CHAPTER 6 - MANEUVERING BOARD MANUAL

PART ONE

OWN SHIP AT CENTER

EXAMPLE 1

CLOSEST POINT OF APPROACH

Situation:

Other ship *M* is observed as follows:

Time	*Bearing*	*Range (yards)*	*Rel. position*
0908........................	275˚	12,000	M_1
0913........................	270˚	10,700	M_2
0916........................	266˚.5	10,000	M_3
0920........................	260˚	9,000	M_4

Required:

(1) Direction of Relative Movement (DRM).
(2) Speed of Relative Movement (SRM).
(3) Bearing and range at Closest Point of Approach (CPA).
(4) Estimated time of Arrival at CPA.

Solution:

(1) Plot and label the relative positions M_1, M_2, etc. The direction of the line M_1 M_4 through them is the direction of relative movement (DRM): 130˚.

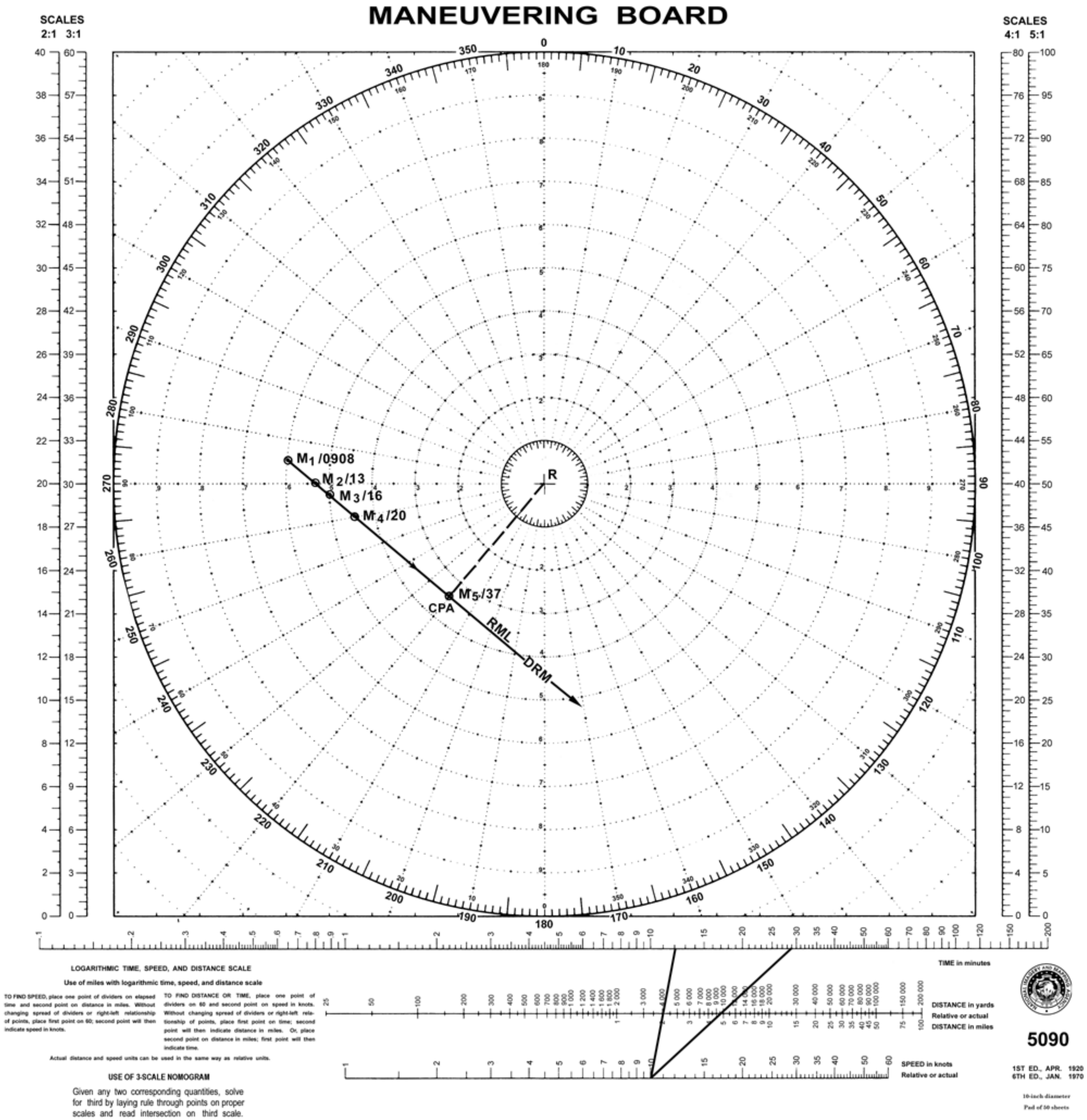
(2) Measure the relative distance (MRM) between any two points on M_1M_4. M_1 to M_4 = 4,035 yards. Using the corresponding time interval (0920 - 0908 = 12^m), obtain the speed of relative movement (SRM) from the Time, Distance, and Speed (TDS) scales: 10 knots.

(3) Extend M_1M_4. Provided *neither* ship alters course or speed, the successive positions of *M* will plot along the relative movement line. Drop a perpendicular from *R* to the relative movement line at M_5. This is the CPA: 220˚, 6,900 yards.

(4) Measure M_1M_5: 9,800 yards. With this MRM and SRM obtain time interval to CPA from TDS scale: 29 minutes. ETA at CPA= 0908 + 29 = 0937.

Answer:

(1) DRM 130˚.
(2) SRM 10 knots.
(3) CPA 220˚, 6,900 yards.
(4) ETA at CPA 0937.



OWN SHIP AT CENTER

EXAMPLE 1

Scale: Distance 2:1 yd.

EXAMPLE 2

COURSE AND SPEED OF OTHER SHIP

Situation:

Own ship R is on course 150˚, speed 18 knots. Ship M is observed as follows:

Time	*Bearing*	*Range (yards)*	*Rel. position*
1100........................	255˚	20,000	M_1
1107........................	260˚	15,700	M_2
1114........................	270˚	11,200	M_3

Required:

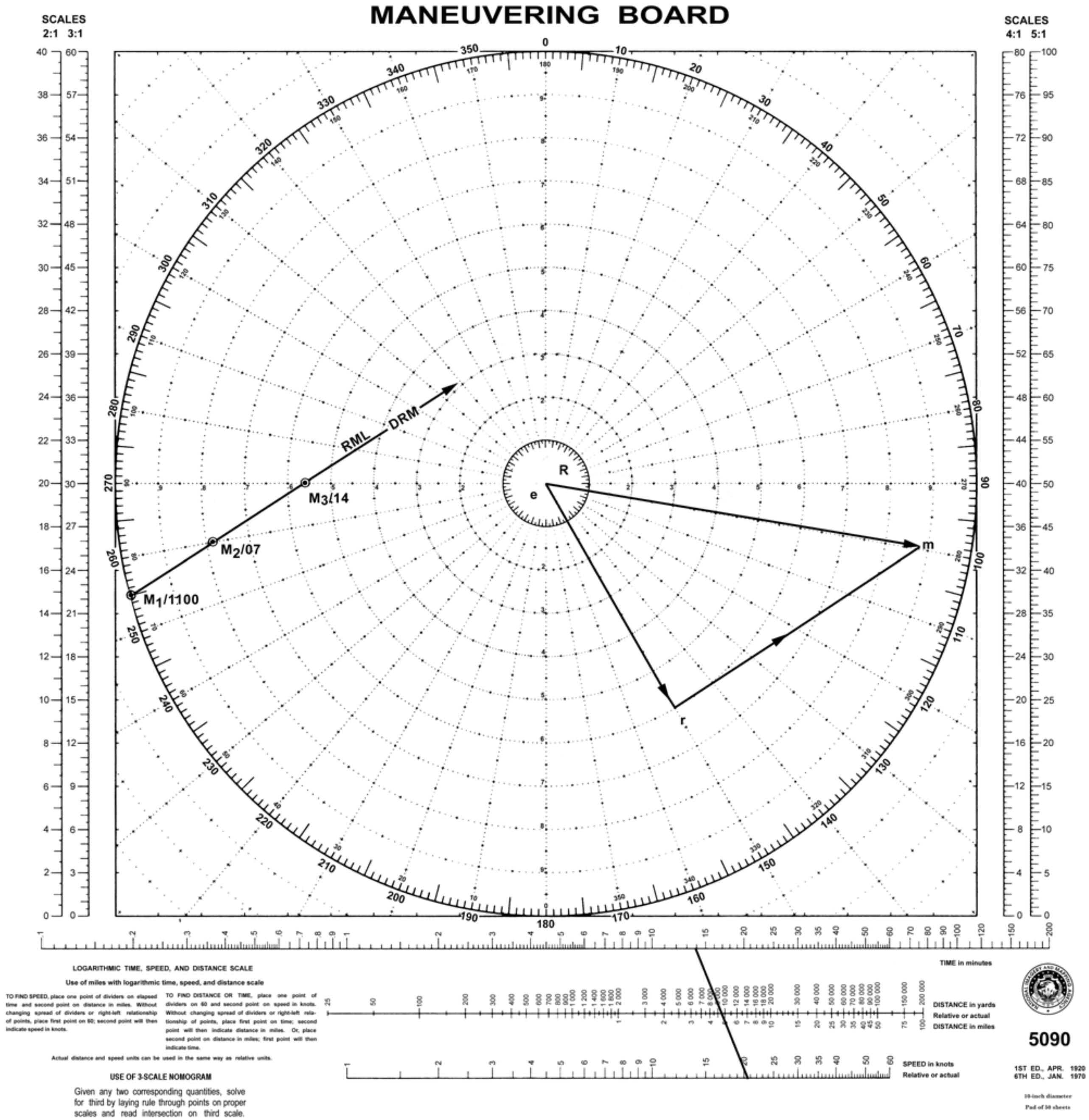
(1) Course and speed of M.

Solution:

(1) Plot M_1, M_2, M_3, and R. Draw the direction of relative movement line (RML) from M_1 through M_3. With the distance $M_1 M_3$ and the interval of time between M_1 and M_3, find the relative speed (SRM) by using the TDS scale: 21 knots. Draw the reference ship vector *er* corresponding to the course and speed of R. Through r draw vector *rm* parallel to and in the direction of $M_1 M_3$ with a length equivalent to the SRM of 21 knots. The third side of the triangle, *em*, is the velocity vector of the ship M: 099˚, 27 knots.

Answer:

(1) Course 099˚, speed 27 knots.



OWN SHIP AT CENTER

EXAMPLE 2

Scale: Speed 3:1;
Distance 2:1 yd.

EXAMPLE 3

COURSE AND SPEED OF OTHER SHIP USING RELATIVE PLOT AS RELATIVE VECTOR

Situation:

Own ship *R* is on course 340°, speed 15 knots. The radar is set on the 12-mile range scale. Ship *M* is observed as follows:

Time	*Bearing*	*Range (mi.)*	*Rel. position*
1000	030°	9.0	M_1
1006	025°	6.3	M_2

Required:

(1) Course and speed of *M*.

Solution:

(1) Plot *M* and M_2. Draw the relative movement line (RML) from M_1 through M_2.

(2) For the interval of time between M_1 and M_2, find the distance own ship *R* travels through the water. Since the time interval is 6 minutes, the distance in nautical miles is one-tenth of the speed of *R* in knots, or 1.5 nautical miles.

(3) Using M_1M_2 directly as the relative vector *rm*, construct the reference ship true vector *er* to the same scale as *rm* (M_1 - M_2), or 1.5 nautical miles in length.

(4) Complete the vector diagram (speed triangle) to obtain the true vector *em* of ship *M*. The length of *em* represents the distance (2.5 nautical miles) traveled by ship *M* in 6 minutes, indicating a true speed of 25 knots.

Note:

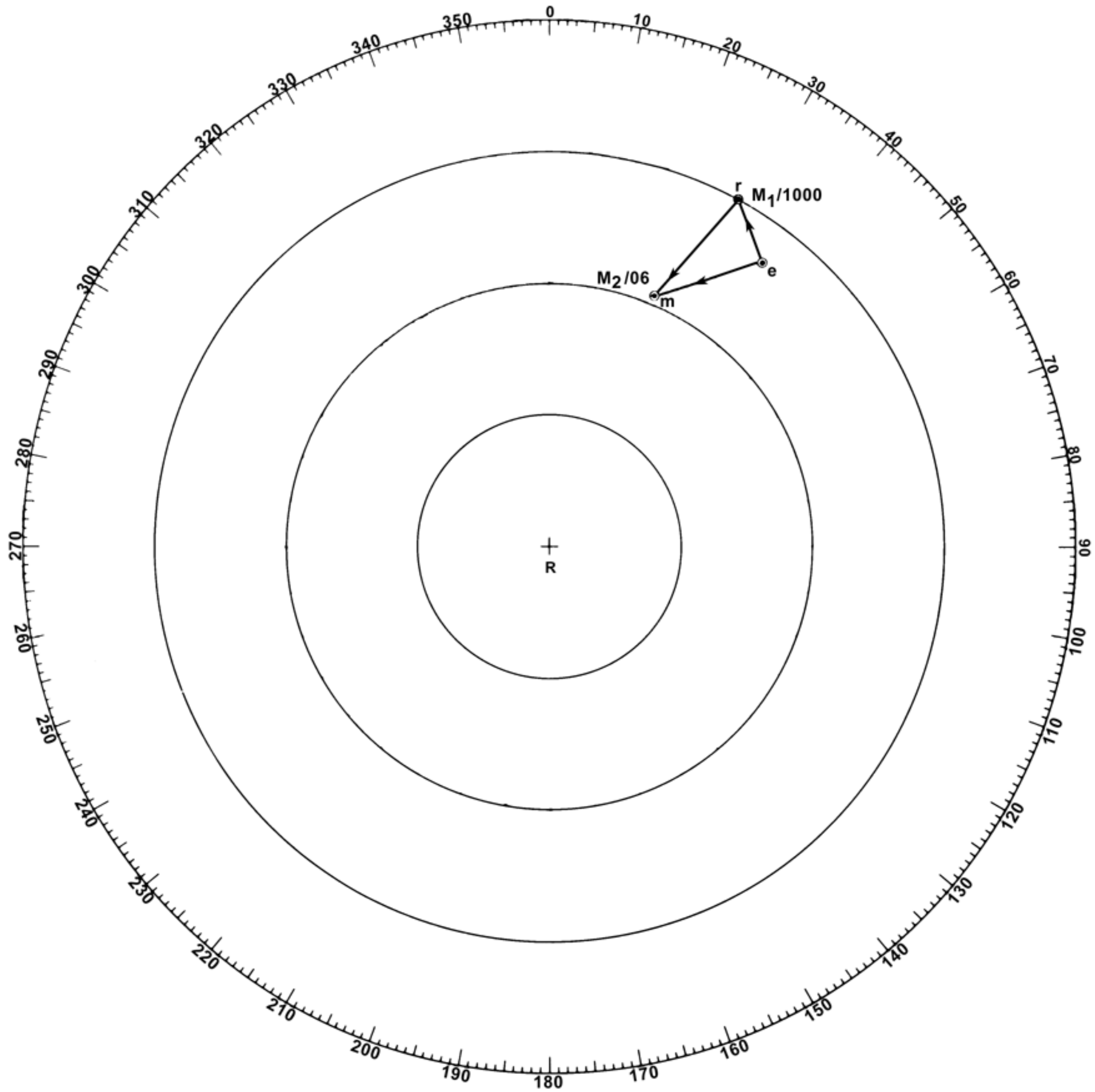
In some cases it may be necessary to construct own ship's true vector originating at the end of the segment of the relative plot used directly as the relative vector. The same results are obtained, but the advantages of the conventional vector notation are lost.

Answer:

(1) Course 252°, speed 25 knots.

Note:

Although at least three relative positions are needed to determine whether the relative plot forms a straight line, for solution and graphical clarity only two relative positions are given in examples 3, 6, and 7.



OWN SHIP AT CENTER

EXAMPLE 3

Scale: 12-mile range setting

EXAMPLE 4

CHANGING STATION WITH TIME, COURSE, OR SPEED SPECIFIED

Situation:

Formation course is 010˚, speed 18 knots. At 0946 when orders are received to change station, the guide *M* bears 140˚, range 7,000 yards. When on new station, the guide will bear 240˚, range 6,000 yards.

Required:

(1) Course and speed to arrive on station at 1000.

(2) Speed and time to station on course 045˚. Upon arrival on station orders are received to close to 3,700 yards.

(3) Course and minimum speed to new station.

(4) Time to station at minimum speed.

Solution:

(1) Plot M_1 140˚, 7,000 yards and M_2 240˚, 6,000 yards from *R*. Draw *em* corresponding to course 010˚ and speed 18 knots. The distance of 5.0 miles from M_1 to M_2 must be covered in 14 minutes. The SRM is therefore 21.4 knots. Draw r_1m parallel to M_1 M_2 and 21.4 knots in length. The vector er_1 denotes the required course and speed: 062˚, 27 knots.

(2) Draw er_2, course 045˚, intersecting r_1m the relative speed vector at the 21-knot circle. By inspection r_2m is 12.1 knots. Thus the distance M_1M_2 of 5.0 miles will be covered in 24.6 minutes.

(3) To *m* draw a line parallel to and in the direction of M_2M_3. Drop a perpendicular from *e* to this line at r_3. Vector er_3 is the course and minimum speed required to complete the final change of station: 330˚, 13.8 knots.

(4) By measurement, the length of r_3 *m* is an SRM of 11.5 knots and the MRM from M_2 to M_3 is 2,300 yards. The required maneuver time MRM/r_3 *m* = 6 minutes.

Answer:

(1) Course 062˚, speed 27 knots.

(2) Speed 21 knots, time 25 minutes.

(3) Course 330˚, speed 13.8 knots.

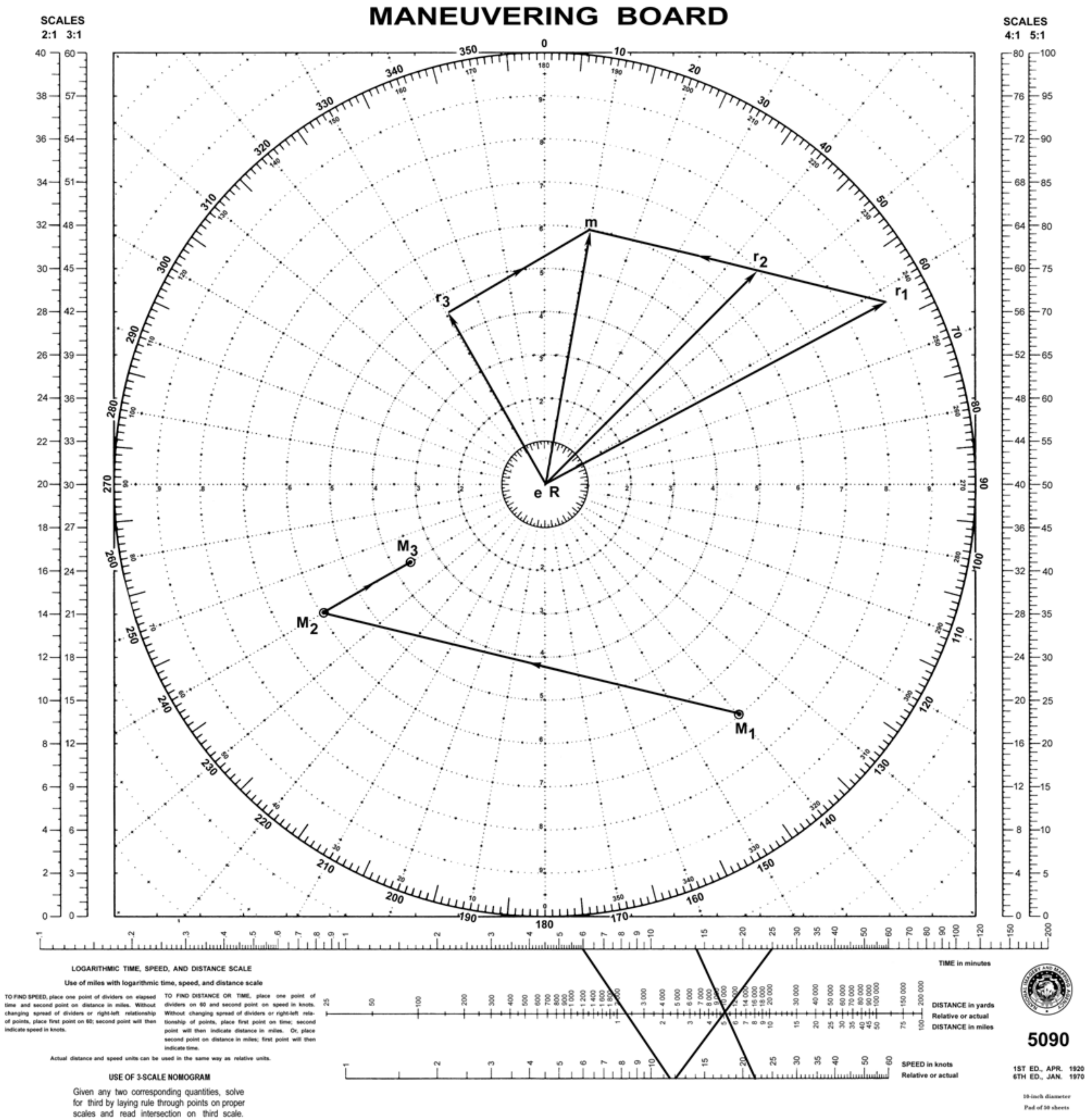
(4) Time 6 minutes.

Explanation:

In solution step (1) the magnitude (SRM) of the *required* relative speed vector *(r_1m)* is established by the relative distance *(M_1M_2)* and the time specified to complete the maneuver (14^m). In solution step (2), however, the magnitude (12.1 knots) of the *resulting* relative speed vector *(r_2m)* is determined by the distance from the head of vector *em* along the reciprocal of the DRM to the point where the required course (045˚) is intersected. Such intersection also establishes the magnitude (21 knots) of vector er_2. The time (25^m) to complete the maneuver is established by the SRM (12.1 knots) and the relative distance (5 miles).

In solution step (3) the course, and minimum speed to make the guide plot along M_2M_3 are established by the shortest true vector for own ship's motion that can be constructed to complete the speed triangle. This vector is perpendicular to the relative vector *(r_3 m)*.

In solution step (4) the time to complete the maneuver is established by the relative distance (2,300 yards) and the relative speed (11.5 knots).



OWN SHIP AT CENTER

EXAMPLE 4

Scale: Speed 3:1;
Distance 1:1 yd.

EXAMPLE 5

THREE-SHIP MANEUVERS

Situation:

Own ship *R* is in formation proceeding on course 000˚, speed 20 knots. The guide *M* bears 090˚, distance 4,000 yards. Ship *N* is 4,000 yards ahead of the guide.

Required:

R and *N* are to take new stations starting at the same time. *N* is to take station 4,000 yards on the guide's starboard beam, using formation speed. *R* is to take *N*'s old station and elects to use 30 knots.

(1) *N*'s course and time to station.
(2) *R*'s course and time to station.
(3) CPA of *N* and *R* to guide.
(4) CPA of *R* to *N*.
(5) Maximum range of *R* from *N*.

Solution:

(1) Plot *R*, M_1, M_2, and N_1. Draw *em*. From M_1 plot *N*'s new station *NM*, bearing 090˚, distance 4,000 yards. From M_2 plot N_3 bearing 090˚, distance 4,000 yards (*N*'s final range and bearing from *M*). Draw N_1NM, the DRM of *N* relative to *M*. From *m*, draw *mn* parallel to and in the direction of N_1NM intersecting the 20-knot speed circle at *n*. *N*'s course to station is vector *en*: 090˚. Time to station N_1NM/mn is 6 minutes.

(2) To *m*, draw a line parallel to and in the direction of M_1M_2 intersecting the 30-knot speed circle at *r*. *R*'s course to station is vector *er*: 017˚. Time to station M_1M_2/rm is 14 minutes.

(3) From M_1 drop a perpendicular to N_1NM. At CPA, *N* bears 045˚, 2,850 yards from *M*. From *R* drop a perpendicular to M_1M_2. At CPA, *R* bears 315˚, 2,850 yards from *M*.

(4) From *r* draw *rn*. This vector is the direction and speed of *N* relative to *R*. From N_1 draw a DRM line of indefinite length parallel to and in the direction of *rn*. From *R* drop a perpendicular to this line. At CPA, *N* bears 069˚, 5,200 yards from *R*.

(5) The intersection of the DRM line from N_1 and the line NMN_3 is N_2, the point at which *N* resumes formation course and speed. Maximum range of *N* from *R* is the distance RN_2, 6,500 yards.

Answer:

(1) *N*'s course 090˚, time 6 minutes.
(2) *R*'s course 017˚, time 14 minutes.
(3) CPA of *N* to *M* 2,850 yards at 045˚. *R* to *M* 2,850 yards at 315˚.
(4) CPA of *N* to *R* 5,200 yards at 069˚.
(5) Range 6,500 yards.

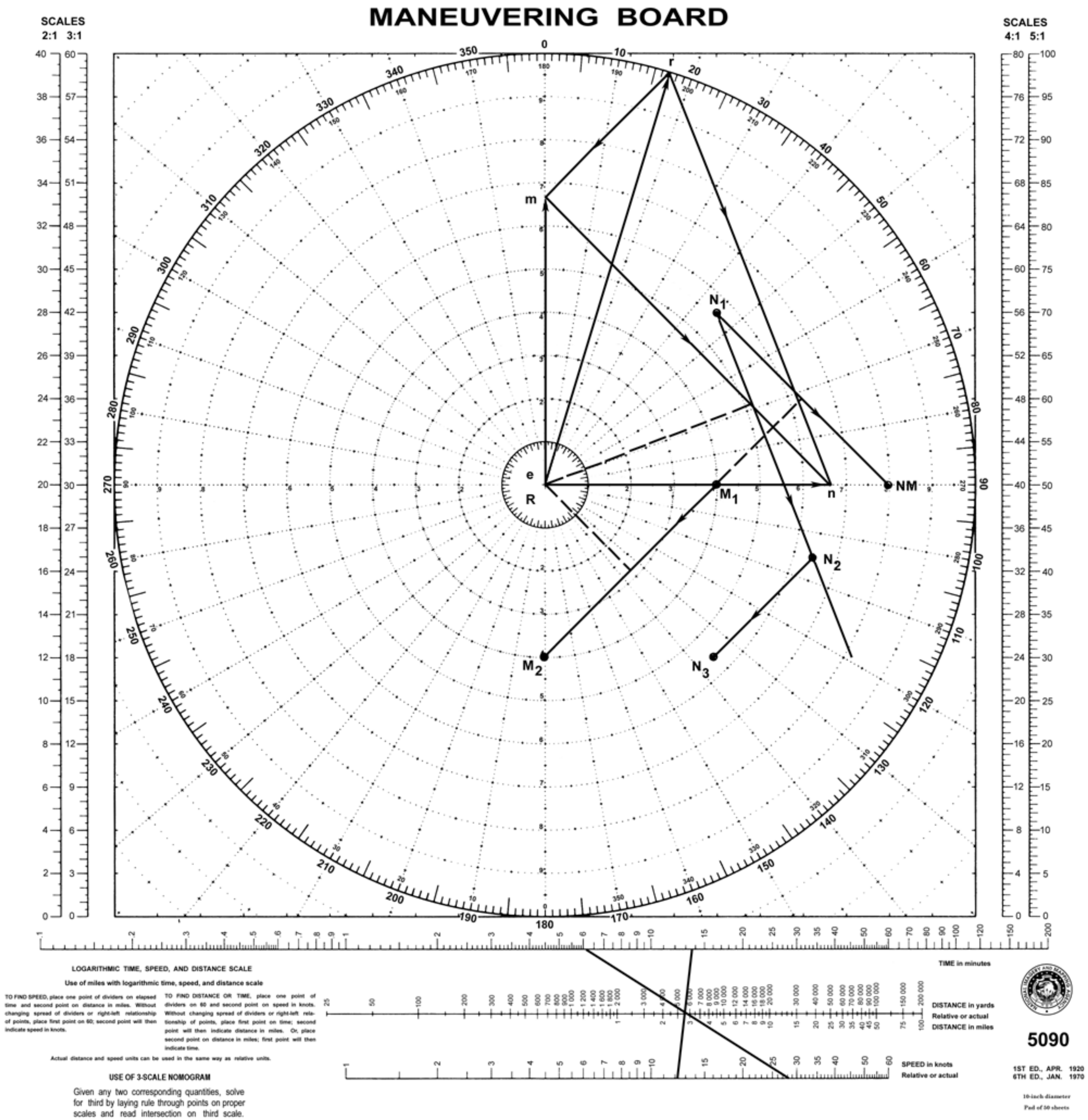
Solution Key:

(1) Solutions for changing station by own ship *R* and ship *N* are effected separately in accordance with the situation and requirements. The CPAs of *N* and *R* to guide are then obtained.

(2) Two solutions for the motion of ship *N* relative to own ship *R* are then obtained: relative motion while *N* is proceeding to new station and relative motion after *N* has taken new station and resumed base course and speed.

Explanation:

In solution step (4) the movement of *N* in relation to *R* is parallel to the direction of vector *rn* and from N_1 until such time that *N* returns to base course and speed. Afterwards, the movement of *N* in relation to *R* is parallel to vector *rm* and from N_2 toward that point, N_3, that *N* will occupy relative to *R* when the maneuver is completed.



OWN SHIP AT CENTER

EXAMPLE 5

Scale: Speed 3:1;
Distance 1:1 yd.

EXAMPLE 6

COURSE AND SPEED TO PASS ANOTHER SHIP AT A SPECIFIED DISTANCE

Situation 1:

Own ship *R* is on course 190˚, speed 12 knots. Other ship *M* is observed as follows:

Time	*Bearing*	*Range (yards)*	*Rel. position*
1730..................	153˚	20,000	M_1
1736..................	153˚	16,700	M_2

Required:

(1) CPA.
(2) Course and speed of *M*.

Situation 2:

It is desired to pass ahead of *M* with a CPA of 3,000 yards.

Required:

(3) Course of *R* at 12 knots if course is changed when range is 13,000 yards.
(4) Bearing and time of CPA.

Solution:

(1) Plot M_1 and M_2 at 153˚, 20,000 yards and 153˚, 16,700 yards, respectively, from *R*. Draw the relative movement line, M_1M_2, extended. Since the bearing is steady and the line passes through *R*, the two ships are on collision courses.

(2) Draw own ship's velocity vector er_1 190˚, 12 knots. Measure M_1M_2, the relative distance traveled by *M* from 1730 to 1736: 3,300 yards. From the TDS scale determine the relative speed, SRM, using 6 minutes and 3,300 yards: 16.5 knots. Draw the relative speed vector r_1m parallel to M_1M_2 and 16.5 knots in length. The velocity vector of *M* is *em*: 287˚, 10 knots.

(3) Plot M_3 bearing 153˚, 13,000 yards from *R*. With *R* as the center describe a circle of 3,000 yards radius, the desired distance at CPA. From M_3 draw a line tangent to the circle at M_4. This places the relative movement line of $M(M_3M_4)$ the required minimum distance of 3,000 yards from *R*. Through *m*, draw r_2m parallel to and in the direction of M_3M_4 intersecting the 12-knot circle (speed of *R*) at r_2. Own ship velocity vector is er_2: course 212˚, speed 12 knots.

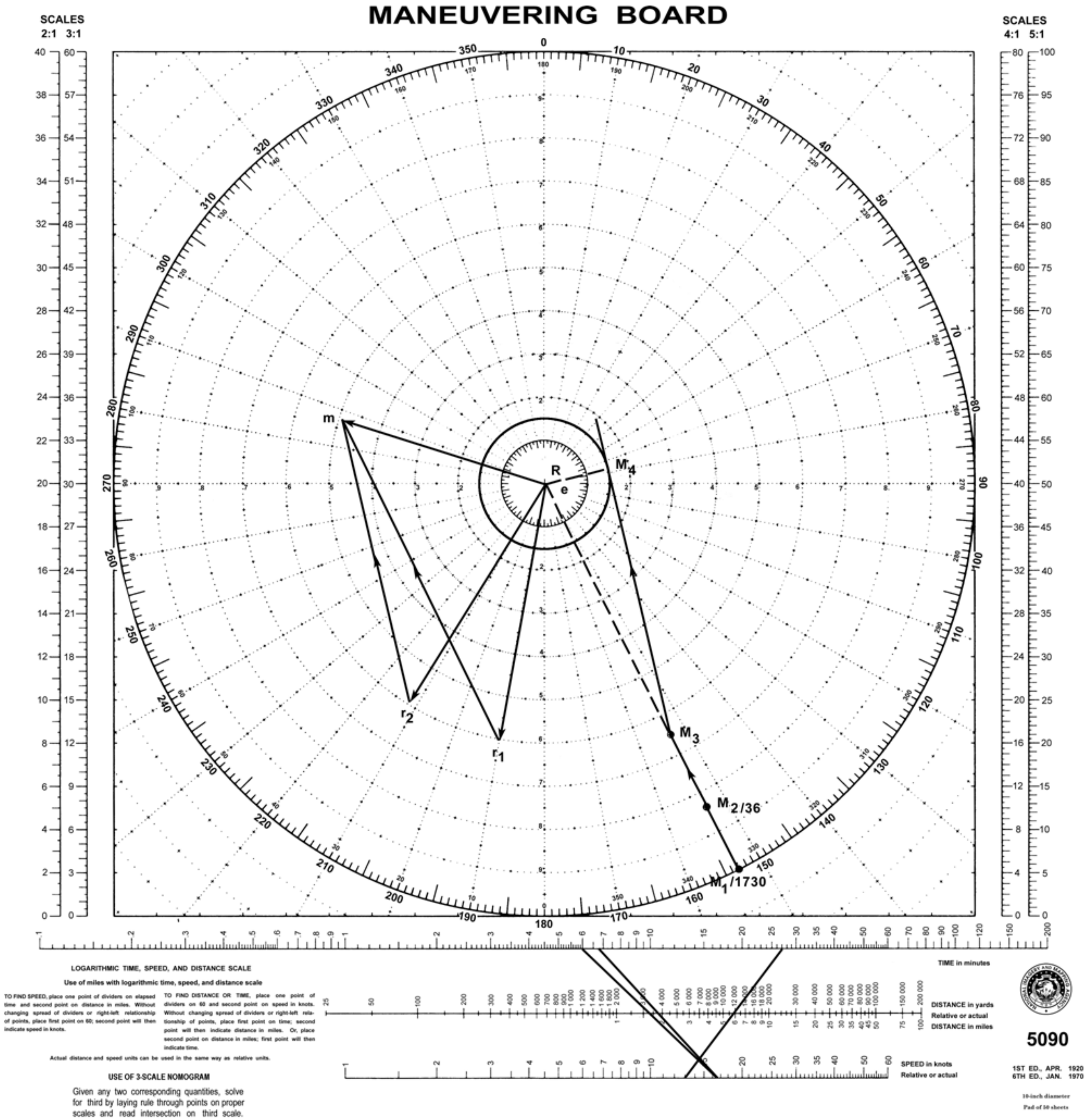
(4) Measure the relative distance (MRM), M_2M_3: 3,700 yards. From the TDS scale determine the time interval between 1736 and the time to change to new course using M_2M_3, 3,700 yards, and an SRM of 16.5 knots: 6.7 minutes. Measure the relative distance M_3M_4: 12,600 yards. Measure the relative speed vector r_2m: 13.4 knots. Using this MRM and SRM, the elapsed time to CPA after changing course is obtained from the TDS scale: 28 minutes. The time of CPA is 1736 + 6.7 + 28 = 1811.

Note:

If *M*'s speed was greater than *R*'s, two courses would be available at 12 knots to produce the desired distance.

Answer:

(1) *M* and *R* are on collision courses and speeds.
(2) Course 287˚, speed 10 knots.
(3) Course 212˚.
(4) Bearing 076˚, time of CPA 1811.



OWN SHIP AT CENTER

EXAMPLE 6

Scale: Speed 2:1;
Distance 2:1 yd.

EXAMPLE 7

COURSE AND SPEED TO PASS ANOTHER SHIP AT A SPECIFIED DISTANCE USING RELATIVE PLOT AS RELATIVE VECTOR

Situation 1:

Own ship *R* is on course 190˚, speed 12 knots. Other ship *M* is observed as follows:

Time	*Bearing*	*Range (mi.)*	*Rel. position*
1730..................	153˚	10.0	M_1
1736..................	153˚	8.3	M_2

Required:

(1) CPA.

(2) Course and speed of *M*.

Situation 2:

It is desired to pass ahead of *M* with a CPA of 1.5 nautical miles.

Required:

(3) Course of *R* at 12 knots if course is changed when range is 6.5 nautical miles.

(4) Bearing and time of CPA.

Solution:

(1) Plot M_1 and M_2 at 153˚, 10.0 nautical miles and 153˚, 8.3 nautical miles, respectively from *R*. Draw the relative movement line, M_1M_2, extended. Since the bearing is steady and the line passes through *R*, the two ships are on collision courses.

(2) For the interval of time between M_1 and M_2, find the distance own ship *R* travels through the water. Since the time interval is 6 minutes, the distance in nautical miles is one-tenth of the speed of *R* in knots, or 1.2 nautical miles.

(3) Using M_1M_2 directly as the relative vector $r_1\,m$, construct the reference ship true vector er_1 to the same scale as $r_1\,m$ (M_1M_2), or 1.2 nautical miles in length.

(4) Complete the vector diagram (speed triangle) to obtain the true vector *em* of ship *M*. The length of *em* represents the distance (1.0 nautical miles) traveled by ship *M* in 6 minutes, indicating a true speed of 10 knots.

(5) Plot M_3 bearing 153˚, 6.5 nautical miles from *R*. With *R* as the center describe a circle of 1.5 nautical miles radius, the desired distance at CPA. From M_3 draw a line tangent to the circle at M_4. This places the relative movement line of *M* (M_3M_4) the required minimum distance of 1.5 nautical miles from *R*.

(6) Construct the true vector of ship *M* as vector *e'm'*, terminating at M_3. From *e'* describe a circle of 1.2 miles radius corresponding to the speed of *R* of 12 knots intersecting the new relative movement line (M_3M_4) extended at point r_2. Own ship *R* true vector required to pass ship *M* at the specified distance is vector $e'r_2$: course 212˚, speed 12 knots.

(7) For practical solutions, the time at CPA may be determined by inspection or through stepping off the relative vectors by dividers or spacing dividers. Thus the time of CPA is 1736 + 6.5 + 28 = 1811.

Note:

If the speed of ship *M* is greater than own ship *R*, there are two courses available at 12 knots to produce the desired distance.

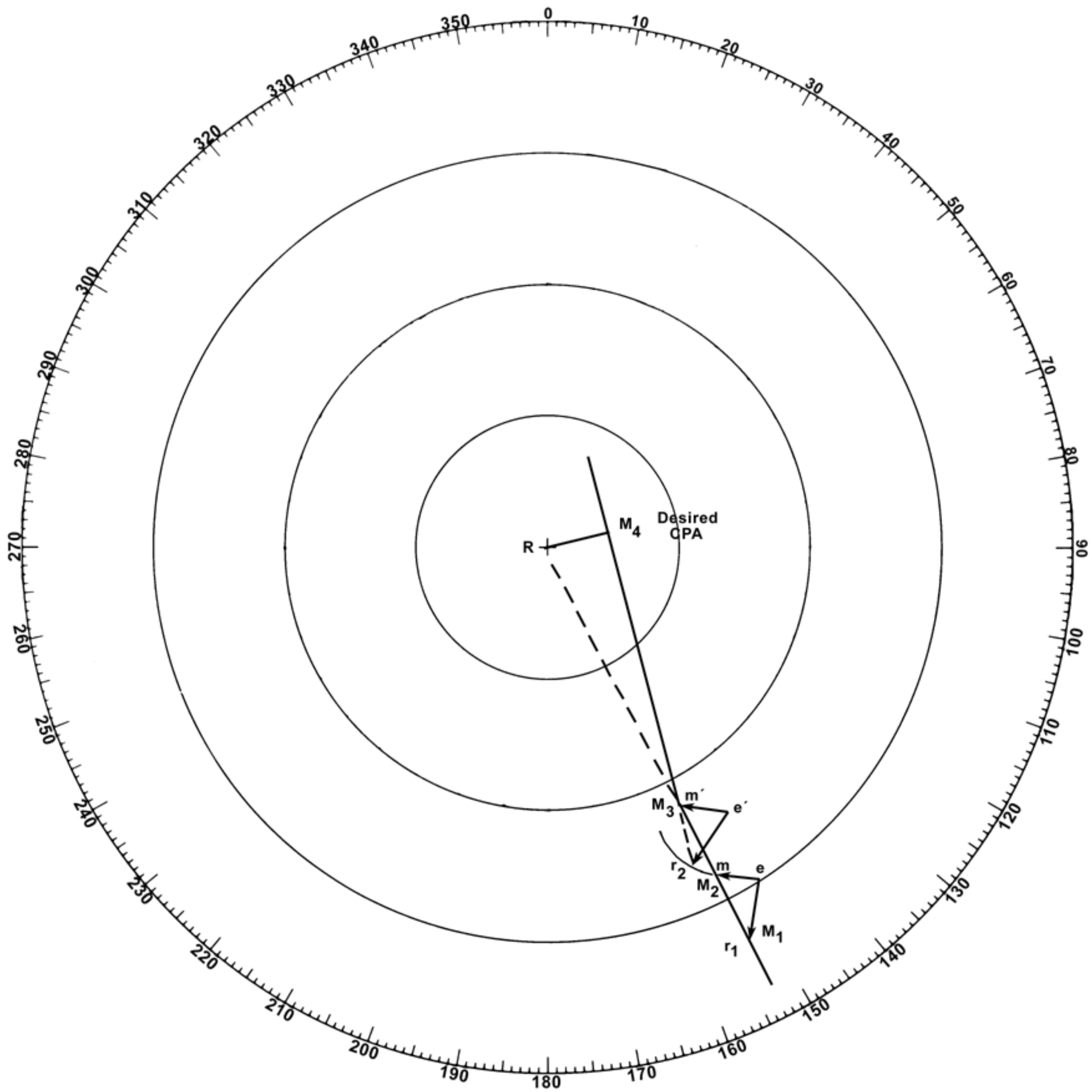
Answer:

(1) *M* and *R* are on collision courses and speeds.

(2) Course 287˚, speed 10 knots.

(3) Course 212˚.

(4) Bearing 076˚, time of CPA 1811.



OWN SHIP AT CENTER

EXAMPLE 7

Scale: 12-mile range setting

EXAMPLE 8

COURSE AT SPECIFIED SPEED TO PASS ANOTHER SHIP AT MAXIMUM AND MINIMUM DISTANCES

Situation:

Ship *M* on course 300˚, speed 30 knots, bears 155˚, range 16 miles from own ship *R* whose maximum speed is 15 knots.

Required:

(1) *R*'s course at 15 knots to pass *M* at (a) maximum distance (b) minimum distance.

(2) CPA for each course found in (1).

(3) Time interval to each CPA.

(4) Relative bearing of *M* from *R* when at CPA on each course.

Solution:

(1) Plot M_1 155˚, 16 miles from *R*. Draw the vector *em* 300˚, 30 knots. With *e* as the center, describe a circle with radius of 15 knots, the speed of *R*. From *m* draw the tangents $r_1\,m$ and $r_2\,m$ which produce the two limiting courses for *R*. Parallel to the tangents plot the relative movement lines through M_1. Course of own ship to pass at maximum distance is er_1: 000˚. Course to pass at minimum distance is er_2: 240˚.

(2) Through *R* draw RM_2 and RM'_2 perpendicular to the two possible relative movement lines. Point M_2 bearing 180˚, 14.5 miles is the CPA for course of 000˚. Point M'_2 bearing 240˚, 1.4 miles is the CPA for course 240˚.

(3) Measure M_1M_2: 6.8 miles, and $M_1M'_2$: 15.9 miles. *M* must travel these relative distances before reaching the CPA on each limiting course. The relative speed of *M* is indicated by the length of the vectors $r_1\,m$ and $r_2\,m$: 26 knots. From the TDS scale the times required to reach M_2 and M'_2 are found: 15.6 minutes and 36.6 minutes, respectively.

