUCTION 9670.1 (Allowance of Electronic Equipment for MSTS ships in service; establishment of). Radiac equipment allowances for MSTS ships in commission are established by and contained in OPNAVINST 09670.2 (Ship Type Electronics Plan).

NOTE. New, improved radic equipment is under continual developement, with a considerable time lag before its shipboard availability. In the meantime, older equipment becomes difficult to maintain and may be declared obsolete. Therefore, this list is not necessarily up to date but does indicate the types of equipment generally available for training purposes.



PP-354 C/PD CHARGER

IM-9B/PD LOW RANGE SELF-READING POCKET DOSIMETER



FILM BADGE AND HOLDER

A FILM BADGE CONSISTS OF A SMALL PACKET CONTAINING SEVERAL PHOTOGRAPHIC FILMS (A-B), A CROSS OF THIN SHEET LEAD (C) IS BENT AROUND THE FILM PACKET (D-E), THEN INSERTED IN A CLIP-ON HOLDER (F) FOR ATTACHMENT TO THE WEARER'S CLOTHING.

V. SUMMARY. - Show, describe and demonstrate the use of the following radiac instruments:

A. Hi-R Equipment. Portable survey equipment capable of detecting and indicating the presence of high intensity of gamma radiation, from 0 to 500 roentgens per hour.

B. Lo-R Equipment. Portable survey equipment capable of detecting and indicating the presence of low intensity (low roentgen) of beta-gamma radiation, from 0 to 500 milliroentgens per hour.

C. Phosphor-Glass Dosimeter. A badge used for personnel protection; has a range of 0 to 600 R/HR. No power such as batteries is required. It is non-indicating and must be read with a computer-indicator.

D. Radiac Computer-Indicator. Designed for computing and indicating the total amount of X-ray and gamma radiation to which dosimeter DT-60/PD has been exposed. Power required for operation is 120 volt AC. Range is 0 to 600 R/HR.

E. Radiac Detector Charger. Used for charging the pocket dosimeter. Power is supplied from a self-contained frictional electrostatic generator (currently, pocket dosimeters are unreliable but a reliable model is being developed).

NOTE: New equipment will be provided as developed and available.

VI. TEST AND APPLICATION.

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

1. Q. Define a "dose rate" meter.
A. A "dose rate" meter is a device that measures the intensity of radiation in roentgens per hours, similar to a speedometer reading in "miles per hours".

2. Q. What is the purpose of a phosphor-glass dosimeter or badge?
A. A phosphor-glass dosimeter is a device used to indicate the accumulated dosage of radiation; it is similar to total miles driven on a speedometer.

3. Q. What is the difference between a high intensity meter and a low intensity meter?
A. High intensity devices read in roentgens (R) and low intensity devices read in milli-roentgens (MR).

4. Q. May shipboard personnel service radiac instruments?
A. No. Shipboard personnel are not permitted to service radiac equipment. These instruments are very delicate and sensitive and must be serviced only in authorized radiac repair shops.

5. Q. Can nuclear radiation be detected by any of the five natural senses?

A. No. It can be detected only with radiac instruments.

6. Q. How is the phosphor-glass dosimeter (DT-60) read?

A. It is read by the use of an auxiliary device called a "Computer-indicator".

7. Q. What radiac equipment is included in allowances of MSTS ships?

A. Radiac set (high intensity)
Radiac set (low intensity)
Phosphor-glass dosimeter, pocket dosimeter, radiac detector-charger, and computer-indicator.

8. Q. Define the term "radiac".

A. "Radiac" is the term given to all radio-activity detection instruments. It stands for Radiological Activity Detection, Identification, and Computation.

9. Q. Name the three basic types of nuclear radiation given off by radioactive elements.

A. Alpha particles, beta particles, gamma rays.

10. Q. Name the three main purposes of monitoring for nuclear radiation.

A. To determine location, intensity and dose rate of radiation to which exposed personnel have been subjected.

B. Application - Have each individual demonstrate his knowledge of and ability to take readings with the various radiac instruments.

R - Radiological
A - Activity
D - Detection
I - Identification
A - And
C - Computation

VII. HANDOUT. A convenient radiation dosage calculator has been placed aboard many ships (see illustration of next page). The following directions for its use may be reproduced as a handout and for reference purposes.

DIRECTIONS FOR USING THE RADIATION DOSAGE CALCULATOR

A. Radiation Hazard. After a nuclear explosion, there is danger of residual radioactivity caused by fallout in the case of an air burst, or by the base surge or radioactive rain in an underwater burst. After the fallout is over, the radioactivity decreases with time, rapidly at first, then more and more slowly, through natural decay.

B. What the Calculator Will Do. The radiation dosage calculator will solve three types of problems:

1. It will predict the dosage rate at any future time (or give the rate for any time past).

2. It will find the total dose accumulated by one person (or persons) up to the present time.

3. It will determine the stay time for any permissible dosage (the length of time one can remain exposed): Entry time, or exit time.

C. Background Information. The master, damage control officer and ABC defense officer should know or determine the following before using the calculator:

1. The units of measurement for DOSE and DOSE-RATE are roentgens (r) and milliroentgens (mr), or one-thousandth of a roentgen. "K" on the outer dial ("A" dial) means thousand, so 1K equals 1000 units. The "A" dial is the one on which all DOSE or DOSE-RATE readings in roentgens or milliroentgens are read. *

2. As in reading from a speedometer, the DOSE-RATE readings are in r/hr or mr/hr and the DOSE readings are in r or mr, as "miles traveled", or amounts of radiation exposure during a given time. *

3. The middle dial (red or "B" dial) is the "TIME after the detonation" dial. All times are measured from the TIME of the incident - the "H" hour. *

4. The inner dial (black - "C" dial) is the "TIME OF EXPOSURE" dial, which is used for all problems involving total DOSE received during any length of time in a contaminated area. *

5. The master must know the permissible whole body doses (if only a part of body is exposed, there is less danger):

a. In peacetime, 5 r is the highest permissible accumulated dose in a year.

b. An accidental or emergency dose of 25 r over the whole body is assumed to have no permanent effect, but this dosage should occur only once in a lifetime.

c. In wartime, military necessity may call for greater exposures than the above.