(4) Bearings are determined by inspection. M_2 bears 180˚ relative because own ship's course is along vector er_1 for maximum CPA. M'_2 bears 000˚ relative when own ship's course is er_2 for minimum passing distance.

Note:

This situation occurs only when own ship *R* is (1) ahead of the other ship and (2) has a maximum speed less than the speed of the other ship. Under these conditions, own ship can intercept (collision course) only if *R* lies between the slopes of M_1M_2 and $M_1M'_2$. Note that for limiting courses, and only for these, CPA occurs when other ship is dead ahead or dead astern. The solution to this problem is applicable to avoiding a tropical storm by taking that course which results in maximum passing distance.

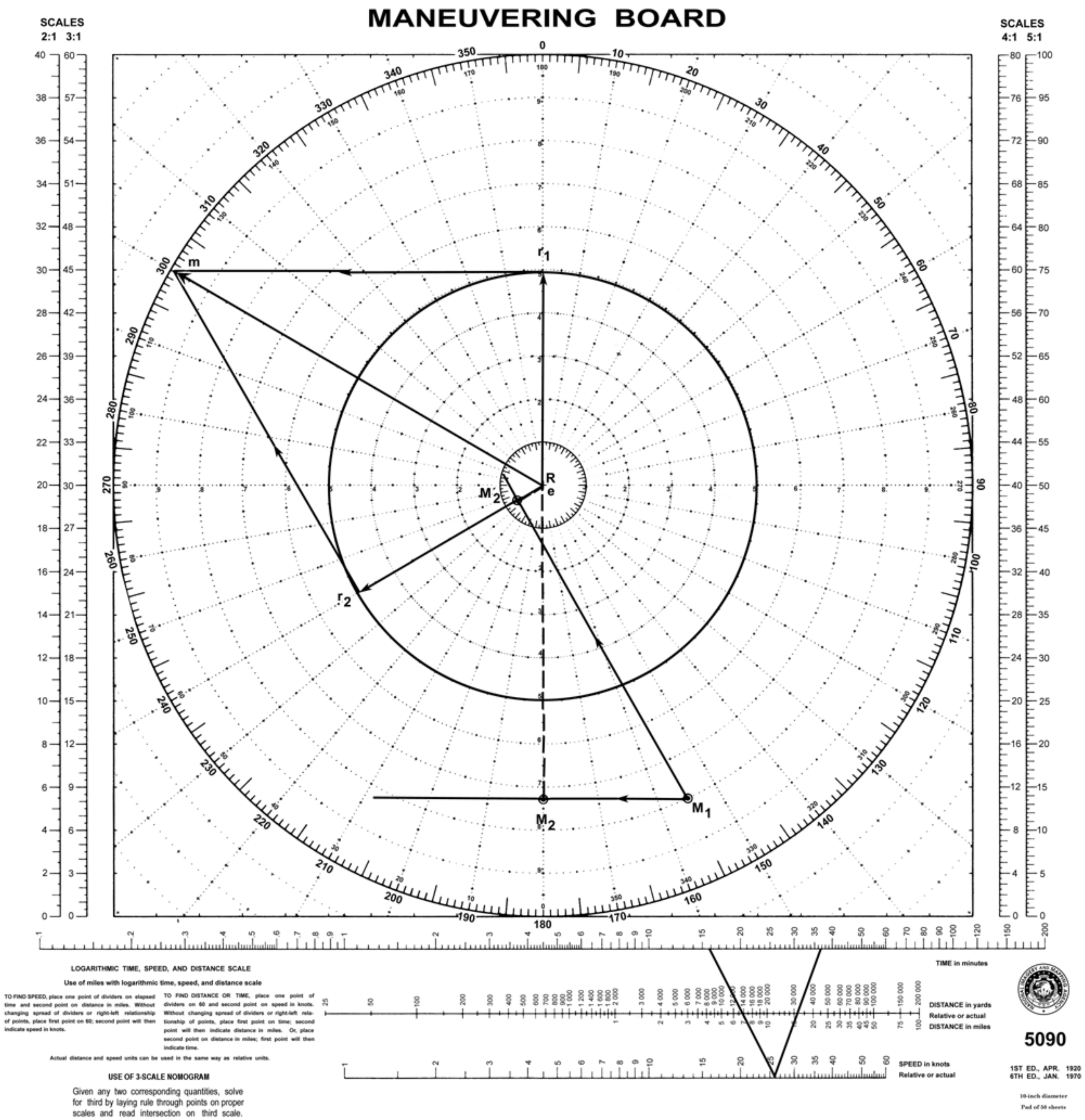
Answer:

(1) Course (a) 000˚; (b) 240˚.

(2) CPA (a) 180˚, 14.5 miles; (b) 240˚, 1.4 miles.

(3) Time (a) 16 minutes; (b) 37 minutes.

(4) Relative bearing (a) 180˚; (b) 000˚.



OWN SHIP AT CENTER

EXAMPLE 8

Scale: Speed 3:1;
Distance 2:1 mi.

EXAMPLE 9

COURSE CHANGE IN COLUMN FORMATION ASSURING LAST SHIP IN COLUMN CLEARS

Situation:

Own ship *D*1 is the guide in the van of a destroyer unit consisting of four destroyers (*D*1, *D*2, *D*3, and *D*4) in column astern, distance 1,000 yards. *D*1 is on station bearing 090˚, 8 miles from the formation guide *M*. Formation course is 135˚, speed 15 knots. The formation guide is at the center of a concentric circular ASW screen stationed on the 4-mile circle.

The destroyer unit is ordered to take new station bearing 235˚, 8 miles from the formation guide. The unit commander in *D*1 decides to use a wheeling maneuver at 27 knots, passing ahead of the screen using two course changes so that the CPA of his unit on each leg is 1,000 yards from the screen.

Required:

(1) New course to clear screen commencing at 1000.
(2) Second course to station.
(3) Bearing and range of *M* from *D*1 at time of coming to second course.
(4) Time of turn to second course.
(5) Time *D*1 will reach new station.

Solution:

(1) Plot own ship *D*1 at the center on course 135˚ with the remaining three destroyers in column as *D*2, *D*3, *D*4. (*D*2 and *D*3 not shown for graphical clarity.) Distance between ships 1,000 yards. Plot the formation guide *M* at M_1 bearing 270˚, 8 miles from *D*1. Draw *em*, the speed vector of *M*. It is required that the last ship in column, *D*4, clear *M* by 9,000 yards (screen radius of 4 miles plus 1,000 yards). At the instant the signal is executed to change station, only *D*1 changes both course and speed. The other destroyers increase speed to 27 knots but remain on formation course of 135˚ until each reaches the turning point. *D*4's movement of 3,000 yards at 27 knots to the turning point requires 3 minutes, 20 seconds. During this interval there is a 12 knot true speed differential between *D*4 and the formation guide *M*. Thus to establish the *relative position of D4 to M at the instant D4 turns*, advance *D*4 to *D*4' ($3^m\ 20^S$ x 12 knots = 1,350 yards). With *D*4' as a center, describe a CPA circle of radius 9,000 yards. Draw a line from M_1 tangent to this circle. This is the relative movement line required for *D*4 to clear the screen by 1,000 yards. Draw a line to *m* parallel to M_1M_2 intersecting the 27-knot circle at r_1. This point determines the initial course, er_1: 194˚.2.

(2) Plot the final relative position of *M* at M_3 bearing 055˚, 8 miles from *D*1. Draw a line from M_3 tangent to the CPA circle and intersecting the first relative movement line at M_2. Draw a line to *m* parallel to and in the direction of M_2M_3. The intersection of this line and the 27-knot circle at r_2 is the second course required, er_2: 252˚.8.

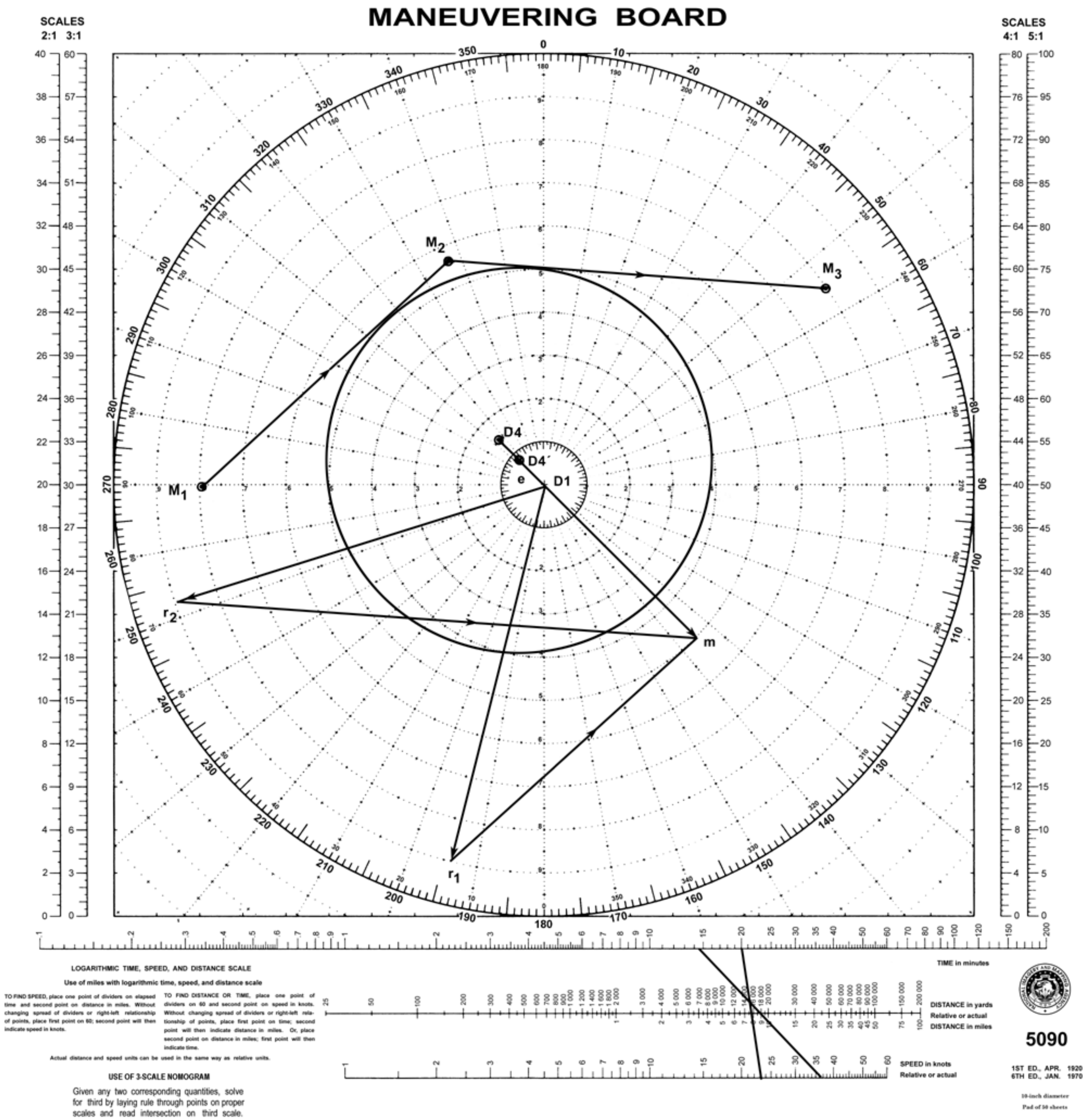
(3) Bearing and range of M_2 from *D*1 is obtained by inspection: 337˚ at 11,250 yards.

(4) Time interval for *M* to travel to M_2 is M_1M_2/r_1m = 7.8 miles/23.2 knots = 20.2 minutes. Time of turn 1000 + 20 = 1020.

(5) Time interval for the second leg is M_2M_3/r_2m = 8.8 miles/36.5 knots =14.2 minutes. *D*1 will arrive at new station at 1034.

Answer:

(1) Course 194˚.
(2) Course 253˚.
(3) Bearing 337˚, range 11,250 yards.
(4) Time 1020.
(5) Time 1034.



OWN SHIP AT CENTER

EXAMPLE 9

Scale: Speed 3:1;
Distance 1:1 mi.

EXAMPLE 10

DETERMINATION OF TRUE WIND

Situation:

A ship is on course 240˚, speed 18 knots. The relative wind across the deck is 30 knots from 040˚ relative.

Required:

Direction and speed of true wind.

Solution:

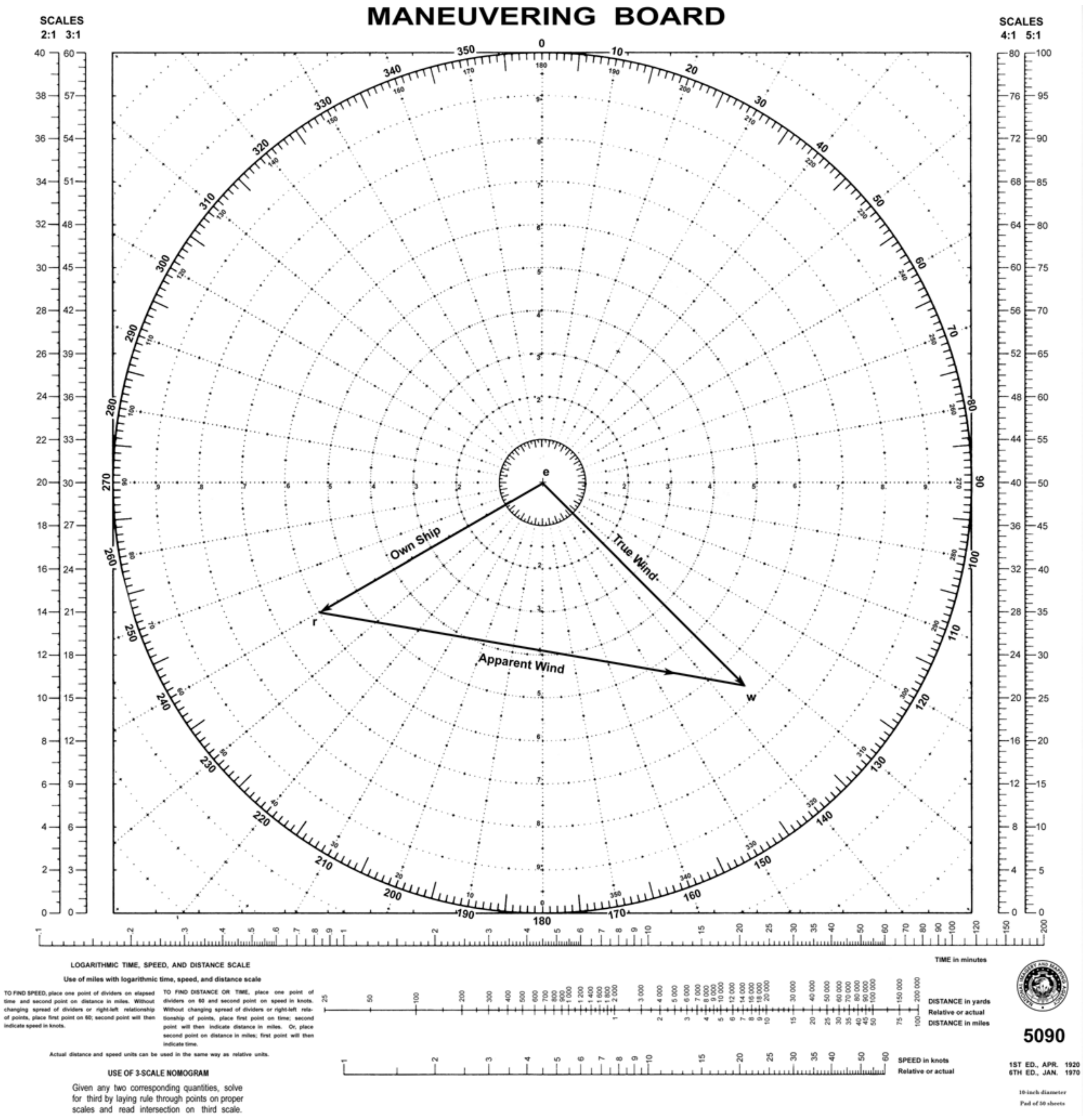
Plot *er*, the ship's vector of 240˚, 18 knots. Convert the relative wind to apparent wind by plotting *rw* 040˚ relative to ship's head which results in a true direction of 280˚T. Plot the apparent wind vector (reciprocal of 280˚T, 30 knots) from the end of the vector *er*. Label the end of the vector *w*. The resultant vector *ew* is the true wind vector of 135˚, 20 knots (wind's course and speed). The true wind, therefore, is *from* 315˚.

Answer:

True wind from 315˚, speed 20 knots.

Note:

As experienced on a moving ship, the direction of true wind is always on the same side and aft of the direction of the apparent wind. The difference in directions increases as ship's speed increases. That is, the faster a ship moves, the more the apparent wind draws ahead of true wind.



OWN SHIP AT CENTER

EXAMPLE 10

Scale: Speed 3:1

EXAMPLE 11a

DESIRED RELATIVE WIND
(First Method)

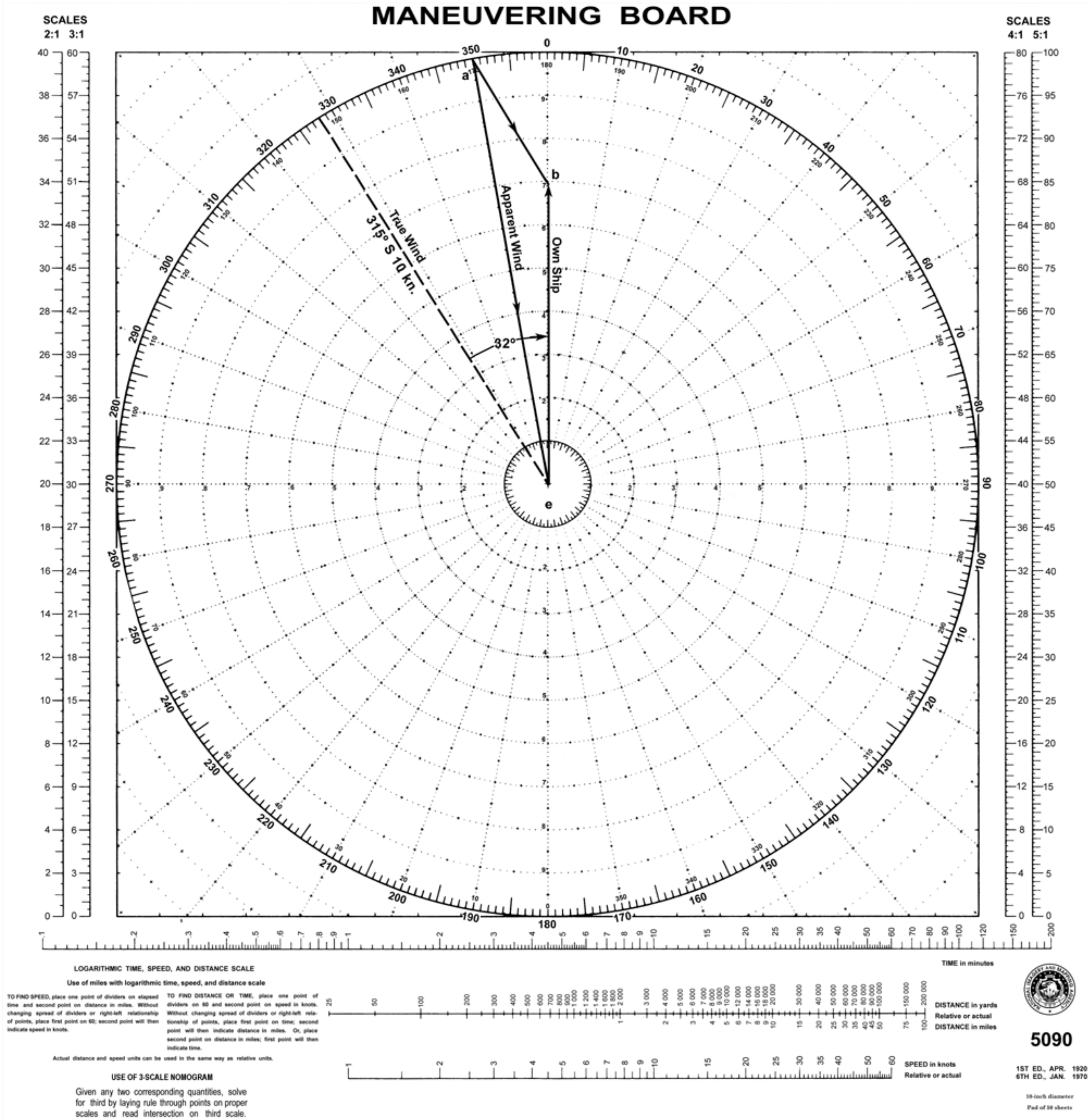
Situation:
An aircraft carrier is proceeding on course 240˚, speed 18 knots. True wind has been determined to be from 315˚, speed 10 knots.

Required:
Determine a launch course and speed that will produce a relative wind across the flight deck of 30 knots from 350˚ relative (10˚ port).

Solution:
Set a pair of dividers for 30 knots using any convenient scale. Place one end of the dividers at the origin *e* of the maneuvering board and the other on the 350˚ line, marking this point *a*. Set the dividers for the true wind speed of 10 knots and place one end on point *a*, the other on the 000˚ line (centerline of the ship). Mark this point on the centerline *b*. Draw a dashed line from origin *e* parallel to *ab*. This produces the angular relationship between the direction from which the true wind is blowing and the launch course. In this problem the *true* wind should be from 32˚ off the port bow (328˚ relative) when the ship is on launch course and speed. The required course and speed is thus 315˚ + 32˚ = 347˚, 21 knots.

Answer:
Course 347˚, speed 21 knots.

Note:
As experienced on a moving ship, the direction of true wind is always on the same side and aft of the direction of the apparent wind. The difference in directions increases as ship's speed increases. That is, the faster a ship moves, the more the apparent wind draws ahead of true wind.



OWN SHIP AT CENTER

EXAMPLE 11a

Scale: Speed 3:1

EXAMPLE 11b

DESIRED RELATIVE WIND
(Second Method)

Situation:

A ship is on course 240˚, speed 18 knots. True wind has been determined to be from 315˚, speed 10 knots.

Required:

Determine a course and speed that will produce a wind across the deck of 30 knots from 350˚ relative (10˚ port).

Solution:

(1) A preliminary step in the desired relative wind solution is to indicate on the polar plotting sheet the direction from which the true wind is blowing. The direction of the true wind is along the radial from 315˚.

(2) The solution is to be effected by first finding the magnitude of the required ship's true (course-speed) vector; knowing the true wind (direction-speed) vector and the magnitude (30 knots) of the relative wind vector, and that the ship's course should be to the right of the direction from which the true wind is blowing, the vector triangle can then be constructed.

(3) Construct the true wind vector *ew*.

(4) With a pencil compass adjusted to the true wind (10 knots), set the point of the compass on the 30-knot circle at a point 10˚ clockwise from the intersection of the 30-knot circle with the radial extending in the direction from which the wind is blowing. Strike an arc intersecting this radial. That part of the radial from the center of the plotting sheet to the intersection* represents the magnitude of the required ship's true vector (21 knots). The direction of a line extending from this intersection to the center of the arc is the direction of the ship's true vector.

(5) From *e* at the center of the plotting sheet, strike an arc of radius equal to 21 knots. From *w* at the head of the true wind vector, strike an arc of radius equal to 30 knots. Label intersection *r*. This intersection is to the right of the direction from which the true wind is blowing.

(6) Alternatively, the ship's true (course-speed) vector can be constructed by drawing vector *er* parallel to the direction established in (4) and to the magnitude also established in (4). On completing the vector triangle, the direction of the relative wind is 10˚ off the port bow.

Answer:

Course 346˚, speed 21 knots.

Note:

If the point of the compass had been set at a point on the 30-knot circle 10˚ counterclockwise from the radial extending in the direction from which the true wind is blowing in (4), the same magnitude of the ship's true vector would have been obtained. However, the direction established for this vector would have been for a 30-knot wind across the deck from 10˚ off the starboard bow.

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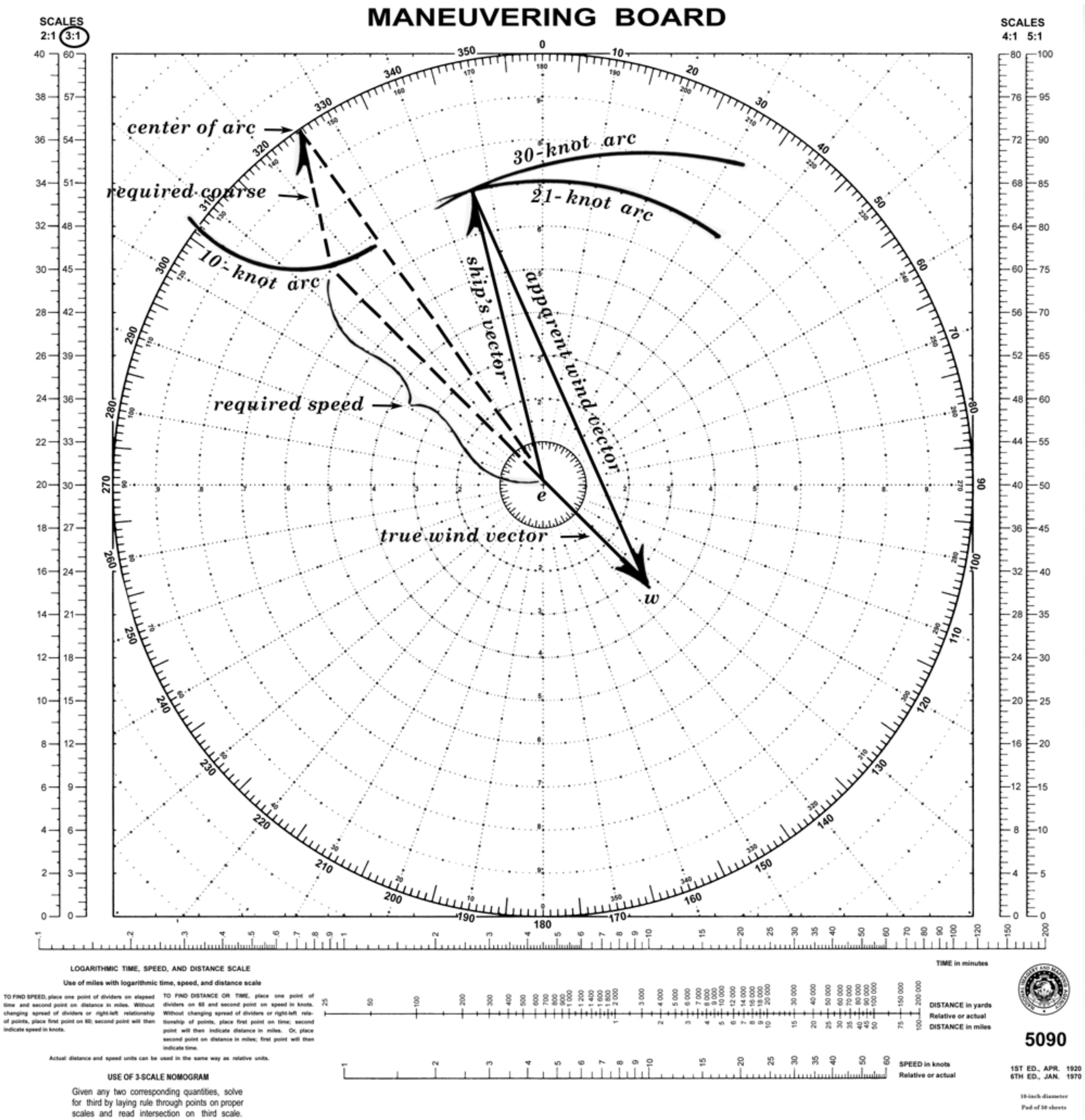
* *Use that intersection closest to the center of the polar diagram.*



OWN SHIP AT CENTER

EXAMPLE 11b

Scale: Speed 3:1

EXAMPLE 11c

DESIRED RELATIVE WIND
(Third Method)

Situation:

A ship is on course 240˚ speed 18 knots. True wind has been determined to be from 315˚ speed 10 knots.

Required:

Determine a course and speed that will produce a wind across the deck of 30 knots from 350˚ relative (10˚ port).

Solution:

(1) A preliminary step in the desired relative wind solution is to indicate on the polar plotting sheet the direction toward which the true wind is blowing. The direction of the true wind is along the radial from 315˚.

(2) The solution is to be effected by first finding the magnitude of the required ship's true (course-speed) vector; knowing the true wind (direction-speed) vector and the magnitude (30 knots) of the relative wind vector, and that the ship's course should be to the right of the direction from which the true wind is blowing, the vector triangle can then be constructed.

(3) Construct the true wind vector *ew*.

(4) With a pencil compass adjusted to the true wind (10 knots), set the point of the compass on the 30-knot circle at a point 10˚ clockwise from the intersection of the 30-knot circle with the radial extending in the direction toward which the wind is blowing. Strike an arc intersecting this radial. That part of the radial from the center of the plotting sheet to the intersection* represents the magnitude of the required ship's true vector (21 knots). The direction of a line extending from the center of the arc to the intersection with the radial is the direction of the ship's true vector.

(5) From *e* at the center of the plotting sheet, strike an arc of radius equal to 21 knots. From *w* at the head of the true wind vector, strike an arc of radius equal to 30 knots. Label intersection *r*. This intersection is to the right of the direction from which the true wind is blowing.

(6) Alternatively, the ship's true (course-speed) vector can be constructed by drawing vector *er* parallel to the direction established in (4) and to the magnitude also established in (4). On completing the vector triangle, the direction of the relative wind is 10˚ off the port bow.

Answer:

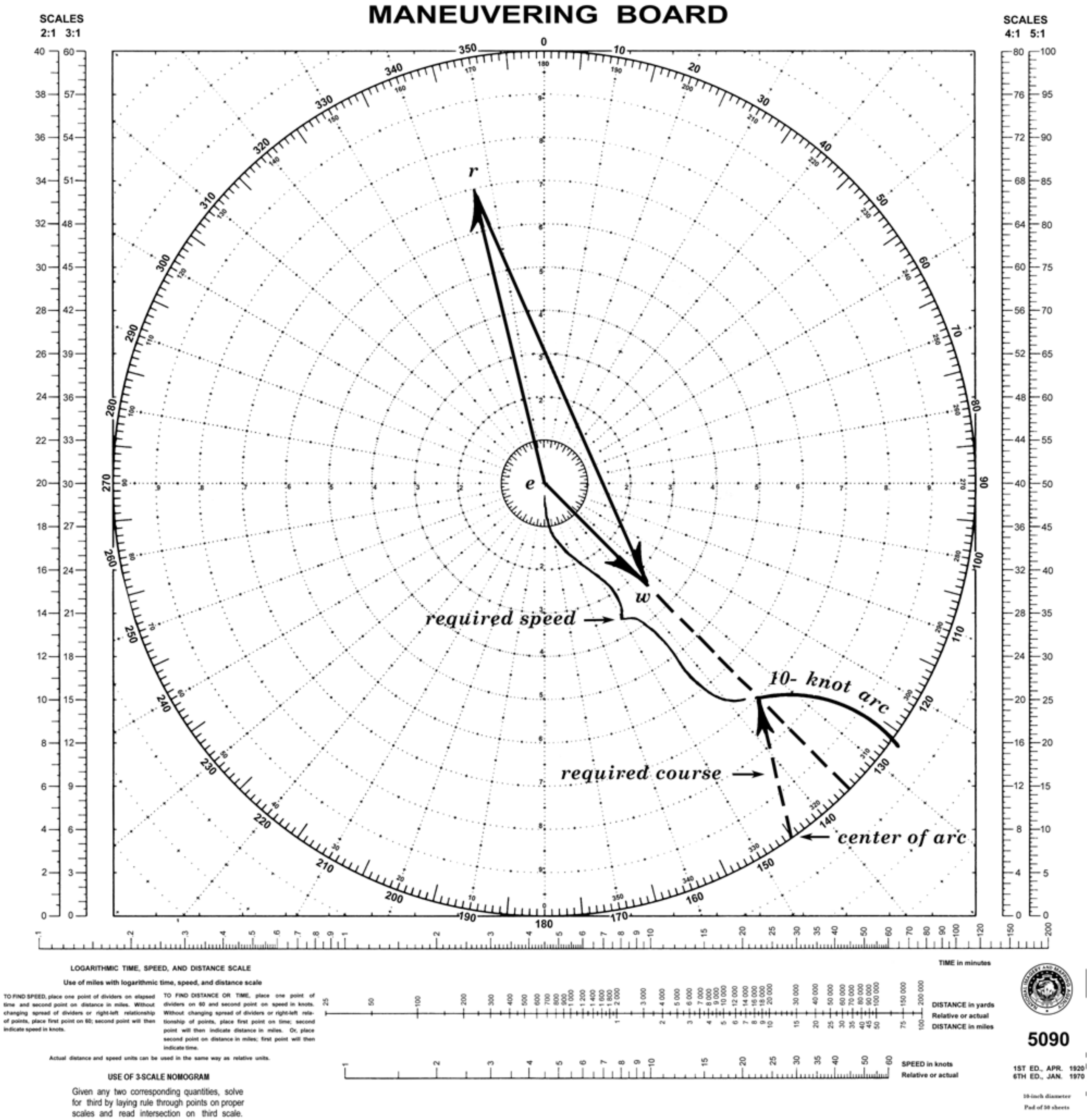
Course 346˚, speed 21 knots.

Note:

If the point of the compass had been set at a point on the 30-knot circle 10˚ counterclockwise from the radial extending in the direction from which the true wind is blowing in (4), the same magnitude of the ship's true vector would have been obtained. However, the direction established for this vector would have been for a 30-knot wind across the deck from 10˚ off the starboard bow.

---

* *Use that intersection closest to the center of the polar diagram.*



OWN SHIP AT CENTER

EXAMPLE 11c

Scale: Speed 3:1

PRACTICAL ASPECTS OF MANEUVERING BOARD SOLUTIONS

The foregoing examples and their accompanying illustrations are based upon the premise that ships are capable of instantaneous changes of course and speed. It is also assumed that an unlimited amount of time is available for determining the solutions.

In actual practice, the interval between the signal for a maneuver and its execution frequently allows insufficient time to reach a complete graphical solution. Nevertheless, under many circumstances, safety and smart seamanship both require prompt and decisive action, even though this action is determined from a quick, mental estimate. The estimate must be based upon the principles of relative motion and therefore should be nearly correct. Course and speed can be modified enroute to new station when a more accurate solution has been obtained from a maneuvering board.

Allowance must be made for those tactical characteristics which vary widely between types of ships and also under varying conditions of sea and loading. Experience has shown that it is impractical to solve for the relative motion that occurs during a turn and that acceptable solutions can be found by eye and mental estimate.

By careful appraisal of the PPI and maneuvering board, the relative movement of own ship and the guide during a turn can be approximated and an estimate made of the relative position upon completion of a turn. Ship's characteristic curves and a few simple thumb rules applicable to own ship type serve as a basis for these estimates. During the final turn the ship can be brought onto station with small compensatory adjustments in engine revolutions and/or course.

EXAMPLE 12

ADVANCE, TRANSFER, ACCELERATION, AND DECELERATION

Situation:

Own ship *R* is a destroyer on station bearing 020˚, 8,000 yards from the guide *M*. Formation course is 000˚, speed 15 knots. *R* is ordered to take station bearing 120˚, 8,000 yards from guide, using 25 knots.

Required:

(1) Course to new station.
(2) Bearing of *M* when order is given to resume formation course and speed.
(3) Time to complete the maneuver.

Solution:

(1) Plot *R* at the center with M_1 bearing 200˚, 8,000 yards and M_2 bearing 300˚, 8,000 yards. Draw the guide's speed vector *em* 000˚, 15 knots.

By eye, it appears *R* will have to make a turn to the right of about 150˚, accelerating from 15 to 25 knots during the turn. Prior to reaching the new station a reverse turn of about the same amount and deceleration to 15 knots will be required. Assume that *R* averages 20 knots during each turn.

Using 30˚ rudder at 20 knots, a DD calibration curve indicates approximately 2˚ turn per second and a 600 yard tactical diameter. Thus, a 150˚ turn will require about 75 seconds and will produce an off-set of about 600 yards. During the turn, *M* will advance 625 yards ($1^1/_4$ minutes at 15 knots). Plotting this approximate off-set distance on the maneuvering board gives a new relative position of M_3 at the time the initial turn is completed. Similarly, a new off-set position at M_4 is determined where *R* should order a left turn to formation course and reduction of speed to 15 knots.

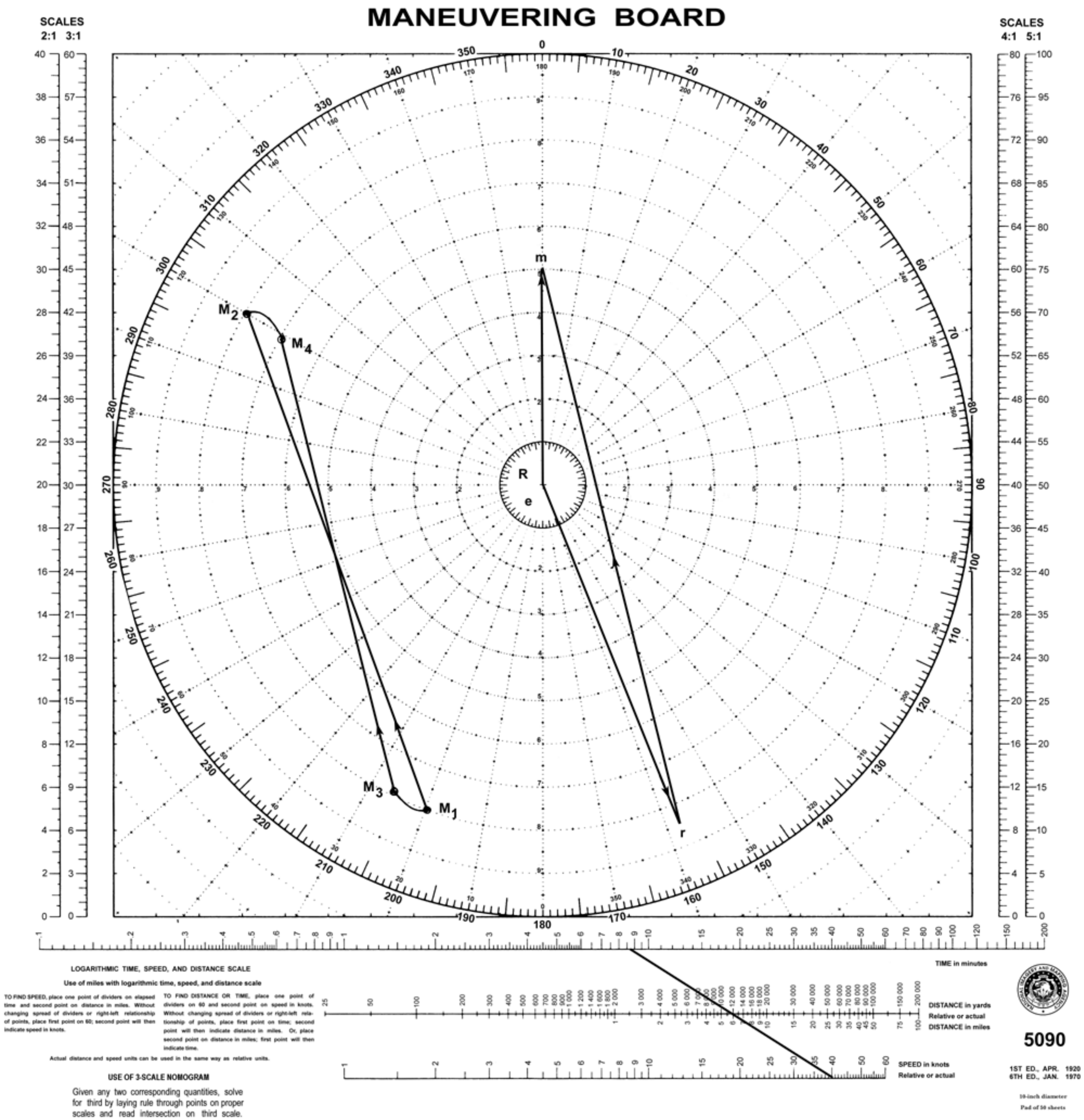
Draw a line to *m* parallel to and in the direction of M_3M_4 and intersecting the 25-knot speed circle at *r*. Vector *er* is the required course of 158˚.

(2) When *M* reaches point M_4 bearing 299˚, turn left to formation course using 30˚ rudder and slow to 15 knots.

(3) Time to complete the maneuver is M_3M_4/SRM + 2.5 minutes = 11,050 yards/39.8 knots + 2.5 minutes = 11 minutes.

Answer:

(1) Course 158˚.
(2) Bearing 299˚.
(3) Time 11 minutes.



OWN SHIP AT CENTER

EXAMPLE 12

Scale: Speed 3:1;
Distance 1:1 yd.

COLLISION AVOIDANCE

Numerous studies and the inventive genius of man have provided the mariner with adequate means for virtually eliminating collisions at sea. One of the most significant of these is radar. However, radar is merely an aid, and is no substitute for good judgment coupled with good seamanship. Its use grants no special license in applying the Rules of the Road in a given situation. Properly interpreted, however, the information it does provide the mariner can be of inestimable value in forewarning him of possible danger.

The following example is a practical problem encountered in the approaches to many of the world's busy ports.

EXAMPLE 13

AVOIDANCE OF MULTIPLE CONTACTS

Situation:

Own ship is proceeding toward a harbor entrance about 30 miles to the southeast. Own ship's course 145˚, speed 15 knots. Visibility is estimated to be 2 miles. Numerous radar contacts are being made. At the present time, 2235, six pips are being plotted on the PPI scope.

Problems:

(1) By visual inspection of the PPI (Fig. 1), which of the contacts appear dangerous and require plotting on a maneuvering board? (Radar is set on 20-mile range scale.)

(2) After plotting the contacts selected in (1), what are their CPA's, true courses and speeds? (Fig. 2 is an example.)

(3) Assume the PPI plots indicate all contacts have maintained a steady course and speed during your solution in (2). What maneuvering action, if any, do you recommend? (Fig. 2 shows one possibility.)

(4) Assume that you maneuver at 2238 and all other ships maintain their courses and speeds. What are the new CPA's of the dangerous contacts in (2) above? (Fig. 2 shows a possible solution.)

(5) Assume that all ships maintain course and speed from 2238 until 2300. What will be the PPI presentation at 2300? (Fig. 3 is an example.)

(6) At what time would you return to original course and speed or make other changes?

Solutions:

(1) Ships *E* and *F* look dangerous. Their bearings are almost steady and range is decreasing rapidly. *F* will reach the center in about one half hour. All other contacts appear safe enough to merely track on the scope. *A* is closing, but too slowly to be of concern for several hours. *B* is overtaking at a very slow rate. *C* should cross well clear astern in about an hour. *D* is harmless and needs only cursory checks.