6. If readings taken through a door continue to rise, keep under cover, since fallout is continuing.

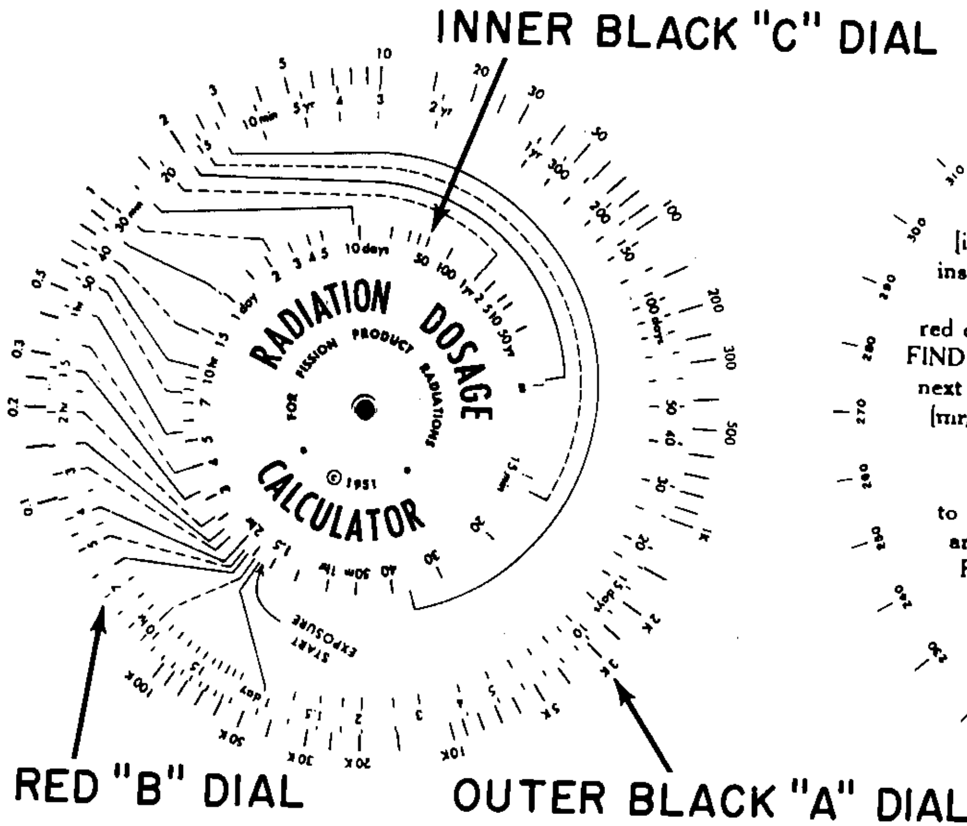
7. Constant, or decreasing, radiation level readings at a selected interior location will indicate when fallout has ceased.

D. Procedure in Solving Problems. *

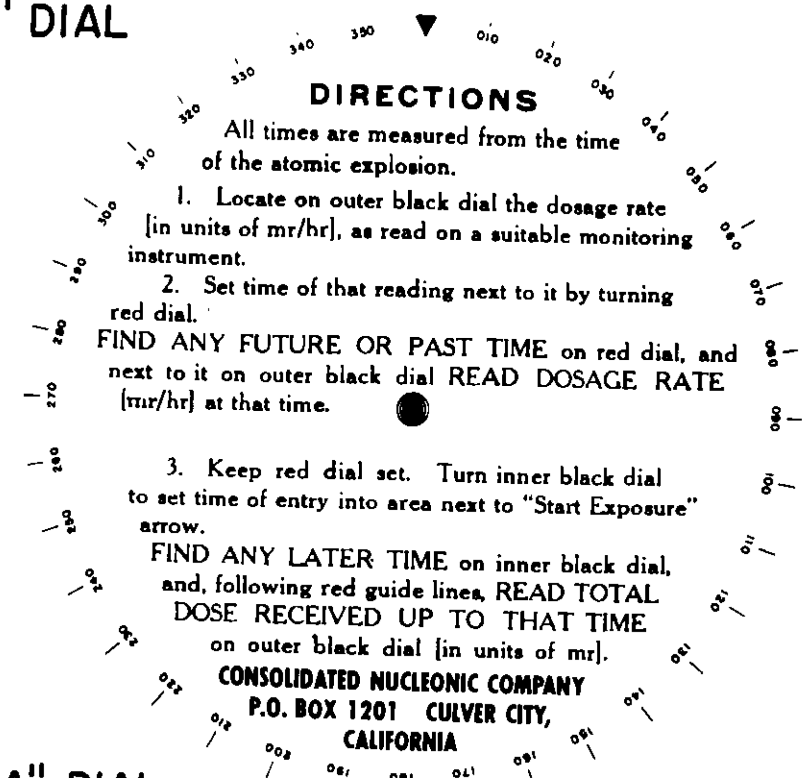
1. Sample DOSE-RATE problem.

3-110-B

FRONT



BACK



DIRECTIONS

All times are measured from the time of the atomic explosion.

1. Locate on outer black dial the dosage rate [in units of mr/hr], as read on a suitable monitoring instrument.

2. Set time of that reading next to it by turning red dial.

FIND ANY FUTURE OR PAST TIME on red dial, and next to it on outer black dial READ DOSAGE RATE (mr/hr) at that time.

3. Keep red dial set. Turn inner black dial to set time of entry into area next to "Start Exposure" arrow.

FIND ANY LATER TIME on inner black dial, and, following red guide lines, READ TOTAL DOSE RECEIVED UP TO THAT TIME on outer black dial [in units of mr].

CONSOLIDATED NUCLEONIC COMPANY
P.O. BOX 1201 CULVER CITY, CALIFORNIA

a. Facts given. Ten hours after the explosion (H + 10) a survey meter gives a reading of 200 mr/hr in a contaminated area.

b. To Find. What will be the DOSE-RATE reading at 1 day (24 hours) after the explosion (H + 1d)?

c. Procedure. Using the outer and middle dials only ("A" and "B" dials), rotate the red "B" dial until the 10 hour mark is directly opposite 200 (mr) on the black "A" dial. Then opposite the 1 day mark on the red "B" dial, read 70 as the answer on the black "A" dial. This is in mr/hr, since your original reading was given in mr/hr. If the original units were r/hr, the answer would be in r/hr. This same setting can be used for determining the predicted DOSE-RATES at any future time - or vice-versa, the time at which any specific dose-rate reading can be expected.

Example: To find the time at which the intensity would fall to 10 mr/hr, based on the same facts as in the previous problem, use the same basic setting, locate 10 on the outer black "A" dial and read 5 days on the red "B" dial as the answer.

2. Sample ACCUMULATED DOSE Problem.

a. Facts given. The dose-rate reading at H - 10 was 20 r/hr. A man was observed entering the area at H + 7.

b. To Find. What will be his accumulated dose to the present time - 10 hours after the explosion (H + 10)?

c. Procedure. The two outer dials are rotated so that 20 (r) on the outer black "A" dial is opposite 10 hrs on the red "B" dial. Rotate inner black dial ("C" dial) until the 7 hr mark is opposite the end of the START EXPOSURE arrow on the red "B" dial. Place the 7 hr mark opposite the end of the arrow, not the line next to it. Now locate the 10 hour mark on the "C" dial, follow the red guide line out to the outer black dial ("A" dial - DOSE reading dial) and read about 80 (80 r, since the original Dose Rate was in r/hr).

NOTE: Since the 10 hour mark on the inner black "C" dial is slightly "behind" the red guide line, a corresponding proportionate correction is made in reading the correct answer off the outer black "A" dial.

3. Sample STAY-TIME Problem.

a. Facts given. The Dose-Rate reading is 3r/hr at H + 5 hrs. The Master has set the MAXIMUM PERMISSIBLE EXPOSURE DOSE (MPE) at 20r.

b. To Find. STAY-TIME in the area for a man who enters at 5 hours after the blast (H + 5).

c. Procedure. Use same basic procedure for setting "A", "B", and "C" dials as for previous problem - except the initial readings and conditions are now 3 r/hr at H + 5. The new condition for which answer is needed is that the man should not be allowed to accumulate more than a dose of 20r, as set by the Master. How long can be STAY in the contaminated area?

After setting 3 (r) on the outer black "A" dial opposite 5 hrs on the "B" dial, and ENTRY time at 5 hrs on the "C" dial, find the maximum dose reading 20 (r) on the outer black "A" dial, follow the red guide line on the "B" dial down inward to the inner black "C" dial and read 1 day. This is TIME AFTER the blast - to determine the approximate number of hours the man should be allowed to STAY in the area after he entered, it would be necessary to subtract the 5 hours (he entered at H + 5) from 1 day. The STAY-TIME then would be:
1 day, or 24 hours, minus 5 hrs., equals 19 hrs. as the answer.

4. Variation. Often you are interested in determining when you can ENTER a contaminated area and STAY for a period of time without exceeding an established radiation exposure limit.

a. Facts given. The MPE is 25r and the original DOSE-RATE reading is 16r at H + 3 hrs.

b. To Find. When can you enter the area to perform rescue work estimated to require 4 hours STAY-TIME without exceeding the MPE of 25r?

c. Procedure. Set the 16 (r) DOSE-RATE on the outer black "A" dial opposite the 3 hr marker on the red "B" dial.

Note the 25(r) DOSE mark on the outer black "A" dial and follow the corresponding red GUIDE LINE down or in toward the "C" dial. This guide line and the "START EXPOSURE" marker now represent the two limits between which you want to place the earliest 4 hrs of STAY-TIME, as indicated on the inner "C" dial. By moving the various hour markers on the "C" dial back and forth so that a total of 4 hrs of elapsed time can be "compressed" between these two limits, it will be seen that the earliest time at which this can be done is with the space between the hour markers of 5 hrs ENTRY TIME and 9 hrs EXIT TIME.

It will be noted that if you place the 4 hr marker at START EXPOSURE, the next 4 hours of elapsed time would carry you beyond the 25r limit line. This, then, indicates that this would be too early as an entry time. In like manner, any trial after 5 hrs Entry Time would indicate that 4 hours elapsed time would fall well within the 25r limit.

Accordingly, the answer to your problem is: ENTRY TIME should be at H + 5.

5. Directions. The directions on the back of the calculator should also be studied and used in solving similar practice problems.

E. Stowage of Calculator. Recommended stowage of the calculator is in a conspicuous cloth pocket in damage control central.

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 (when available). 26 minutes

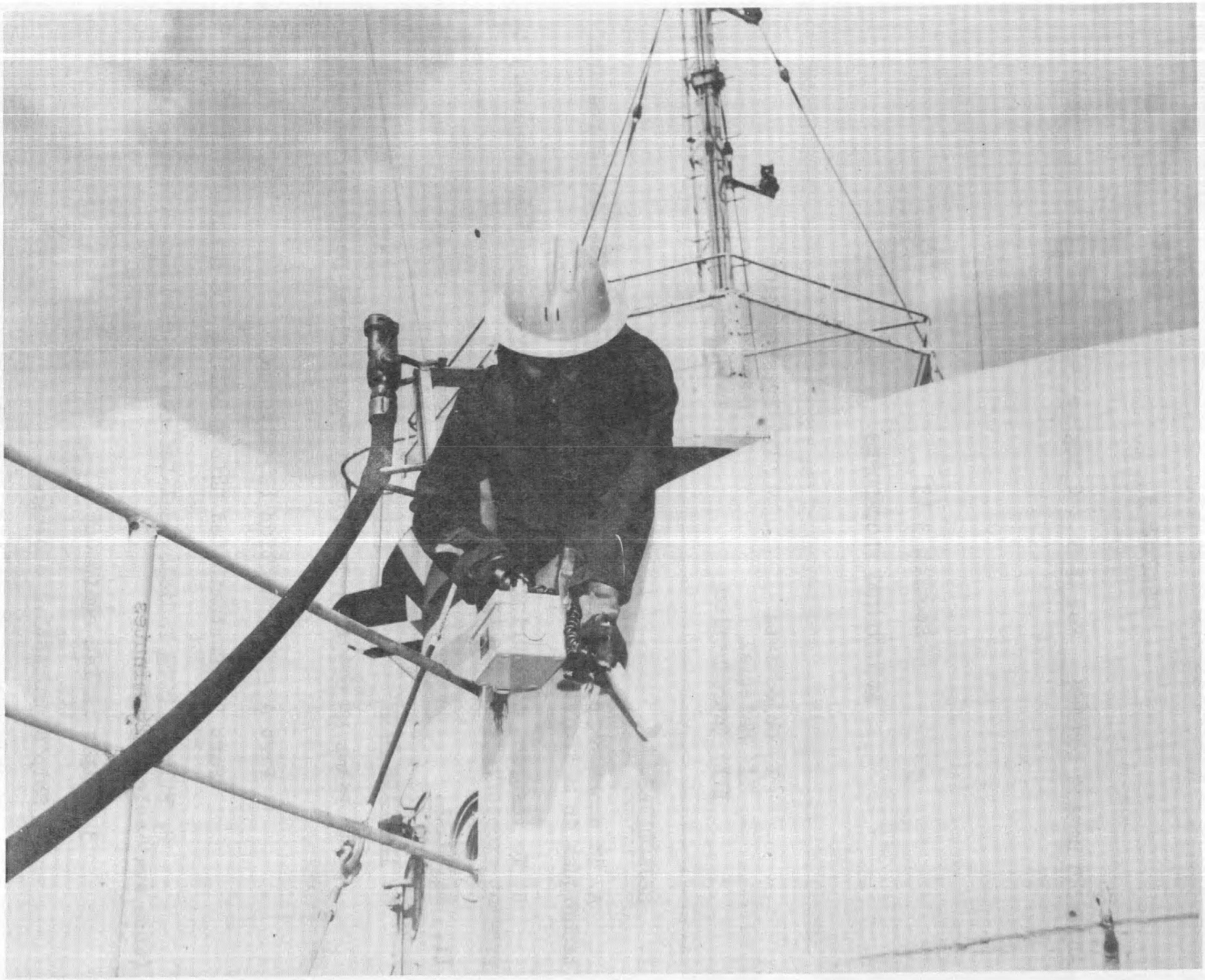
3. Ship's radiac equipment.

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. Radiological Defense - Volumes II and IV.

2. Instruction Guide for Shipboard Atomic Defense (Radiological Aspects, NAVPERS 10886).

3. ABC Warfare Defense, NAVPERS 10099.

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, ABC 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.