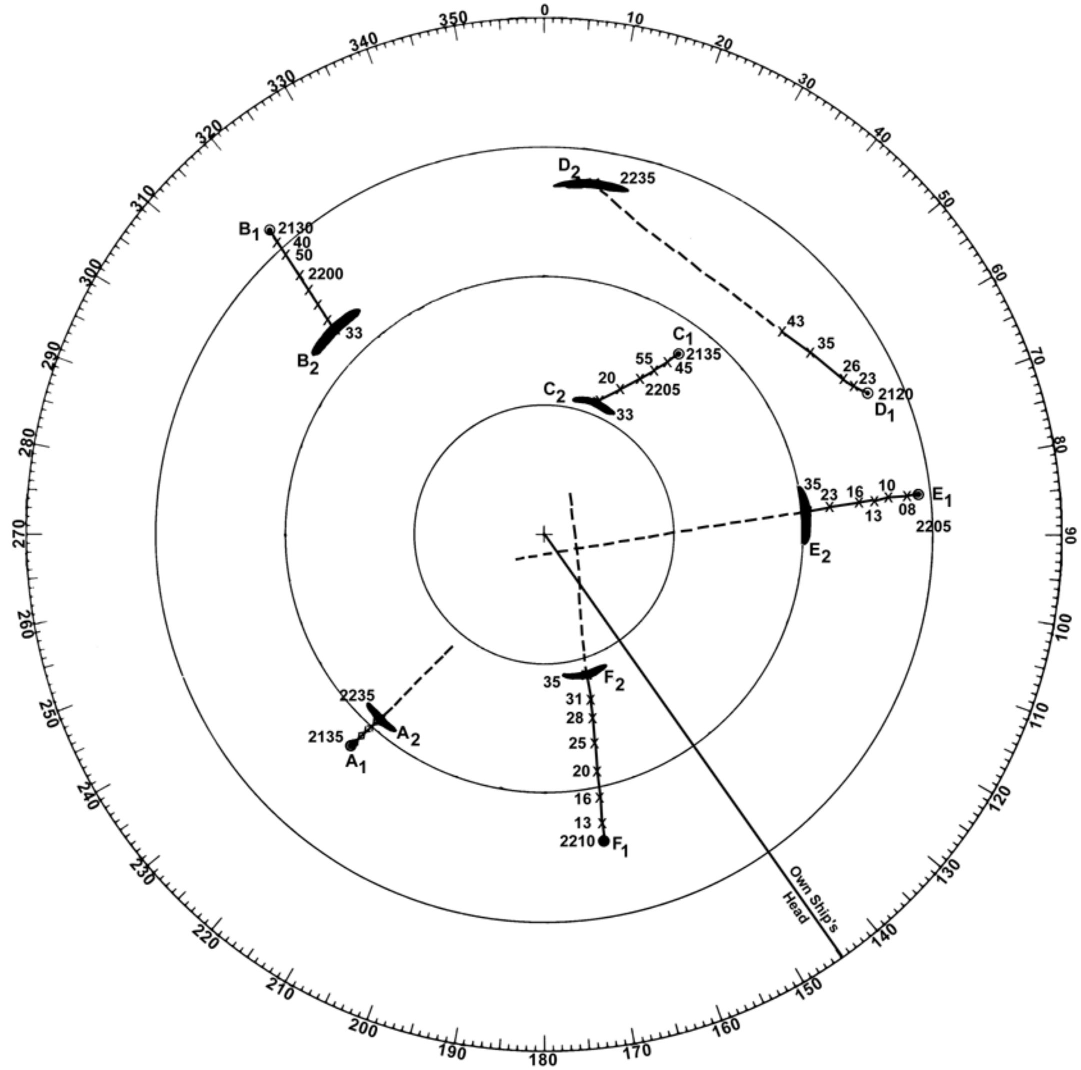
		CPA	Time	Course	Speed
(2)	Ship *F* ...	1,700 yds.	2258	069˚	7.5 knots
	Ship *E* ...	1,900 yds.	2338	182˚	14.0 knots

(3) Change course to 180˚, maintain 15 knots.

		CPA	Time
(4)	Ship *F* ...	6,300 yds.	2250
	Ship *E* ...	17,700 yds.	(Both own ship and *E* are now on about the same course with *E* drawing very slowly astern. CPA thus has little meaning.)

(5) See Fig. 3. *D* has faded from the scope.

(6) With *F* well clear at 2300, a return to original course appears desirable. Apparently *A*, *B*, and *C* also are making the same approach and should cause no trouble. The intentions of *E* are unknown but you have about an hour's time before convergence.



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EXAMPLE 13 Figure 1

PPI SCOPE (20-mile scale)

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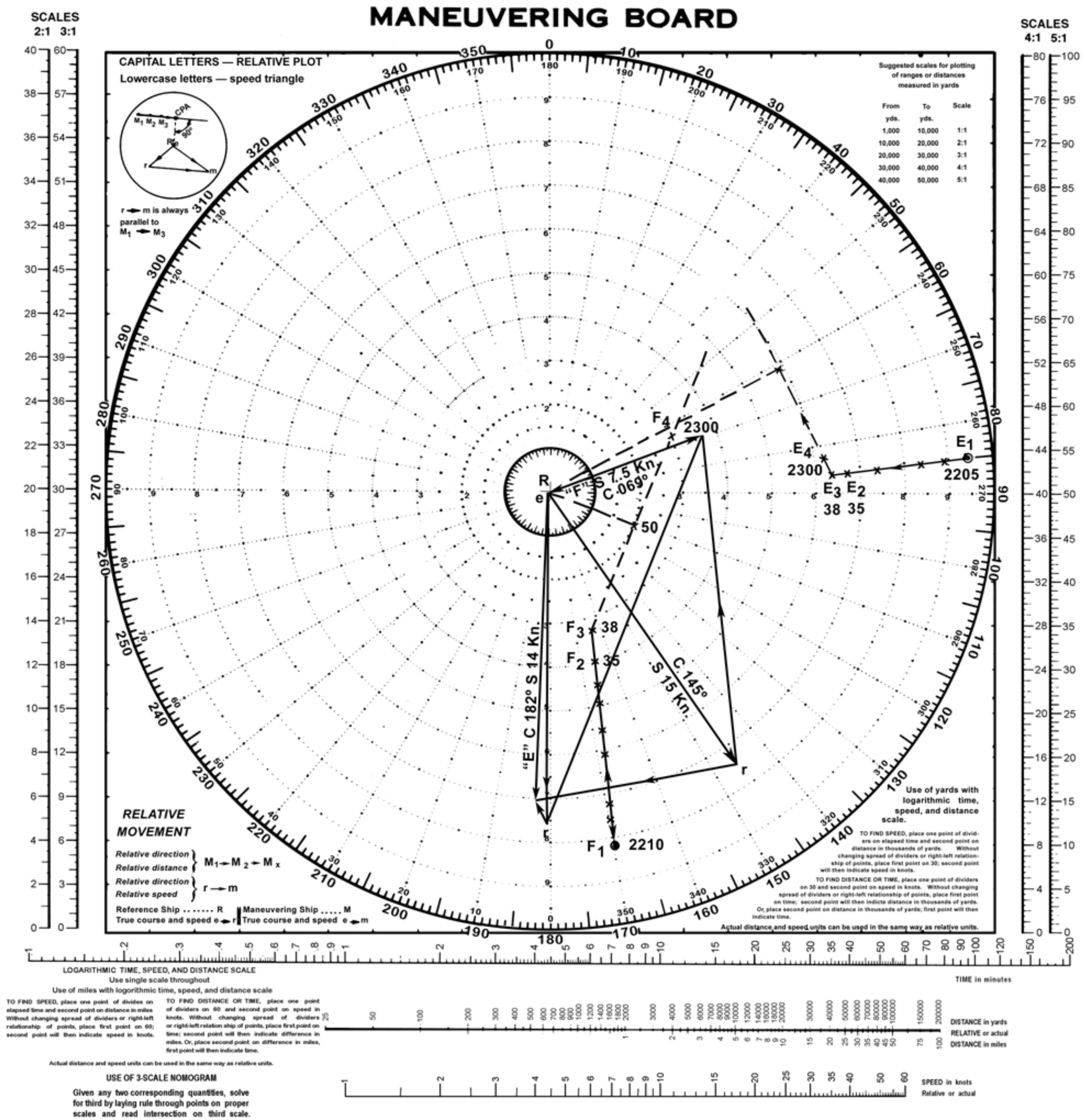

EXAMPLE 13 Figure 2

Scale: Speed 2:1;
Distance 3:1 yd.

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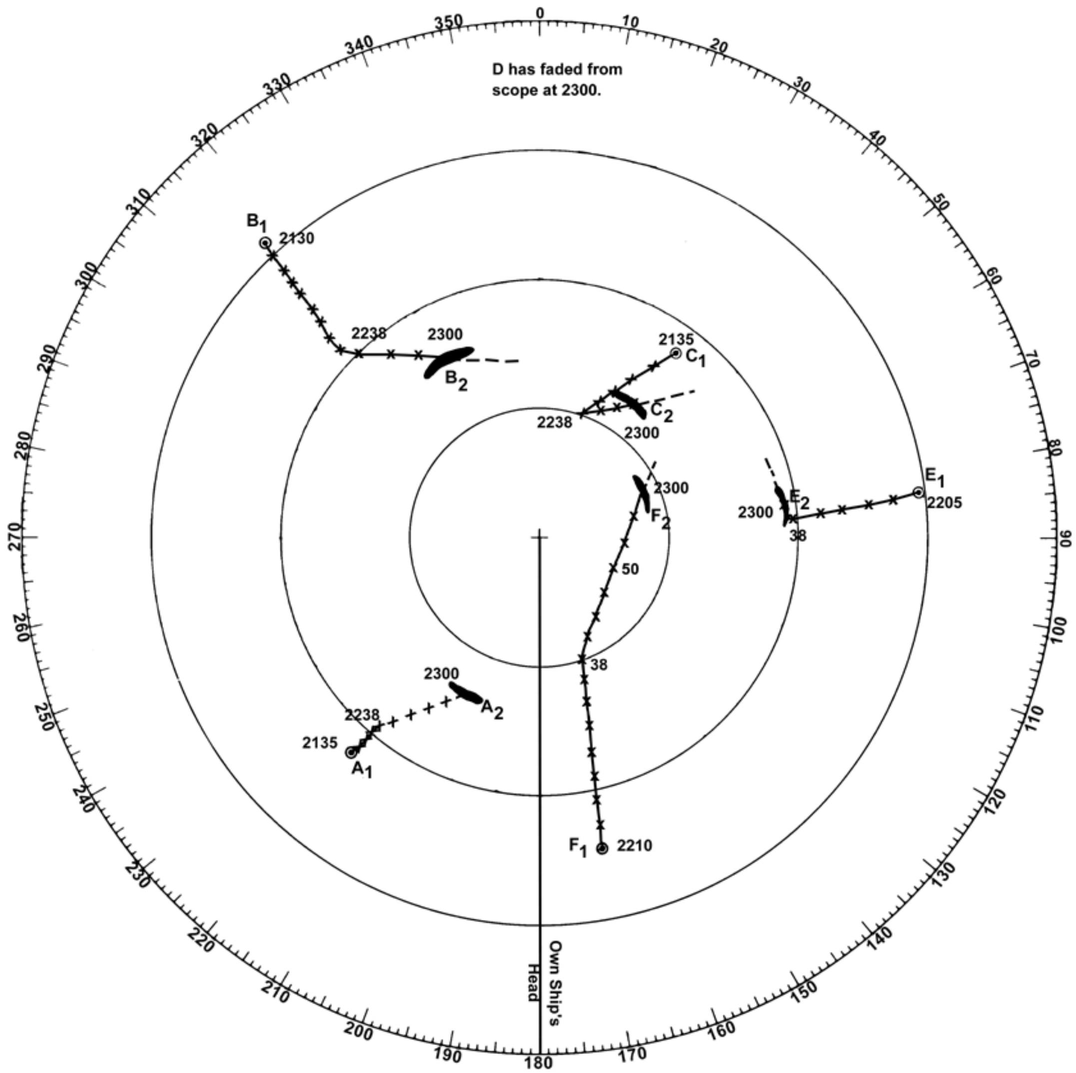


EXAMPLE 13 Figure 3

PPI SCOPE (20-mile scale)

EXAMPLE 14

AVOIDANCE OF MULTIPLE CONTACTS WITHOUT FIRST DETERMINING THE TRUE COURSES AND SPEEDS OF THE CONTACTS

Situation:

Own ship *R* is on course 000˚, speed 20 knots. With the relative motion presentation radar set at the 12-mile range setting, radar contacts are observed as follows:

		Time 1000	
	Bearing	*Range (mi.)*	*Rel. position*
Contact *A*	050˚	9.0	A_1
Contact *B*	320˚	8.0	B_1
Contact *C*	235˚	8.0	C_1

		Time 1006	
	Bearing	*Range (mi.)*	*Rel. position*
Contact *A*	050˚	7.5	A_2
Contact *B*	333˚	6.0	B_2
Contact *C*	225˚	6.0	C_2

Required:

(1) Determine the new relative movement lines for contacts *A*, *B*, and *C* which would result from own ship changing course to 065˚ and speed to 15 knots at time 1006.

(2) Determine whether such course and speed change will result in desirable or acceptable CPA's for all contacts.

Solution:

(1) With the center of the radarscope as their origin, draw own ship's true vectors *er* and *er'* for the speed in effect or to be put in effect at times 1000 and 1006, respectively. Using the distance scale of the radar presentation, draw each vector of length equal to the distance own ship *R* will travel through the water during the time interval of the relative plot (relative vector), 6 minutes. Vector *er*, having a speed of 20 knots, is drawn 2.0 miles in length in true direction 000˚; vector *er'*, having a speed of 15 knots, is drawn 1.5 miles in length in true direction 065˚.

(2) Draw a dashed line between *r* and *r'*.

(3) For Contacts *A*, *B*, and *C*, offset the initial plots (A_1, B_1, and C_1) in the same direction and distance as the dashed line *r-r'*; label each such offset plot *r'*.

(4) In each relative plot, draw a straight line from the offset initial plot, *r'*, through the final plot (A_2 or B_2 or C_2). The lines $r'A_2$, $r'B_2$, and $r'C_2$ represent the new RML's which would result from a course change to 065˚ and speed change to 15 knots at time 1006.

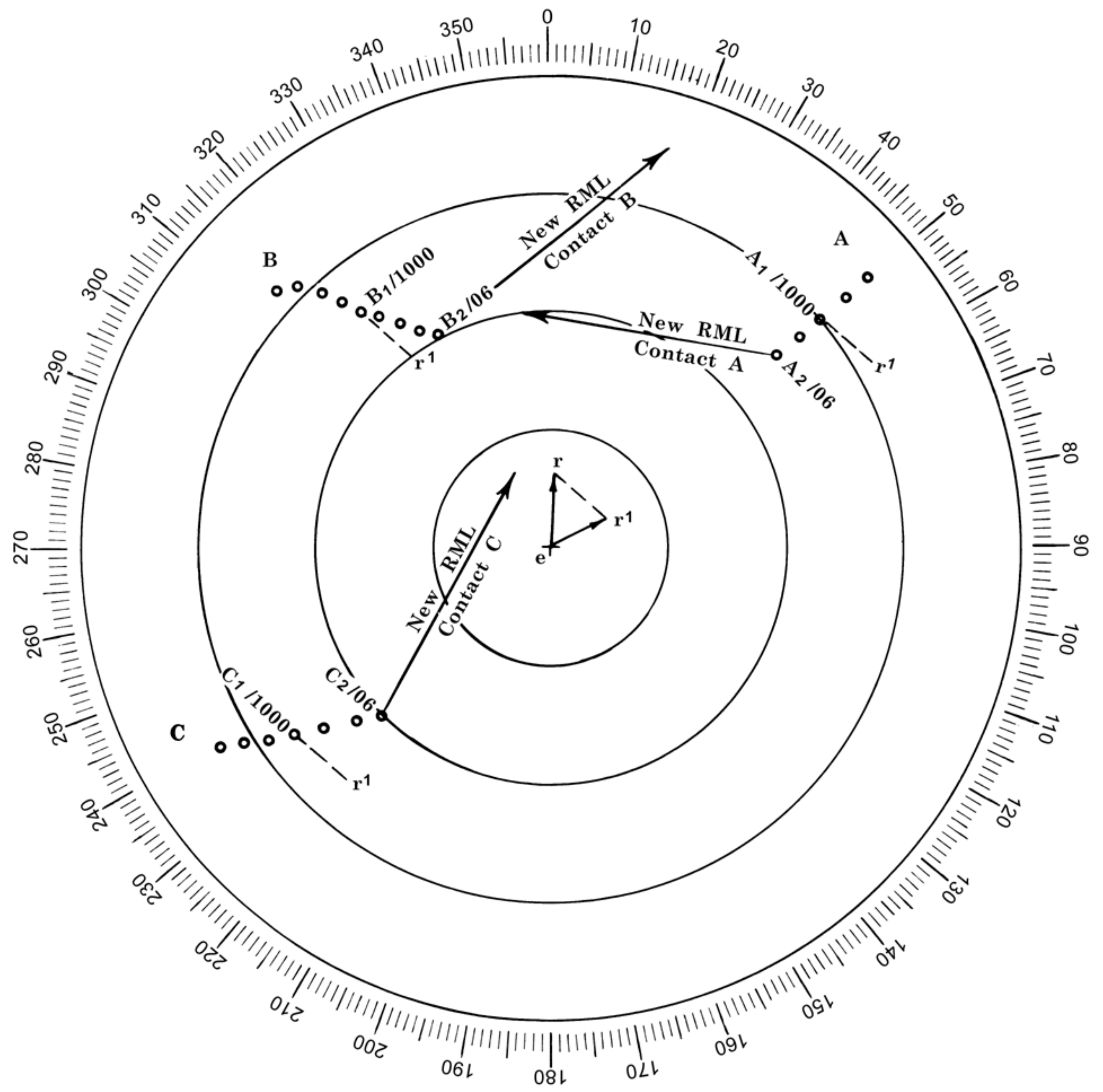
Answer:

(1) New DRM of Contact *A* 280˚.
New DRM of Contact *B* 051˚.
New DRM of Contact *C* 028˚.

(2) Inspection of the new relative movement lines for all contacts indicates that if all contacts maintain course and speed, all contacts will plot along their respective relative movement lines at safe distances from own ship *R* on course 065˚, speed 15 knots.

Explanation:

The solution method is based upon the use of the relative plot as the relative vector as illustrated in Example 4. With each contact maintaining true course and speed, the *em* vector for each contact remains static while own ship's vector is rotated about *e* to the new course and changed in magnitude corresponding to the new speed.



OWN SHIP AT CENTER

EXAMPLE 14

Scale: 12-mile range setting

EXAMPLE 15

DETERMINING THE CLOSEST POINT OF APPROACH FROM THE GEOGRAPHICAL PLOT

Situation:

Own ship is on course 000°, speed 10 knots. The true bearings and ranges of another ship are plotted from own ship's successive positions to form a geographical (navigational) plot:

Time	*Bearing*	*Range (mi.)*	*True position*
0200	074°	7.3	T_1
0206	071°	6.3	T_2
0212	067°	5.3	T_3

Required:

(1) Determine the Closest Point of Approach.

Solution:

(1) Since the successive *timed* positions of each ship of the geographical plot indicate rate of movement and true direction of travel for each ship, each line segment between successive plots represents a true velocity vector. Equal spacing of the plots timed at regular intervals and the successive plotting of the true positions in a straight line indicate that the other ship is maintaining constant course and speed.

(2) The solution is essentially a reversal of the procedure in relative motion solutions in which, from the relative plot and own ship's true vector, the true vector of the other ship is determined. Accordingly, the true vectors from the two true plots for the same time interval, 0206-0212 for example, are subtracted to obtain the relative vector $(\overrightarrow{rm} = \overrightarrow{em} - \overrightarrow{er})$.

(3) The relative (DRM-SRM) vector *rm* is extended beyond own ship's 0212 position to form the relative movement line (RML).

(4) The closest point of approach (CPA) is found by drawing a line from own ship's 0212 plot perpendicular to the relative movement line.

Answer:

(1) CPA 001°, 2.2 miles.

Explanation:

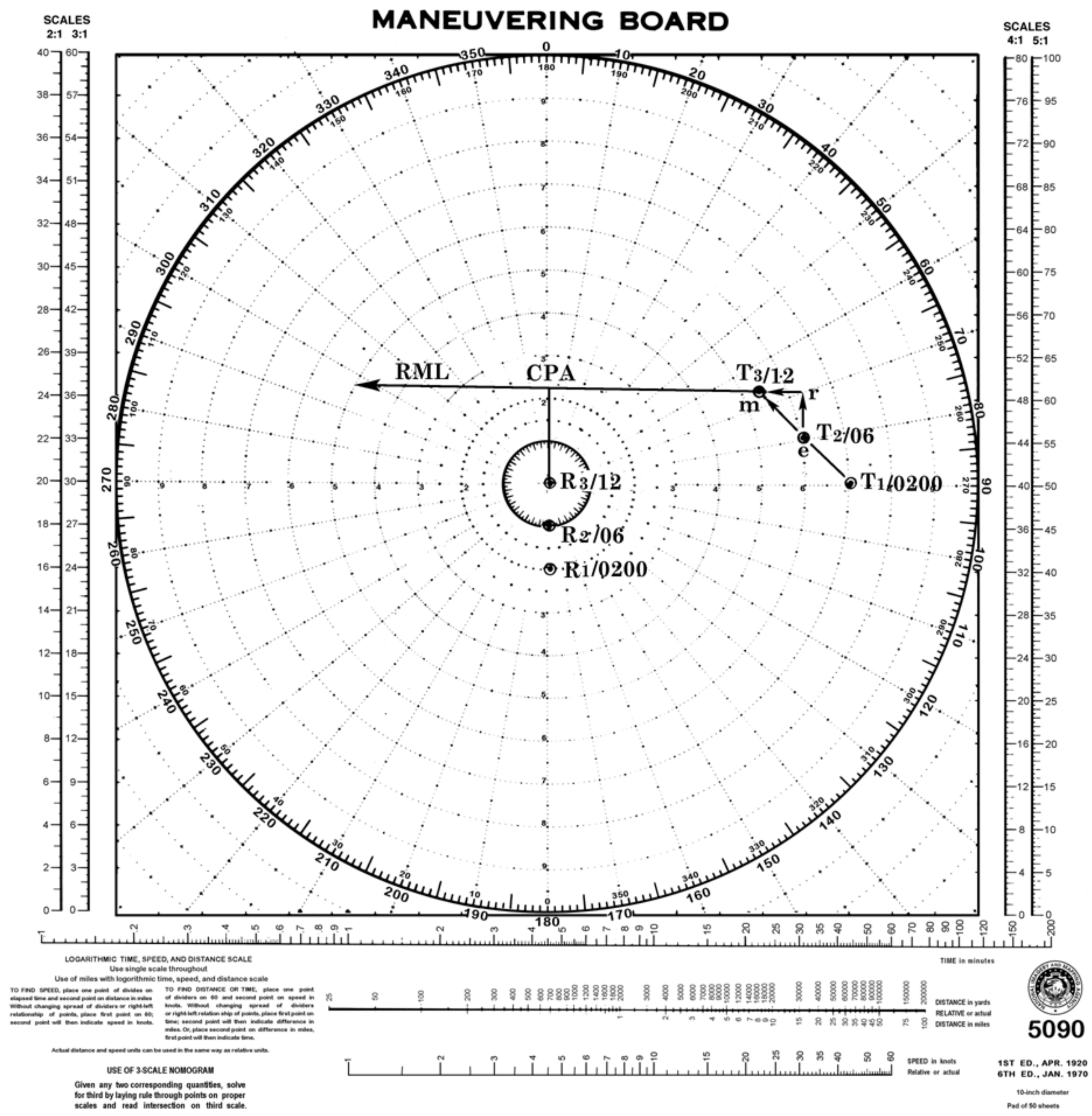
This solution is essentially a reversal of the procedure in relative motion solutions in which, from the relative plot and own ship's true vector, the true vector of the other ship is determined. See Example 3.

Notes:

(1) Either the time 0200, 0206, or 0212 plots of the other ship can be used as the origin of the true vectors of the vector diagram. Using the time 0200 plot as the origin and a time interval of 6 minutes for vector magnitude, the line perpendicular to the extended relative movement line would be drawn from the time 0206 plot of own ship.

(2) A practical solution for CPA in the true motion mode of operation of a radar is based on the fact that the end of the Interscan (electronic bearing cursor) moves from the point, at which initially set, in the direction of own ship's course at a rate equivalent to own ship's speed. With the contact at this point, initially, the contact moves away from the point in the direction of its true course at a rate equivalent to its speed. Thus, as time passes, a vector triangle is being continuously generated. At any instant, the vertices are the initial point, the position of the contact, and the end of the Interscan. The side of the triangle between the end of the Interscan and the contact is the *rm* vector, the origin of which is at the end of the Interscan.

The CPA is found by setting the end of the Interscan at the contact, and, after the vector triangle has been generated, extending the *rm* vector beyond own ship's position of the PPI.



OWN SHIP AT CENTER

EXAMPLE 15

Scale: Distance: 1:1 mi.

EXAMPLE 16

COURSE AND SPEED BETWEEN TWO STATIONS, REMAINING WITHIN A SPECIFIED RANGE FOR SPECIFIED TIME INTERVAL ENROUTE

Situation:

Own ship *R* is on station bearing 280˚, 5 miles from the guide *M* which is on course 190˚, speed 20 knots.

Required:

At 1500 proceed to new station bearing 055˚, 20 miles, arriving at 1630. Remain within a 10-mile range for 1 hour. The commanding officer elects to proceed directly to new station adjusting course and speed to comply.

(1) Course and speed to remain within 10 miles for 1 hour.

(2) Course and speed required at 1600.

(3) Bearing of *M* at 1600.

Solution:

(1) Plot the 1500 and 1630 positions of *M* at M_1 and M_3, respectively. Draw the relative motion line, M_1M_3, intersecting the 10-mile circle at M_2. Draw *em*. Measure M_1M_2: 13.6 miles. The time required to transit this distance is 1 hour at an SRM of 13.6 knots. Through *m* draw r_1 *m* 13.6 knots in length, parallel to and in the direction M_1M_3. Vector er_1 is 147˚.5, 16.2 knots.

(2) Measure M_2M_3, 10.3 miles, which requires an SRM of 20.6 knots for one half hour. Through *m* draw r_2 *m*. Vector er_2 is 125˚.5, 18.2 knots.

(3) By inspection, M_2 bears 226˚ from *R* at 1600.

Answer:

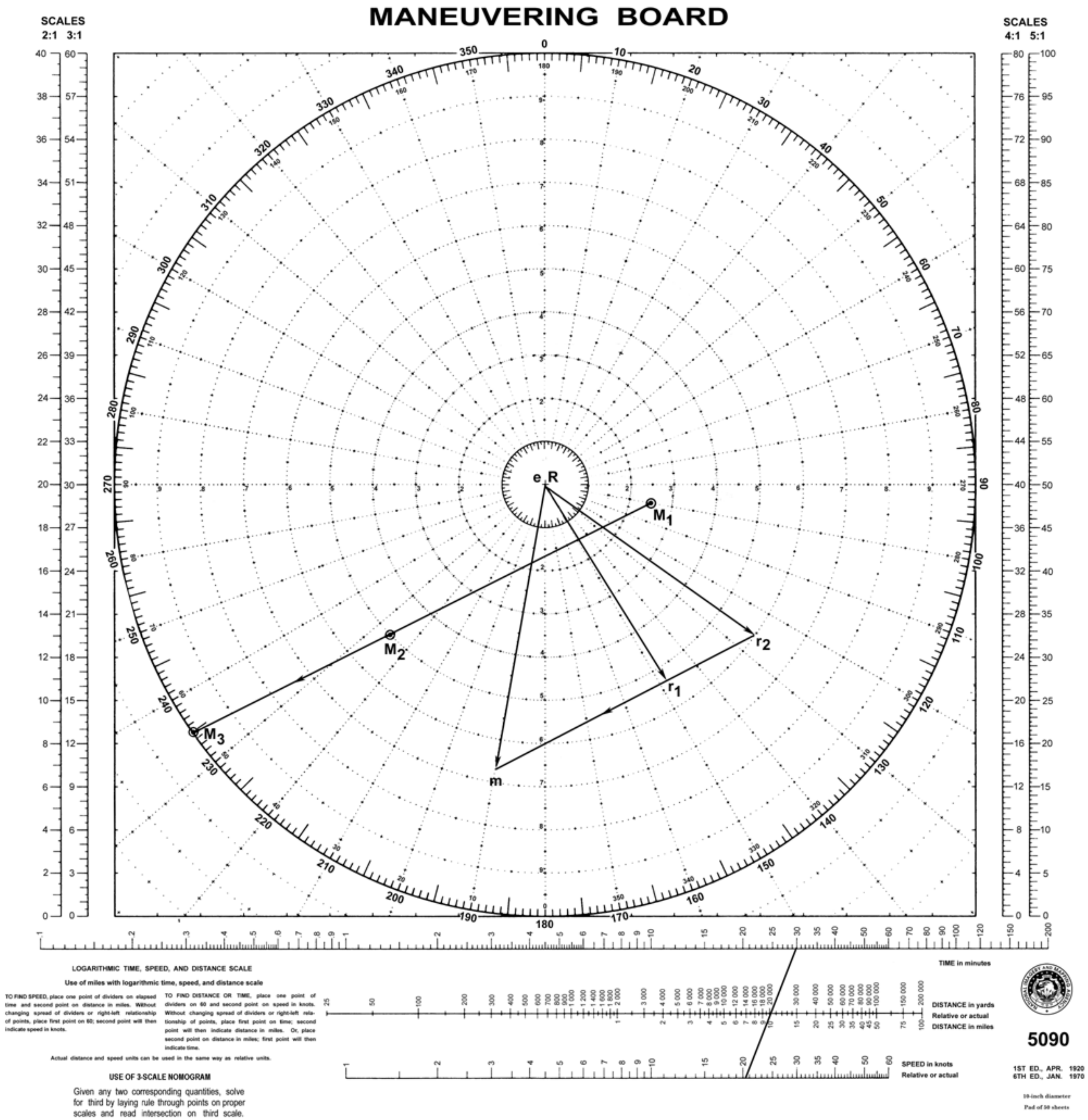
(1) Course 148˚, speed 16.2 knots.

(2) Course 126˚, speed 18.2 knots.

(3) Bearing 226˚.

Explanation:

Since own ship *R* must remain within 10 miles of the guide for 1 hour, *M* must not plot along M_1M_2 farther than M_2 prior to 1600. The required magnitudes of the relative speed vectors for time intervals 1500 to 1600 and 1600 to 1630 together with their common direction are combined with the true vector of the guide to obtain the two true course vectors for own ship.



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EXAMPLE 16

Scale: Speed 3:1;
Distance 2:1 mi.

EXAMPLE 17

COURSE AT MAXIMUM SPEED TO OPEN RANGE TO A SPECIFIED DISTANCE IN MINIMUM TIME

Situation:

Own ship *R* has guide *M* bearing 240˚, range 12 miles. The guide is on course 120˚, speed 15 knots. Own ship's maximum speed is 30 knots.

Required:

Open range to 18 miles as quickly as possible.

(1) Course at 30 knots.

(2) Time to complete the maneuver.

(3) Bearing of guide upon arrival at specified range.

Solution:

The key to this solution is to find that relative position (*M'*) of the guide that could exist *before* the problems starts in order to be able to draw the RML through the given relative position (M_1) and *M'* to intersect the specified range circle.

(1) Plot *R* and M_1. About *R* describe a circle of radius 18 miles. Draw *em*. On the reciprocal of *M*'s course plot *M'* 9 miles from *R*.

$$\frac{\text{Speed of } M}{\text{Speed of } R} \times 18 \text{ miles} = 9 \text{ miles}$$

Draw a line through *M'* and M_1 and extend it to intersect the 18-mile range circle at M_2.

Through *m* draw *rm* parallel to and in the direction M_1M_2. The intersection of *rm* and the 30-knot speed circle is the course required to complete the maneuver in minimum time. Vector *er* is 042˚.6, 30 knots.

(2) SRM is 30.5 knots. MRM is 7.5 miles. Time to complete the maneuver: 14.8 minutes.

(3) Upon reaching the 18-mile range circle, *M* is dead astern of *R* bearing 222˚.6.

Answer:

(1) Course 043˚.

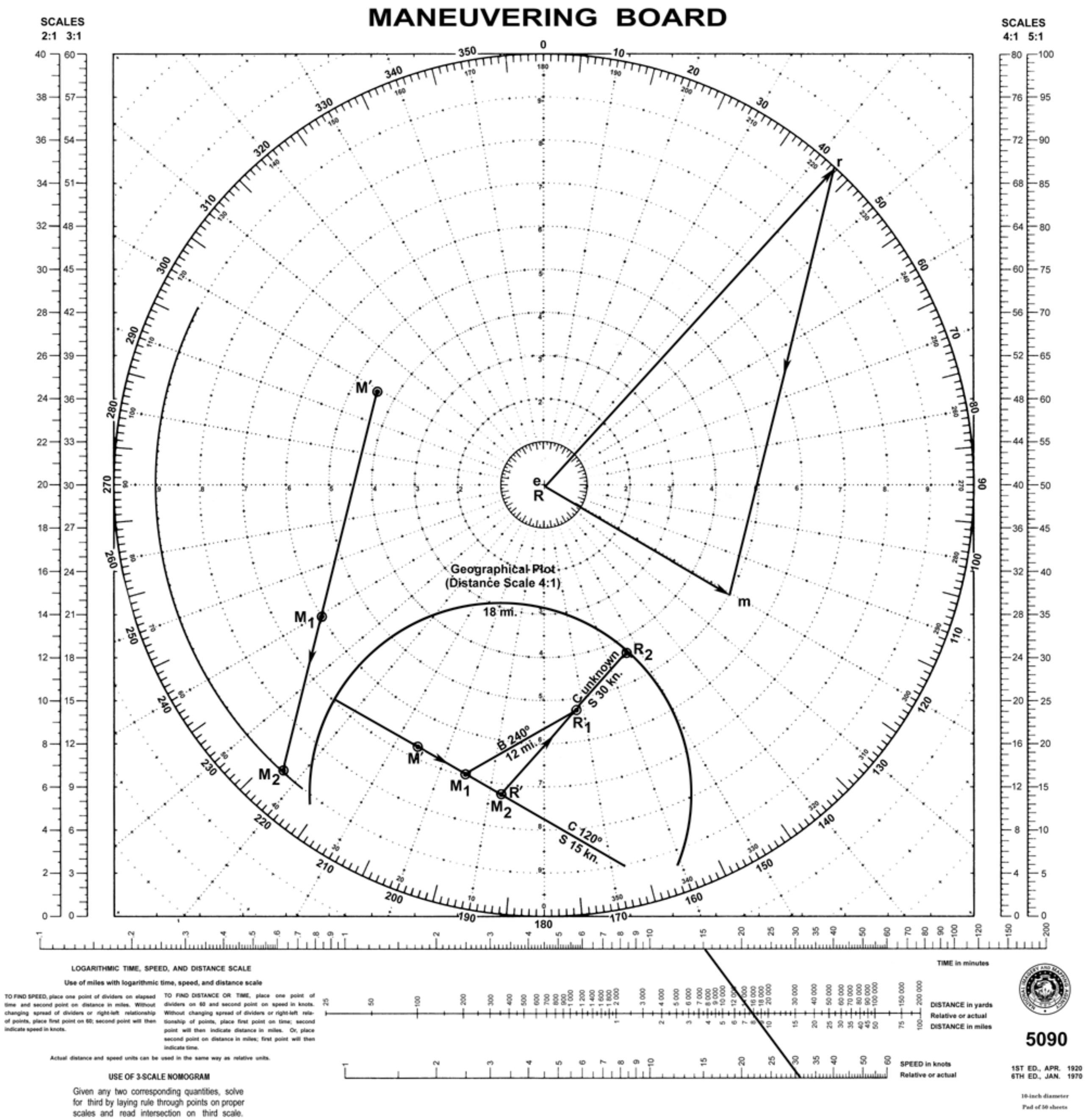
(2) Time 15 minutes.

(3) Bearing 223˚.

Explanation:

For *R* to open or close to a specified range in minimum time, *R* must travel the shortest geographical distance at maximum speed. The shortest distance is along the radius of a circle centered at the position occupied by *M* at the instant *R* reaches the specified range circle.

In the "opening range" problem, determine hypothetical relative positions of *M* and *R* that could exist *before the problem starts*. Referring to the **geographical plot**, assume *R* starts from position *R'* and proceeds outward along some radius 18 miles in length on an unknown course at 30 knots. If *M* moves toward its final position at M_2 along the given course of 120˚, speed 15 knots, it should arrive at M_2 the instant *R* reaches the 18-mile circle. At this instant, the problem conditions are satisfied by *R* being 18 miles distant from *M*. However, own ship's course required to reach this position is not yet known. During the time interval *R* opens 18 miles at 30 knots, *M* moves 9 miles at 15 knots from *M'* on *M*'s track. This provides the needed second relative position of *M'* from *R'*, 9 miles bearing 300˚. This position is then transferred to the **relative plot**.



OWN SHIP AT CENTER

EXAMPLE 17

Scale: Speed 3:1;
Distance 2:1 mi.

EXAMPLE 18

COURSE AT MAXIMUM SPEED TO CLOSE RANGE TO A SPECIFIED DISTANCE IN MINIMUM TIME

Situation:

Own ship *R* has the guide *M* bearing 280˚, range 10 miles. The guide is on course 020˚, speed 15 knots. Own ship's maximum speed is 24 knots.

Required:

Close range to 2 miles as quickly as possible.
(1) Course at 24 knots.
(2) Time to complete the maneuver.
(3) Bearing of guide upon arrival at the specified range.

Solution:

The key to this solution is to find that relative position (M') of the guide that could exist *after* the problem starts in order to be able to draw the RML through the given relative position (M_1) and M' to intersect the specified range circle.

(1) Plot *R* and M_1. About *R* describe a circle of radius 2 miles. Draw *em*. On *M*'s course plot M' 1.25 miles from *R*.

$$\frac{\text{Speed of } M}{\text{Speed of } R} \times 2 \text{ miles} \;=\; 1.25 \text{ miles}$$

Draw a line through M' and M_1. The intersection of this line and the 2-mile range circle is M_2.

To *m* draw a line parallel to and in the direction M_1M_2. The intersection of this line and the 24-knot speed circle is the course required to complete the maneuver in minimum time. Vector *er* is 309˚.8, 24 knots.

(2) SRM is 23.6 knots. MRM is 8.3 miles. Time to complete the maneuver: 21.1 minutes.

(3) Upon reaching the 2-mile range circle, *M* is dead ahead of *R* on a bearing 309˚.8.

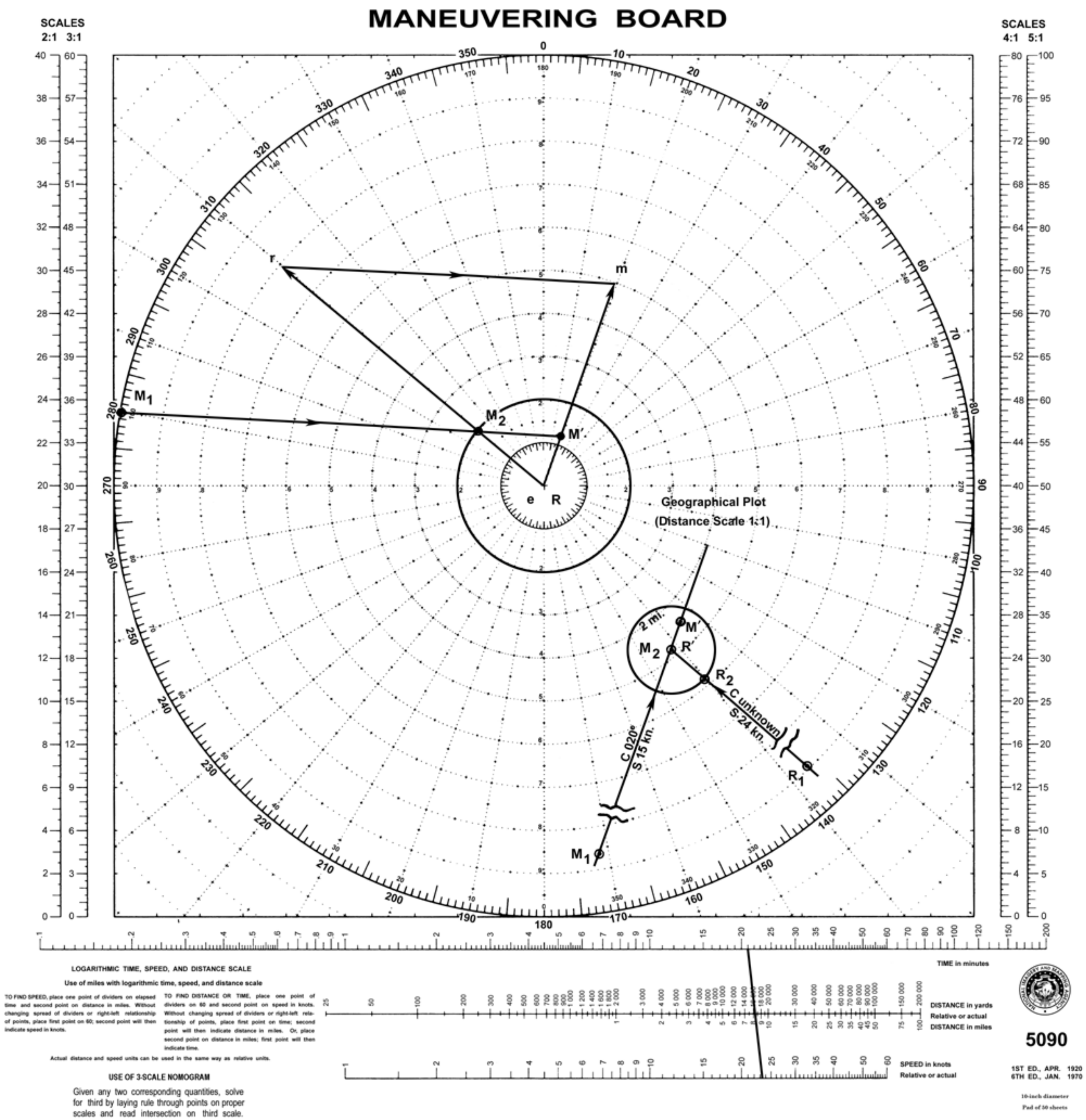
Answer:

(1) Course 310˚.
(2) Time 21 minutes.
(3) Bearings 310˚.

Explanation:

For *R* to open or close to a specified range in minimum time, *R* must travel the shortest geographical distance at maximum speed. The shortest distance is along the radius of a circle centered at the position occupied by *M* at the instant *R* reaches the specified range circle.

In the "closing range" problem, determine hypothetical relative positions of *M* and *R* that could exist *after the problem ends*. Referring to the **geographical plot**, assume *R* starts from position R_1 and proceeds inward along some radius on an unknown course at 24 knots. If *M* moves toward its final position at M_2 along the given course 020˚, speed 15 knots, it should arrive at M_2 the instant *R* reaches the 2-mile circle. At this instant the problem conditions are satisfied although the solution for own ship's course is not yet known. Assume that *R* continues on the same course and speed through the 2 miles to the center of the circle while *M* moves away from the center on course 020˚, speed 15 knots. During the time interval *R* moves these 2 miles at 24 knots, *M* opens 1.25 miles. This provides the needed second relative position of M' from R': 1.25 miles, bearing 020˚. This position is then transferred to the **relative plot**.



OWN SHIP AT CENTER

EXAMPLE 18

Scale: Speed 3:1;
Distance 1:1 mi.

EXAMPLE 19

COURSE AT MAXIMUM SPEED TO REMAIN WITHIN A SPECIFIED RANGE FOR MAXIMUM TIME

Situation:

Ship *M* bears 110˚, 4 miles from *R*. *M* is on course 230˚, 18 knots. Maximum speed of *R* is 9 knots.

Required:

Remain within a 10-mile range of *M* for as long as possible.
(1) Course at maximum speed.
(2) Bearing of *M* upon arrival at specified range.
(3) Length of time within specified range.
(4) CPA.

Solution:

(1) Plot *R* and *M*. About *R* describe circles of radius 9 knots and range 10 miles. Draw *em*. On *M*'s course, plot *M'* 20 miles from *R*.

$$\frac{\text{Speed of } M}{\text{Speed of } R} \times 10 \text{ miles} \;=\; 20 \text{ miles}$$

Draw a line through *M'* and M_1. The intersection of the 10-mile range circle and $M'M_1$ is M_2, the point beyond which the specified or limiting range is exceeded. Through *m* draw *rm* parallel to and in the direction M_1M_2. The intersection of *rm* and the 9-knot speed circle is the course required for *R*, at 9 knots, to remain within 10 miles of *M*. Vector *er* is 220˚.8, 9 knots.

(2) Upon arrival at limiting range at M_2, *M* is dead ahead of *R* bearing 220˚.8.

(3) The time interval within specified range is:

$$\frac{\mathrm{M_1M_2}}{\mathrm{rm}} = \frac{12 \text{ miles}}{9.1 \text{ knots}} = 78.8 \text{ minutes}$$

(4) Drop a perpendicular from *R* to M_1M_2. CPA is 148˚.9, 3.1 miles.