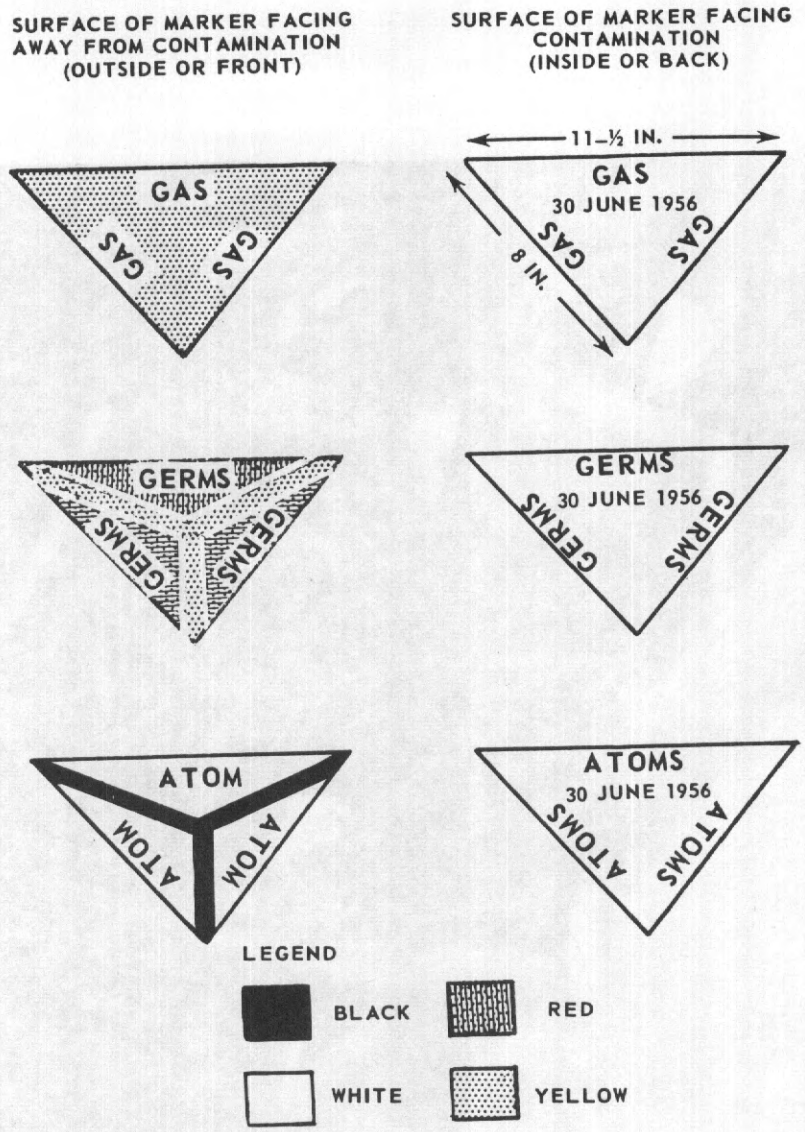
e. Monitor openings to weather deck areas.

V. <u>SUMMARY</u>.

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.

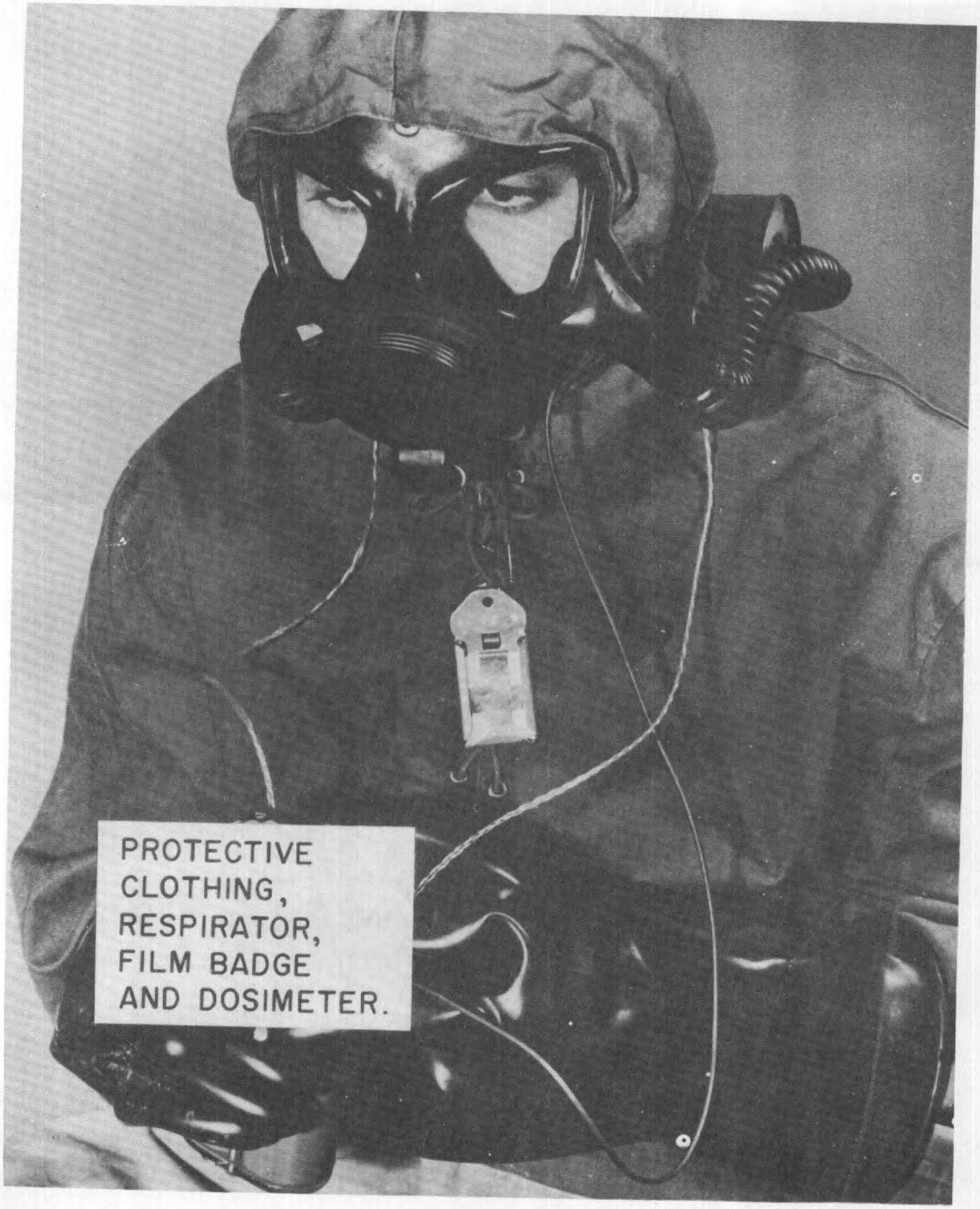
8. Q. After contaminated personnel have taken a hot shower with several soapings and rinses, what is the next step in the decontamination process?
A. Monitor them thoroughly and re-shower if necessary.

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.

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.

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 ABC 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 locker or other interior location.

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

Continue the washdown until conditions are determined to be safe and the fallout 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 on page 3-110A 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.

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4. The ~~repair party officer or assistant~~ OinC monitoring teams will:

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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 ABC officer.

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.

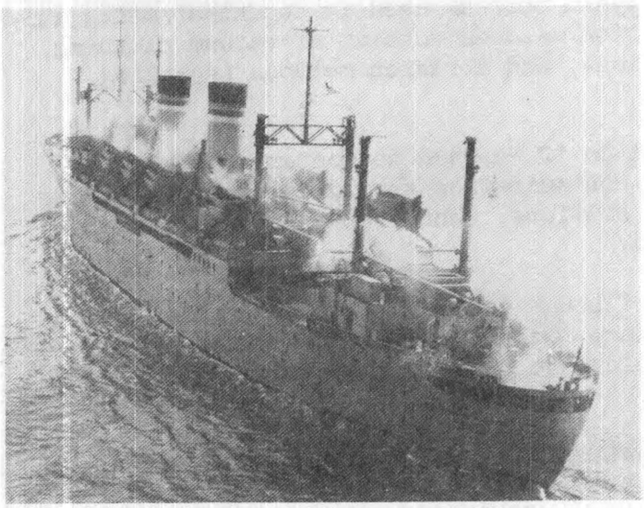
11. Q. What is "detailed contamination"? State the three main procedures used.

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.

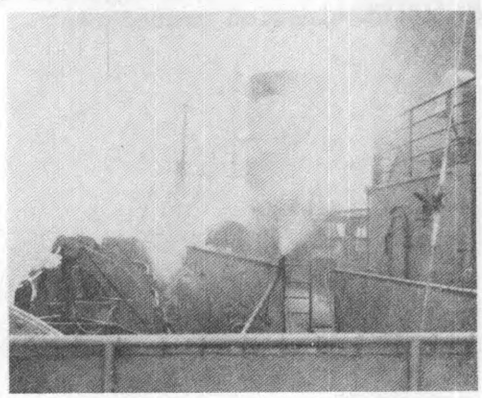
The addition to the list is the MSTS washdown system of countering radioactive contamination. Now in a state of readiness on all nucleus ships, it has been adopted by the Maritime Administration at the suggestion of C. P. Milne, Assistant Secretary of the Navy (Material), following tests by BuShips. 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.

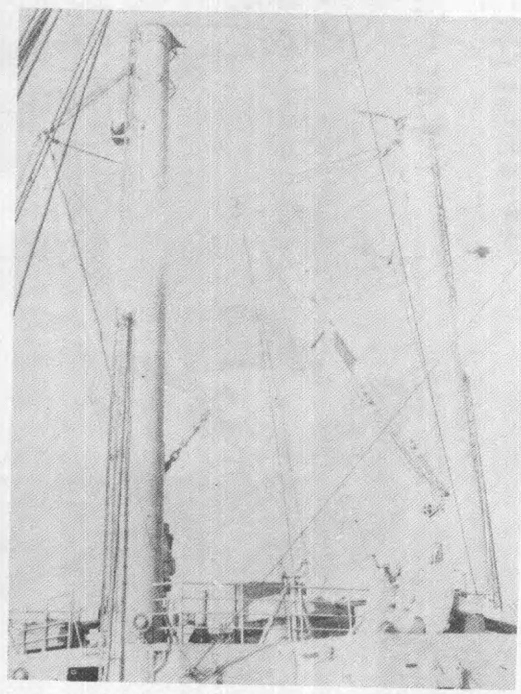
"To be readily available in the event of mobilization or surprise attack, the Department recommends that a method for washdown be provided on all merchant ships . . . installing clips similar to those now in use on ships in the Military Sea Transportation Service . . . .

"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.


DAMAGE CONTROL
LOCKER NO.1

CHAPTER 4

OFFICERS DAMAGE CONTROL

Section

USNS MISSION SAN MIGUEL
LOST THROUGH GROUNDING
ON MARO REEF, HAWAIIAN IS.,
8 OCT. 1957

CHAPTER 4

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

SECTION 4.1

FUNDAMENTALS OF SHIPS STABILITY

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

C. Of all the facets of damage control, stability is the most important. In order to have the ability to right itself, the ship must have buoyancy, proper weight distribution built into the ship, and good cargo, fuel or other weight stowage. Some of these elements of stability are fixed by being built into a ship, others are adjustable by the ship's officers. The inherent moment of forces righting the ship in excess of the moments heeling the ship is the margin of stability. Measuring and providing this margin is the purpose of all stability studies. The purpose of this lesson is to examine each of the elements making up a ship's stability and to understand its contribution to the final situation.

1. Any weight added, removed, or shifted in a ship may affect its stability. As a ship assumes deeper drafts, due to the addition of weights, its reserve buoyancy is reduced. The location of these weights has a definite relationship to the resultant stability. A vessel may be well within her load-line requirements and yet be deficient in stability.

2. The addition of any foreign weights, such as the water from flooding after a collision, ruptured piping, or fire fighting tactics, can be extremely hazardous. This is not only because of the added weight but also due to the free surface effect of the liquid which causes a virtual rise of the ship's center of gravity. Free surface effects in slack tanks have the same effect and should therefore be kept to a minimum. Each ship has its own stability characteristics and its officers should become familiar with them and be governed accordingly and, in addition, apply the basic concepts of stability at all times.

D. In a ship whose master and officers have the knowledge to plan "What to do in Case of Disaster," the chance of survival in a casualty situation are greatly increased. 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 buoyance 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 free board. 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 3 to 5 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. The free water in the bilges reduced her stability further; the list became greater 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 page 7-54.)

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.)

E. Stability is therefore a factor that must be constantly guarded and which, in time of war, becomes even more important when - to the dangers of collision, grounding and storm, the possibility of attack from the sea or air is added. Nevertheless, whether in peace or in war, the importance of stability should be strongly emphasized, because a ship is a large investment, both in lives and in property, and the loss a major disaster to any owner or nation.

IV. PRESENTATION.

A. Basic Principles.

1. Density. The weight of a substance per unit volume is called DENSITY. This can be expressed as follows: Density equals weight divided by volume. In the English system, the density of fresh water at average temperature is 62.4 lbs. per cubic foot. Similarly, ordinary salt water is 64 lbs. per cubic foot. In the metric system, fresh water is one gram per cubic centimeter. As an example, a piece wood 6' x 1' x $\frac{1}{2}$' would have a volume of 3 cubic feet. If its weight is 90 lbs., its density would be:

$$\text{Density equals } \frac{90}{3} \text{ equals 30 lbs. per cubic foot}$$

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

3. Reaction. For every action of a force there is an equal and opposite reaction. For instance, a box weighing 100 lbs placed on a firm support will create a reaction of 100 lbs acting in the same direction as that of the weight or force exerted by the box.

4. Equilibrium. A body cannot be in equilibrium under the action of a single force. If a force and its reaction balance they must have the same line of action, the same magnitude, and must be opposite in sense in order to establish "equilibrium."

5. Center of Gravity. The center of gravity (CG) of a body or mass is the point at which the total weight of the body acts. For instance, the CG of a uniformly thick circular disc would be in the center of the circle and thickness. In a square or rectangular board it would be in the middle at the intersection of the diagonals. In a triangle, the CG would be located 1/3 of the height above the base of the triangle.

6. Moment. The moment of a force, area or weight, with respect to a reference point or axis, is the product of the force, area or weight, and the perpendicular distance from its line of action to the reference point. Figures 1, 2, and 3 illustrate "moment:"

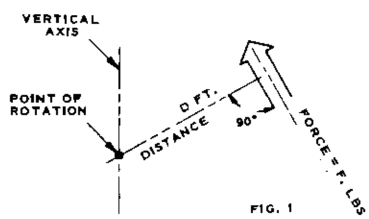


FIG. 1

MOMENT = F X D = FT.-LBS

OR $D = \frac{MOM}{F}$

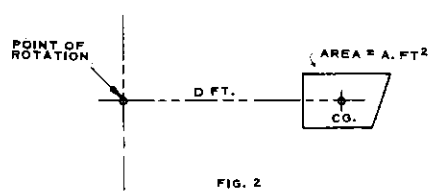


FIG. 2

MOMENT = A X D

OR $D = \frac{MOM}{A}$

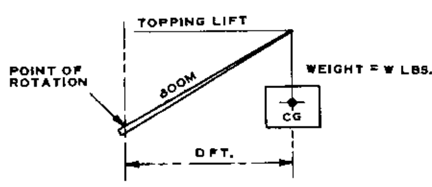


FIG. 3

MOMENT = W X D

OR $D = \frac{MOM}{W}$

a. As a further example of moment, consider a seesaw where a man of 200 lbs. is sitting on one side 2.5 feet from the pivoting point and a boy of 50 lbs. is on the opposite side 10 feet from the pivoting point. What would the moment be and would the seesaw be balanced or in equilibrium?