Note:

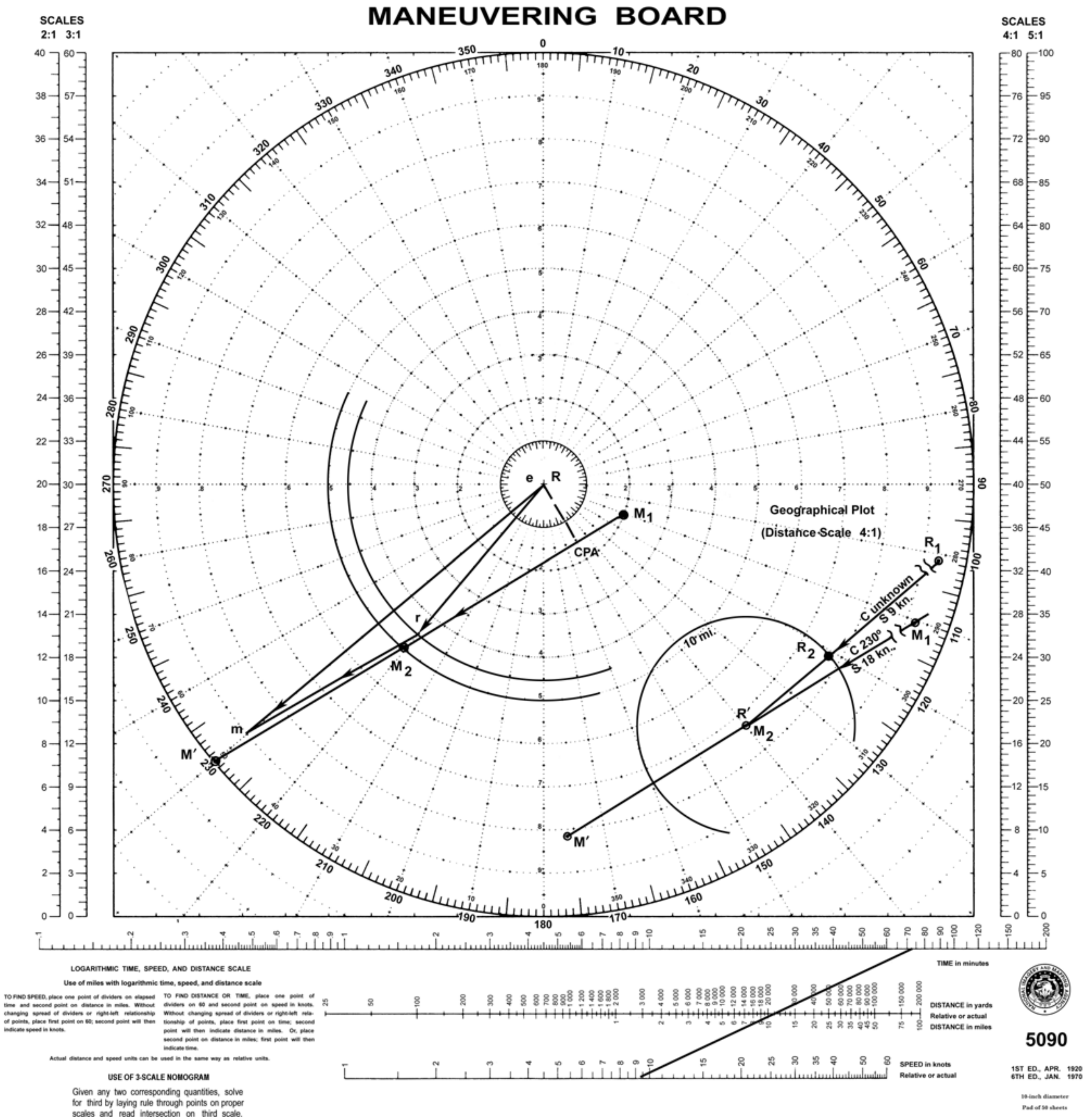
When *R*'s speed is equal to or greater than that of *M*, a special case exists in which there is no problem insofar as remaining within a specified range.

Answer:

(1) Course 221˚.
(2) Bearing 221˚.
(3) Time 79 minutes.
(4) CPA 149˚, 3.1 miles.

Explanation:

As in the "closing range" problem, example 18, determine hypothetical relative positions of *M* and *R* that could exist *after the problem ends*. Referring to the **geographical plot**, assume *R* starts from position R_1 and proceeds inward along some radius on an unknown course at 9 knots. *M* is on course 230˚ at 18 knots. At the instant *M* passes through M_2, *R* reaches the 10-mile limiting range at R_2. At this instant the problem conditions are satisfied although the solution is not yet known. Assume that *R* continues on the same course and speed the 10 miles to the center of the circle while *M* moves away from the center on course 230˚, speed 18 knots. During the time interval *R* closes 10 miles at 9 knots, *M* opens 20 miles at 18 knots. This provides the needed second relative position of *M'* from *R'*, 20 miles bearing 230˚. This position is then transferred to the **relative plot**.



OWN SHIP AT CENTER

EXAMPLE 19

Scale: Speed 2:1;
Distance 2:1 mi.

EXAMPLE 20

COURSE AT MAXIMUM SPEED TO REMAIN OUTSIDE OF A SPECIFIED RANGE FOR MAXIMUM TIME

Situation:

Ship *M* bears 020˚, 14 miles from own ship *R*. *M* is on course 210˚, speed 18 knots. Maximum speed of *R* is 10 knots.

Required:

Remain outside a 10-mile range from *M* for as long as possible.
(1) Course at maximum speed.
(2) Bearing of *M* upon arrival at specified range.
(3) Time interval before reaching specified range.

Solution:

(1) Plot *R* and M_1. About *e* and *R*, describe circles of radius 10 knots and 10 miles. Draw *em*. On the reciprocal of *M*'s course, plot *M'* 18 miles from *R*.

$$\frac{\text{Speed of } M}{\text{Speed of } R} \times 10 \text{ miles} = 18 \text{ miles}$$

Draw a line through *M'* and M_1 intersecting the 10-mile range circle at M_2 and M_3.

To *m* draw a line parallel to and in the direction of M_1M_2 intersecting the 10-knot speed circle at r_1 and r_2. M_2 and er_1 are selected for use in completing the solution. M_2 is the first point at which limiting range is reached and r_1m is the minimum relative speed vector which gives the maximum time. Vector er_1 is 175˚.9, 10 knots.

(2) Upon arrival at limiting range at point M_2, *M* is dead astern of *R* bearing 355˚.9.

(3) The time interval outside of specified range is:

$$\frac{M_1M_2}{r_1m} = \frac{6.3 \text{ miles}}{11.1 \text{ knots}} = 34.2 \text{ minutes}$$

Note:

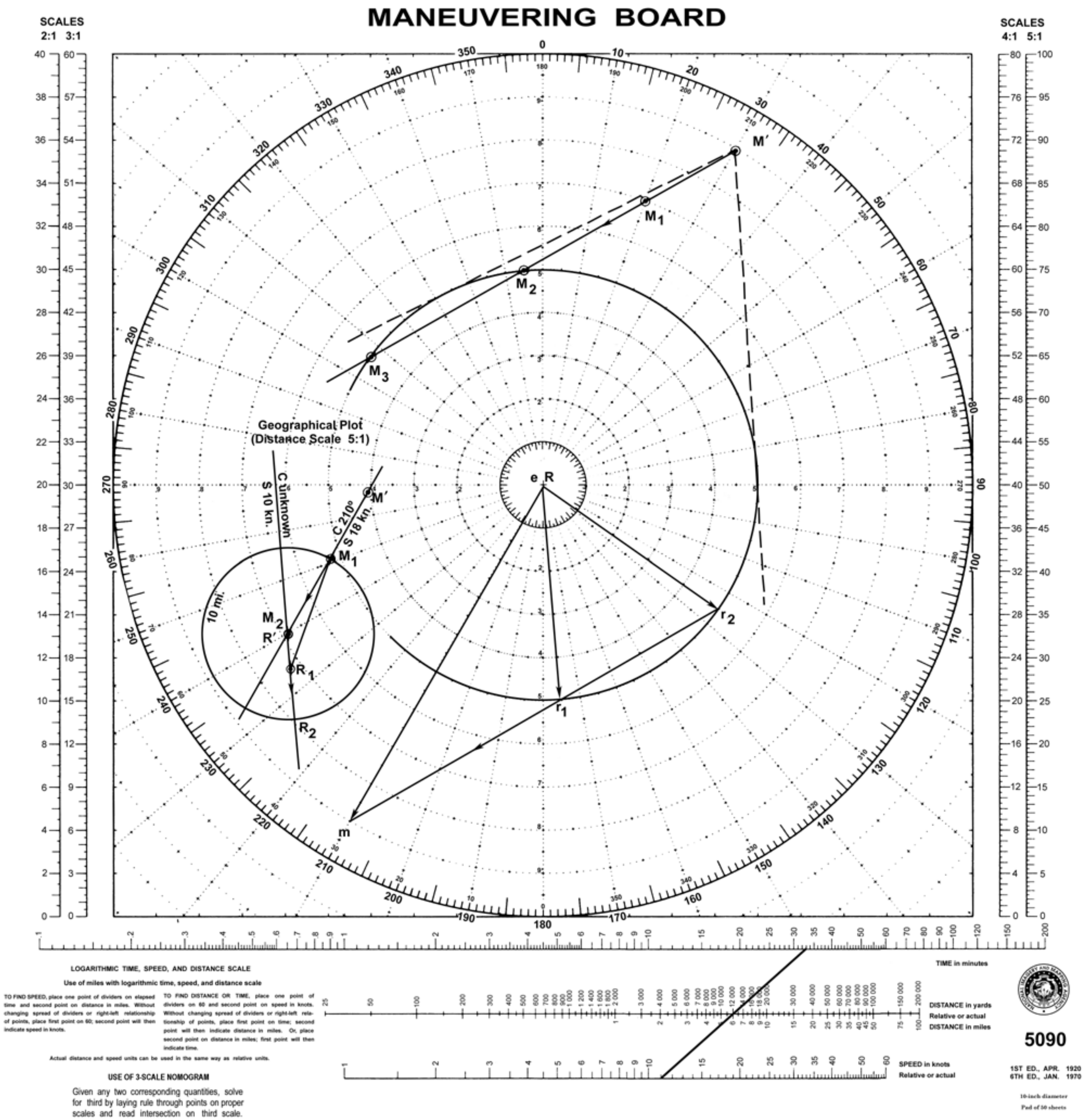
Own ship can remain outside the limiting range indefinitely if M_1 falls outside the area between two tangents drawn to the limiting range circle from *M'*.

Answer:

(1) Course 176˚.
(2) Bearing 356˚.
(3) Time 34 minutes.

Explanation:

To determine a course to remain outside of a given range for maximum time, determine hypothetical relative positions of *M* and *R* that could exist *before the problem starts*. Referring to the **geographical plot**, assume *R* starts from position *R'* and proceeds outward along some radius on an unknown course at 10 knots. If *M* moves toward its final position at M_2 along the given course 210˚, speed 18 knots, it should arrive at M_2 the instant *R* reaches the 10 mile circle at R_2. At this instant the problem conditions are satisfied although the solution for own ship's course is not yet known. During the time interval required for *R* to move from *R'* to R_2, 10 miles at 10 knots, *M* moves from *M'* to M_2, 18 miles at 18 knots along the given course 210˚. This provides the needed second relative positions. *M'* bears 030˚, 18 miles from *R'*. This position is then transferred to the **relative plot**.



OWN SHIP AT CENTER

EXAMPLE 20

Scale: Speed 2:1;
Distance 2:1 mi.

USE OF A FICTITIOUS SHIP

The examples given thus far have been confined to ships that have either maintained constant courses and speeds during a maneuver or else have engaged in a succession of such maneuvers requiring only repeated application of the same principles. When one of the ships alters course and/or speed during a maneuver, a preliminary adjustment is necessary before these principles can be applied.

This adjustment consists, in effect, of substituting a **fictitious ship** for the ship making the alteration. This fictitious ship is presumed to:

(1) maintain a constant course and speed throughout the problem (this is the *final* course and speed of the actual ship).

(2) start and finish its run at times and positions determined by the conditions established in the problem.

For example, the course and speed of advance of a ship zig-zagging are considered to be the constant course and speed of a fictitious ship which departs from a given position at a given time simultaneously with the actual ship, and arrives simultaneously with the actual ship at the same final position. The principles discussed in previous examples are just as valid for a fictitious ship as for an actual ship, both in the relative plot and speed triangle. A **geographical plot** facilitates the solution of problems of this type.

EXAMPLE 21

ONE SHIP ALTERS COURSE AND/OR SPEED DURING MANEUVER

Situation:

At 0630 ship *M* bears 250˚, range 32 miles. *M* is on course 345˚, speed 15 knots but at 0730 will change course to 020˚ and speed to 10 knots.

Required:

Own ship *R* takes station 4 miles on the starboard beam of *M* using 12 knots speed.

(1) Course to comply.

(2) Time to complete maneuver.

Solution:

The key to this solution is to determine the 0630 position of a **fictitious ship** that by steering course 020˚, speed 10 knots, will pass through the actual ship's 0730 position. In this way the fictitious ship travels on a steady course of 020˚ and speed 10 knots throughout the problem.

(1) Plot *R*, M_1, and M_3. Draw em_1 and em_2/emf.

Construct a **geographical plot** with initial position M_1. Plot M_1 and M_2, *M*'s 0630-0730 travel along course 345˚, distance 15 miles. Plot MF_1, the fictitious ship's initial position, on bearing 200˚, 10 miles from M_2. MF_1 to MF_2 is the fictitious ship's 0630-0730 travel.

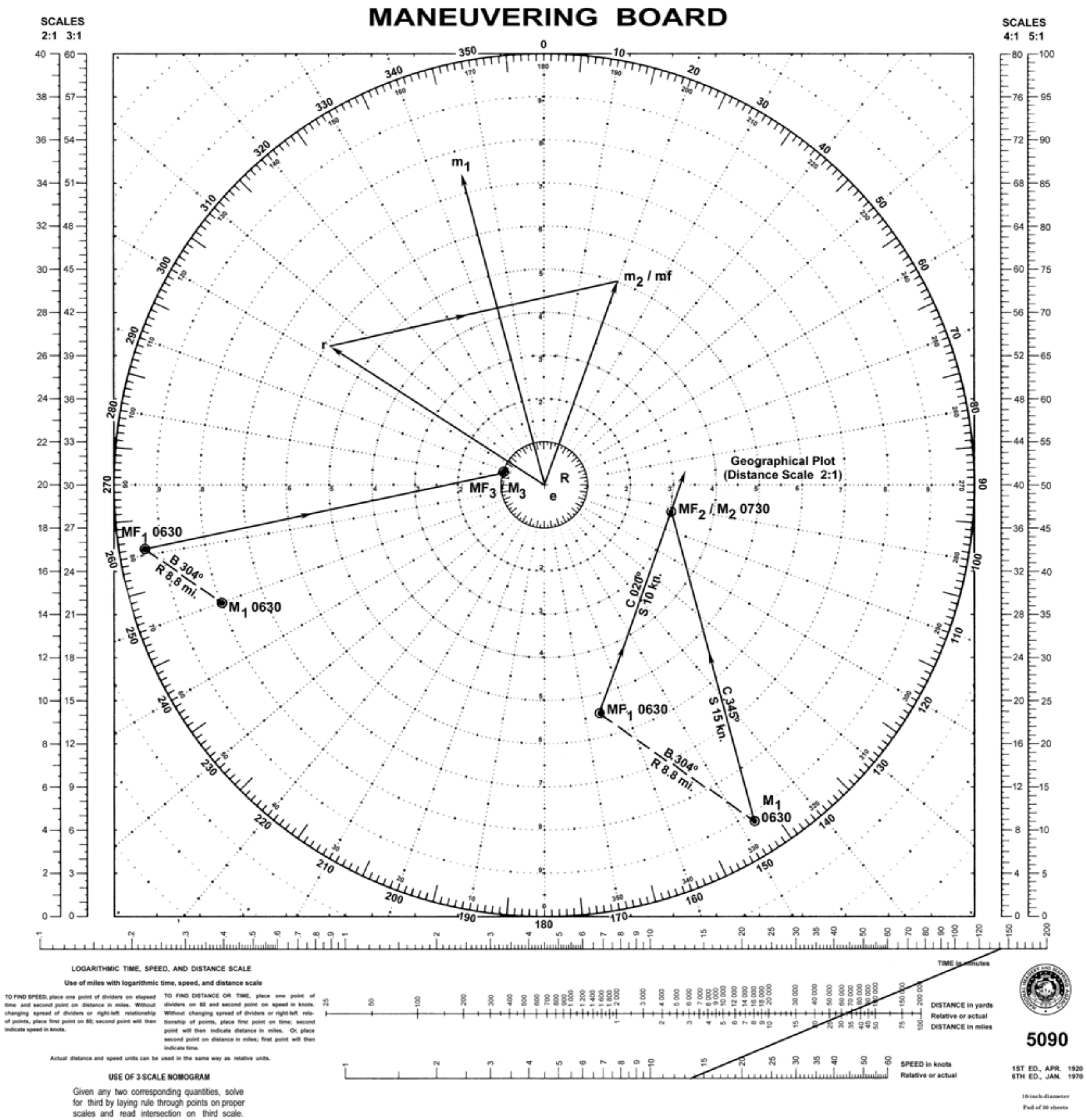
Transfer the relative positions of M_1 and MF_1 to the **relative plot**. MF_1MF_3 is the required DRM and MRM for problem solution. Draw rm_2 parallel to and in the direction of MF_1MF_3. The intersection of rm_2 and the 12-knot speed circle is the course, *er*: 303˚, required by *R* in changing stations while *M* maneuvers.

(2) The time to complete the maneuver is obtained from the TDS scale using fictitious ship's MRM from MF_1 to MF_3 and the SRM of *rmf*.

Answer:

(1) Course 303˚.

(2) Time 2 hours 29 minutes.



OWN SHIP AT CENTER

EXAMPLE 21

Scale: Speed 2:1;
Distance 4:1 mi.

EXAMPLE 22

BOTH SHIPS ALTER COURSE AND/OR SPEED DURING MANEUVER

Situation:

At 0800 *M* is on course 105˚, speed 15 knots and will change course to 350˚, speed 18 knots at 0930. Own ship *R* is maintaining station bearing 330˚, 4 miles from *M*. *R* is ordered to take station bearing 100˚, 12 miles from *M*, arriving at 1200.

Required:

(1) Course and speed for *R* to comply if maneuver is begun at 0800.

(2) Course for *R* to comply if *R* delays the course change as long as possible and remains at 15 knots speed throughout the maneuver.

(3) Time to turn to course determined in (2).

Solution:

Since the relative positions of *R* and *M* at the beginning and end of the maneuver and the time interval for the maneuver are given, the solution for (1) can be obtained directly from a **geographical plot**. Solve the remainder of the problem using a **relative plot**.

(1) Using a geographical plot, lay out *M*'s 0800-1200 track through points M_1, M_2, and M_3. Plot R_1 and R_3 relative to M_1 and M_3, respectively. The course of 040˚ from R_1 to R_3 can be measured directly from the plot. *R* will require a speed of 10.8 knots to move 43.4 miles in 4 hours.

(This solution can be verified on the relative plot. First, using a geographical plot, determine the 0800 position of a **fictitious ship**, MF_1, such that by departing this point at 0800 on course 350˚, 18 knots it will arrive at point MF_2 simultaneously with the maneuvering ship *M*. MF_1 bears 141˚, 41.7 miles from M_1. Transfer the positions of M_1 and MF_1 to the relative plot. Plot *R* and M_2. Draw the fictitious ship's vector, emf_1. To mf_1 construct the SRM vector parallel to MF_1 MF_2 and 13.8 knots in length. Vector er_1 is the required course of 040˚.)

(2) To find the two legs of *R*'s 0800-1200 track, use a relative plot. Draw er_2, own ship's speed vector which is given as 105˚, 15 knots. At this stage of the solution, disregard *M* and consider own ship *R* to maneuver relative to a new fictitious ship. Own ship on course 040˚, 10.8 knots from part (1) is the fictitious ship used. Label vector er_1 as emf_2, the fictitious ship's vector. From point r_2 draw a line through mf_2 extended to intersect the 15-knot speed circle at r_3. Draw er_3, the second course of 012˚ required by *R* in changing station.

(3) To find the time on each leg draw a time line from r_2 using any convenient scale. Through r_3 draw r_3X. Through r_1 draw r_1Y parallel to r_3X. Similar triangles exist; thus, the time line is divided into proportional time intervals for the two legs: XY is the time on the first leg: 1 hour 22 minutes. The remainder of the 4 hours is spent on the second leg.

Answer:

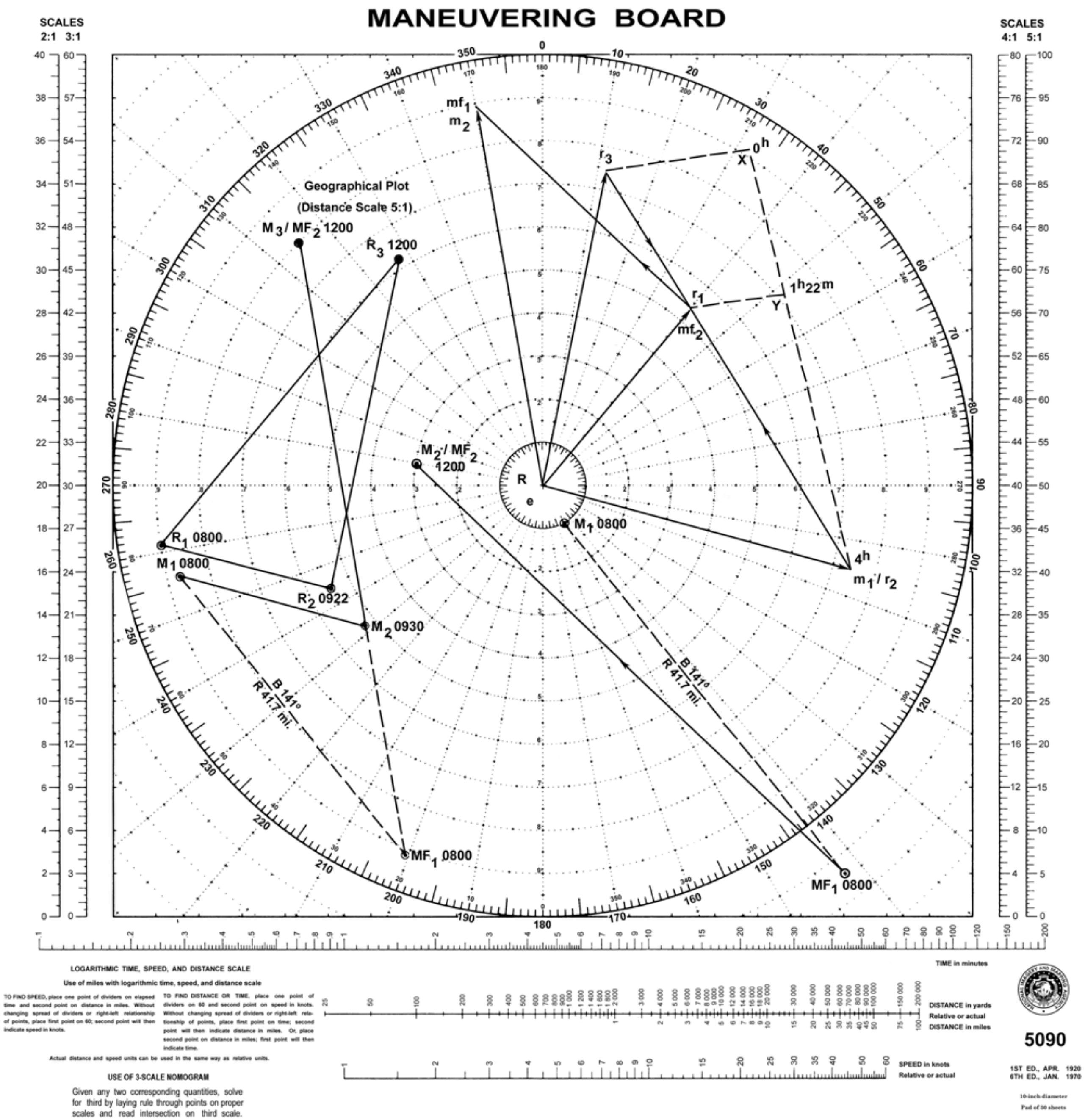
(1) Course 040˚, 10.8 knots.

(2) Course 012˚.

(3) Time 0922.

Note:

In the above example, an alternative construction of the time line as defined in the glossary is used so that the line can be drawn to a convenient scale. The proportionality is maintained by constructing similar triangles. See Note with example 24.



OWN SHIP AT CENTER

EXAMPLE 22

Scale: Speed 2:1; Distance 4:1 mi.

EXAMPLE 23

COURSES AT A SPECIFIED SPEED TO SCOUT OUTWARD ON PRESENT BEARING AND RETURN AT A SPECIFIED TIME

Situation:

Own ship *R* is maintaining station on *M* which bears 110˚, range 5 miles. Formation course is 055˚, speed 15 knots.

Required:

Commencing at 1730, scout outward on present bearing and return to present station at 2030. Use 20 knots speed.

(1) Course for first leg.
(2) Course for second leg.
(3) Time to turn.
(4) Maximum distance from the guide.

Solution:

(1) Plot *R* and M_1. Draw *em*. The DRM "out" is along the bearing of *M* from *R*. The DRM "in" is along the bearing of *R* from *M*. Through *m* draw a line parallel to the DRM's intersecting the 20-knot circle at r_1 and r_2. Vector r_1m is the DRM "out". Vector er_1 is 327˚.8, the course "out".

(2) Vector r_2m is the DRM "in". Vector er_2 is 072˚, the course "in".

(3) To find the time on each leg, draw a time line from r_1 using any convenient scale. Through r_2 draw r_2X. Through *m* draw *m*Y parallel to r_2X. Similar triangles exist; thus, the time line is divided into proportional time intervals for the two legs. XY is the time on the first leg, 41 minutes. The remainder of the time is spent on the second leg returning to station.

(4) Range of *M* when course is changed to "in" leg is 21.7 miles. Initial range + (r_1m x *time* on "out" leg).

Answer:

(1) Course 328˚.
(2) Course 072˚.
(3) Time 1811.
(4) Distance 21.7 miles.

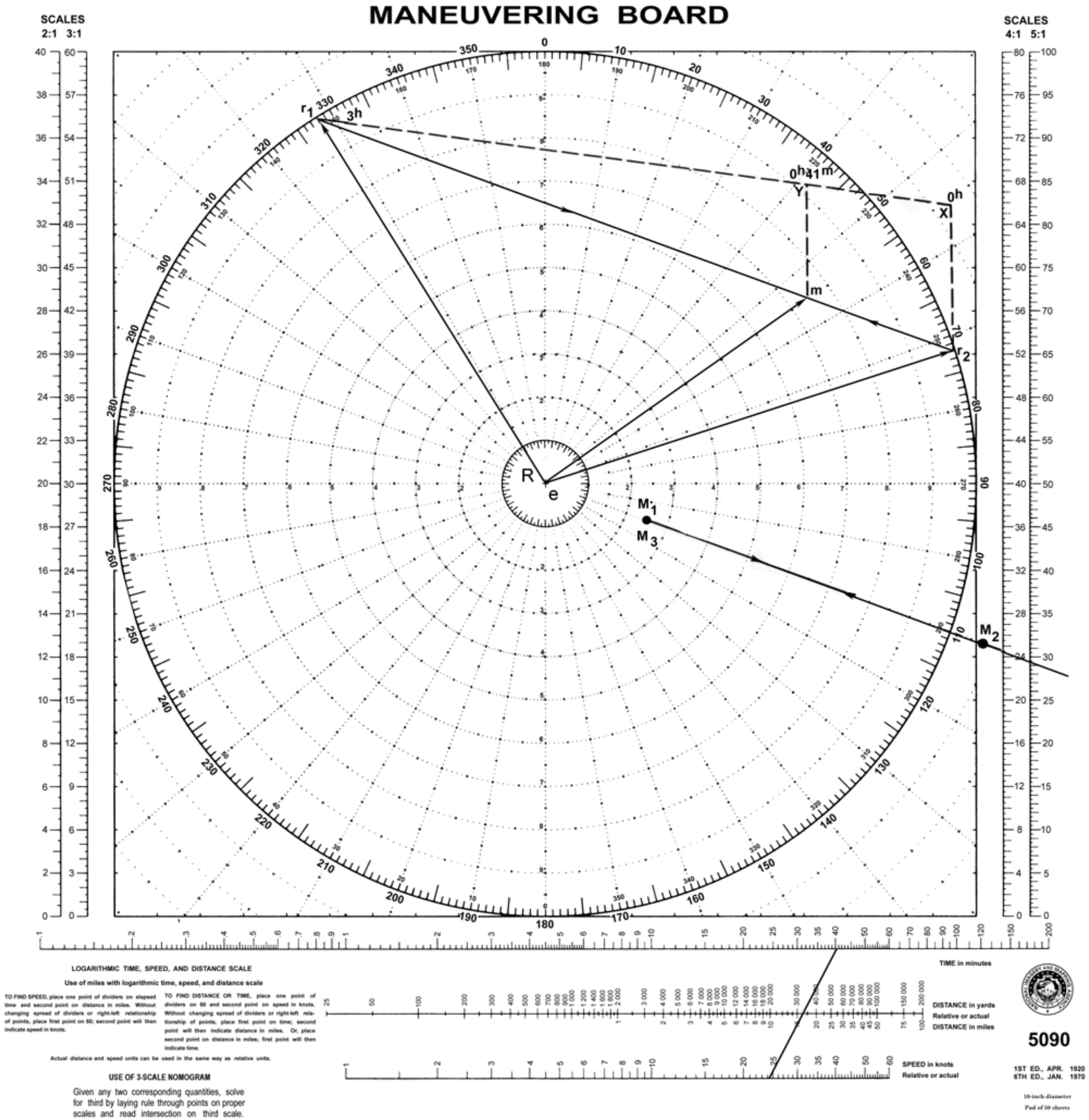
Explanation:

Since own ship *R* returns to present station, relative distances out and in are equal. In going equal distances, time varies inversely as speed:

$$\frac{\text{time (out)}}{\text{time (in)}} = \frac{\text{relative speed (in)}}{\text{relative speed (out)}} = \frac{r_1m \text{ (in)}}{r_2m \text{ (out)}}$$

Therefore, the time out part of the specified time (3^h) is obtained by simple proportion or graphically.

As defined in the glossary, the time line is the line joining the heads of vectors er_1 and er_2. This line is divided by the head of vector *em* into segments inversely proportional to the times spent by own ship *R* on the first (out) and second (in) legs. In the above example an alternative construction is used so that the line can be drawn to a convenient scale. The proportionality is maintained by constructing similar triangles.



OWN SHIP AT CENTER

EXAMPLE 23

Scale: Speed 2:1;
Distance 2:1 mi.

EXAMPLE 24

COURSES AND MINIMUM SPEED TO CHANGE STATIONS WITHIN A SPECIFIED TIME, WHILE SCOUTING ENROUTE

Situation:

Own ship *R* bears 130˚, 8 miles from the guide *M* which is on course 040˚, speed 12 knots.

Required:

Proceed to new station bearing 060˚, 10 miles from the guide, passing through a point bearing 085˚, 25 miles from the guide. Complete the maneuver in 4.5 hours using minimum speed.

(1) First and second courses for *R*.

(2) Minimum speed.

(3) Time to turn to second course.

Solution:

(1) Plot M_1, M_2 and M_3. Draw *em*. From *m* draw lines of indefinite length parallel to and in the direction of M_1M_2 and M_2M_3. Assume that a **fictitious ship**, *MF*, departs M_1 simultaneously with *M* and proceeds directly to M_3 arriving at the same time as *M* which traveled through M_2 enroute. The fictitious ship covers a relative distance of 10.5 miles in 4.5 hours. SRM of the fictitious ship is 2.3 knots. To *m* draw *mfm* 2.3 knots in length parallel to and in the direction of M_1M_3. Vector *emf* is the true course and speed vector of the fictitious ship. With *mf* as a pivot, rotate a straight line so that it intersects the two previously drawn lines on the same speed circle. The points of intersection are r_1 and r_2. Vector er_1 is the course out: 049˚. Vector er_2 is the course in: 316˚.9.

(2) Vectors r_1 and r_2 lie on the 17.2 knot circle which is the minimum speed to complete the maneuver.

(3) From r_2 lay off a 4.5 hour time line using any convenient scale. Draw r_1X. Draw *mf*Y parallel to r_1X. The point Y divides the time line into parts that are inversely proportional to the relative speeds r_2mf and r_1mf. XY the time “in” is 51 minutes. Yr_2 the time “out” is 3 hours 39 minutes. Time on each leg may also be determined mathematically by the formula MRM/SRM=time.

Answer:

(1) First course 049˚, second course 317˚.

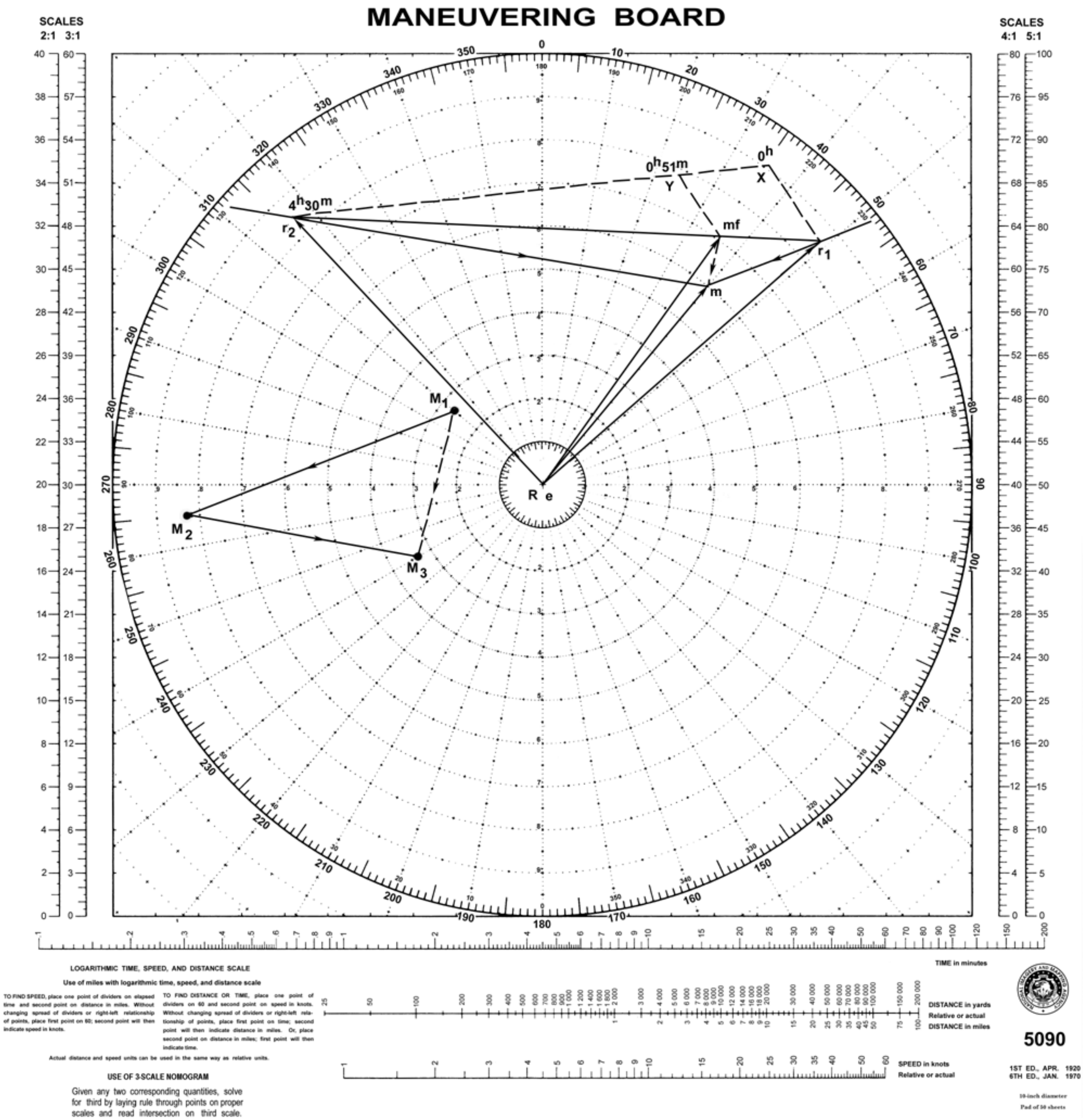
(2) Speed 17.2 knots.

(3) Time 3 hours and 39 minutes.

Note:

The *time line*, as defined in the glossary, is the line joining the heads of vectors er_1 and er_2 and touching the head of the fictitious ship vector *emf*. This time line is divided by the head of the fictitious ship vector into segments inversely proportional to the times spent by the unit on the first and second legs.

In the above example, an alternative construction of the time line is used so that the line can be drawn to a convenient scale. The proportionality is maintained by constructing similar triangles.



OWN SHIP AT CENTER

EXAMPLE 24

Scale: Speed 2:1;
Distance 3:1 mi.

EXAMPLE 25

COURSE, SPEED, AND POSITION DERIVED FROM BEARINGS ONLY

Situation:

Own ship is on course 090˚, speed 15 knots. The true bearings of another ship are observed as follows:

Time	*Bearing*
1300	010˚
1430	358˚
1600	341˚

At 1600 own ship changes course to 050˚ and increases speed to 22 knots. The following bearings of ship *M* are then observed:

Time	*Bearing*
1630	330˚
1730	302˚
1830	274˚.5

Required:

(1) Course and speed of ship *M*.
(2) Distance of *M* at time of last bearing.

Solution:

(1) Draw own ship's vector er_1.
(2) Plot first three bearings and label in order observed, B_1, B_2, and B_3.
(3) At any point on B_1, construct perpendicular which intersects B_2 and B_3. Label these points P_1, P_2, and P_3.
(4) Measure the distance P_1 to P_2 and plot point *X* at the same distance from P_2 towards P_3.
(5) From *X* draw a line parallel to B_1 until it intersects B_3. Label this intersection *Y*.
(6) From *Y* draw a line through P_2 until it intersects B_1 at *Z*.
(7) From head of own ship's vector er_1, draw a line parallel to *YZ*. This establishes the DRM on the original course and speed. The head of the *em* vector of ship *M* lies on the line drawn parallel to *YZ*. It is now necessary to find the DRM following a course and/or speed change by own ship. The intersection of the two lines drawn in the direction of relative movement from the heads of own ship's vector establishes the head of vector *em*.
(8) Following course and speed change made to produce a good bearing drift, three more bearings are plotted; the new direction of relative movement is obtained following the procedure given in steps (3) through (7). The lines drawn in the directions of relative movement from the heads of vector er_1 and er_2 intersect at the head of the vector *em*. Ship *M* is on course 170˚ at 10 knots.
(9) From relative vector r_2m, the SRM is found as 28.4 knots during the second set of observations.
(10) Compute the relative distance traveled during the second set of observations (MRM 56.8 mi.).
(11) On the line *ZY* for the second set of observations, lay off the relative distance *ZA*. From *A* draw a line parallel to B_4 until it intersects B_6. Label this point *B*. This is the position of *M* at the time of the last bearing.

Answer:

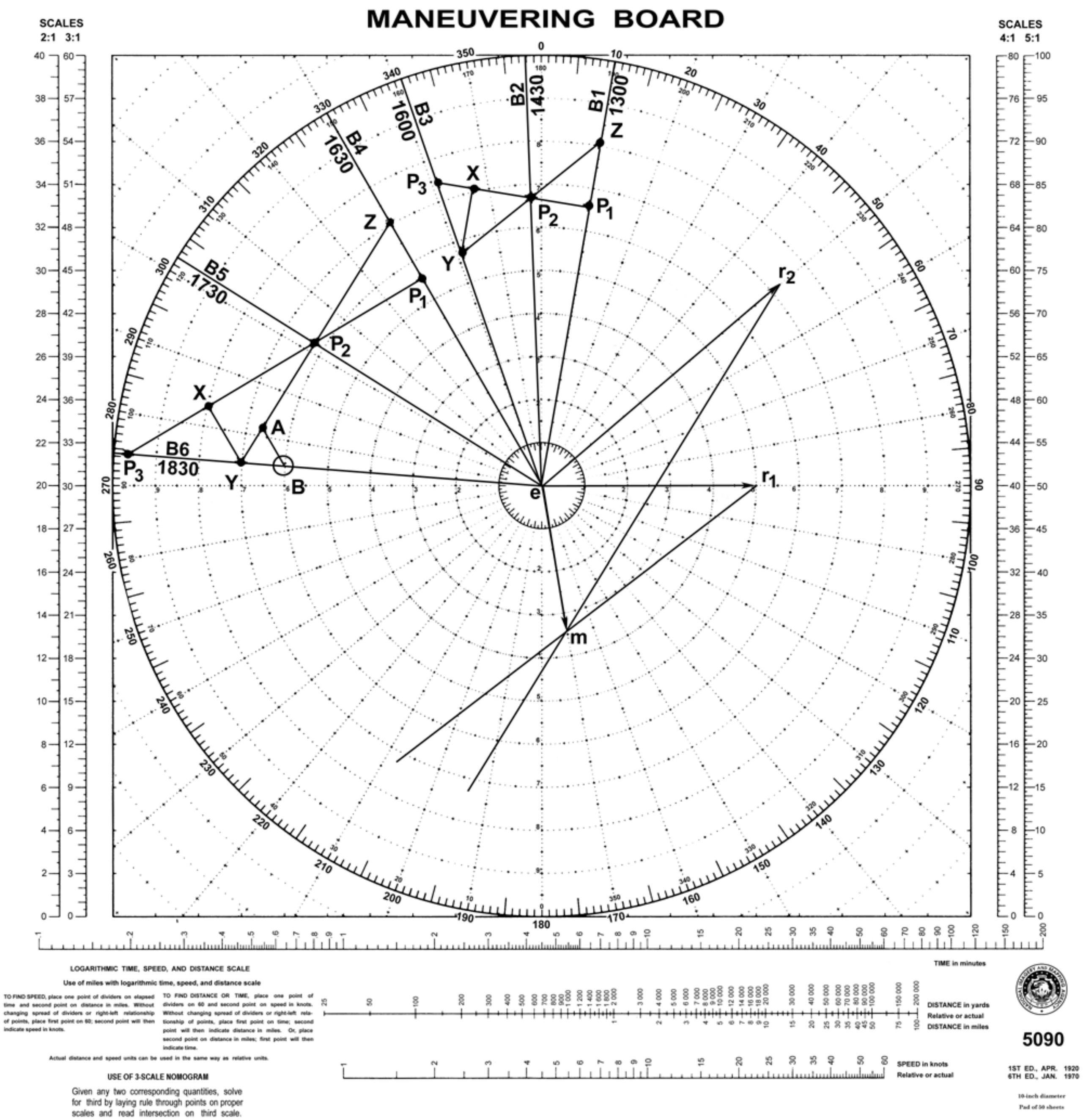
(1) Course 170˚, speed 10 knots.
(2) Position of *M* at 1830: 274˚.5 at 61 miles.

Note:

These procedures are based on bearings observed at equal intervals. For unequal intervals, use the following proportion:

$$\frac{\text{Time difference between } B_1 \text{ and } B_2}{\text{Distance from } P_1 \text{ to } P_2} = \frac{\text{Time difference between } B_2 \text{ and } B_3}{\text{Distance from } P_2 \text{ to } X}.$$

OWN SHIP AT CENTER



EXAMPLE 25

Scale: Speed 3:1;
Distance 10:1 mi.

EXAMPLE 26

LIMITING LINES OF APPROACH
(single ship)

Situation:

Own ship *R*'s course and speed is 000˚, 20 knots. At 0930, both sonar and radar report a contact bearing 085˚, distance 22,500. At 0931, radar loses contact and at 0932 sonar loses contact. Last known position was 085˚, distance 20,000. Datum error is 1,000 yards.

Required:

(1) Advanced position.

(2) Limiting lines of approach for submarine with maximum quiet speed of 15 knots.

Solution:

(1) Plot *R* at center of maneuvering board and draw the vector "*er*" 000˚, 20 knots.

(2) Plot datum position from own ship (085˚, 20,000 yards).