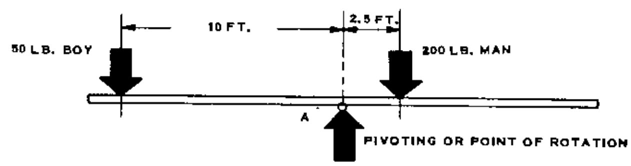


FIG. 4

The moment of the left side of A would be M equals 50 lbs. x 10 ft. equals 500 ft. lbs. The moment on the right side of A would be M equals 200 lbs. x 2.5 ft. equals 500 ft. lbs. This shows that the moment to the left as well as to the right of the pivoting point A is the same and therefore the seesaw will be in equilibrium.

b. Couple. A special case of moment is that where two parallel forces, acting in the same plane and of equal magnitude, but different in sense and line of action, form what is called a "couple." The perpendicular distance between the lines of action of the two forces is called the "arm" of the couple. The following illustrates the particulars of a couple.

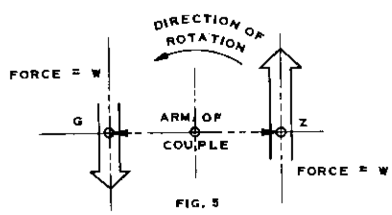


FIG. 5

Therefore, in accordance with the above definition, the couple shown would have a moment: M equals W(GZ). If the two forces are viewed from the middle of the arm (GZ), it is evident that the couple would create a rotation counterclockwise in the direction shown by the arrow.

B. Calculation of CG.

1. Example #1. As a clarification of moment and the center of gravity (CG), Fig. 6 shows several weights and their relation to a reference line or axis. It is required that the moment and CG of this group of weights be determined relative to the reference line.

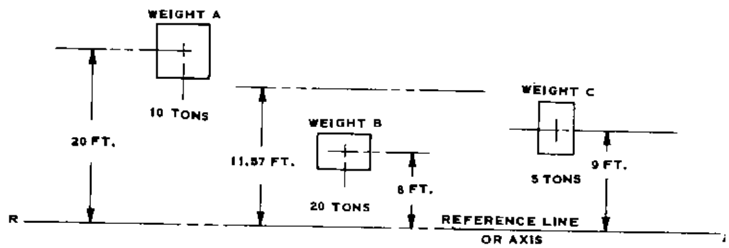


FIG. 6

	Weight		Vertical Distance Above Base Line		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

Then the location of the center of gravity CG above the reference line equals 405 divided by 35 or 11.57 feet. In other words, if the total of weights A, B, and C (35 tons) was placed at the line through the CG, 11.57 ft. above the reference line, it would produce the identical moment to that obtained by adding the individual moments from each of the separate weights A, B, and C. The location of the CG of the system corresponds to the definition of CG as the point at which the total weight of the body acts. This is because the total effect of the 35 tons at the CG 11.57 ft. above the base line would produce a moment 11.57 ft. x 35 tons equals 405 ft-tons, which is identical to the summation of the moments from the individual weights.

2. Example #2. When dealing with weights and centers it is important to recognize the overall effect caused by changing the quantity and location of an individual weight. This is illustrated by increasing B as used in Fig. 6 to 30 tons and the vertical distance to 12 ft.; Fig. 7 shows the effect of this change.

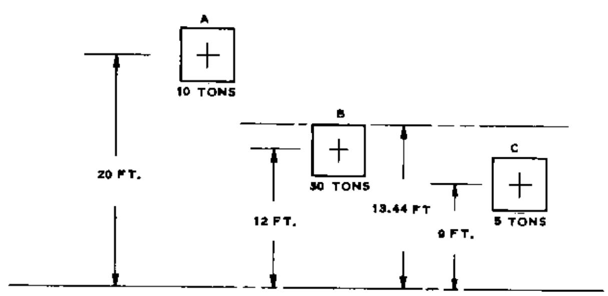


FIG. 7

	Weight		Vertical Distance Above Base Line		Vertical Moment
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

Then vertical CG equals $\frac{605}{45}$ equals 13.44 feet or the rise in the CG equals 13.44-11.57 equals 1.87'

3. Determination of CG in a ship. As illustrated in the above calculations, the total moment divided by the total weight gives the distance of the CG 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 horizontal and vertical 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. Location of CG vertically. The vertical CG is usually at some point in the centerline plane of the ship, except where there may be an unequal weight distribution between the port and starboard side off centerline. Where an unsymmetrical weight distribution exists, an additional moment calculation must be made to determine the horizontal position of the CG relative to the centerline or to an arbitrary selected reference line parallel to the vertical centerline of the ship.

5. Location of CG fore and aft. To determine the fore and aft position of the CG, a moment calculation is also made, usually using the forward perpendicular of the ship as the reference line. If the midship ordinate is used, the forward moments are assigned a plus value and those aft of midship a minus value. Their difference indicates whether the resulting moment is forward or aft of the ordinate. This, however, is conductive to errors in signs and therefore many designers prefer using the forward perpendicular as the reference line.

C. The Flotation of a Ship.

1. Ship upright. When a ship is floating at rest in still water, two resulting forces establish equilibrium:

a. The weight of the ship acts vertically downward through the center of gravity (CG).

b. A reactive force of the same magnitude acts vertically upwards through the center of gravity of the immersed hull, the center of buoyancy (CB).

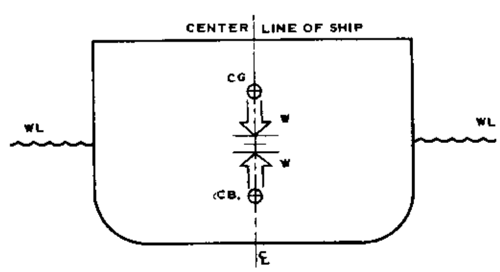


FIG. 8

Illustration, Fig. 8 shows a transverse section of a ship as she floats upright in water. In this instance, the weight of the ship, W, acting downward through the CG of the mass of the ship, is equal to the reactive force acting upward through CB and both forces are therefore in the same vertical line. For this reason, the ship will be in a state of equilibrium and will remain in an upright position unless external forces such as wind and waves disturb its equilibrium and causes it to heel to one side as shown in Fig. 9.

2. Ship heeled. In Fig. 9, the weight of the ship, W, is acting downward through the CG of the ship. This CG does not change due to the heel but remains a fixed point unless a change of weight location is made in the ship itself or by adding or removing cargo or any other heavy weights.

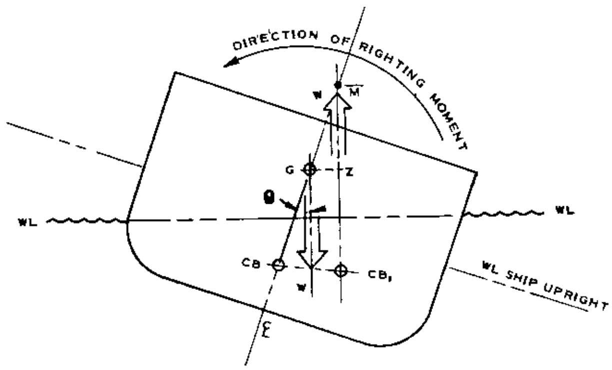


FIG. 9

With the ship heeled, the center of buoyancy, CB, has now moved from the centerline of the ship to a new position, CB_1, to starboard of the centerline. Bearing in mind that the CB is the center of gravity of the water displaced, its change of position is a result of the change in shape of the displaced water.

a. Righting moment. In contrast to the ship when upright, as in Fig. 8, the weight of the ship acting downward through the CG and the equal upwards force acting through CB_1 now forms a couple with an arm, GZ, creating a righting moment. This righting moment, M equals W x GZ, tends to return the ship to its upright position. The magnitude of the righting moment is a measure of the ship's ability to survive when its watertight integrity is seriously damaged.

3. Initial stability, GM, righting moment. In Fig. 9, note that a change in the righting arm, GZ, affects the distance GM. This distance, GM, is a measure of the ship's initial stability. Within a limited heel of 10 to 15 degrees, the GM, which indicates the ship's initial stability, can be expressed as follows:

$$GM \text{ equals } \frac{GZ}{\sin \theta^o}$$
$$GZ \text{ equals } GM \times \sin \theta^o$$

If the value of GZ is substituted in the equation M equals W x GZ, the ship's righting moment would be:

$$\text{Righting Moment (M) equals } W \times GM \times \sin \theta^o$$

EXAMPLE: Figure 10 illustrates the use of this equation. What would be the beam wind load which would heel the following ship 7.5 degrees? (Note: For wind loads, the assumption is usually made that the wind force acting at the CG of the above water profile forms a couple with the reaction force of the water against the underwater profile; this reaction is assumed to act at one half the draft. Assume the center of above water area is 9 feet above ship's water line.)

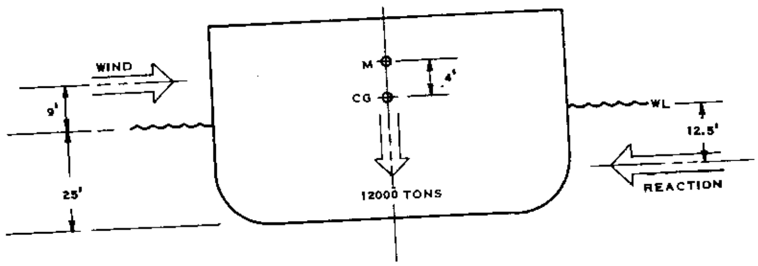


FIG. 10

The heeling moment M equals 50 tons x 20' equals 12000 tons x 3.5' sin θ^o

Sin θ^o equals $\frac{50 \times 20}{12000 \times 3.50}$ equals .0238

θ^o equals 1^o - 22' approximately

As a further illustration consider the ship in Fig. 11 and assume that instead of the wind load a 50 ton weight is placed 20 ft. to one side of the centerline of the ship, assuming a GM of 3.50 ft. but with no change in draft or displacement.

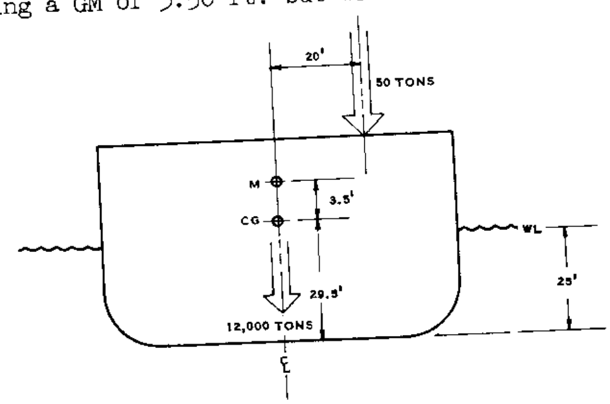


FIG. 11

M equals W x GM x sin θ^o

M equals Wind Force x (9 plus 12.5) equals 12000 tons x 4' GM x sin 7.5^o heel

or 21.50 x Wind Force equals 12000 x 4 x .1305

or Wind Force equals $\frac{12000 \times 4 \times .1305}{21.50}$ equals 292 tons

4. Unstable ship. So far we have considered a ship of characteristics which will provide stability under normal operating conditions. However, other conditions may exist where a ship may be unstable. Fig. 12 shows the relations of characteristics for an unstable ship.

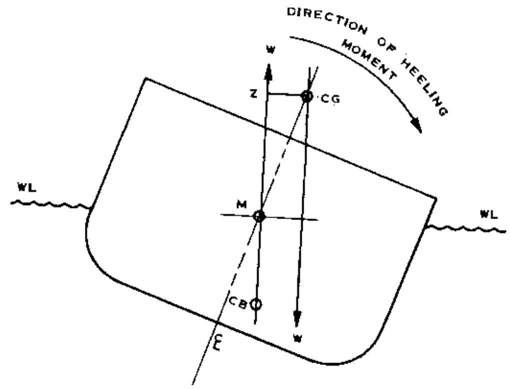


FIG. 12

As indicated, the CG is above the metacenter, M, and the moment W x GZ now tends to increase the heel rather than oppose it as for the stable ship in Fig. 9. Considering the ship represented by Fig. 11, addition of weight such as snow, or deck cargo or burning out of fuel will raise the center of gravity and may result in an unstable condition. For example, what result will burning of 1500 tons of fuel from the double bottom tanks (KG-2 ft.) cause upon the stability of the ship, assuming no change in location of metacenter?

$$\text{New displacement} = 12{,}000 - 1500 \quad 10{,}500 \text{ tons}$$

$$\text{New location of CG} = \frac{\text{Original moment - moment of weight removed}}{\text{New displacement}}$$

$$= \frac{12{,}000 \times 29.5 - 1500 \times 2.0}{10{,}500}$$

$$= 33.4 \text{ ft. KG}$$

This places the center of gravity above the metacenter (33.0 ft. KM) and results in the ship being unstable. On this size of ship, such fuel consumption may readily be experienced in a voyage. The problem of loss of stability will be further considered in the next lesson outline.