(3) Plot datum error (circle of radius 1,000 yards) around datum.

(4) Compute own ship's advanced position using the formula:

$$\frac{\text{Torpedo Firing Range}}{\text{Torpedo Speed}} \times \text{Vessel Speed} = \frac{10{,}000 \text{ yds}}{45 \text{ kts}} \times 20 \text{ kts} = 4{,}444 \text{ yds}$$

(5) Plot advanced position along own ship's course and speed vector.

(6) Plot Torpedo Danger Zone (10,000 yard circle) around advanced position.

(7) From "*r*", describe an arc with a radius of 15 nautical miles (the assumed quiet speed of the submarine).

(8) Draw the tangent vector "*eMq*" until it intersects the edge of the maneuvering board plotting circle. Do this on both sides of the ship's head. The true bearing of the tangent lines are the limiting lines of approach.

(9) Parallel the tangent vectors "*eMq*" until they are tangent to the Torpedo Danger Zone to complete the plotting picture.

Answer:

(1) Advanced position = 4,444 yards.

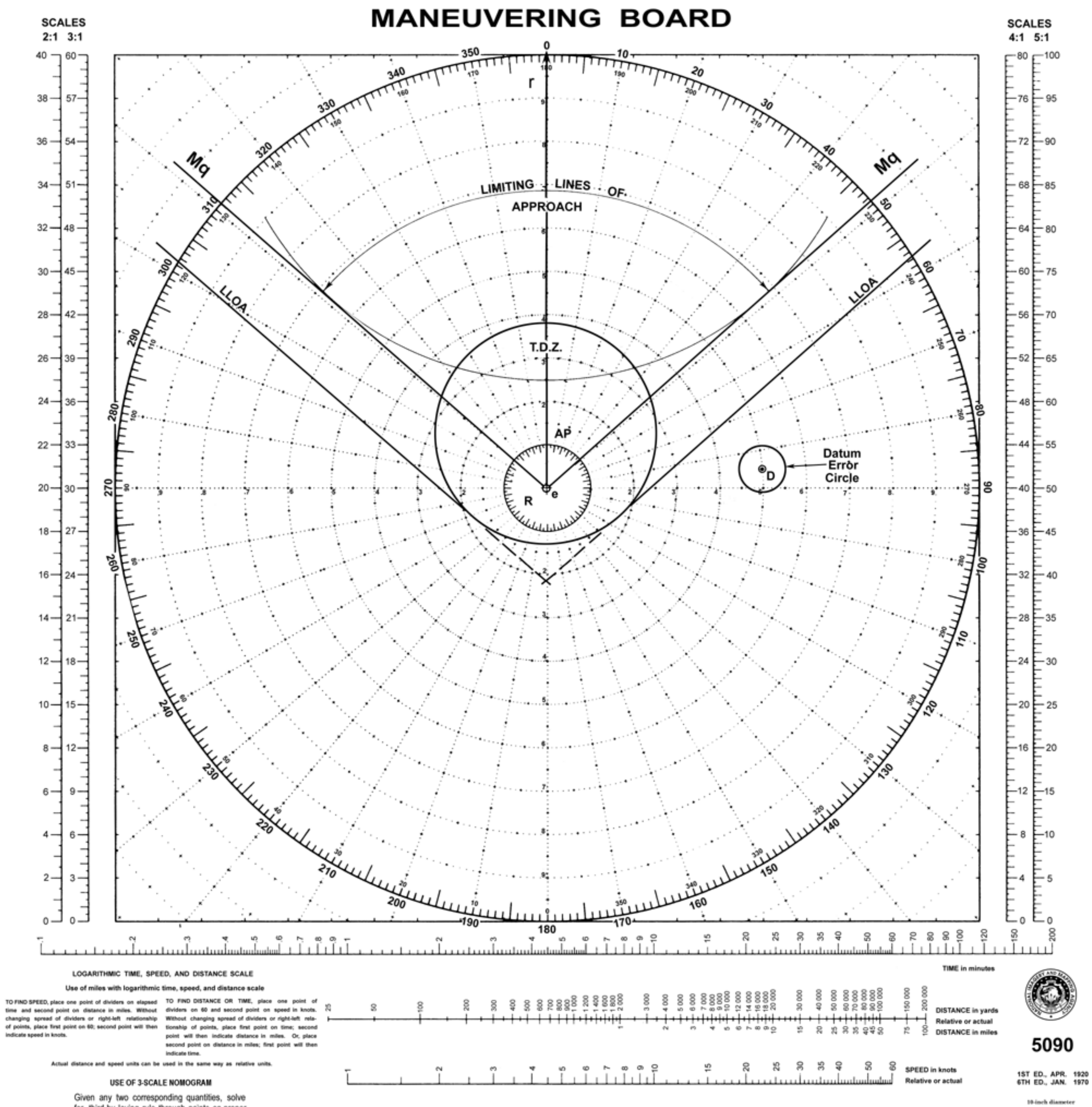
(2) Left side limiting line = 310˚.
Right side limiting line = 050˚.
Limiting lines of approach = 310˚ - 050˚.

Notes:

(1) Limiting lines of approach are read clockwise.

(2) This example assumes the submarine maintains a constant speed throughout the approach.

(3) The submarine and torpedo data were chosen for example purposes and should NOT be used as real estimates. Consult appropriate intelligence publications for correct data.



OWN SHIP AT CENTER

EXAMPLE 26

Scale: Speed 1:1;
Distance 1:1 mi.

EXAMPLE 27a

CONES OF COURSES
Solution: 1

Situation:

Own ship *R* is on course 000˚, 15 knots. At 1600, submarine *M* is reported bearing 325˚, 40 miles from *R*. Maximum assumed speed for *M* is 10 knots.

Required:

(1) Courses at 10 knots the submarine *M* will steer to intercept *R*.

(2) Time of the first and last intercept opportunities for submarine *M* against *R* at the assumed speed of 10 knots.

Solution:

(1) Plot the 1600 position of the submarine *M* 325˚, 40 miles from *R*. Draw the vector "*er*" 000˚, 15 knots. From *M*, draw a DRM line to *R* and from "*r*" draw the vector "*rm*" parallel and in the same direction as the DRM. With "*e*" as the center, describe an arc with radius of 10 knots, the assumed speed of *M*. The points em_1 and em_2 where the arc intersects the "*rm*" vector, define the courses at 10 knots that the submarine will steer to intercept *R*. Courses between "em_1" and "em_2" are lower assumed speed intercepts and "em_L", the perpendicular line from *R* to "*rm*", is the course for the lowest possible assumed speed at which the submarine can move and still intercept *R*.

(2) Parallel the "em_1" and "em_2" lines as vectors to the 1600 position at *M* and extend "*er*" until it crosses these vectors; the area enclosed by these 3 vectors represents the true geographic area through which the submarine will move at or below 10 knots to intercept *R*. The elapsed times to the first ("t_1") and the last ("t_2") intercept opportunities is obtained by dividing the relative distance at 1600 (*RM*) by the respective relative speed ("rm_1" and "rm_2").

Answer:

(1) Courses 024˚ to 086˚.

(2) $$\text{"}t_1\text{"} = \frac{RM}{\text{"}rm_1\text{"}} = \frac{40 \text{ miles}}{17.5 \text{ knots}} = 2 \text{ hrs } 17 \text{ mins}$$

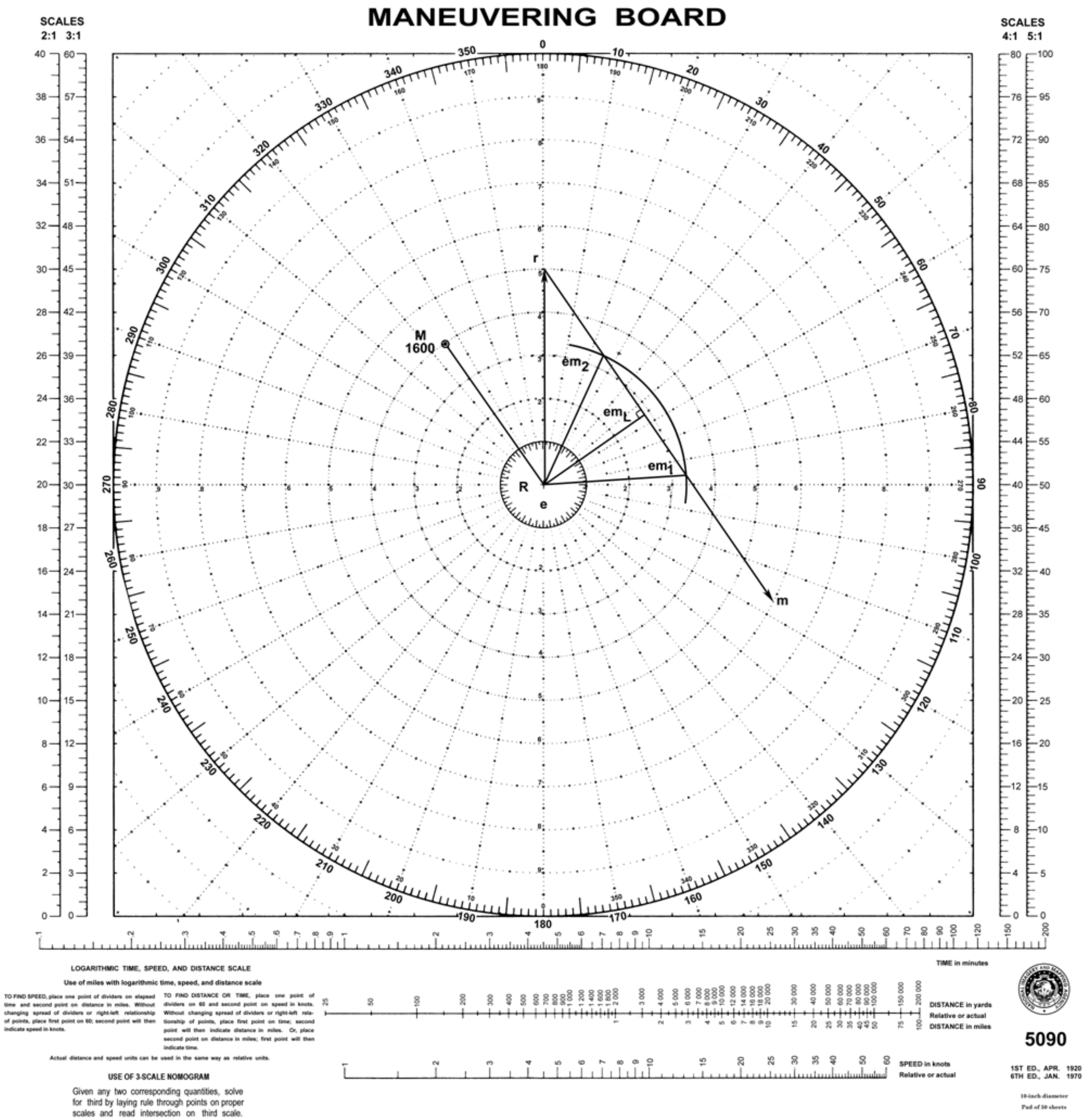
$$T_1 = 1600 + \text{"}t_1\text{"} = 1817$$

$$\text{"}t_2\text{"} = \frac{RM}{\text{"}rm_2\text{"}} = \frac{40 \text{ miles}}{7 \text{ knots}} = 5 \text{ hrs } 43 \text{ mins}$$

$$T_2 = 1600 + \text{"}t_2\text{"} = 2143$$

Note:

If the submarine's position involves an error (i.e., datum error) and a main body or convoy formation is present (with an associated Torpedo Danger Zone (TDZ) around it) the DRM from *M* to *R* becomes tangential lines drawn from "*r*" with a high speed and low speed leg corresponding to a forward or aft DRM on the formation.



OWN SHIP AT CENTER

EXAMPLE 27a

Scale: Speed 3:1;
Distance 10:1 mi.

EXAMPLE 27b

CONES OF COURSES
Solution: 2

Situation:

Own ship *R* is on course 000˚, 15 knots. At 1600, submarine *M* is reported bearing 325˚, 40 miles from *R*. Maximum assumed speed for *M* is 10 knots.

Required:

(1) Courses at 10 knots the submarine *M* will steer to intercept *R*.

(2) Time of the first and last intercept opportunities for submarine *M* against *R* at the assumed speed of 10 knots.

Solution:

(1) Plot the 1600 position of the submarine *M* 325˚, 40 miles from *R*. Draw the vector "*er*" 000˚, 15 knots. From *M*, draw a DRM line to *R* and from "*r*" draw the vector "*rm*" parallel and in the same direction as the DRM. With "*e*" as the center, describe an arc with radius of 10 knots, the assumed speed of *M*. The points EM_1 and EM_2 where the arc intersects the "*rm*" vector, define the courses at 10 knots that the submarine will steer to intercept *R*. Courses between "em_1" and "em_2" are lower assumed speed intercepts and "em_2", the perpendicular line from *R* to "*rm*", is the course for the lowest possible assumed speed at which the submarine can move and still intercept *R*.

(2) Parallel the "em_1" and "em_2" lines as vectors to the 1600 position at *M* and extend "*er*" until it crosses these vectors; the area enclosed by these 3 vectors represents the true geographic area through which the submarine will move at or below 10 knots to intercept *R*. The elapsed times to the first ("t_1") and the last ("t_2") intercept opportunities is obtained by dividing the relative distance at 1600 (*RM*) by the respective relative speed ("rm_1" and "rm_2").

Answer:

(1) Courses 024˚ to 086˚.

(2)

$$"t_1" = \frac{RM}{"rm_1"} = \frac{40 \text{ miles}}{17.5 \text{ knots}} = 2 \text{ hrs } 17 \text{ mins}$$

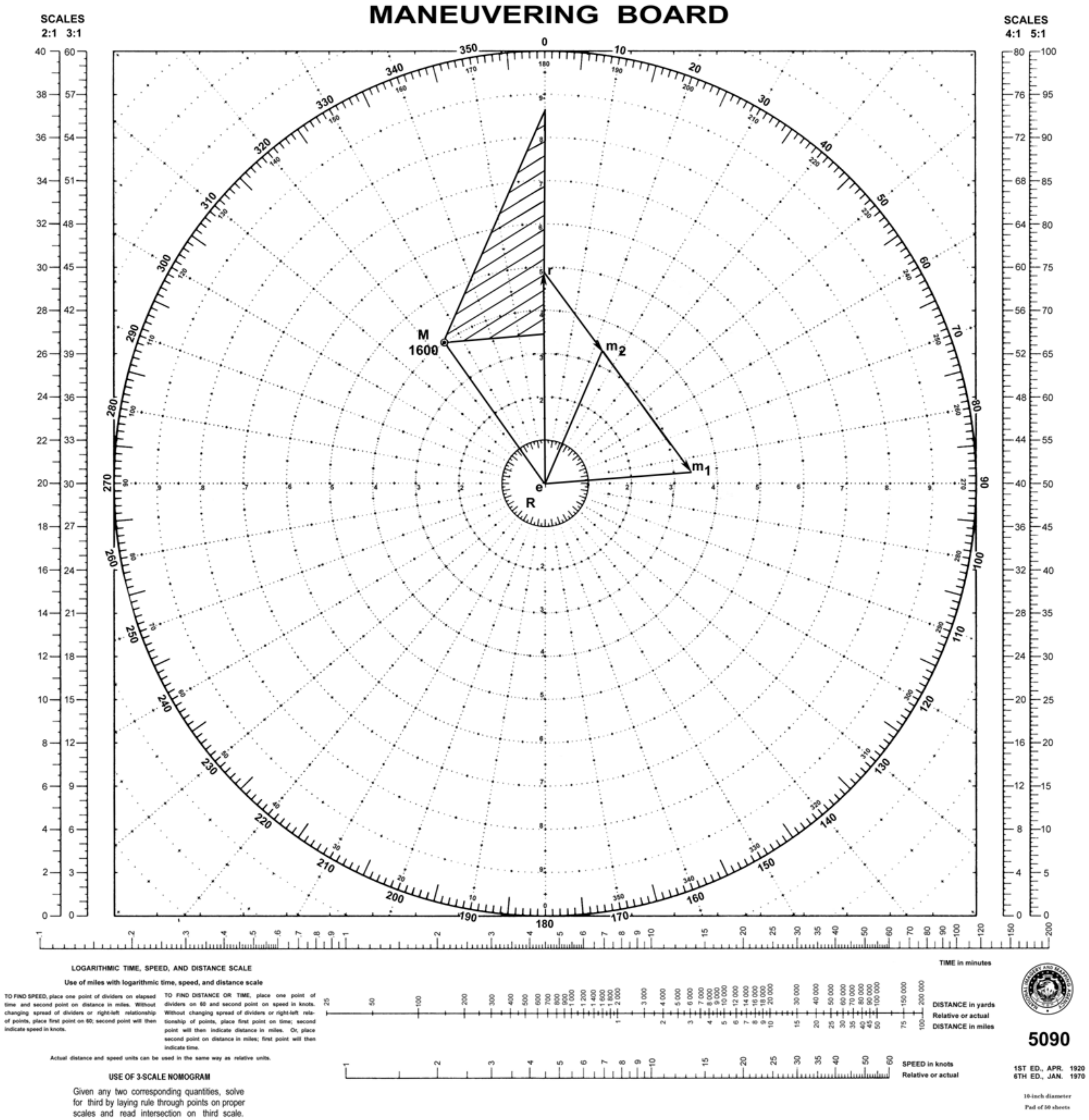
$$T_1 = 1600 + "t_1" = 1817$$

$$"t_2" = \frac{RM}{"rm_2"} = \frac{40 \text{ miles}}{7 \text{ knots}} = 5 \text{ hrs } 43 \text{ mins}$$

$$T_2 = 1600 + "t_2" = 2143$$

Note:

If the submarine's position involves an error (i.e., datum error) and a main body or convoy formation is present (with an associated Torpedo Danger Zone (TDZ) around it) the DRM from *M* to *R* becomes tangential lines drawn from "*r*" with a high speed and low speed leg corresponding to a forward or aft DRM on the formation.



OWN SHIP AT CENTER

EXAMPLE 27b

Scale: Speed 3:1;
Distance 10:1 mi.

EXAMPLE 28

EVASIVE ACTION AGAINST A TARGET MOVING AT SLOW SPEED

Situation:

A vessel possessing a speed advantage is always capable of taking evasive action against a slow-moving enemy. It may be necessary to take evasive action against a slow-moving enemy. For example, when a surface vessel is attempting to evade attack by a submarine.

Required:

The essence of the problem is to find the course for the maneuvering ship at which no matter how the enemy maneuvers he will not be able to come any closer than distance D (Torpedo/Missile Danger Zone) to the maneuvering ship. In order to accomplish this, the maneuvering ship should press the slow-moving enemy at a relative bearing greater than critical.

Solution:

Evasive action is graphically calculated in the following manner. The position of the slow-moving enemy vessel K_0 is plotted on a maneuvering board and the distance it travels from the moment of detection to the beginning of evasive action is calculated:

$$S = V_k(T_1 - T_0)$$

where T_1 = time at which evasive action begins;

T_0 = time of detection of the enemy.

The accuracy of determination of the position of the enemy, assumed to be within the datum error zone, (r) is also verified. Then the minimum divergence from the enemy (d) is determined (e.g., 2 - 3 times the range of fire of torpedoes or 1.5 to 2 times the sonar detection range). Adding up the selected values, with a radius of:

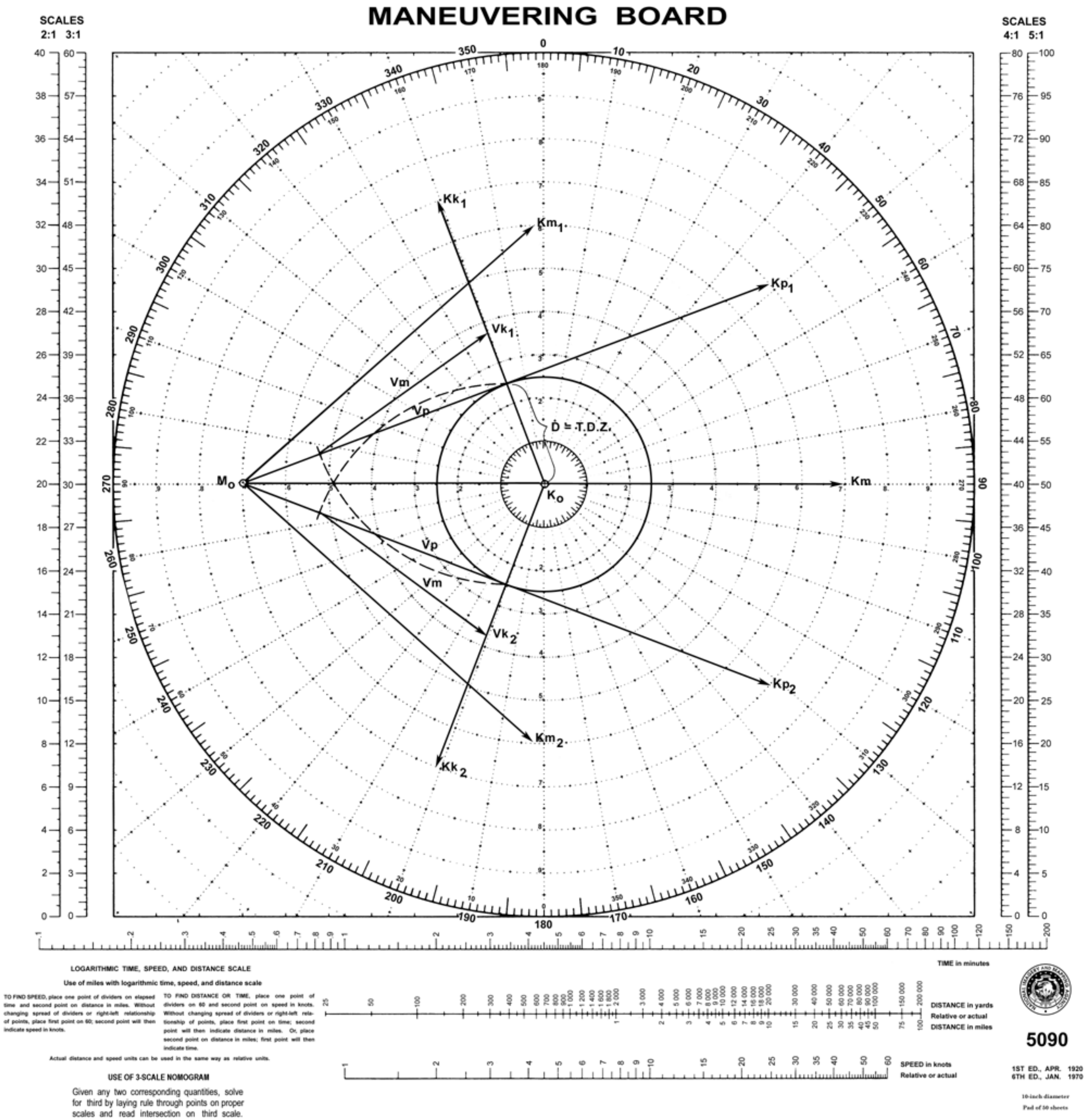
$$D_1 = r + S + d,$$

we have a circle about the initial position of the enemy K_0.

Constructing a tangent to this circle from the position of the maneuvering ship (point M_0) and, constructing a speed triangle at the point of tangency, we obtain the course of the maneuvering vessel Km_1 or Km_2 which the latter must steer in order to avoid meeting the enemy.

Note:

As a rule, the point of turn to the previous course after taking evasive action is not calculated and the turn is usually executed after the bearing on the point of detection of the slow-moving enemy vessel changes more than 90˚.



OWN SHIP AT CENTER

EXAMPLE 28

Scale: Speed 1:1;
Distance 1:1 mi.

PART TWO

GUIDE AT CENTER

EXAMPLE 29

CHANGING STATION WITH TIME, COURSE, OR SPEED SPECIFIED

Situation:

Formation course is 010˚, speed 18 knots. At 0946 when orders are received to change station, the guide *R* bears 140˚, range 7,000 yards. When on new station, the guide will bear 240˚, range 6,000 yards.

Required:

(1) Course and speed to arrive on station at 1000.

(2) Speed and time to station on course 045˚. Upon arrival on station orders are received to close to 3,700 yards.

(3) Course and minimum speed to new station.

(4) Time to station at minimum speed.

Solution:

(1) Plot M_1 320˚, 7,000 yards and M_2 060˚, 6,000 yards from *R*. Draw *er* corresponding to course 010˚ and speed 18 knots. The relative distance of 10,000 yards from M_1 to M_2 must be covered in 14 minutes. SRM is therefore 21.4 knots. Draw rm_1 parallel to M_1M_2, and 21.4 knots in length. On completing the vector diagram, the vector em_1 denotes the required course and speed: 062˚, 27 knots.

(2) Draw em_2, course 045˚, intersecting the relative speed vector rm_1 at the 21-knot circle. The length rm_2 is 12.1 knots. Thus the relative distance M_1M_2 of 10,000 yards will be covered in 24.6 minutes.

(3) Plot M_3 060˚, 3,700 yards from *R* after closing. Through *r* draw a line parallel to and in the direction of M_2M_3. Drop a perpendicular from *e* to this line at m_3. Vector em_3 is the course and minimum speed required to complete the final change of station: 330˚, 13.8 knots.

(4) By measurement, the length of rm_3 is an SRM of 11.5 knots; the distance from M_2 to M_3 is 2,300 yards. M_2M_3/rm_3 is the required maneuver time: 6 minutes.

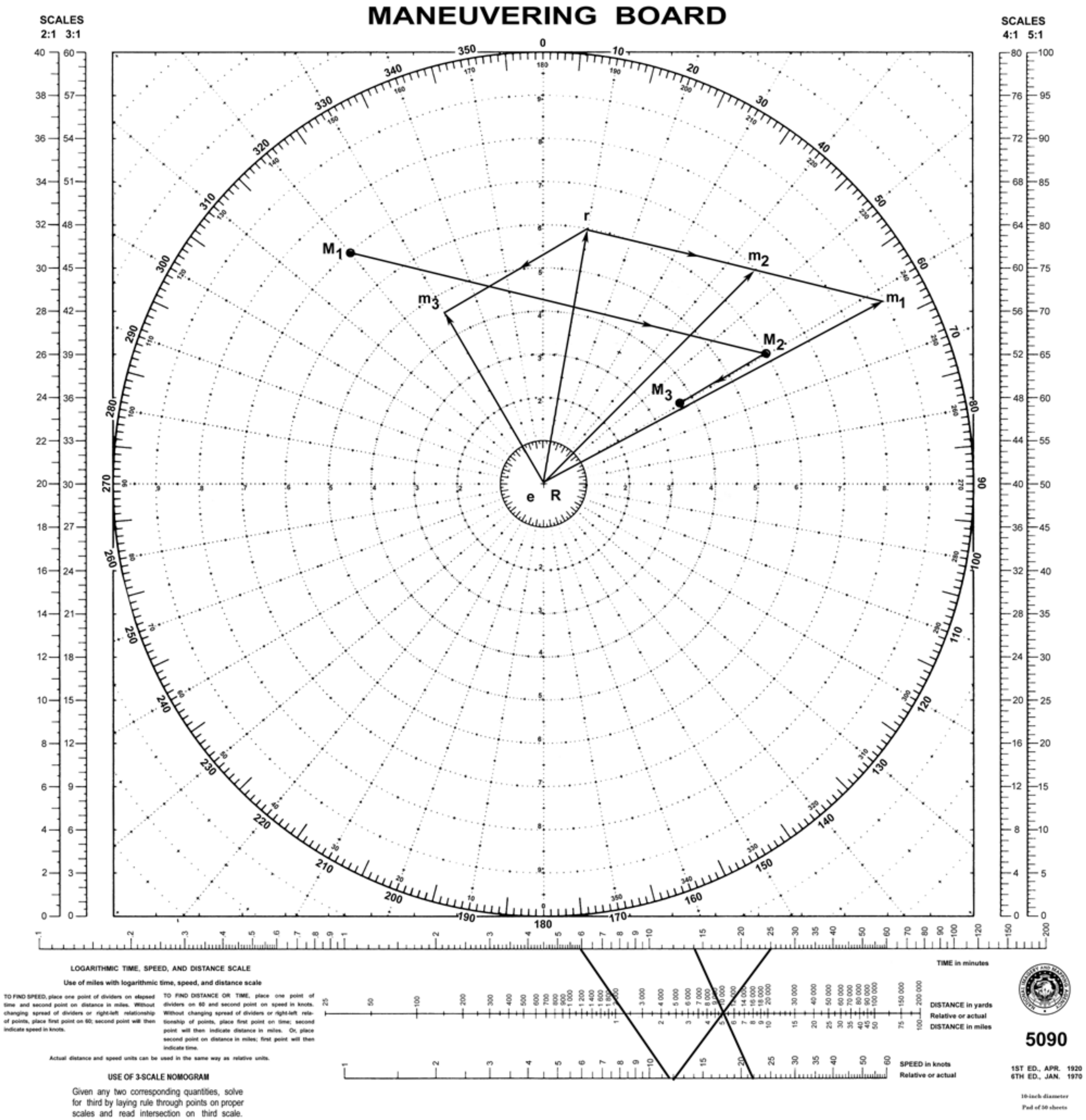
Answer:

(1) Course 062˚, speed 27 knots.

(2) Speed 21 knots, time 25 minutes.

(3) Course 330˚, speed 13.8 knots.

(4) Time 6 minutes.



GUIDE AT CENTER

EXAMPLE 29

Scale: Speed 3:1;
Distance 1:1 yd.

EXAMPLE 30

THREE-SHIP MANEUVERS

Situation:

Own ship *M* is in formation proceeding on course 000˚, speed 20 knots. The guide *R* bears 090˚, distance 4,000 yards. Ship *N* is 4,000 yards ahead of the guide.

Required:

M and *N* are to take new stations starting at the same time. *N* is to take station 4,000 yards on the guide's starboard beam using formation speed. *M* is to take *N*'s old station and elects to use 30 knots.

(1) *N*'s course and time to station.
(2) *M*'s course and time to station.
(3) CPA of *M* and *N* to guide.
(4) CPA of *M* to *N*.
(5) Maximum range of *M* from *N*.

Solution:

(1) Plot *R* at the center with M_1 at 270˚, 4,000 yards; M_2 and N_1 at 000˚, 4,000 yards. Draw *er* 000˚, 20 knots. From *R* plot *N*'s new station *NR*, bearing 090˚, distance 4,000 yards. In relation to *R*, *N* moves from N_1 to *NR*. From *r*, draw a line parallel to and in the direction of N_1 *NR* and intersecting the 20-knot speed circle at *n*. *N*'s course to station is vector *en*: 090˚. Time to station N_1 *NR/rn* is 6 minutes.

(2) In relation to *R*, *M* moves from M_1 to M_2. From *r*, draw *rm* parallel to and in the direction of M_1M_2 and intersecting the 30-knot speed circle at *m*. *M*'s course to station is vector *em*: 017˚. Time to station M_1M_2/rm is 14 minutes.

(3) From *R* drop a perpendicular to N_1NR. At CPA, *N* bears 045˚, 2,850 yards from *R*. From *R* drop a perpendicular to M_1M_2. At CPA, *M* bears 315˚, 2,850 yards from *R*.

(4) In relation to *M*, *N* travels from N_1 to N_2 to N_3. Plot N_3 bearing 135˚, 5,700 yards from M_1. From point *m* draw the relative speed vector *mn*. Draw a relative movement line from N_1 parallel to and in the same direction as *mn*. When *N* arrives on new station and returns to base course the relative speed between *M* and *N* is the same as *rm*. From N_3 draw a relative movement line parallel to and in the same direction as *rm*. These lines intersect at N_2. From M_1 drop a perpendicular to line N_1N_2. At CPA, *N* bears 069˚, 5,200 yards from *M*.

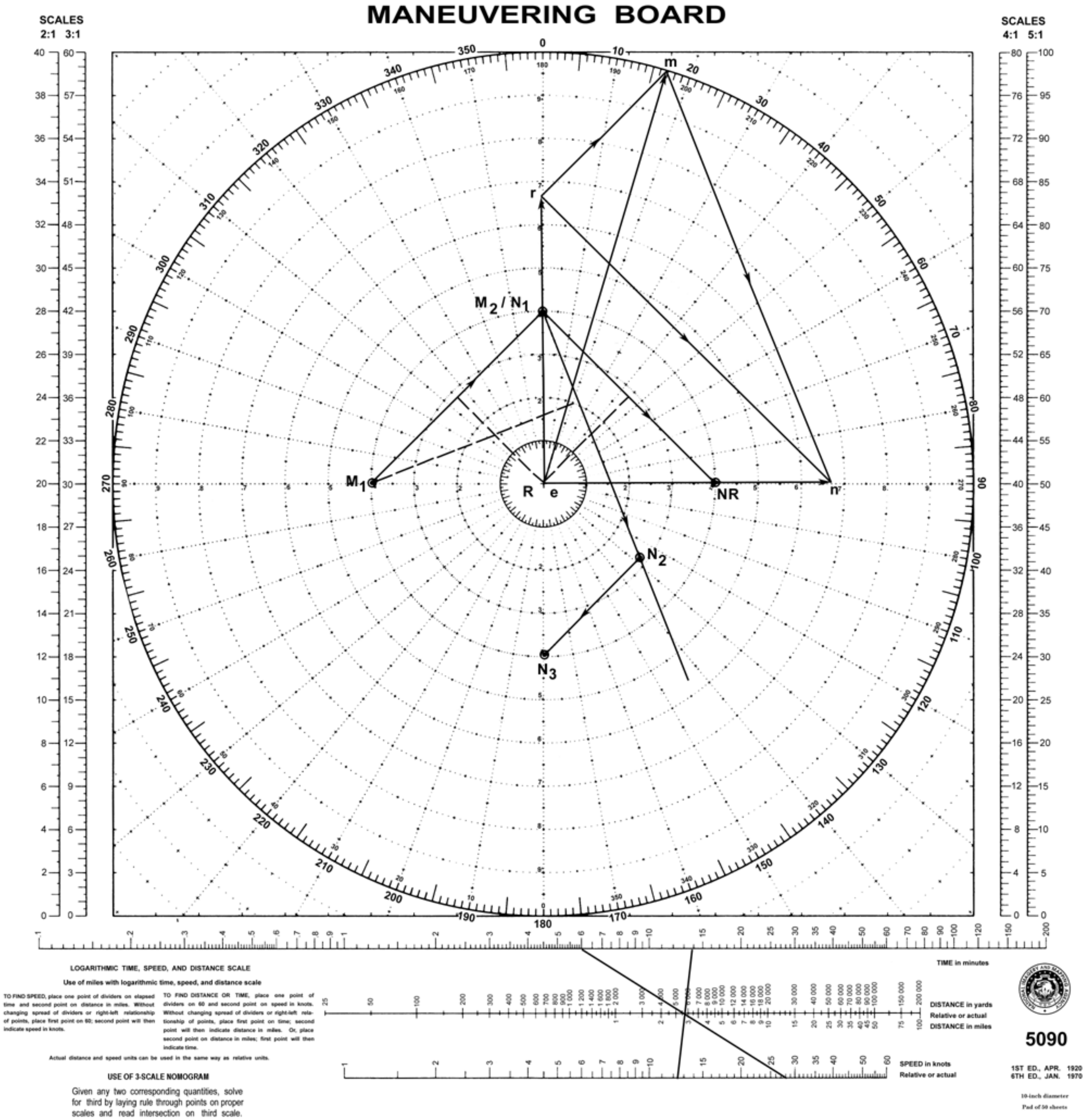
(5) The point at which *N* resumes formation course and speed N_2, is the maximum range of *N* from *M*; 6,500 yards.

Answer:

(1) *N*'s course 090˚, time 6 minutes.
(2) *M*'s course 017˚, time 14 minutes.
(3) CPA: *N* to *R* 2,850 yards at 045˚; *M* to *R* 2,850 yards at 315˚.
(4) CPA of *N* to *M* 5,200 yards at 069˚.
(5) Range 6,500 yards.

Explanation:

In solution step (4), the movement of *N* in relation to *M* is parallel to the direction of vector *mn* and from N_1 until such time that *N* returns to base course and speed. Afterwards, the movement of *N* in relation to *M* is parallel to vector *rm* and from N_2 toward that point, N_3, that *N* will occupy relative to *M* when the maneuver is completed.



GUIDE AT CENTER

EXAMPLE 30

Scale: Speed 3:1; Distance 1:1 yd.

EXAMPLE 31

COURSE AND SPEED TO PASS ANOTHER SHIP AT A SPECIFIED DISTANCE

Situation:

At 1743 own ship *M* is on course 190˚, speed 12 knots. Another ship *R* is observed bearing 153˚, 13,000 yards on course 287˚, speed 10 knots. It is desired to pass ahead of *R* with a CPA of 3,000 yards.

Required:

(1) Course of *M* at 12 knots.
(2) Bearing of *R* and time at CPA.

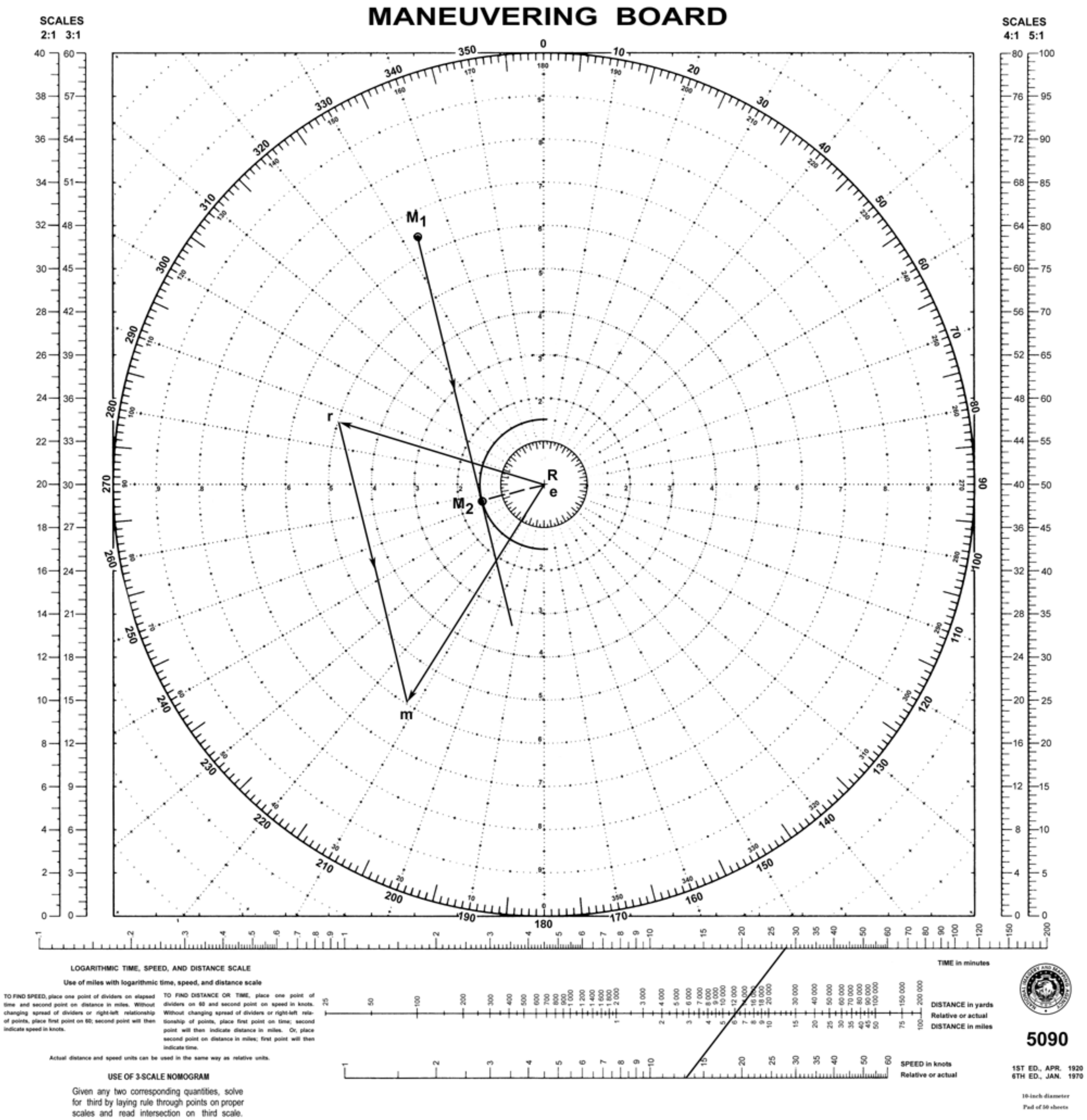
Solution:

(1) Plot *R* at the center of M_1 bearing 333˚, 13,000 yards from *R*. Draw the other ship's vector *er* 287˚, 10 knots. With *R* as a center, describe a circle of radius 3,000 yards. From M_1 draw a line tangent to the circle at M_2. This satisfies the requirement of passing with a CPA of 3,000 yards from *R*. From *r* draw a line parallel to and in the same direction as M_1M_2, intersecting the 12-knot speed circle at *m*. Draw *em*, own ship's vector 212˚, 12 knots.

(2) From *R* drop a perpendicular to M_2. When own ship reaches M_2, *R* will bear 076˚. Measure the relative distance M_1M_2, 12,600 yards, and the relative speed vector *rm*, 13.4 knots. Using this distance and speed, the elapsed time to CPA is obtained from the TDS scale: 28 minutes. The time at CPA is 1743 + 28 = 1811.

Answer:

(1) Course 212˚.
(2) Bearing 076˚, time at CPA 1811.



GUIDE AT CENTER

EXAMPLE 31

Scale: Speed 2:1; Distance 2:1 yd.

EXAMPLE 32

COURSE AT SPECIFIED SPEED TO PASS ANOTHER SHIP AT MAXIMUM AND MINIMUM DISTANCES

Situation:

Ship *R* on course 300˚, speed 30 knots, bears 155˚, range 16 miles from own ship *M* whose maximum speed is 15 knots.

Required:

(1) *M*’s course at 15 knots to pass *R* at (a) maximum distance, (b) minimum distance.

(2) CPA for each course found in (1).

(3) Time interval to each CPA.

(4) Relative bearing of *R* from *M* when at CPA on each course.

Solution:

(1) Plot M_1 335˚, 16 miles from *R*. Draw the vector *er* 300˚, 30 knots. With *e* as the center, draw a circle with radius of 15 knots, the speed of *M*. From *r* draw the tangents rm_1 and rm_2 which produce the two limiting courses for *M*. Parallel to the tangents plot the relative movement lines from M_1. Course of own ship to pass at maximum distance is em_1: 000˚. Course to pass at minimum distance is em_2: 240˚.

(2) Through *R* draw RM_2 and RM'_2 perpendicular to the two possible relative movement lines. *R* bearing 180˚, 14.5 miles from M_2 is the CPA for course of 000˚. *R* bearing 240˚, 1.4 miles from M'_2 is the CPA for course 240˚.

(3) Measure M_1M_2: 6.8 miles, and $M_1M'_2$: 15.9 miles. *M* must travel these relative distances before reaching the CPA on each limiting course. The relative speed of *M* is indicated by the length of the vectors rm_1 and rm_2: 26 knots. From the TDS scale the times required to reach M_2 and M'_2 are found: 15.6 minutes and 36.6 minutes, respectively.

(4) Bearings are determined by inspection. *R* bears 180˚ relative because own ship’s course is along vector em_1 for maximum CPA. *R* bears 000˚ relative when own ship’s course is em_2 for minimum passing distance.

Note:

This situation occurs only when own ship *M* is (1) ahead of the other ship and (2) has a maximum speed less than the speed of the other ship. Under these conditions, own ship can intercept (collision course) only if *R* lies between the slopes of M_1M_2 and $M_1M'_2$. Note that for limiting courses, and only for these, CPA occurs when other ship is dead ahead or dead astern. The solution to this problem is applicable to avoiding a tropical storm by taking that course which results in maximum passing distance.