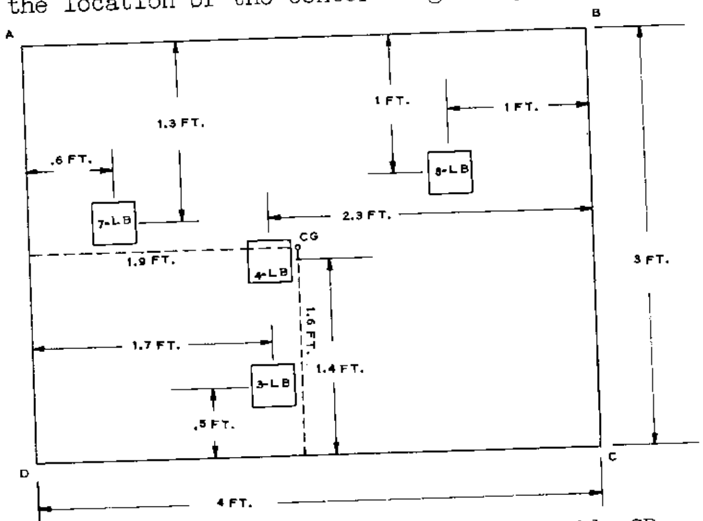
V. SUMMARY.

In summary, the ships stability, stated in its simplest terms, is the combined effect of buoyant forces as determined by the underwater shape of the ship and the weight distribution of the ship. It is in controlling the weight distribution of the ship that the ship's officer controls its stability. This problem, which he must solve, is one involving the ship's center of gravity and its moment as determined by weights and their locations as they are added, removed or shifted. The keys to the problem are, first: Know the starting condition for which the displacement and location of the center of gravity and center of buoyancy are known. Second: Correct the starting condition by adding or subtracting, as appropriate, the weights so that the actual or anticipated condition is reached. This is done with respect to weight (displacement) and moments about base line or other convenient reference line and new centers calculated. Determine if the CG is above or below the metacenter. It must be below for positive stability. Evaluate the degree of positive stability available to assure it is adequate to the anticipated voyage and regulations. Finally, take action with cargo or liquids to increase stability by lowering the CG as needed. As a baby cannot walk until it learns how to balance its weight, and gains strength and skill only by practice, so an officer in thinking for his ship must learn to balance the ship's weight and gain skill through frequent solving of the stability problems constantly presented by his ship as it loads different cargoes and is threatened by hazards of the sea.

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 feet	1.57 feet from CD	44.0

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.

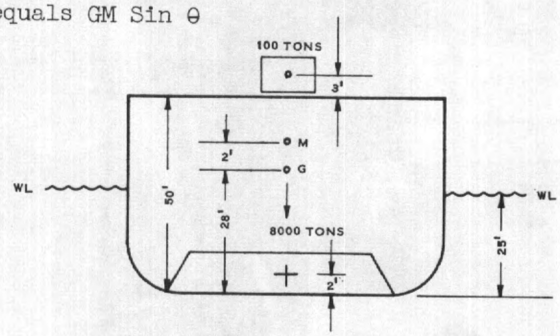
A. That point at which all the vertically upward forces of buoyancy are considered to be concentrated; the center of volume of the immersed portion of the vessel.

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?

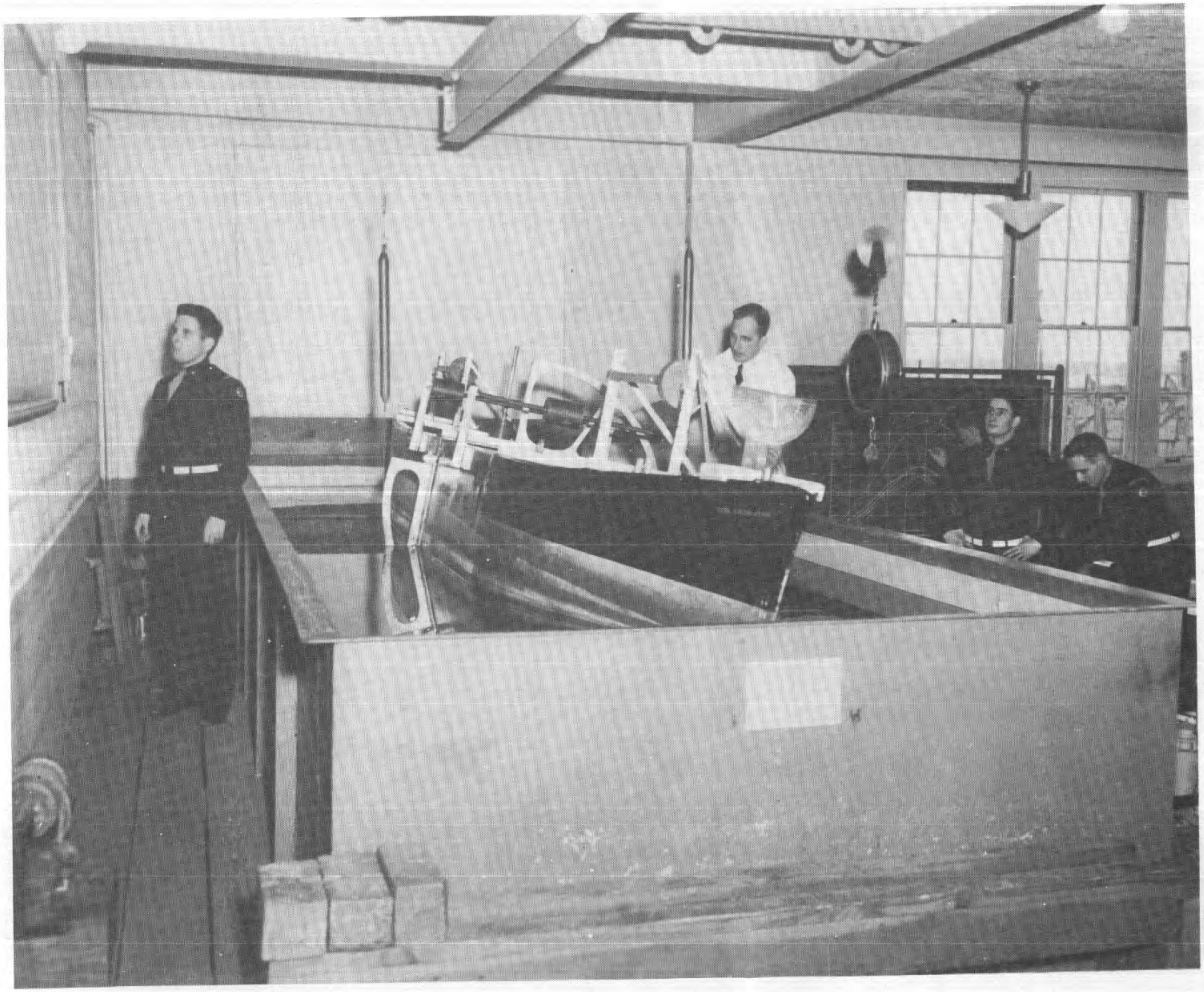
A. 8000 x 28 equals 224,000
-500 x 2 equals -1,000
7500 223,000

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.

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 water-tight 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.

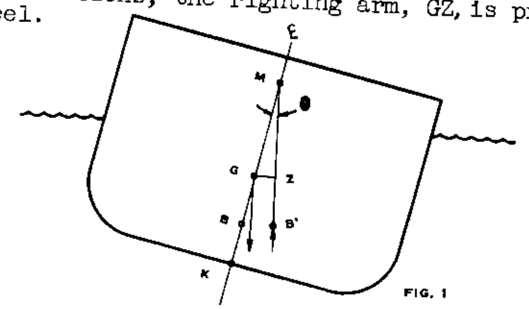


FIG. 1

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.

(4) 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.

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.