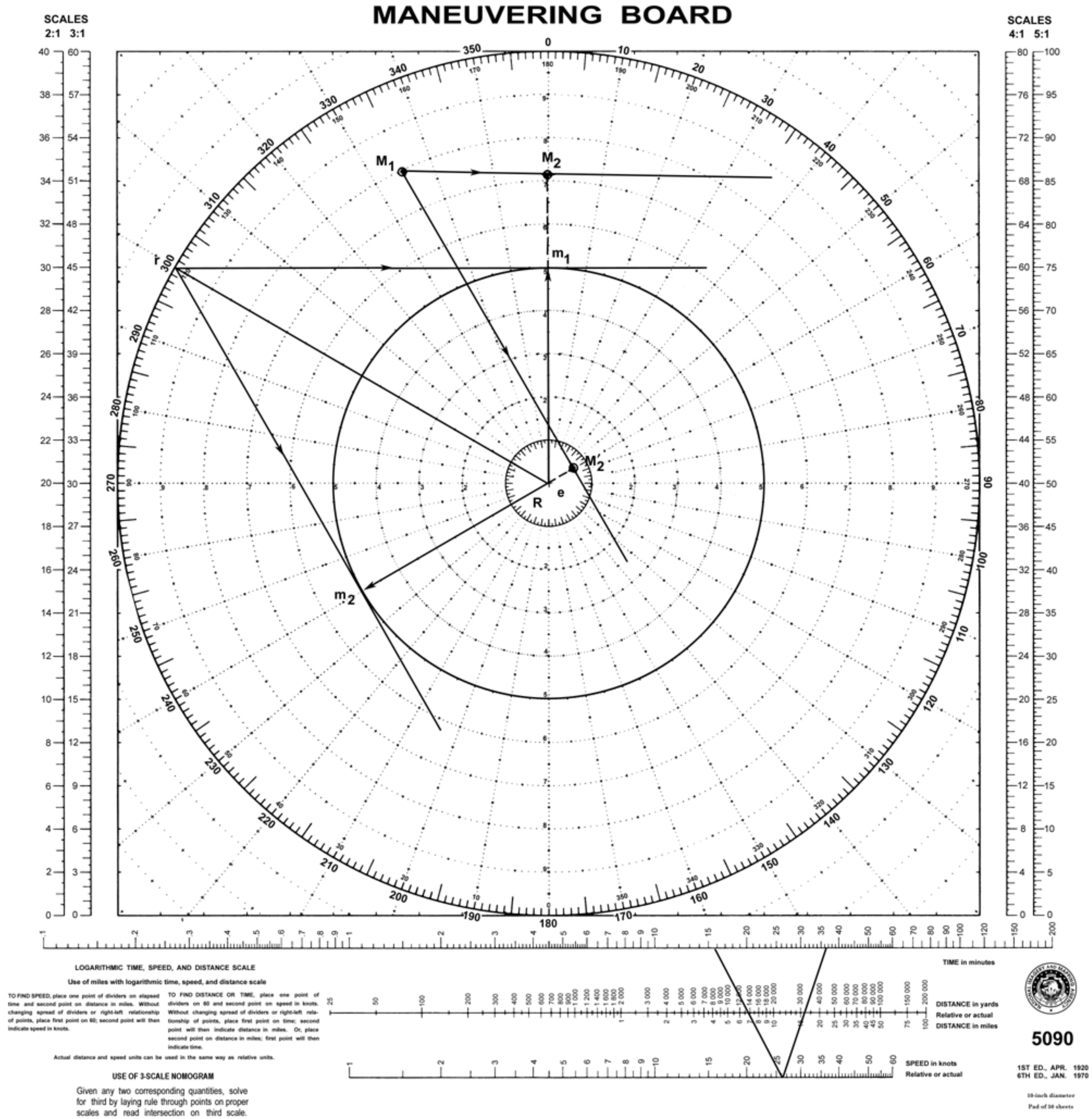
Answer:

(1) Course (a) 000˚; (b) 240˚.

(2) CPA (a) 180˚, 14.5 miles; (b) 240˚, 1.4 miles.

(3) Time (a) 16 minutes; (b) 37 minutes.

(4) Relative bearing (a) 180˚; (b) 000˚.



GUIDE AT CENTER

EXAMPLE 32

Scale: Speed 3:1;
Distance 2:1 mi.

EXAMPLE 33

COURSE CHANGE IN COLUMN FORMATION ASSURING LAST SHIP IN COLUMN CLEARS

Situation:

Own ship *D*1 is the guide in the van of a destroyer unit consisting of four destroyers (*D*1, *D*2, *D*3, and *D*4) in column astern, distance 1,000 yards. *D*1 is on station bearing 090˚, 8 miles from the formation guide *R*. Formation course is 135˚, speed 15 knots. The formation guide is at the center of a concentric circular ASW screen stationed on the 4-mile circle.

The destroyer unit is ordered to take new station bearing 235˚, 8 miles from the formation guide. The unit commander in *D*1 decides to use a wheeling maneuver at 27 knots, passing ahead of the screen using two course changes so that the CPA of his unit on each leg is 1,000 yards from the screen.

Required:

(1) New course to clear screen commencing at 1000.
(2) Second course to station.
(3) Bearing and range of *R* and *D*1 at time of coming to second course.
(4) Time of turn to second course.
(5) Time *D*1 will reach new station.

Solution:

(1) Plot the formation guide *R* at the center. Plot own ship *D*1 bearing 090˚, 8 miles from *R*. Plot the remaining three destroyers in column astern of *D*1, distance between ships 1,000 yards. Draw *er*, the speed vector of *R*, 135˚, 15 knots. It is required that the destroyer column clear *R* by a minimum of 9,000 yards (screen radius of 4 miles plus 1,000 yards). At the instant the signal is executed, only *D*1 changes both course and speed. The other destroyers increase speed to 27 knots but remain on formation course of 135˚ until each reaches the turning point. Advance *R* along the formation course the distance *R* would move at 15 knots while *D*4 advances to the turning point at 27 knots. The distance is equal to:

$$\frac{\text{Speed of } R}{\text{Speed of } D4} \times 3,000 \text{ yards} = 1,666 \text{ yards}$$

Draw a circle of radius 9,000 yards about the advanced position of the guide *R'*. Draw a line from *D*1 (the turning point) tangent to the circle. This is the relative movement line required for *D*4 to clear the screen by 1,000 yards on the first leg. Draw a line from *r* parallel to this line and intersecting the 27-knot circle at m_1. This produces em_1, the initial course of 194˚.2.

(2) Plot the final relative position of *D*1 at *D*1' bearing 235˚, 8 miles from *R*. Draw a line from *D*1' tangent to the 9,000 yard circle and intersecting the first relative movement line at *D*1". Draw a line parallel to and in the direction of *D*1"*D*1' from *r*. The intersection of this line and the 27-knot circle at m_2 is the second course required, em_2 252˚.8.

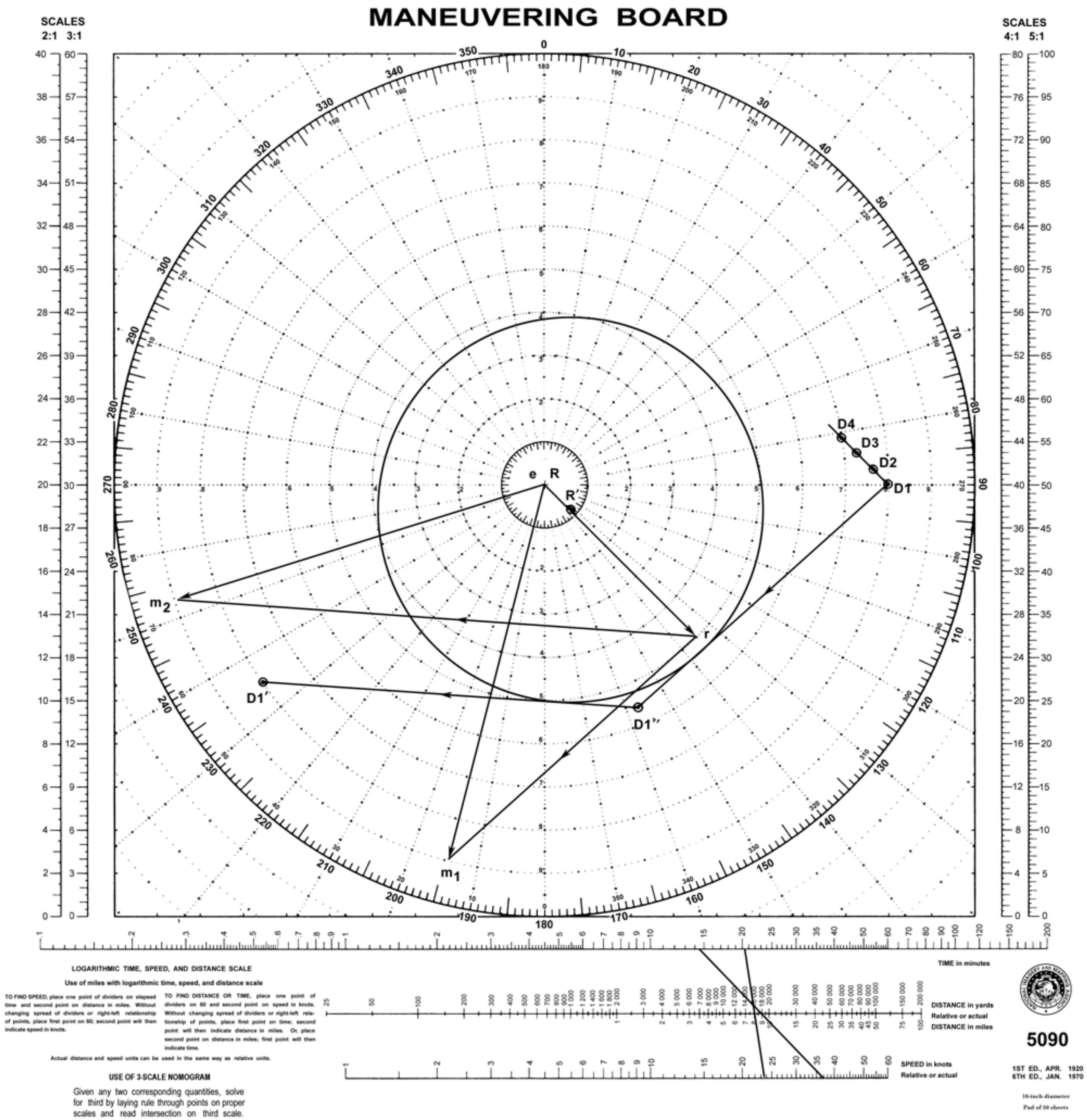
(3) Bearing and range of *R* from *D*1" is 337˚ at 11,250 yards.

(4) Time interval for *D*1 to travel to *D*1" is: $D1D1''/rm_1$ = 7.8 miles/23.2 knots = 20.2 minutes. Time of turn 1000 + 20 = 1020.

(5) Time interval for the second leg is: $D1''D1'/rm_2$ = 8.8 miles/36.5 knots = 14.2 minutes. *D*1 will arrive at new station at 1034.

Answer:

(1) Course 194˚.
(2) Course 253˚.
(3) Bearing 337˚, range 11,250 yards.
(4) Time 1020.
(5) Time 1034.



GUIDE AT CENTER

EXAMPLE 33

Scale: Speed 3:1;
Distance 1:1 mi.

PRACTICAL ASPECTS OF MANEUVERING BOARD SOLUTIONS

The foregoing examples and their accompanying illustrations are based upon the premise that ships are capable of instantaneous changes of course and speed. It is also assumed that an unlimited amount of time is available for determining the solutions.

In actual practice, the interval between the signal for a maneuver and its execution frequently allows insufficient time to reach a complete, graphical solution. Nevertheless, under many circumstances, safety and smart seamanship both require prompt and decisive action, even though this action is determined from a quick, mental estimate. The estimate must be based upon the principles of relative motion and therefore should be nearly correct. Course and speed can be modified enroute to new station when a more accurate solution has been obtained from a maneuvering board.

Allowance must be made for those tactical characteristics which vary widely between types of ships and also under varying conditions of sea and loading. Experience has shown that it is impractical to solve for the relative motion that occurs during a turn and that acceptable solutions can be found by eye and mental estimate.

By careful appraisal of the PPI and maneuvering board, the relative movement of own ship and the guide during a turn can be approximated and an estimate made of the relative position upon completion of a turn. Ships' characteristic curves and a few simple thumb rules applicable to own ship type serve as a basis for these estimates. During the final turn the ship can be brought onto station with small compensatory adjustments in engine revolutions and/or course.

EXAMPLE 34

ADVANCE, TRANSFER, ACCELERATION, AND DECELERATION

Situation:

Own ship *M* is a destroyer on station bearing 020˚, 8,000 yards from the guide *R*. Formation course is 000˚, speed 15 knots. *M* is ordered to take station bearing 120˚, 8,000 yards from guide, using 25 knots.

Required:

(1) Course to new station.
(2) Bearing of *R* when order is given to resume formation course and speed.
(3) Time to complete the maneuver.

Solution:

(1) Plot *R* at the center with M_1 bearing 020˚, 8,000 yards and M_2 bearing 120˚, 8,000 yards. Draw guide's vector, *er*, 000˚, 15 knots.

By eye, it appears *M* will have to make a turn to the right of about 150˚, accelerating from 15 to 25 knots during the turn. Prior to reaching the new station a reverse turn of about the same amount and deceleration to 15 knots will be required. Assume that *M* averages 20 knots during each turn.

Using 30˚ rudder at 20 knots, a DD calibration curve indicates approximately 2˚ turn per second and a 600 yard diameter. Thus, a 150˚ turn will require about 75 seconds and will produce a transfer of about 600 yards. During the turn, *R* will advance 625 yards ($1^{1/4}$ minutes at 15 knots). Plotting this approximate off-set distance on the maneuvering board gives a new relative position of M_3 at the time the initial turn is completed. Similarly, a new off-set position at M_4 is determined where a left turn to formation course and reduction of speed to 15 knots should be ordered.

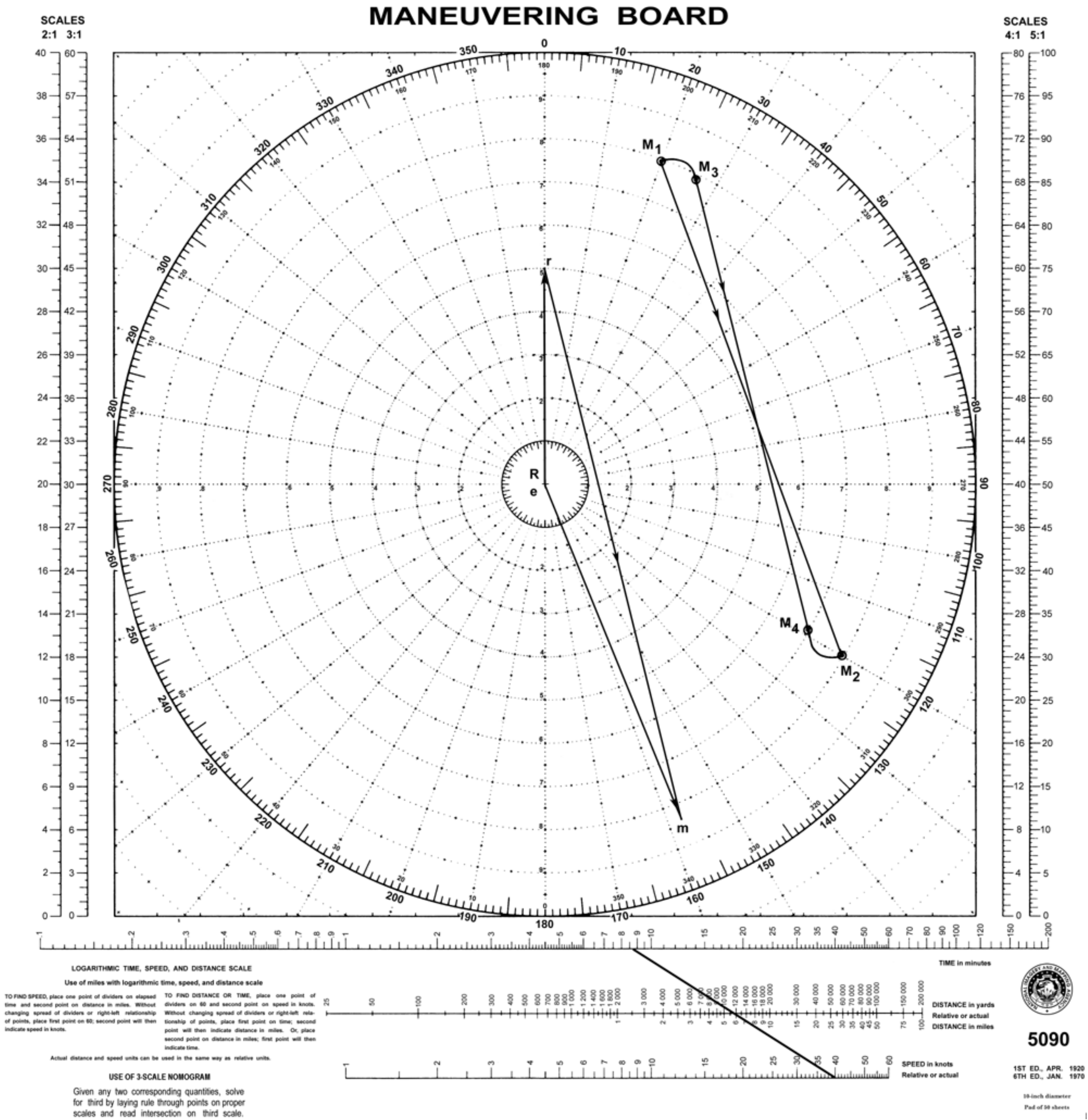
Draw a line from *r* parallel to M_3M_4 and intersecting the 25-knot speed circle at *m*. Vector *em* is the required course of 158˚.

(2) When *M* reaches point M_4 with *R* bearing 299˚, turn left to formation course using 30˚ rudder and slow to 15 knots.

(3) Time to complete the maneuver is M_3M_4/SRM + 2.5 minutes = 11,050 yards/39.8 knots + 2.5 minutes = 11 minutes.

Answer:

(1) Course 158˚.
(2) Bearing 299˚.
(3) Time 11 minutes.



GUIDE AT CENTER

EXAMPLE 34

Scale: Speed 3:1;
Distance 1:1 yd.

MANEUVERING BY SEAMAN'S EYE

In many circumstances it is impossible to use a maneuvering board in the solution of relative movement problems. When the distance between old and new stations is short and well abaft the beam, it may be impractical to attempt to complete the theoretically required turns and travel along an M_1M_2 path. In such cases, a reduction in speed, fishtailing, or various modifications of a fishtail may be required.

In the following example, it is assumed that a destroyer type ship is proceeding at formation speed and using standard rudder which yields a perfect turning circle of 1,000 yards diameter and 3,150 yards circumference. It is also assumed that a 13% reduction in speed is produced by large turns.

Based upon these assumptions, a ship using a 45˚ fishtail either side of formation course will fall behind old station by about 400 yards. By using a 60˚ fishtail, it will drop back about 700 yards. Approximate distances for any amount of course change can be computed if desired; however, the above quantities used as thumb rules should be sufficient. Repeated application of either will produce larger "drop backs" and also offer the advantage of not using excessive sea room.

If it is desired to move laterally as well as fall back, a turn of 45˚ to *one side only* and then immediate return to original course will produce a 300 yard transfer and a 200 yard drop back.

If time is not a consideration and the relative movement line is relatively very short, a reduction in speed may prove most desirable.

EXAMPLE 35

Situation:

Own ship *M* is on formation course 225˚, speed 15 knots, with guide *R* bearing 000˚, 3,000 yards.

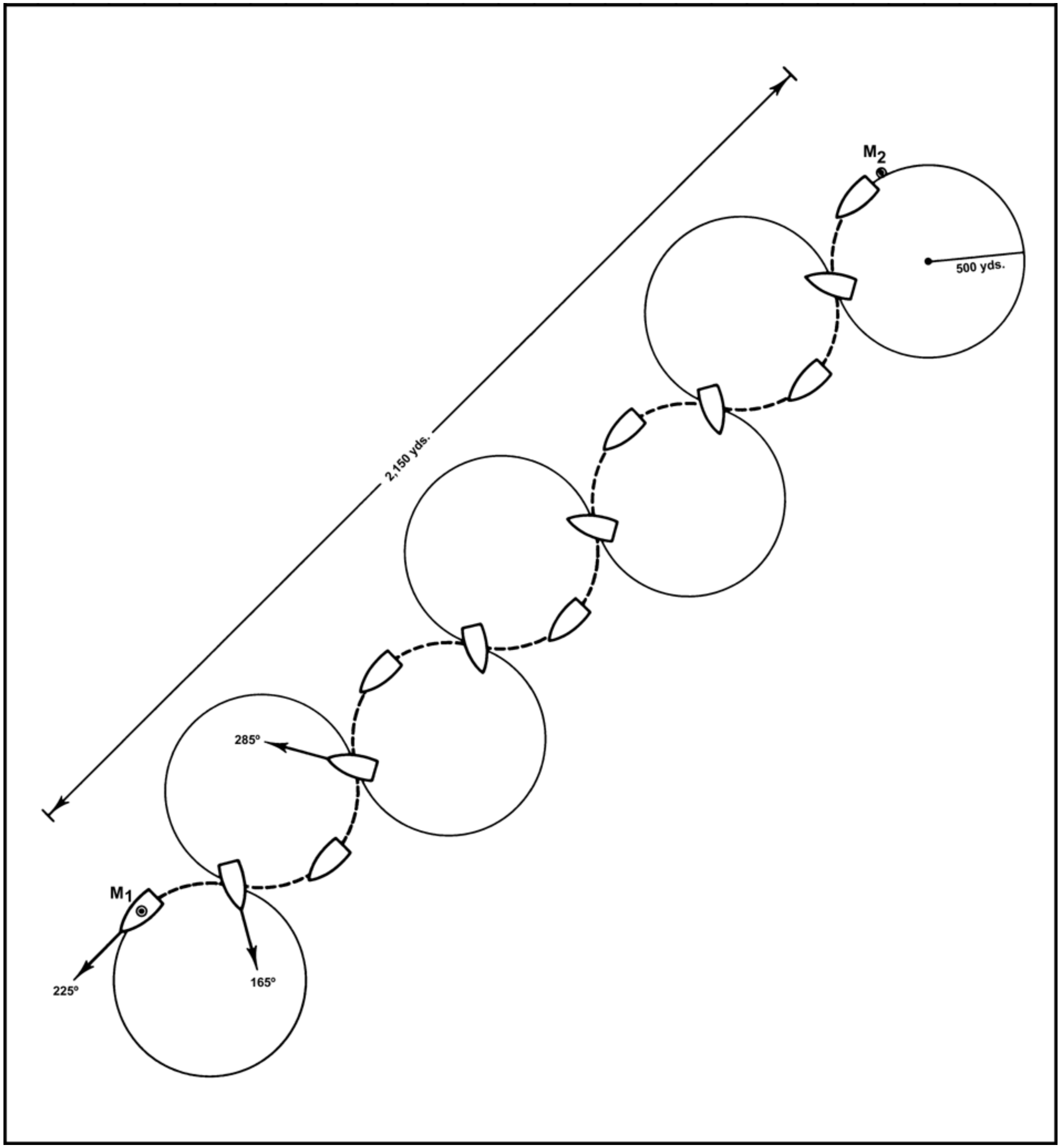
Required:

Take station 2,000 yards broad on the port beam of the guide.

Solution:

An attempt to solve this problem by normal maneuvering board procedures will prove impractical. M_2 is directly astern of M_1 at a distance of 2,150 yards. Any combination of course changes in an attempt to travel a line from M_1 to M_2 will result in own ship falling far astern of the new station. Even a simple 360˚ turn will drop own ship back 3,600 yards, almost twice the desired movement.

By fishtailing 60˚ to either side using courses of 165˚ and 285˚ three times per side, own ship will drop straight back approximately 2,000 yards, within 150 yards of station. Final adjustment to station can be effected by normal station keeping maneuvers such as rapidly shifting the rudder between maximum positions or reduction in engine revolutions.



CHANGING STATIONS BY FISHTAIL METHOD

EXAMPLE 35

EXAMPLE 36

FORMATION AXIS ROTATION—GUIDE IN CENTER

Situation:

The formation is on course 240˚, speed 15 knots. The formation axis is 130˚. The guide is in station Zero and own ship is in station 6330. The OTC rotates the formation axis to 070˚. Stationing speed is 20 knots.

Required:

(1) Course at 20 knots to regain station relative to the new formation axis, 070˚.

Solution:

(1) Mark the initial and new formation axes at 130˚ and 070˚, respectively. Plot the guide's station in the center (station Zero) and label as *R*. Plot own ship's initial position M_1 on circle 6 in a direction from the formation center 330˚ relative to the initial formation axis. Draw *er* corresponding to guide's course 240˚ and speed 15 knots.

(2) Plot own ship's new position M_2 oriented to the new axis. The original station assignments are retained, except the stations are now relative to the new axis.

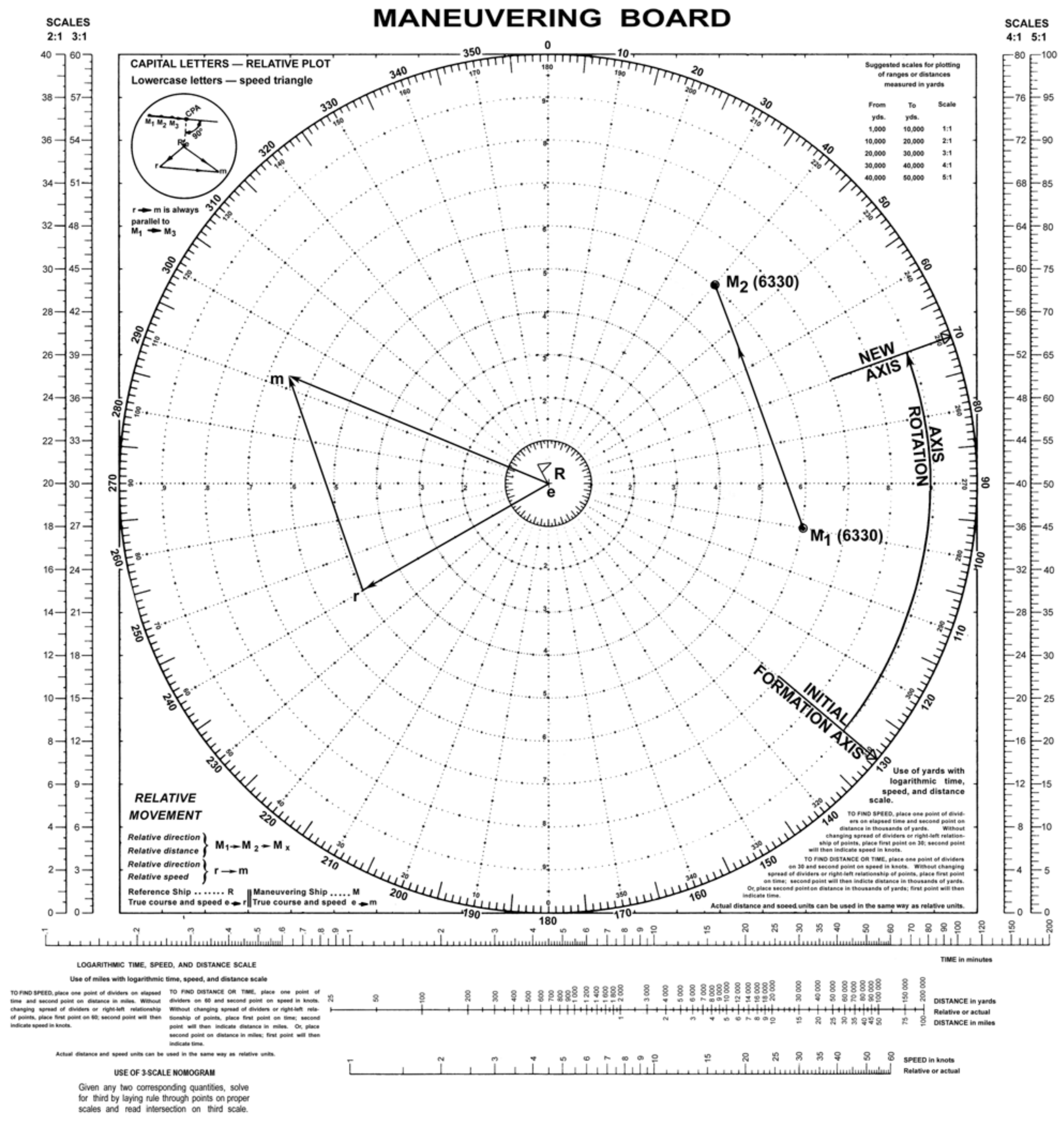
(3) Draw the direction of relative movement line (DRM) from M_1 through M_2.

(4) Through *r* draw a line in the direction of relative movement intersecting the 20-knot circle at *m*.

(5) Own ship's true vector is *em*: course 293˚, speed 20 knots.

Answer:

(1) Course 293˚ to regain station relative to the new axis.



GUIDE AT CENTER

EXAMPLE 36

Scale: Speed 3:1;
Distance 1:1 thousands of yds.

EXAMPLE 37

FORMATION AXIS ROTATION—GUIDE OUT OF CENTER
FORMATION CENTER KEPT IN CENTER OF PLOT

Situation:

The formation is on course 275˚, speed 18 knots. The formation axis is 190˚. The guide is in station 3030 and own ship is in station 7300. The OTC rotates the formation axis to 140˚. Stationing speed is 20 knots.

Required:

(1) Course at 20 knots to regain station relative to the new formation axis, 140˚.

Solution:

(1) Mark the initial and new formation axes at 190˚ and 140˚, respectively. Plot the guide's initial station R_1 on circle 3 in a direction from the formation center 30˚ relative to the initial formation axis. Plot own ship's initial station S_1 on circle 7 in a direction from the formation center 300˚ relative to the initial formation axis. Draw *er* corresponding to guide's course 275˚ and speed 18 knots.

(2) Plot the guide's new station R_2 oriented to the new formation axis; plot own ship's new station S_2 oriented to the new formation axis.

(3) Measure the bearings and distances of S_1 and S_2 from R_1 and R_2, respectively.

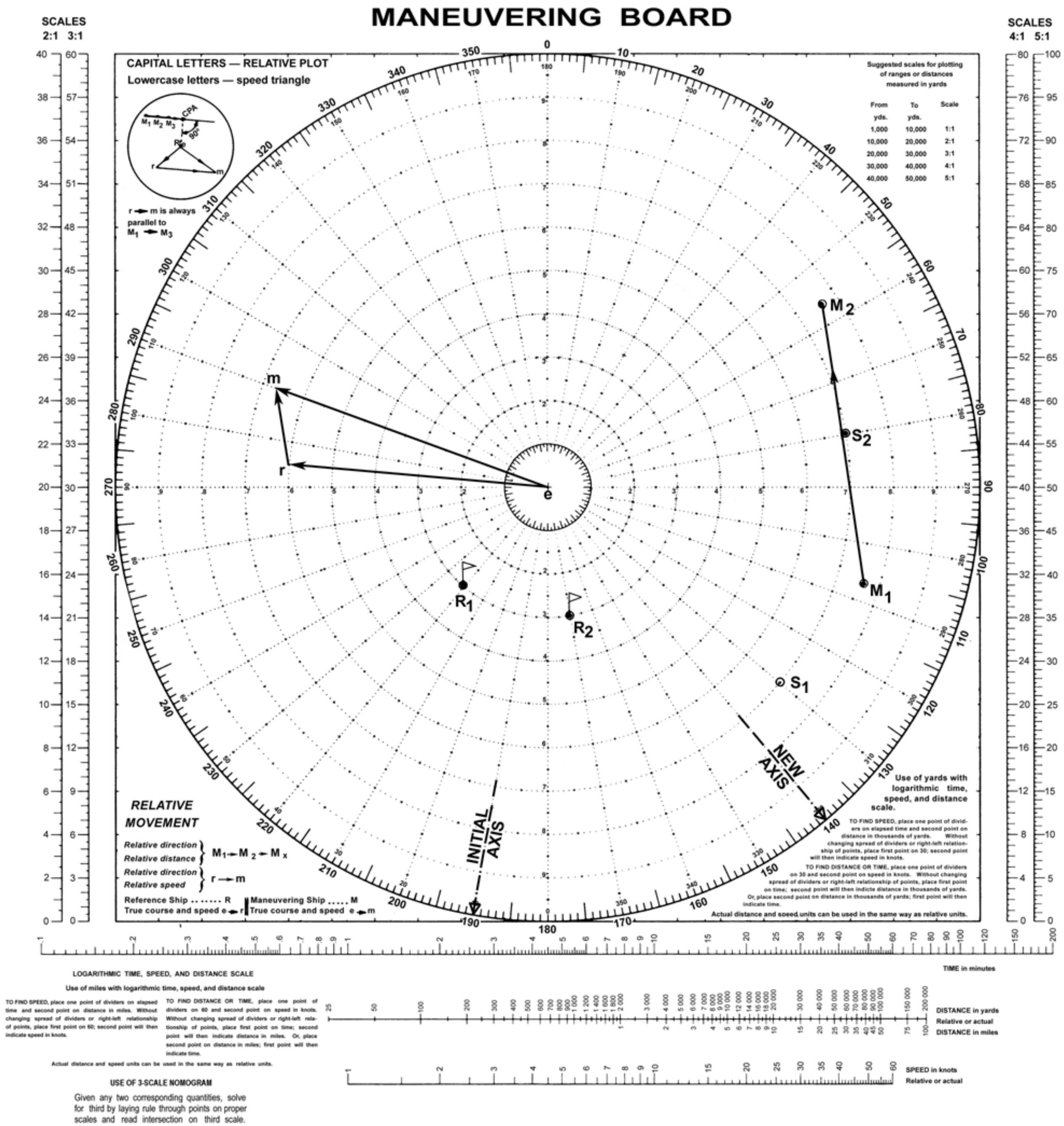
(4) From the center, plot the bearing and distance of S_1 from R_1 as M_1 and the bearing and distance of S_2 from R_2 as M_2.

(5) Since the line from M_1 to M_2 represents the required DRM for own ship to regain station relative to the new axis, draw a line through *r* in the direction of relative movement.

(6) Own ship's true vector is *em*: course 291˚, speed 20 knots.

Answer:

(1) Course 291˚ to regain station relative to the new axis.



GUIDE OUT OF CENTER

EXAMPLE 37

Scale: Speed 3:1;
Distance 1:1 thousands of yds.

EXAMPLE 38

FORMATION AXIS ROTATION—GUIDE OUT OF CENTER

Situation:

The formation is on course 275˚, speed 18 knots. The formation axis is 190˚. The guide is in station 3030 and own ship is in station 7300. The OTC rotates the formation axis to 140˚. Stationing speed is 20 knots.

Required:

(1) Course at 20 knots to regain station relative to the new formation axis, 140˚.

Solution:

(1) Mark the initial and new formation axes at 190˚ and 140˚, respectively. Plot the guide's station R_1 on circle 3 in a direction from the formation center 30˚ relative to the initial formation axis. Plot own ship's station M_1 on circle 7 in a direction from the formation center 300˚ relative to the initial formation axis. Draw *er* corresponding to guide's course 275˚ and speed 18 knots.

(2) Plot the guide's station, R_2, oriented to the new formation axis. Plot own ship's position M_3 oriented to the new axis. The original station assignments are retained, except the stations are now relative to the new axis.

(3) Shift the initial position of own ship's station at M_1 in the direction and distance of the fictitious shift of the guide to its position relative to the new axis. Mark the initial position so shifted as M_2.

(4) Draw the direction of relative movement lines (DRM) from M_2 through M_3.

(5) Through *r* draw a line in the direction of relative movement intersecting the 20-knot circle at *m*.

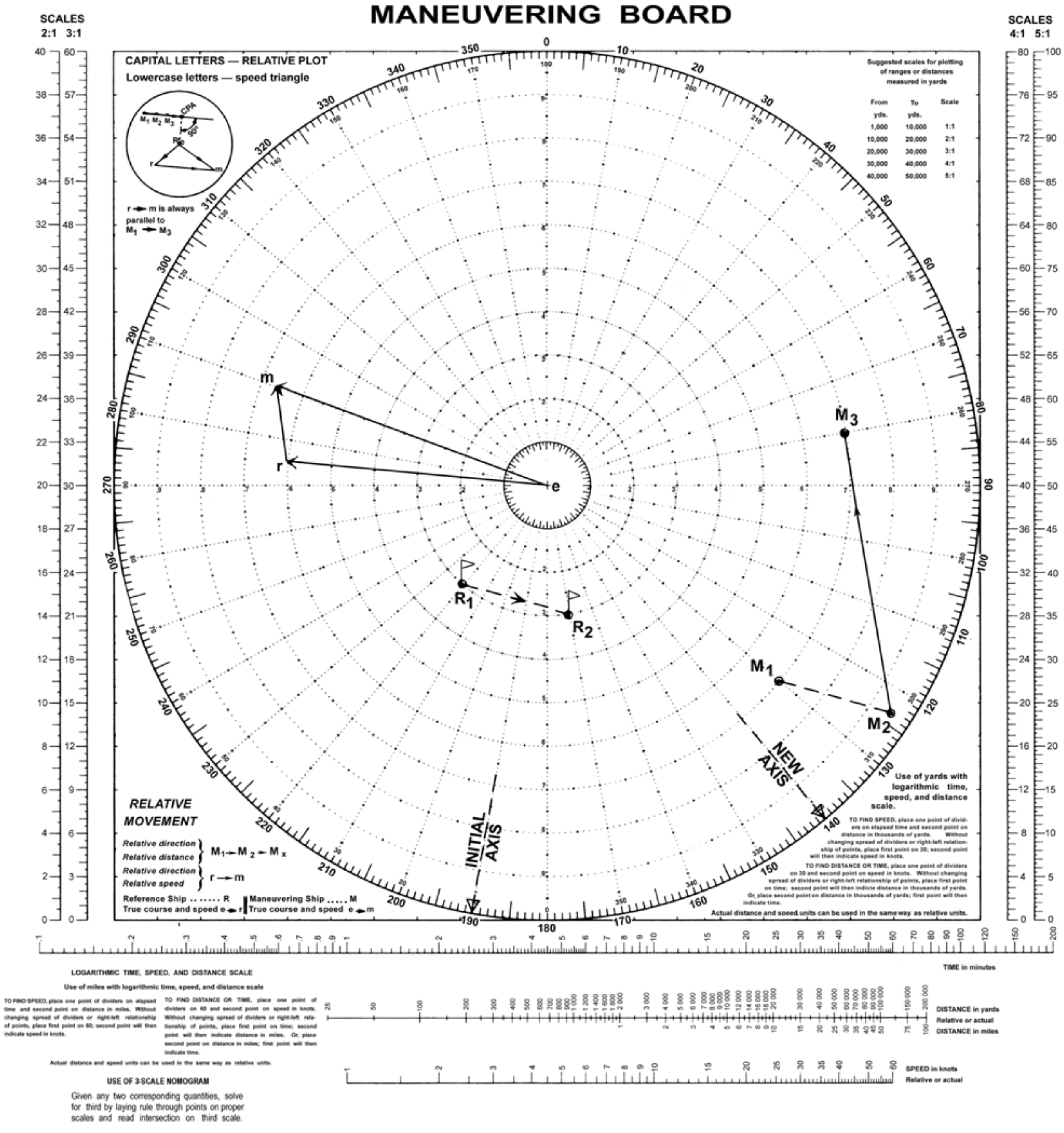
(6) Own ship's true vector is *em*: course 291˚, speed 20 knots.

Answer:

(1) Course 291˚ to regain station relative to the new axis.

Explanation:

Since the guide does not actually move relative to the initial formation center while maintaining course and speed during the formation maneuver, all initial positions of stations in the formation must be moved in the same direction and distance as the fictitious movement of the guide to its new position.



GUIDE OUT OF CENTER

EXAMPLE 38

Scale: Speed 3:1;
Distance 1:1 thousands of yds.

EXAMPLE 39

COURSE AND SPEED BETWEEN TWO STATIONS, REMAINING WITHIN A SPECIFIED RANGE FOR SPECIFIED TIME INTERVAL ENROUTE

Situation:

Own ship *M* is on station bearing 280˚, 5 miles from the guide *R* on formation course 190˚, speed 20 knots.

Required:

At 1500 own ship *M* is ordered to proceed to new station bearing 055˚, 20 miles, arriving at 1630 and to remain within a 10-mile range for 1 hour. The commanding officer elects to proceed directly to new station, adjusting course and speed as necessary to comply with the foregoing requirements.

(1) Course and speed to remain within 10 miles for 1 hour.

(2) Course and speed required at 1600.

(3) Bearing of *R* at 1600.

Solution:

(1) Plot the 1500 and 1630 positions of *M* at M_1 and M_3, respectively. Draw the relative motion line, M_1M_3, intersecting the 10-mile circle at M_2. Draw *er*. Measure M_1M_2: 13.6 miles. The time required to transit this distance is 1 hour at an SRM of 13.6 knots. Through *r* draw rm_1 13.6 knots in length, parallel to and in the direction M_1M_3. Vector em_1 is 147˚.5, 16.2 knots.

(2) Measure M_2M_3, 10.3 miles, which requires an SRM of 20.6 knots for one half hour. Through *r* draw rm_2. Vector em_2 is 125˚.5, 18.2 knots.

(3) By inspection, *R* bears 226˚ from M_2 at 1600.

Answer:

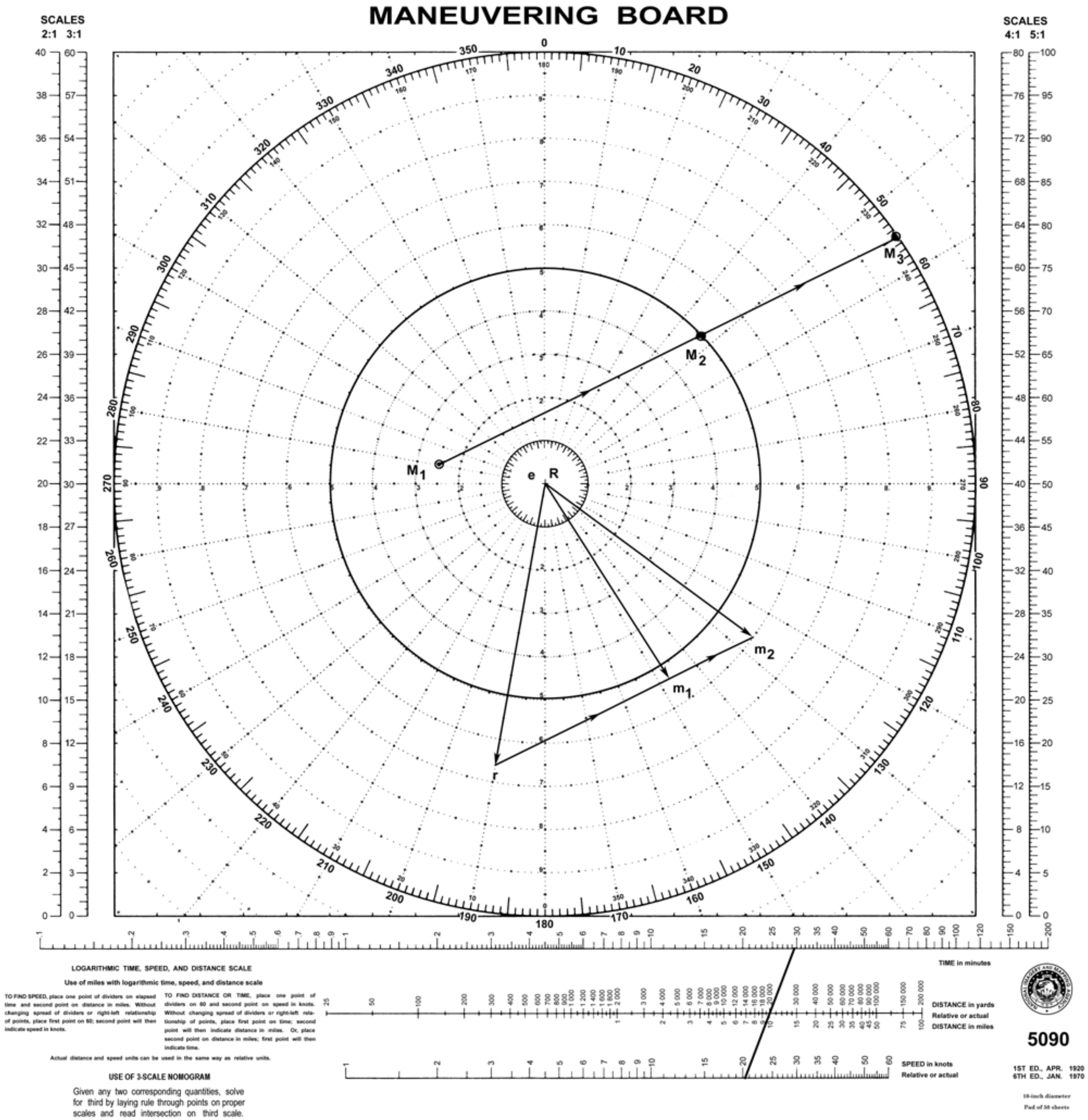
(1) Course 148˚, speed 16.2 knots.

(2) Course 126˚, speed 18.2 knots.

(3) Bearing 226˚.

Explanation:

Since own ship *M* must remain within 10 miles of the guide for 1 hour, *M* must not plot along M_1M_2 farther than M_2 prior to 1600. The required magnitudes of the relative speed vectors for time intervals 1500 to 1600 and 1600 to 1630 together with their common direction are combined with the true vector of the guide to obtain the two true course vectors for own ship.



GUIDE AT CENTER

EXAMPLE 39

Scale: Speed 3:1;
Distance 2:1 mi.

EXAMPLE 40

COURSE AT MAXIMUM SPEED TO OPEN RANGE TO A SPECIFIED DISTANCE IN MINIMUM TIME

Situation:

Own ship *M* has guide *R* bearing 240˚, range 12 miles. The guide is on course 120˚, speed 15 knots. Own ship's maximum speed is 30 knots.

Required:

Open range to 18 miles as quickly as possible.

(1) Course at 30 knots.

(2) Time to complete the maneuver.

(3) Bearing of guide upon arrival at specified range.

Solution:

The key to this solution is to find that relative position (*M*') of the guide that could exist *before* the problem starts in order to be able to draw the RML through the given relative position (M_1) and *M'* to intersect the specified range circle.

(1) Plot *R* and M_1. About *R* describe a circle of radius 18 miles. Draw *er*. Along *R*'s course plot *M'* 9 miles from *R*.

$$\frac{\text{Speed of } R}{\text{Speed of } M} \times 18 \text{ miles} = 9 \text{ miles}$$

Draw a line through *M'* and M_1 and extend it to intersect the 18-mile range circle at M_2.

From *r* draw *rm* parallel to and in the direction M_1M_2. The intersection of *rm* and the 30-knot speed circle is the course required to complete the maneuver in minimum time. Vector *em* is 042˚.6, 30 knots.

(2) SRM is 30.5 knots. MRM is 7.5 miles. Time to complete the maneuver: 14.8 minutes.

(3) Upon reaching the 18-mile range circle, *R* is dead astern of *M* bearing 222˚.6.

Answer:

(1) Course 043˚.

(2) Time 15 minutes.

(3) Bearing 223˚.

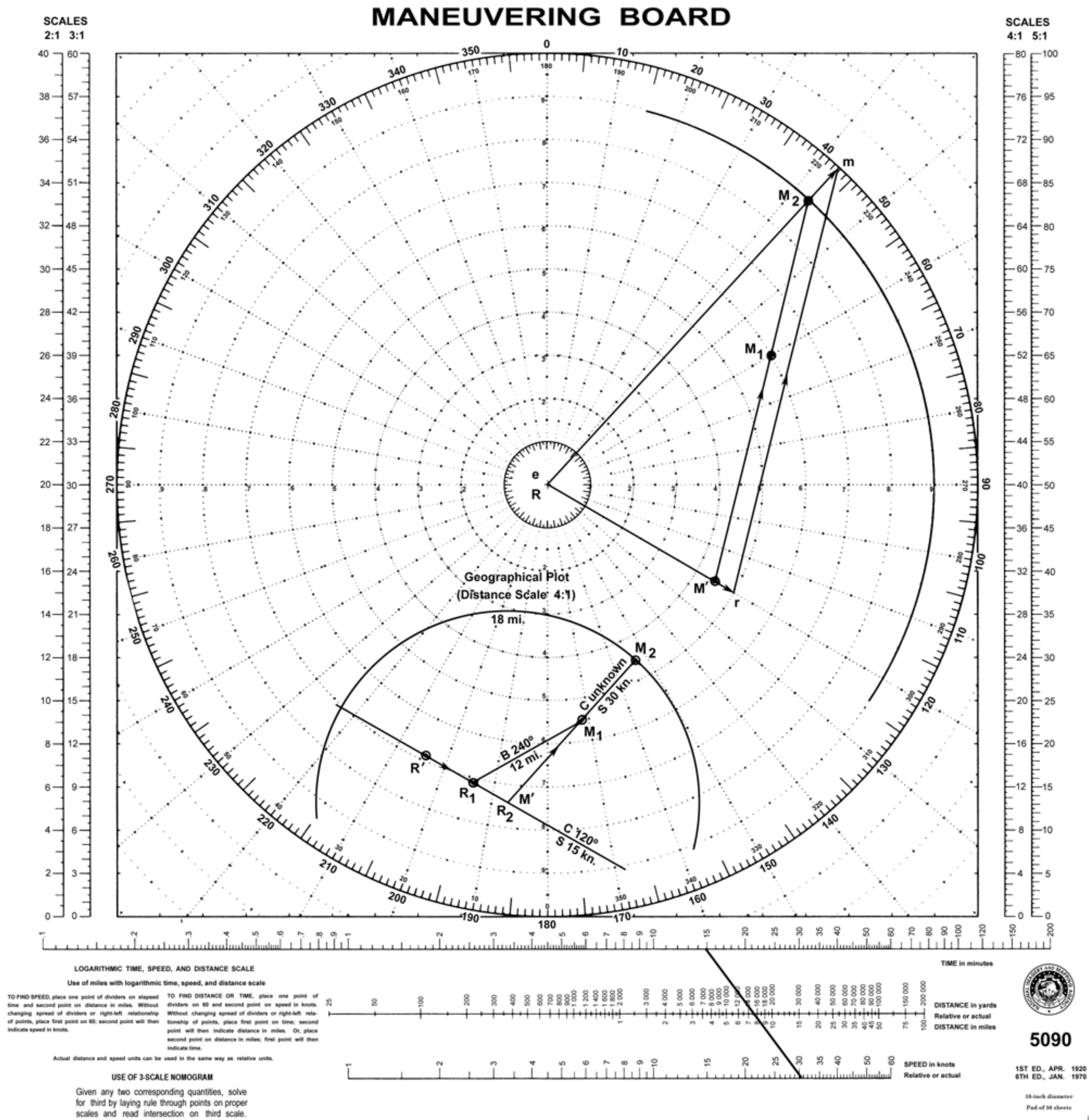
Explanation:

For *M* to open or close to a specified range in minimum time, *M* must travel the shortest geographical distance at maximum speed. The shortest distance is along the radius of a circle centered at the position occupied by *R* at the instant *M* reaches the specified range circle.

In the "opening range" problem, determine hypothetical relative positions of *M* and *R* that could exist *before the problem starts*. Referring to the **geographical plot**, assume *M* starts from position *M'* and proceeds outward along some radius 18 miles in length on an unknown course at 30 knots. If *R* moves toward its final position at R_2 along the given course of 120˚, speed 15 knots, it should arrive at R_2 the instant *M* reaches the 18-mile circle. At this instant, the problem conditions are satisfied by *M* being 18 miles distant from *R*. However, own ship's course required to reach this position is not yet known. During the time interval *M* opened 18 miles at 30 knots, *R* moved 9 miles at 15 knots from *R'* to R_2.

$$\frac{\text{Speed of } M}{\text{Speed of } R} \times 18 \text{ miles} = 9 \text{ miles}$$

This provides the needed second relative position of *M'* from *R'*, 9 miles bearing 120˚. This position is then transferred to the **relative plot**.



GUIDE AT CENTER

EXAMPLE 40

Scale: Speed 3:1; Distance 2:1 mi.

EXAMPLE 41

COURSE AT MAXIMUM SPEED TO CLOSE RANGE TO A SPECIFIED DISTANCE IN MINIMUM TIME

Situation:

Own ship *M* has the guide *R* bearing 280˚, range 10 miles. The guide is on course 020˚, speed 15 knots. Own ship's maximum speed is 24 knots.

Required:

Close range to 2 miles as quickly as possible.

(1) Course at 24 knots.

(2) Time to complete the maneuver.

(3) Bearing of guide upon arrival at the specified range.

Solution:

The key to this solution is to find that relative position *(M')* of the guide that could exist *after* the problem starts in order to be able to draw the RML through the given relative position (M_1) and *M'* to intersect the specified range circle.

(1) Plot *R* and M_1. About *R* describe a circle of radius 2 miles. Draw *er*, guide's speed vector 020˚, 15 knots. On reciprocal of *R*'s course plot *M'* 1.25 miles from *R*.

$$\frac{\text{Speed of } R}{\text{Speed of } M} \times 2 \text{ miles} = 1.25 \text{ miles}$$

Draw a line through *M'* and M_1. The intersection of this line and the 2-mile range circle is M_2.

From *r* draw a line parallel to and in the direction M_1M_2. The intersection of this line and the 24-knot speed circle at *m* is the course required to complete the maneuver in minimum time. Vector *em* 309˚.8, 24 knots.

(2) SRM is 23.6 knots. MRM is 8.3 miles. Time to complete the maneuver: 21.1 minutes.

(3) Upon reaching the 2-mile range circle, *R* is dead ahead of *M* on a bearing 309˚.8.

Answer:

(1) Course 310˚.

(2) Time 21 minutes.

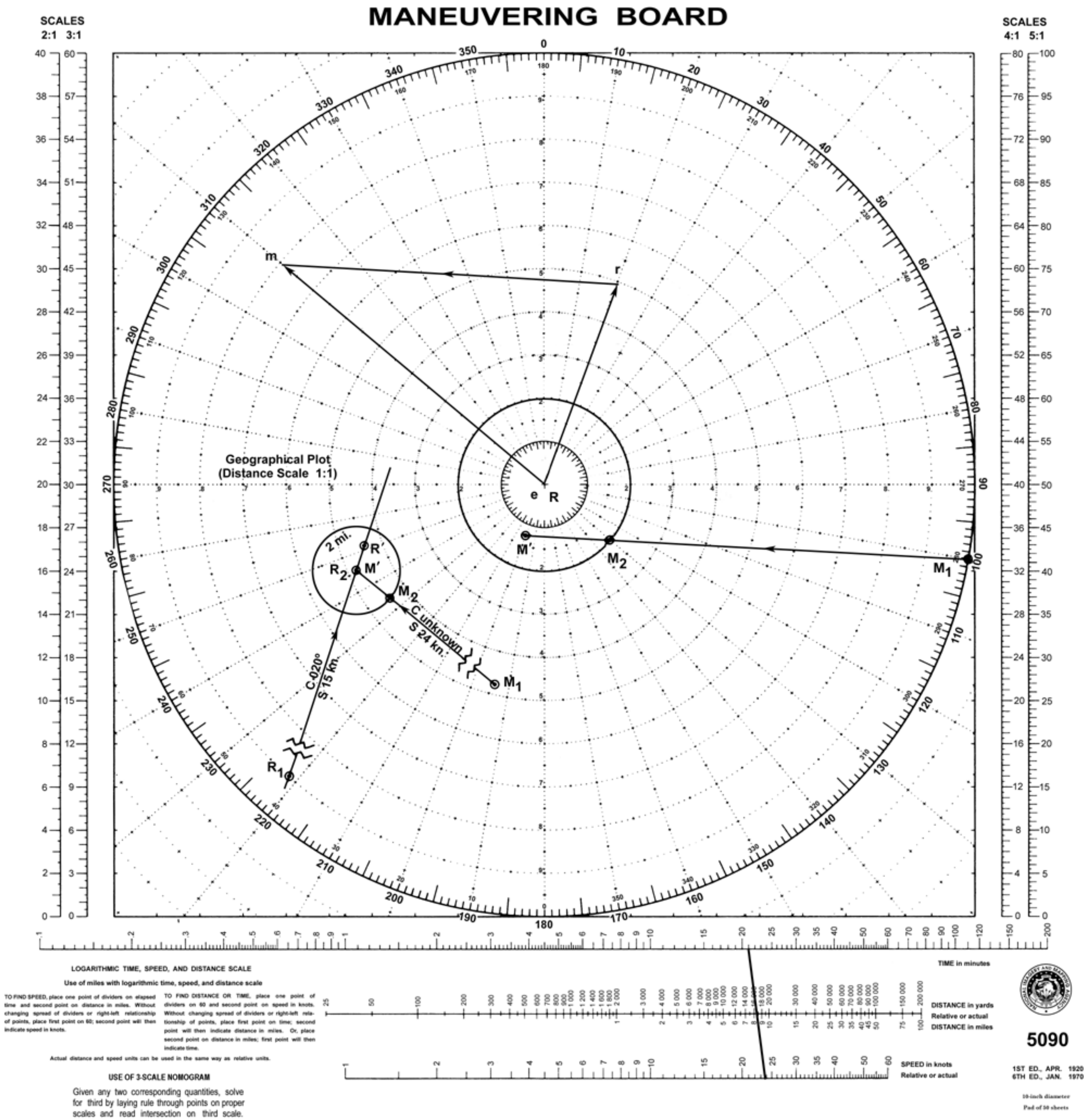
(3) Bearing 310˚.

Explanation:

Referring to the **geographical plot**, assume *M* starts from position M_1 and proceeds inward along some radius on an unknown course at 24 knots. If *R* moves toward its final position at R_2 along the given course 020˚, speed 15 knots, it should arrive at R_2 the instant *M* reaches the 2-mile circle. At this instant the problem conditions are satisfied although the solution for own ship's course is not yet known. Assume that *M* continues on the same course and speed through the 2 miles to *M'* at the center of the circle while *R* moves away from the center on course 020˚, speed 15 knots. During the time interval that *M* moves these 2 miles at 24 knots, *R* opens 1.25 miles.

$$\frac{\text{Speed of } R}{\text{Speed of } M} \times 2 \text{ miles} = 1.25 \text{ miles}$$

This provides the needed second relative position of *M'* from *R'*: 1.25 miles, bearing 200˚. This position is then transferred to the **relative plot**.



GUIDE AT CENTER

EXAMPLE 41

Scale: Speed 3:1;
Distance 1:1 mi.

EXAMPLE 42

COURSE AT MAXIMUM SPEED TO REMAIN WITHIN A SPECIFIED RANGE FOR MAXIMUM TIME

Situation:

Ship *R* bears 110˚, 4 miles from *M*. *R* is on course 230˚, 18 knots. Maximum speed of *M* is 9 knots.

Required:

Remain within a 10-mile range of *R* for as long as possible.
(1) Course at maximum speed.
(2) Bearing of *R* upon arrival at specified range.
(3) Length of time within specified range.
(4) CPA.

Solution:

(1) Plot *R* at the center and M_1 bearing 290˚, 4 miles from *R*. About *R* describe arcs of radius 9 knots and 10 miles. Draw *er* 230˚, 18 knots. Along the reciprocal of *R*'s course, plot *M'* 20 miles from *R*.

$$\frac{\text{Speed of } R}{\text{Speed of } M} \times 10 \text{ miles} = 20 \text{ miles}$$

Draw a line through *M'* and M_1. The intersection of $M'M_1$ and the 10-mile range circle is M_2, the point beyond which the specified or limiting range is exceeded. Through *r* draw a line parallel to and in the direction M_1M_2. The intersection of this line at point *m* on the 9-knot speed circle is the required course to remain within 10 miles of *R*. Vector *em* is 220˚.8, 9 knots.

(2) Upon arrival at limiting range at M_2, *R* is dead ahead of *M* bearing 220˚.8.

(3) The time interval within specified range is:

$$\frac{M_1M_2}{rm} = \frac{12 \text{ miles}}{9.1 \text{ knots}} = 78.8 \text{ minutes}$$

(4) Drop a perpendicular from *R* to M_1M_2. CPA is 148˚.9, 3.1 miles.

Note:

When *M*'s speed is equal to or greater than that of *R*, a special case exists in which there is no problem insofar as remaining within a specified range.

Answer:

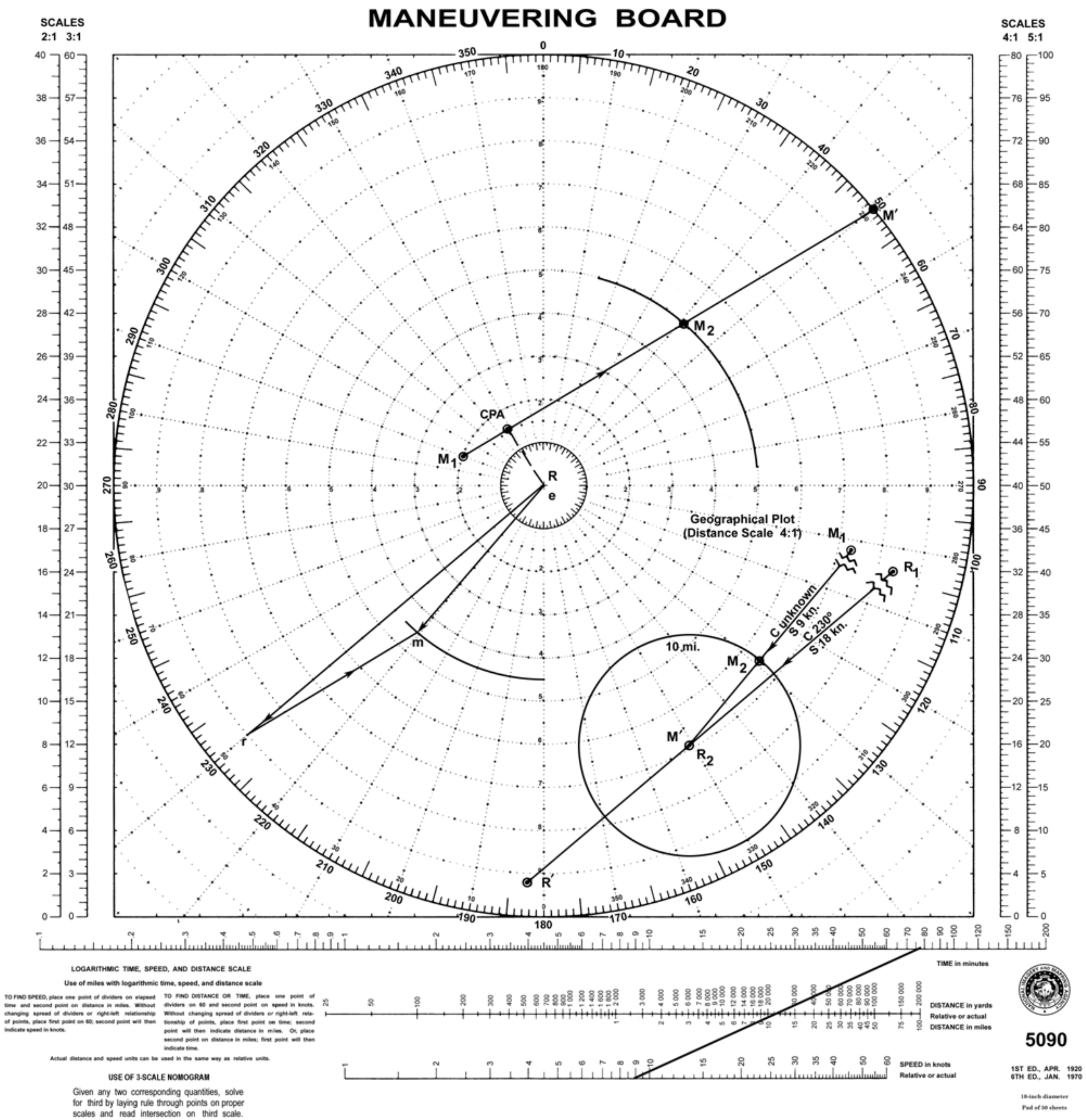
(1) Course 221˚.
(2) Bearing 221˚.
(3) Time 79 minutes.
(4) CPA 149˚, 3.1 miles.

Explanation:

As in the "closing range" problem, example 39, determine hypothetical relative positions of *M* and *R* that could exist *after the problem ends*. Referring to the **geographical plot**, assume *M* starts from position M_1 and proceeds inward along some radius on an unknown course at 9 knots. *R* is on course 230˚ at 18 knots. At the instant *R* passes through R_2, *M* reaches the 10-mile limiting range at M_2. At this instant the problem conditions are satisfied although the solution is not yet known. Assume that *M* continues on the same course and speed for 10 miles to the center of the circle while *R* moves away from the center on course 230˚, speed 18 knots. During the time interval *M* closes 10 miles toward the center, *R* opens 20 miles at 18 knots.

$$\frac{\text{Speed of } R}{\text{Speed of } M} \times 10 \text{ miles} = 20 \text{ miles}$$

This then gives us the needed second relative position of *R'* from *M'*, 20 miles bearing 230˚. This position is then transferred to the **relative plot**.



GUIDE AT CENTER

EXAMPLE 42

Scale: Speed 2:1;
Distance 2:1 mi.

EXAMPLE 43

COURSE AT MAXIMUM SPEED TO REMAIN OUTSIDE OF A SPECIFIED RANGE FOR MAXIMUM TIME

Situation:

Ship R bears 020˚, 14 miles from own ship M. R is on course 210˚, speed 18 knots. Maximum speed of M is 9 knots.

Required:

Remain outside a 10-mile range from R for as long as possible.

(1) Course at maximum speed.

(2) Bearing of R upon arrival at specified range.

(3) Time interval before reaching specified range.

Solution:

(1) Plot R at the center and M_1 bearing 200˚, 14 miles from R. About R, describe circles of radius 9 knots and 10 miles. Draw *er* 210˚, speed 18 knots. Along R's course, plot M' 20 miles from R.

$$\frac{\text{Speed of } R}{\text{Speed of } M} \times 10 \text{ miles} = 20 \text{ miles}$$

Draw a line through M' and M_1 intersecting the 10-mile range circle at M_2. Through r draw a line parallel to and in the direction of M_1M_2 intersecting the 9-knot speed circle at m. Completion of the speed triangle produces *em*, the required course of 184˚.2 at 9 knots.

(2) Upon arrival at limiting range at point M_2, R is dead astern of M bearing 004˚.2.

(3) The time interval outside of specified range is:

$$\frac{M_1M_2}{rm} = \frac{5.2 \text{ miles}}{10.7 \text{ knots}} = 30 \text{ minutes}$$

Note:

Own ship can remain outside the limiting range indefinitely if M_1 falls outside the area between two tangents drawn to the limiting range circle from M' and if R remains on the same course and speed.

Answer:

(1) Course 184˚.

(2) Bearing 004˚.

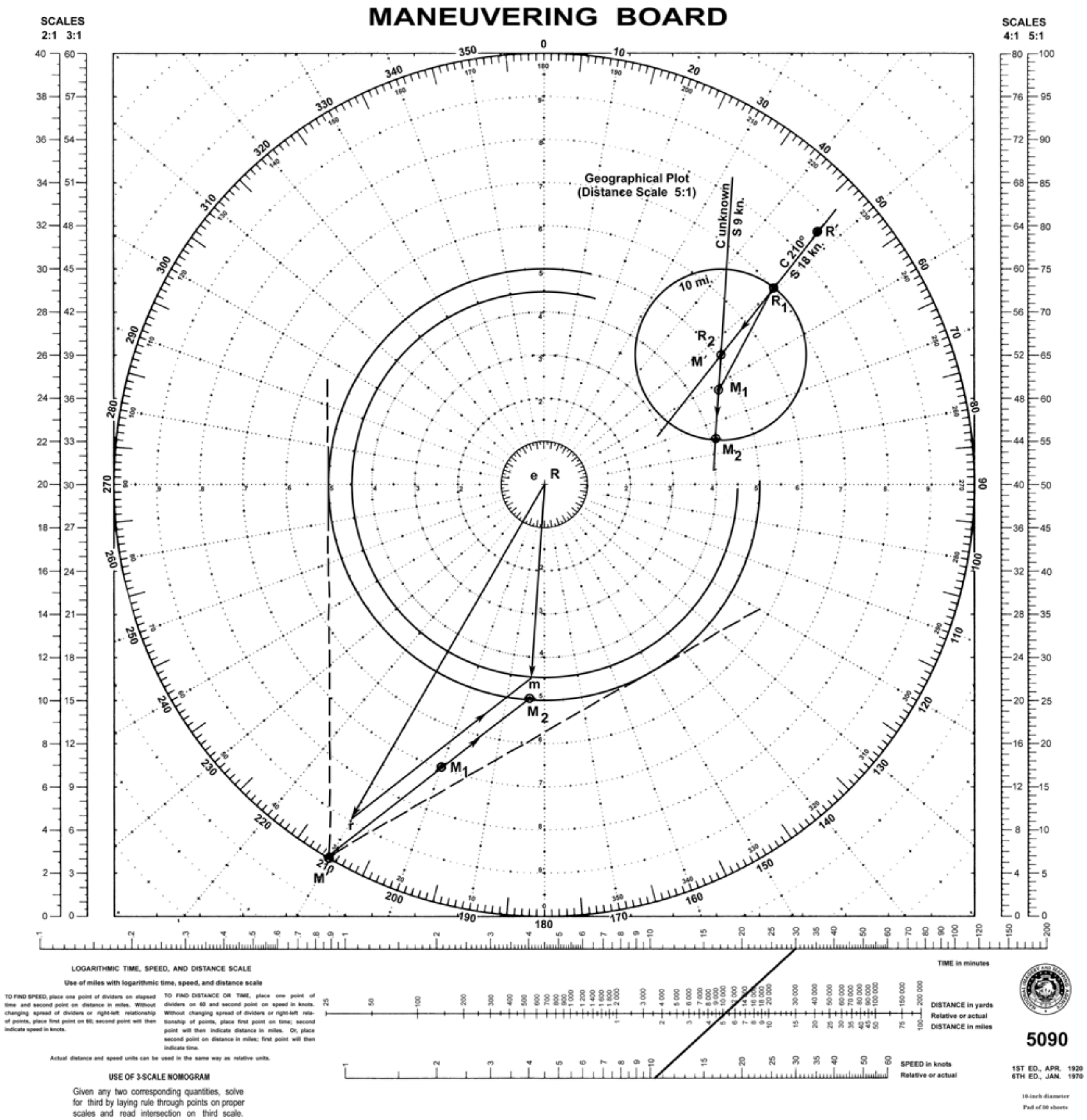
(3) Time 30 minutes.

Explanation:

To determine a course to remain outside of a given range for maximum time, determine hypothetical relative positions of M and R that could exist *before the problem starts*. Referring to the **geographical plot**, assume M starts from position M' and proceeds outward along some radius on an unknown course at 9 knots. If R moves toward its final position R_2 along the given course 210˚, speed 18 knots, it should arrive at R_2 the instant M reaches the 10-mile circle at M_2. At this instant the problem conditions are satisfied although the solution for own ship's course is not yet known. During the time interval required for M to move from M' to M_2, 10 miles at 9 knots, R moves from R' to R_2, 20 miles at 18 knots along the given course 210˚.

$$\frac{\text{Speed of } R}{\text{Speed of } M} \times 10 \text{ miles} = 20 \text{ miles}$$

This provides the needed second relative position, M' bearing 210˚, 20 miles from R'. This position is then transferred to the **relative plot**.



GUIDE AT CENTER

EXAMPLE 43

Scale: Speed 2:1;
Distance 2:1 mi.

USE OF A FICTITIOUS SHIP

The examples given thus far in PART TWO have been confined to ships that have either maintained constant courses and speeds during a maneuver or else have engaged in a succession of such maneuvers requiring only repeated application of the same principles. When one of the ships alters course and/or speed during a maneuver, a preliminary adjustment is necessary before these principles can be applied.

This adjustment consists, in effect, of substituting a **fictitious ship** for the ship making the alteration. This fictitious ship is presumed to:

(1) maintain a constant course and speed throughout the problem (this is the *final* course and speed of the actual ship).

(2) start and finish its run at times and positions determined by the conditions established in the problem.

For example, the course and speed of advance of a ship zig-zagging are considered to be the constant course and speed of a fictitious ship which departs from a given position at a given time simultaneously with the actual ship, and arrives simultaneously with the actual ship at the same final position. The principles discussed in previous examples are just as valid for a fictitious ship as for an actual ship, both in the relative plot and speed triangle. A **geographical plot** facilitates the solution of this type.

EXAMPLE 44

ONE SHIP ALTERS COURSE AND/OR SPEED DURING MANEUVER

Situation:

At 0630 ship *R* bears 250˚, range 32 miles. *R* is on course 345˚, speed 15 knots but at 0730 will change course to 020˚ and speed to 10 knots.

Required:

Own ship *M* take station 4 miles ahead of *R* using 12 knots speed.

(1) Course to comply.

(2) Time to complete maneuver.

Solution:

Determine the 0630 position of a fictitious ship *F* that, by steering course 020˚ at speed 10 knots, will pass through the 0730 position simultaneously with the actual ship. In this way the **fictitious ship** travels on a steady course of 020˚, speed 10 knots throughout the problem.

(1) Construct a **geographical plot** with *R* and R_1 the 0630 and 0730 positions respectively of ship *R* moving along course 345˚ at 15 knots. Plot *F*, the 0630 position of the fictitious ship bearing 200˚, 10 miles from R_1. By measurement, *F* bears 304˚, 8.8 miles from *R*. Transfer this position to a relative plot with *R* at the center.

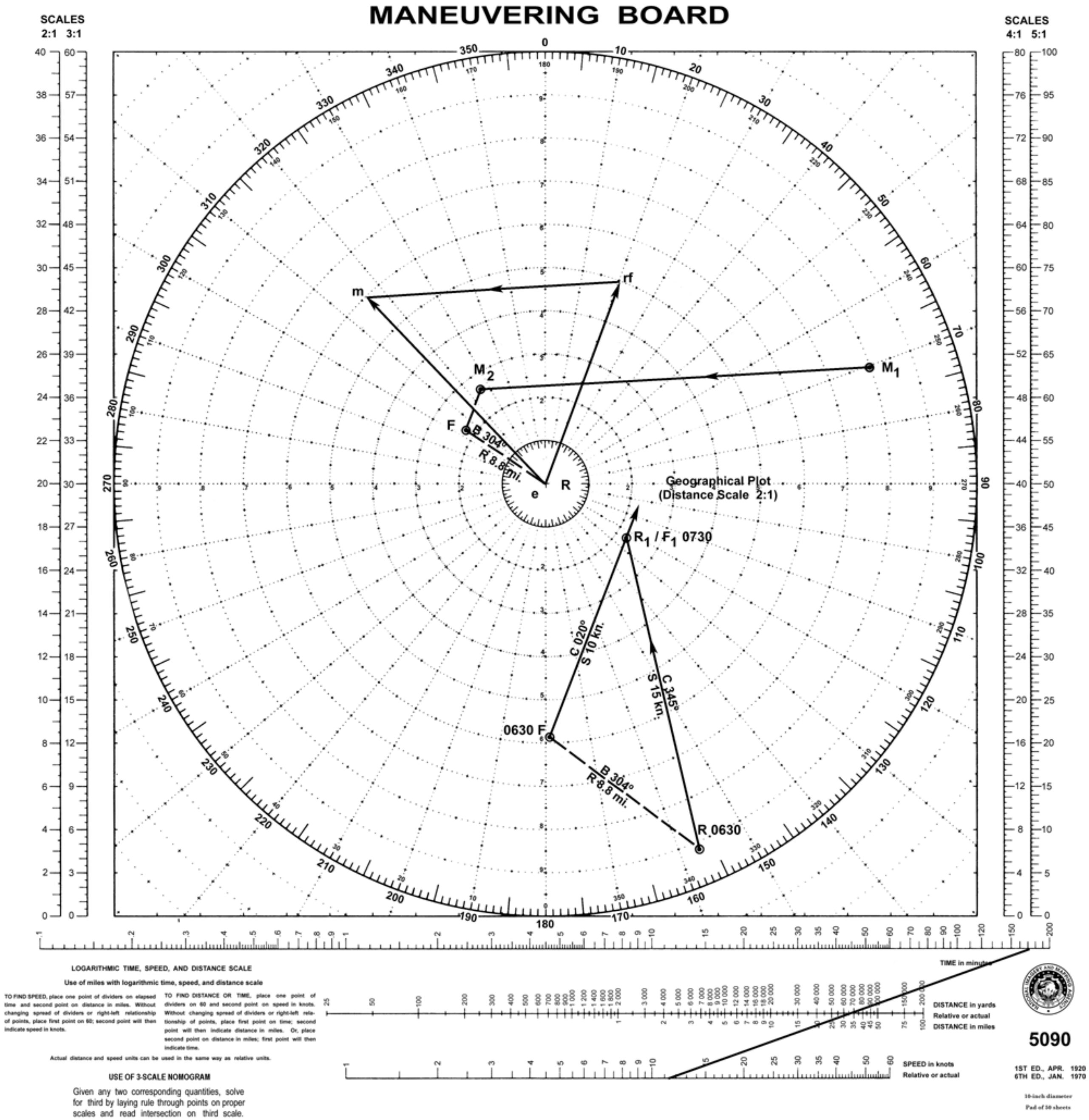
Plot own ship at M_1 bearing 070˚, 32 miles from *R*. Draw *erf*, the fictitious ship's vector, 020˚, 10 knots. Lay off own ship's final position, M_2, 4 miles ahead of *F* along its final course 020˚. Draw the relative movement line M_1M_2 and, parallel to it, construct the relative speed vector from *rf* to its intersection with the 12-knot circle at *m*. This produces *em* the required course of 316˚.

(2) The time to complete the maneuver can be obtained from the TDS scale using MRM of 36.4 miles and SRM of 11.8 knots which gives a time of 3.1 hours.

Answer:

(1) Course 316˚.

(2) Time 3 hours 6 minutes.



GUIDE AT CENTER

EXAMPLE 44

Scale: Speed 2:1;
Distance 4:1 mi.

EXAMPLE 45

BOTH SHIPS ALTER COURSE AND/OR SPEED DURING MANEUVER

Situation:

At 0800 *R* is on course 105˚, speed 15 knots and will change course to 350˚, speed 18 knots at 0930. Own ship *M* is maintaining station bearing 330˚, 4 miles from *R*. *M* is ordered to take station bearing 100˚, 12 miles from *R*, arriving at 1200.

Required:

(1) Course and speed for *M* to comply if maneuver is begun at 0800.

(2) Course for *M* to comply if *M* delays the course change as long as possible and remains at 15 knots speed throughout the maneuver.

(3) Time to turn to course determined in (2).

Solution:

Since the relative positions of *R* and *M* at the beginning and end of the maneuver and the time interval for the maneuver are given, the solution for (1) can be obtained directly from a **geographical plot**. Solve the remainder of the problem using a **relative plot**.

(1) Using a geographical plot, lay out *R*'s 0800-1200 track through points R_1, R_2, and R_3. Plot M_1 and M_3 relative to R_1 and R_3, respectively. The course 040˚ from M_1 to M_3 can be measured directly from the plot. *M* will require a speed of 10.8 knots to move 43.4 miles in 4 hours.

This solution may be verified on a relative plot by means of a fictitious ship. First, using a geographical plot, determine the 0800 position of a **fictitious ship** that, by steering 350˚, speed 18 knots, will pass through the 0930 position simultaneously with *R*. At 0800 own ship at M_1 bears 322˚, 45.7 miles from the fictitious ship at F_1. Transfer these positions to a relative plot, placing *F* at the center. Plot own ship's 1200 position at M_3 bearing 100˚, 12 miles from *F*. Draw the fictitious ship's vector erf_1 350˚, 18 knots. From rf_1, construct the relative speed vector parallel to M_1M_3 and 13.8 knots in length. (MRM of 55.2 miles/4 hours = 13.8 knots.) Draw em_1, the required course of 040˚, 10.8 knots.

(2) To find the two legs of *M*'s 0800-1200 track, use a relative plot. Draw em_2, own ship's vector which is given as 105˚, 15 knots. At this stage of the solution, disregard *R* and consider own ship *M* to maneuver relative to a *new* fictitious ship. Own ship on course 040˚, 10.8 knots from part (1) is the fictitious ship used. Label vector em_1 as erf_2, the fictitious ship's vector. From point m_2 draw a line through rf_2 extended to intersect the 15-knot speed circle at m_3. Draw em_3, the second course of 012˚ required by *M* in changing station.

(3) To find the time on each leg draw a time line from m_2 using any convenient scale. Through m_3 draw m_3X. Through m_1 draw m_1Y parallel to m_3X. Similar triangles exist; thus, the time line is divided into proportional time intervals for two legs. XY is the time on the first leg: 1 hour 22 minutes. The remainder of the 4 hours is spent on the second leg.

Answer:

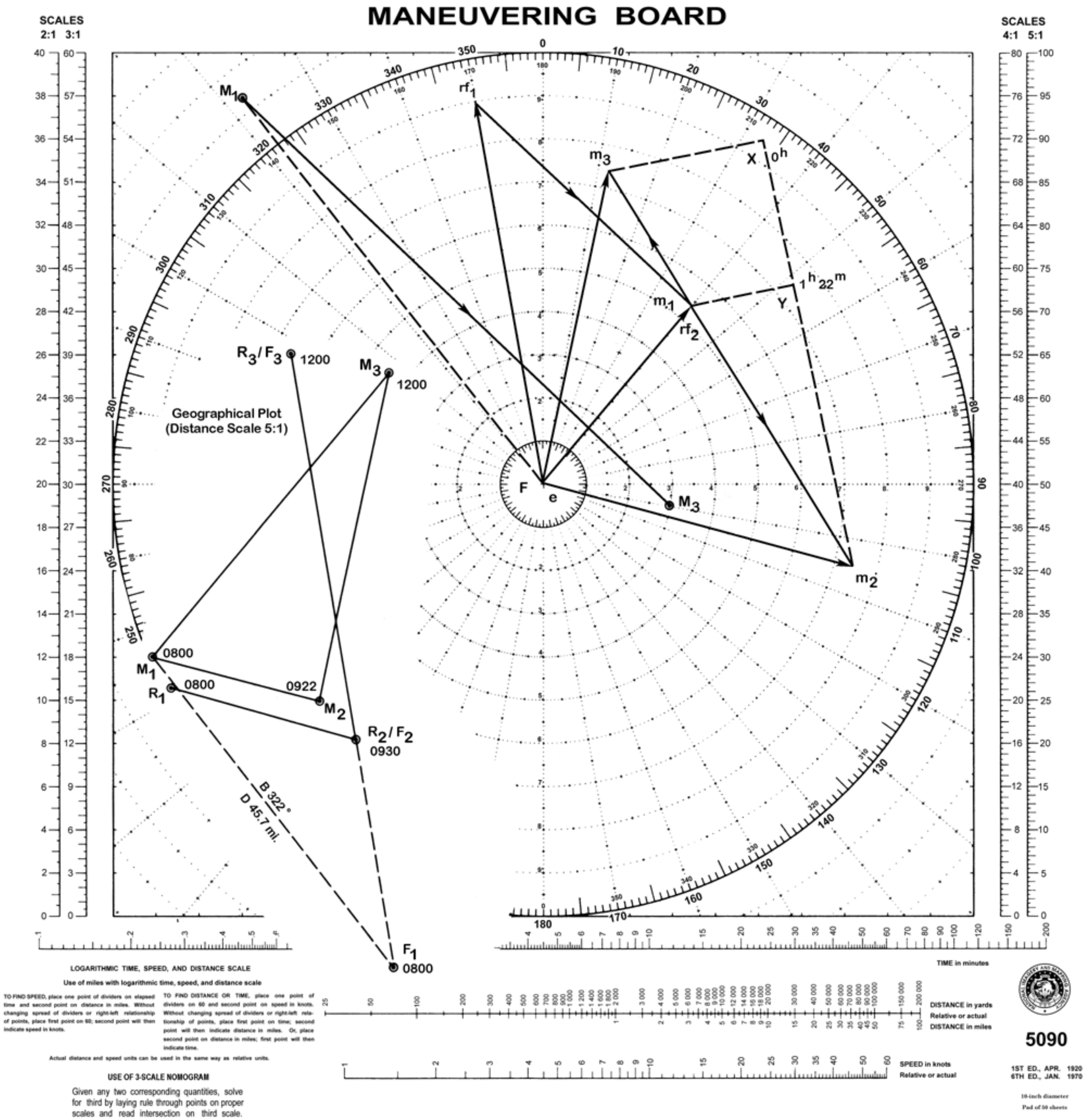
(1) Course 040˚, 10.8 knots.

(2) Course 012˚.

(3) Time 0922.

Note:

In the above example, an alternative construction of the time line as defined in the glossary is used so that the line can be drawn to a convenient scale. The proportionality is maintained by constructing similar triangles. See Note with example 47.



GUIDE AT CENTER

EXAMPLE 45

Scale: Speed 2:1;
Distance 4:1 mi.

EXAMPLE 46

COURSES AT A SPECIFIED SPEED TO SCOUT OUTWARD ON PRESENT BEARING AND RETURN AT A SPECIFIED TIME

Situation:

Own ship *M* is maintaining station on the guide *R* which bears 110˚, range 5 miles. Formation course is 055˚, speed 15 knots.

Required:

Commencing at 1730, scout outward on present bearing and return to present station at 2030. Use 20 knots speed.

(1) Course for first leg.
(2) Course for second leg.
(3) Time to turn.
(4) Maximum distance from the guide.

Solution:

(1) Plot *R* at the center and M_1 bearing 290˚, 5 miles from *R*. Draw *er* 055˚, 15 knots. The DRM "out" is along the bearing of *M* from *R*. The DRM "in" is along the bearing of *R* from *M*. Through *r* draw a line parallel to the DRM's and intersecting the 20-knot circle at m_1 and m_2. Vector rm_1 is the DRM "out". Vector em_1 is 327˚.8, the course "out".

(2) Vector rm_2 is the DRM "in". Vector em_2 is 072˚, the course "in".

(3) To find the time on each leg, draw a time line from m_1 using any convenient scale. Through m_2 draw m_2X. Through *r* draw *r*Y parallel to m_2X. Similar triangles exist; thus, the time line is divided into proportional time intervals for the two legs. XY is the time on the first leg, 41 minutes. The remainder of the time is spent on the second leg returning to station.

(4) Range of *R* when course is changed to "in" leg is 21.7 miles. Initial range + (rm_1 **x** *time* on "out" leg).

Answer:

(1) Course 328˚.
(2) Course 072˚.
(3) Time 1811.
(4) Distance 21.7 miles.

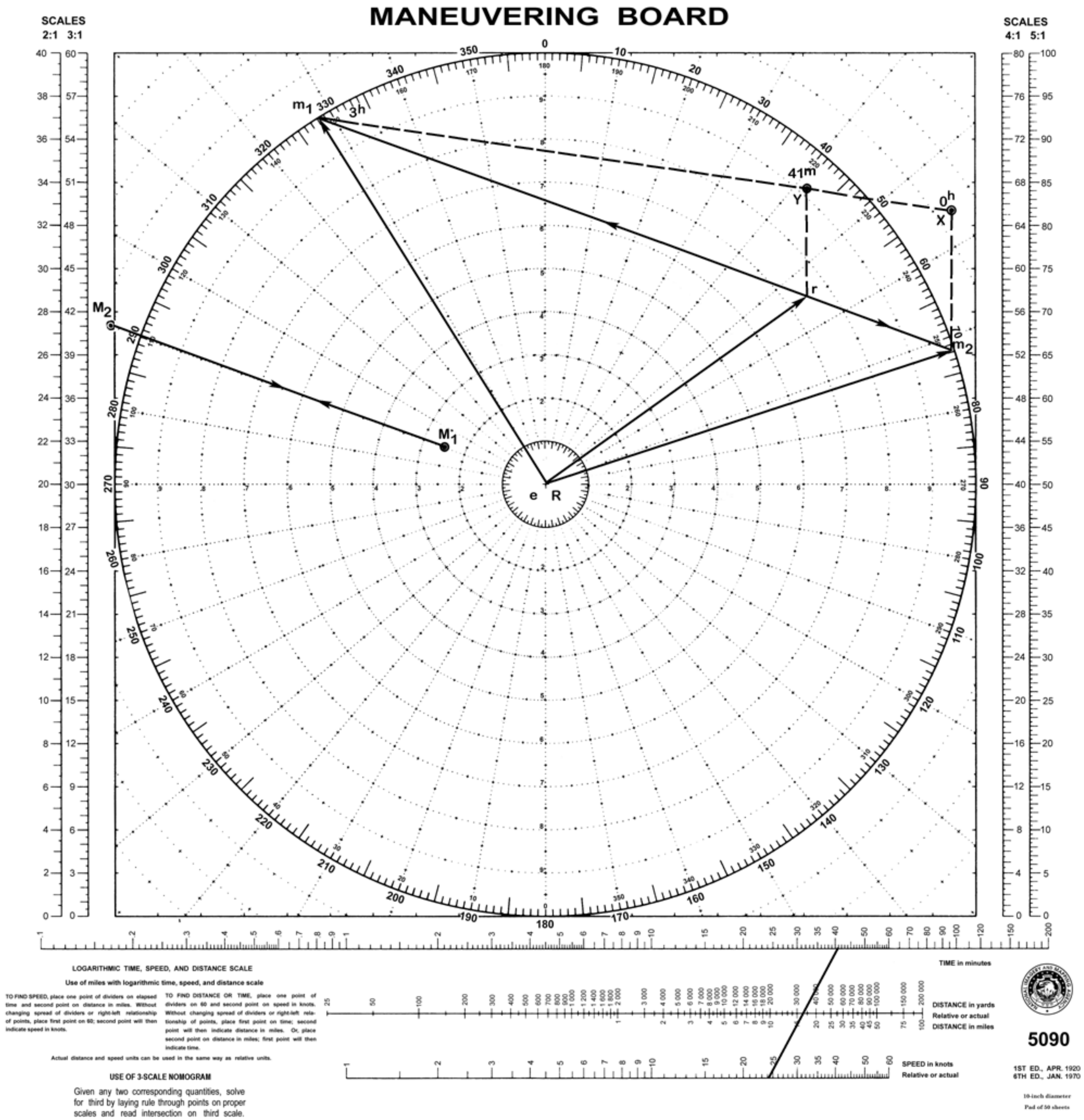
Explanation:

Since own ship *R* returns to present station, relative distances out and in are equal. In going equal distances, time varies inversely as speed:

$$\frac{\text{time (out)}}{\text{time (in)}} = \frac{\text{relative speed (in)}}{\text{relative speed (out)}} = \frac{rm_1\text{(in)}}{rm_2\text{(out)}}$$

Therefore, the time out part of the specified time (3^h) is obtained by simple proportion or graphically.

As defined in the glossary, the time line is the line joining the heads of vectors em_1 and em_2. This line is divided by the head of vector *er* into segments inversely proportional to the times spent by own ship *R* on the first (out) and second (in) legs. In the above example an alternative construction is used so that the line can be drawn to a convenient scale. The proportionality is maintained by constructing similar triangles.



GUIDE AT CENTER

EXAMPLE 46

Scale: Speed 2:1;
Distance 2:1 mi.

EXAMPLE 47

COURSES AND MINIMUM SPEED TO CHANGE STATIONS WITHIN A SPECIFIED TIME, WHILE SCOUTING ENROUTE

Situation:

Own ship *M* bears 130˚, 8 miles from the guide *R* which is on course 040˚, speed 12 knots.

Required:

Proceed to new station bearing 060˚, 10 miles from the guide, passing through a point bearing 085˚, 25 miles from the guide. Complete the maneuver in 4.5 hours using minimum speed.

(1) First and second courses for *M*.

(2) Minimum speed.

(3) Time to turn to second course.

Solution:

(1) Plot M_1, M_2 and M_3 at 130˚, 8 miles; 085˚, 25 miles; and 060˚, 10 miles from *R*, respectively. Draw *er* 040˚, 12 knots. From *r* draw lines of indefinite length parallel to and in the direction of M_1M_2 and M_2M_3. Assume that a **fictitious ship**, *F*, departs M_1 simultaneously with *M* and proceeds directly to M_3 arriving at the same time as *M* which traveled through M_2 enroute. The fictitious ship covers a relative distance of 10.5 miles in 4.5 hours. SRM of the fictitious ship is 2.3 knots. Through *r* draw *rrf*, the relative speed vector, 2.3 knots parallel to and in the direction of M_1M_3. Vector *erf* is the true course and speed vector of the fictitious ship. With *rf* as a pivot, rotate a straight line so that it intersects the two previously drawn lines on the same speed circle. The points of intersection are m_1 and m_2. Vector em_1 is the course out: 049˚. Vector em_2 is the course in: 316˚.9.

(2) Points m_1 and m_2 lie on the 17.2 knot circle which is the minimum speed to complete the maneuver.

(3) From m_2 lay off a 4.5 hour time line using any convenient scale. Draw m_1X. Draw *rf*Y parallel to m_1X. The point Y divides the time line into parts that are inversely proportional to the relative speeds rfm_1 and rfm_2. XY the time “in” is 51 minutes. Ym_2 the time “out” is 3 hours 39 minutes. Time on each leg may also be determined mathematically by the formula MRM/SRM = time.

Answer:

(1) First course 049˚, second 317˚.

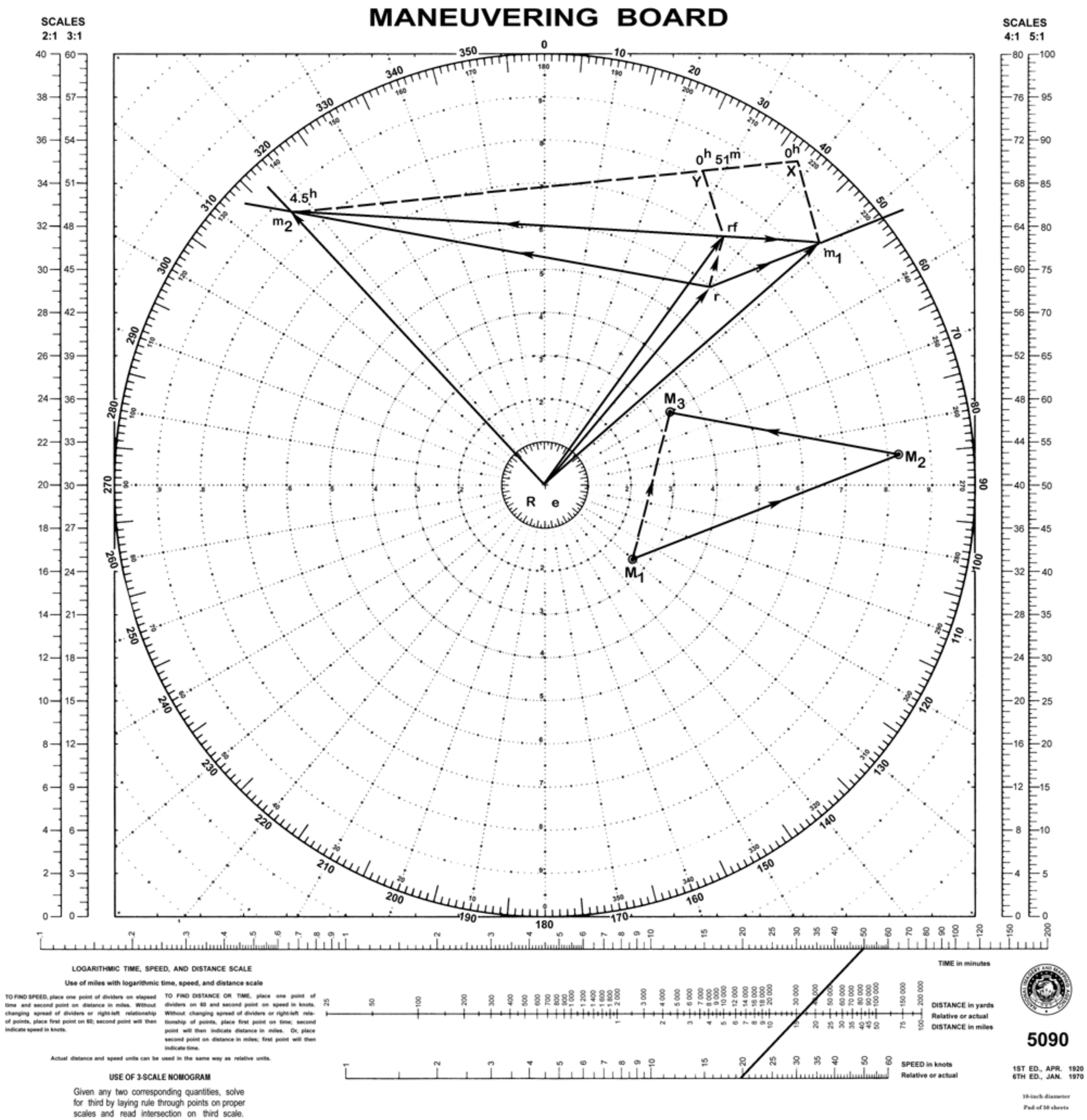
(2) Speed 17.2 knots.

(3) Time 3 hours and 39 minutes.

Note:

The *time line*, as defined in the glossary, is the line joining the heads of vectors em_1 and em_2 and touching the head of the fictitious ship vector *erf*. This time line is divided by the head of the fictitious ship vector into segments inversely proportional to the times spent by the unit on the first and second legs.

In the above example, an alternative construction of the time line is used so that the line can be drawn to a convenient scale. The proportionality is maintained by constructing similar triangles.



GUIDE AT CENTER

EXAMPLE 47

Scale: Speed 2:1;
Distance 3:1 mi.

EXAMPLE 48

LIMITING LINES OF APPROACH

Situation:

A circular formation of ships 4 miles across, with guide *R* the center is proceeding on course 000˚, 15 knots. An enemy torpedo firing submarine is suspected to be in a position some distance ahead of the formation with a maximum speed capability corresponding to modes of operation of:

Submerged (SU) speed:	5 knots
Quiet (Q) speed:	8 knots
Snorkel (SN) speed:	10 knots
Surfaced (S) speed:	12 knots

Note:

The maximum speeds above were chosen for example purposes and should *NOT* be used as real estimates. Consult appropriate intelligence publications on individual submarines for correct speeds.

Required:

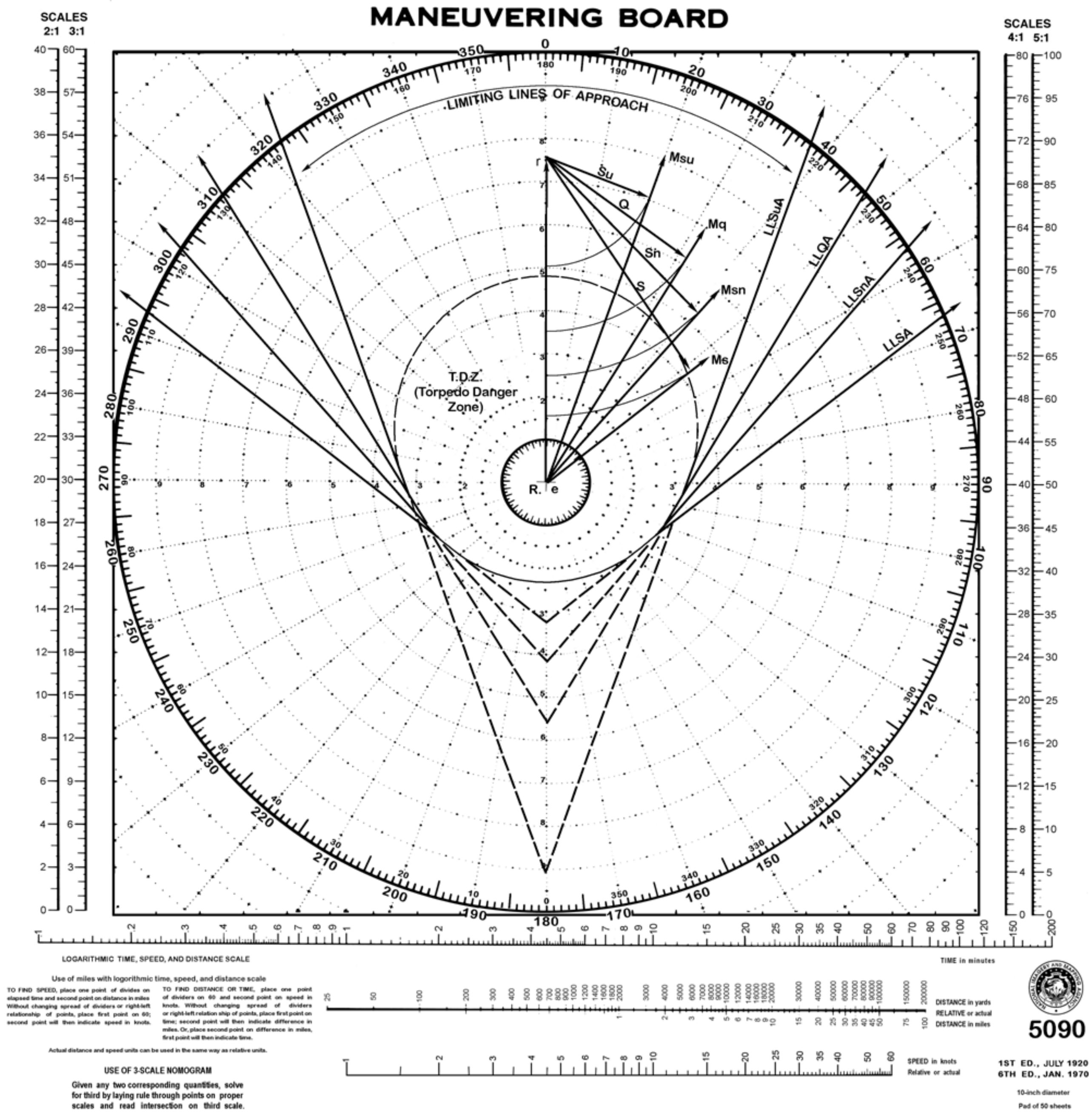
(1) Construct Limiting Lines of Submerged Approach (LLSUA).
(2) Construct Limiting Lines of Quiet Approach (LLQA).
(3) Construct Limiting Lines of Snorkel Approach (LLSNA).
(4) Construct Limiting Lines of Surfaced Approach (LLSA).

Solution:

(1) Plot *R* at the center of the maneuvering board and draw the vector "*er*" 000˚, 15 knots. Construct the TDZ for the assumed effective torpedo firing range (e.g., 5 miles) and torpedo speed (e.g., 30 knots). From "*r*" describe an arc (with radius of 5 knots), the assumed submerged speed. Draw the tangent vector *"emsu"* to the arc and parallel this vector to the TDZ. By extending the parallel vector until it intersects the formation course vector, the other limiting line to the TDZ can be constructed (the area enclosed by the Limiting Lines of Submerged Approach (LLSUA) and the aft perimeter of the TDZ defines the submarine Danger Zone). Solutions (2) through (4) use the similar construction principles as in solution (1) to construct the LLQA, LLSNA and LLSA using their respective assumed speeds.

Note:

This construction assumes the submarine maintains a constant speed throughout the approach.



GUIDE AT CENTER

EXAMPLE 48

Scale: Speed 2:1;
Distance 4:1 mi.

EXAMPLE 49

TORPEDO DANGER ZONE (TDZ)

Situation:

A circular formation of ships 4 miles across, with guide *R* at the center is proceeding on course 000˚, at 15 knots. An enemy torpedo carrying submarine is suspected of being in the area with weapon parameters of:

Maximum effective torpedo firing range:	5 miles
Speed:	30 knots

Required:

Torpedo Danger Zone (TDZ)

Solution:

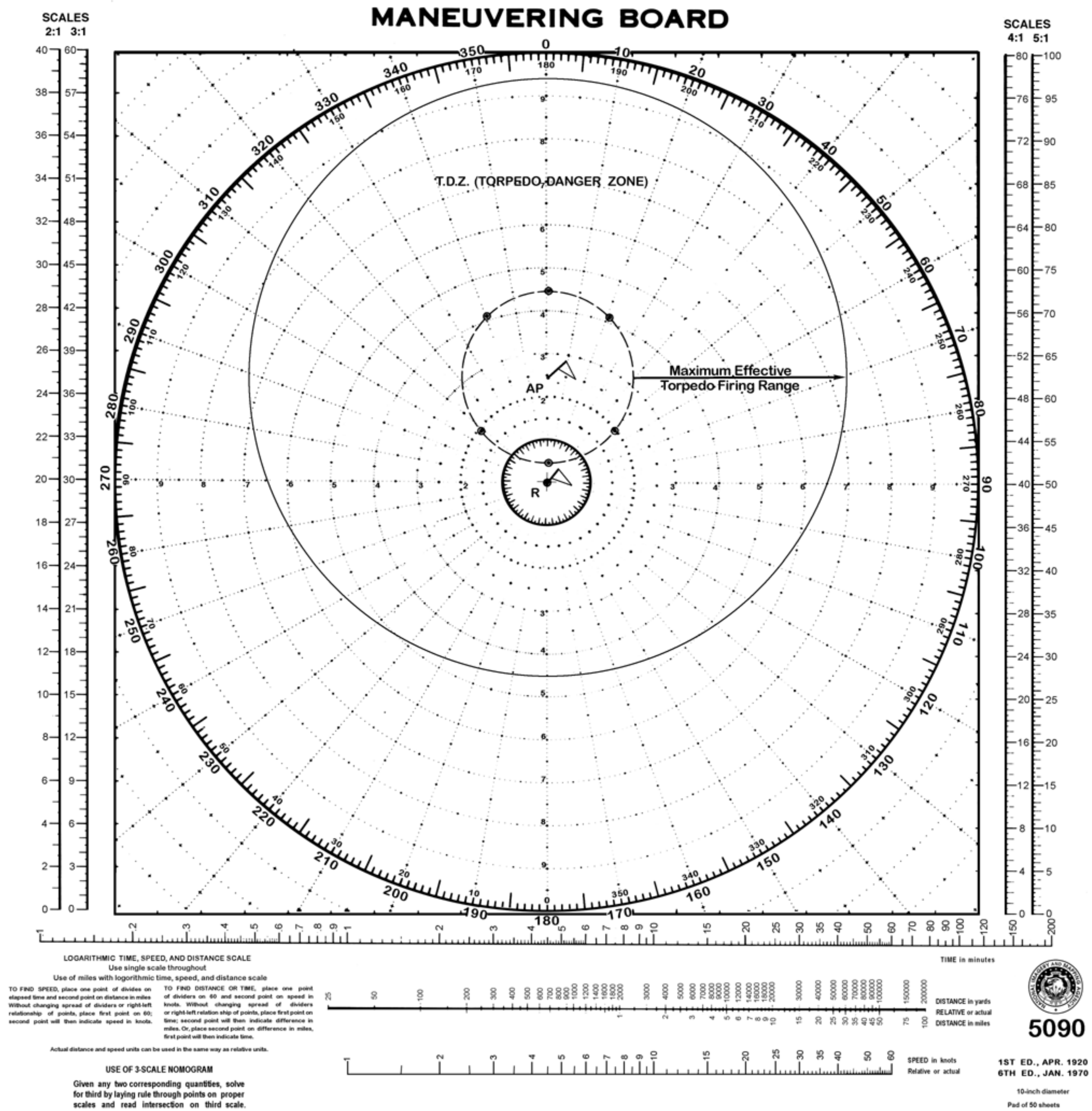
Plot *R* at the center of the maneuvering board. Calculate the formation's advanced position (i.e., *R*'s future position along the formation direction of advance if a torpedo is fired when *R* was located at board center) by:

$$\text{Advanced Position} = \frac{\begin{array}{c}\text{Maximum Effective Torpedo}\\ \text{Firing Range} \times \text{Formation Speed}\end{array}}{\text{Torpedo Speed}}$$

Label this position AP and plot the formation around AP. Construct the TDZ outer boundary by plotting points at a distance equal to the maximum effective torpedo firing range (e.g., 5 miles) from the perimeter of the formation. The area enclosed is the TDZ relative to the formation in its original position around *R*.

Note:

The torpedo range and speed were chosen for example purposes only and should not be used as real estimates. Consult appropriate intelligence publications on individual submarine torpedoes for correct ranges and speeds.



GUIDE AT CENTER

EXAMPLE 49

Scale: Speed 3:1;
Distance 2:1 mi.

EXAMPLE 50

MISSILE DANGER ZONE (MDZ)

Situation:

A circular formation of ships 4 miles across with guide *R* at the center is proceeding on course 000˚ at 15 knots. An enemy missile carrying submarine is suspected of being in the area with weapon parameters of:

Maximum effective missile firing range:	20 miles
Speed:	600 mph

Required:

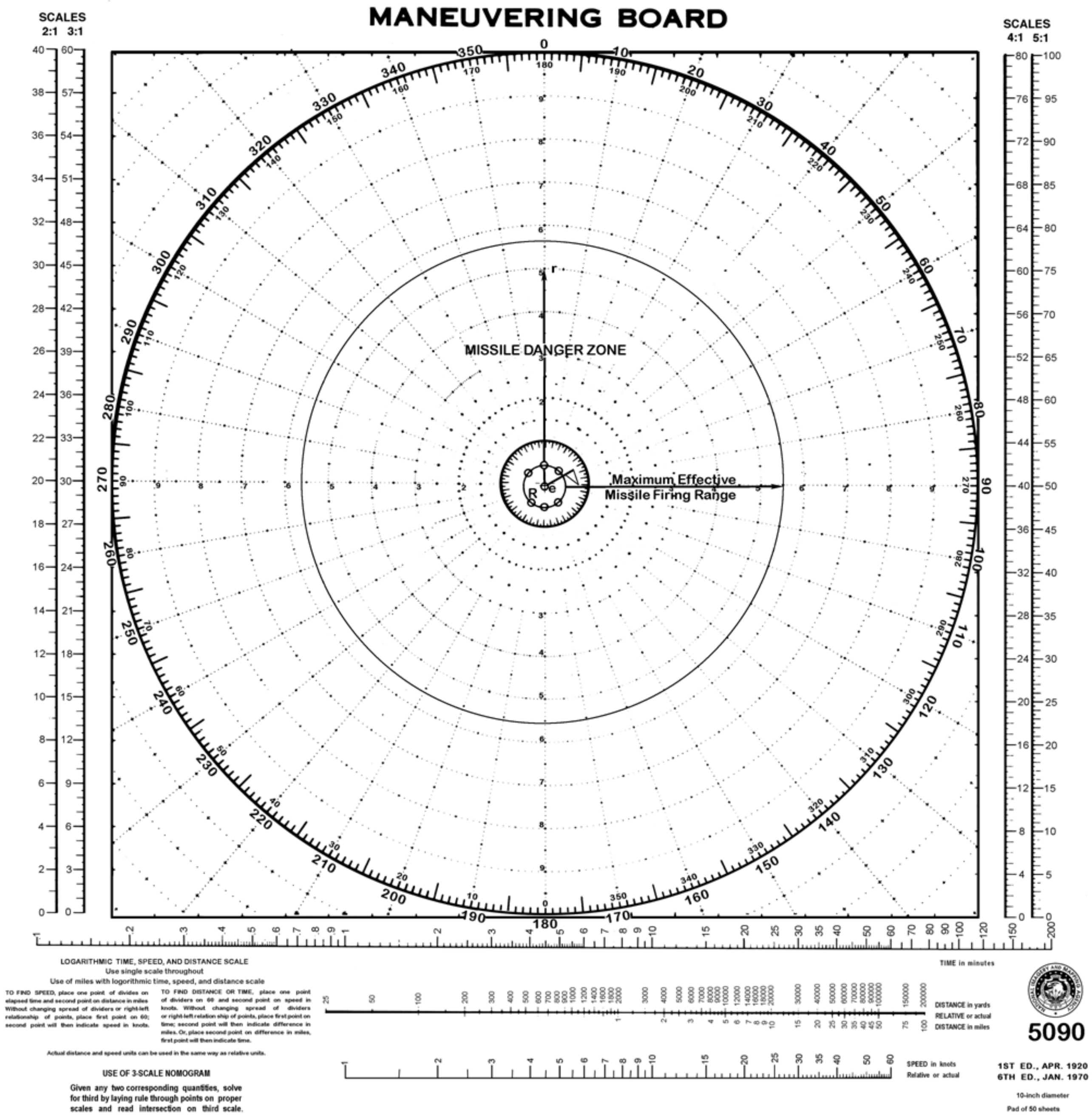
Missile Danger Zone (MDZ)

Solution:

Plot *R* at the center of the maneuvering board. Since the enemy's missile travels at 40 times the formation's speed, the formation will not appreciably advance during the missile's time of flight. The missile's maximum effective firing range (20 miles) is added to the perimeter of the formation and plotted around the formation. The area enclosed is the MDZ.

Note:

The missile range and speed were chosen for example purposes only and should not be used as real estimates. Consult appropriate intelligence publications on individual submarine missiles for correct ranges and speeds.



GUIDE AT CENTER

EXAMPLE 50

Scale: Speed 3:1;
Distance 8:1 mi.

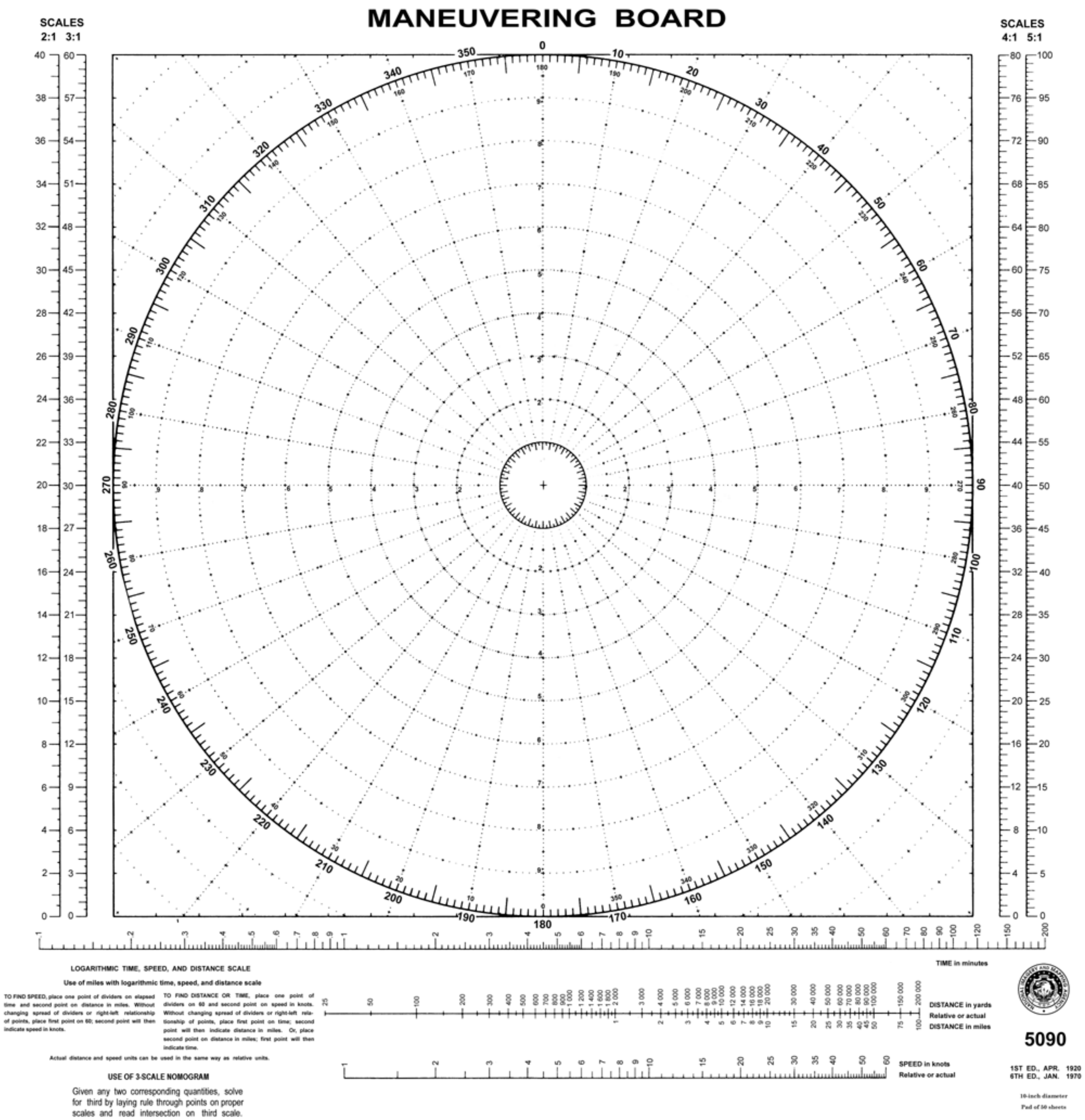
Space is provided for user's insertion of example according to his needs

Situation:

Solution:

Required:

Answers:



Scale: Speed :1;
Distance :1 thousands of yds.

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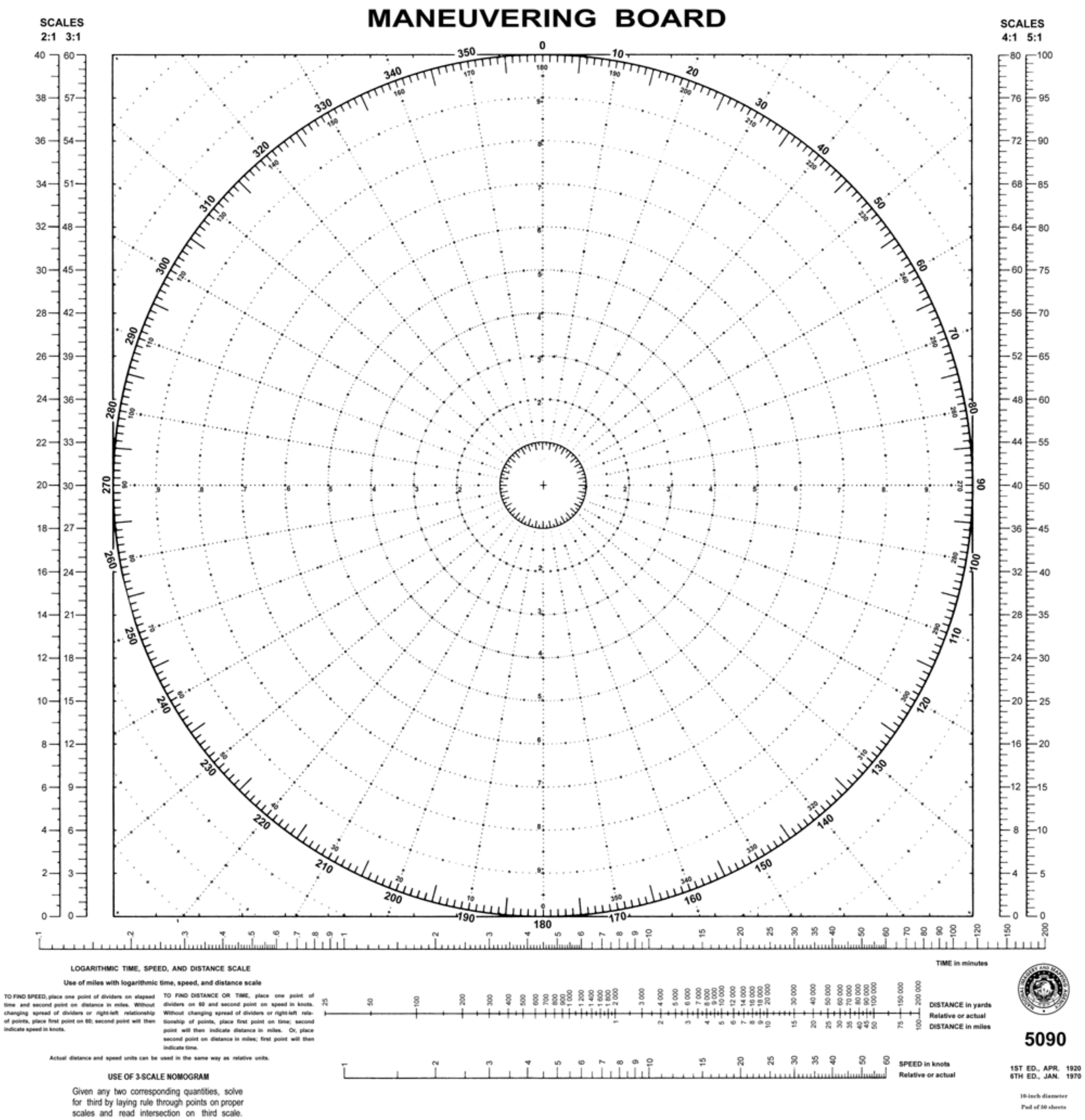
Situation:

Solution:

Required:

Answers:



Scale: Speed :1;
Distance :1 thousands of yds.

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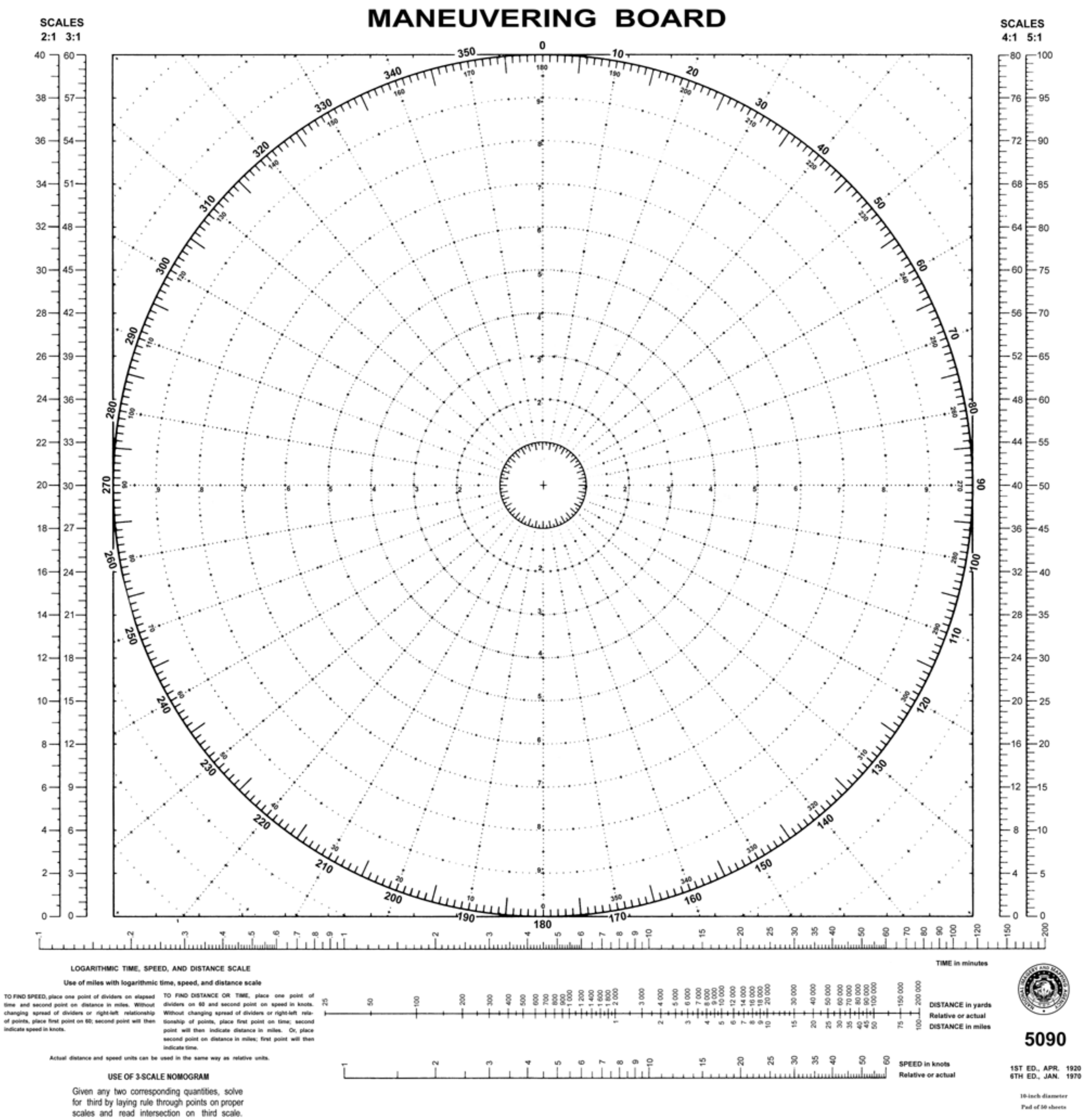
Situation:

Solution:

Required:

Answers:



Scale: Speed   :1;
Distance   :1 thousands of yds.

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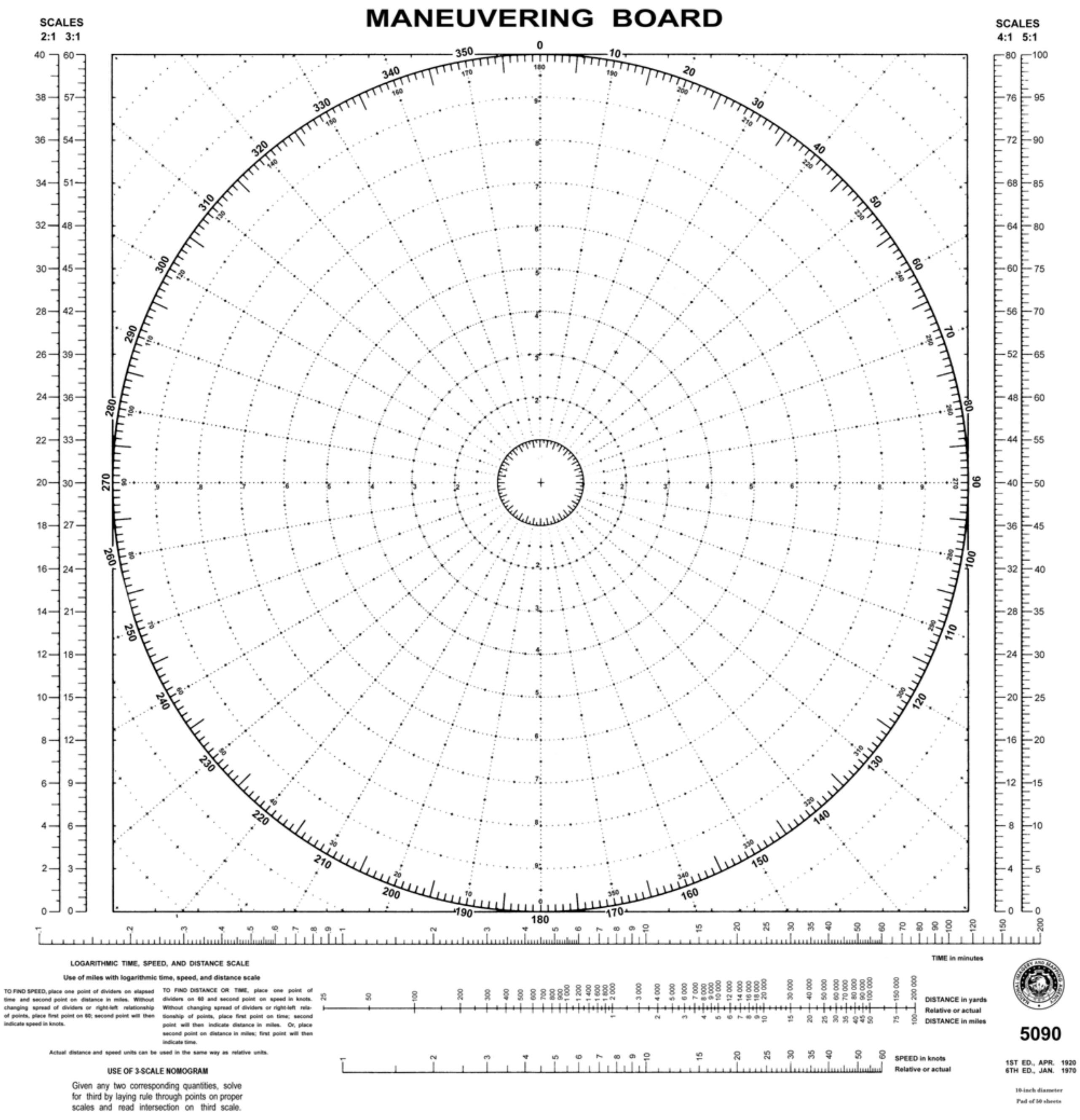
Situation:

Solution:

Required:

Answers:



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Distance :1 thousands of yds.

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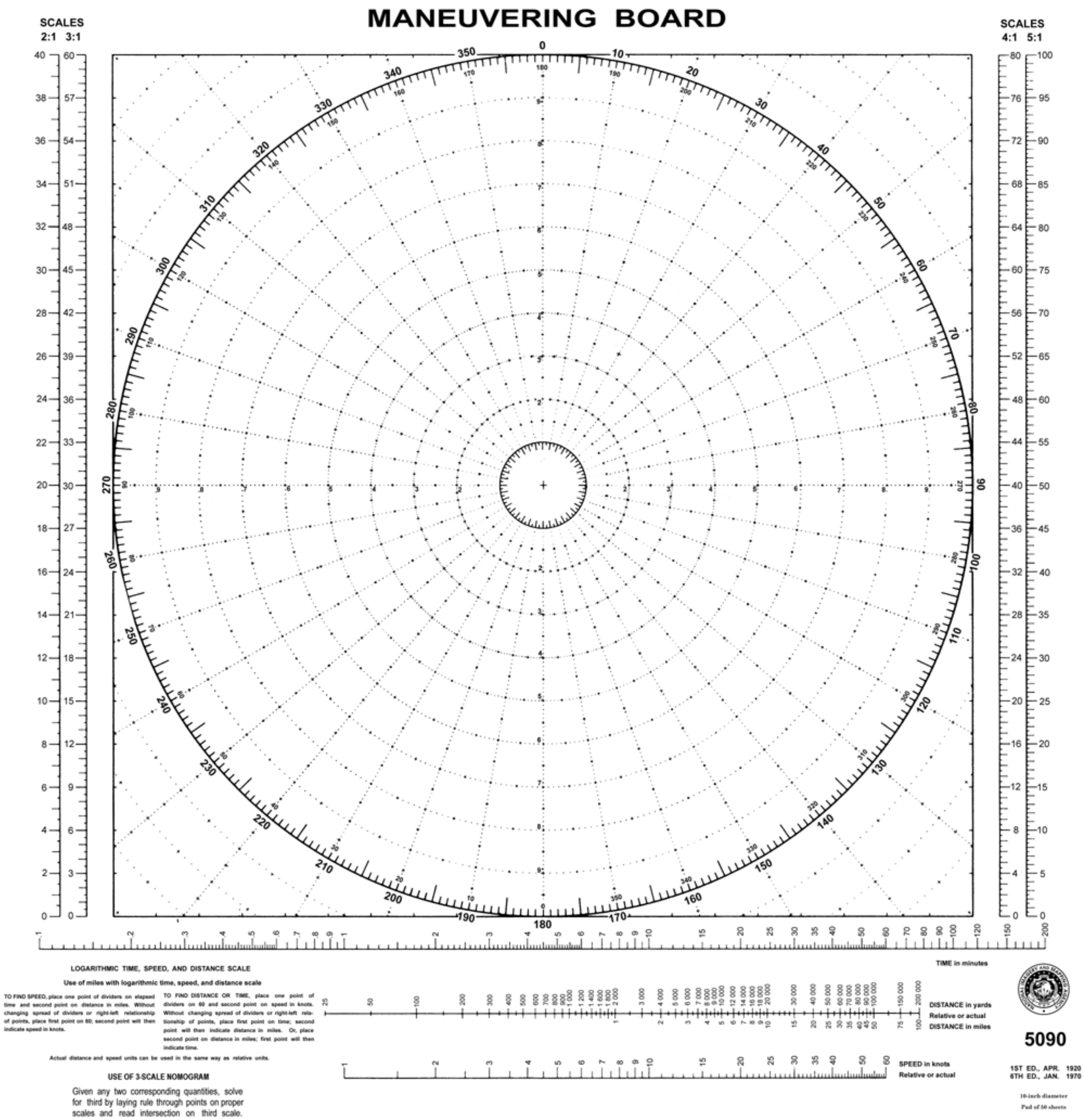
Situation:

Solution:

Required:

Answers:



Scale: Speed :1;
Distance :1 thousands of yds.

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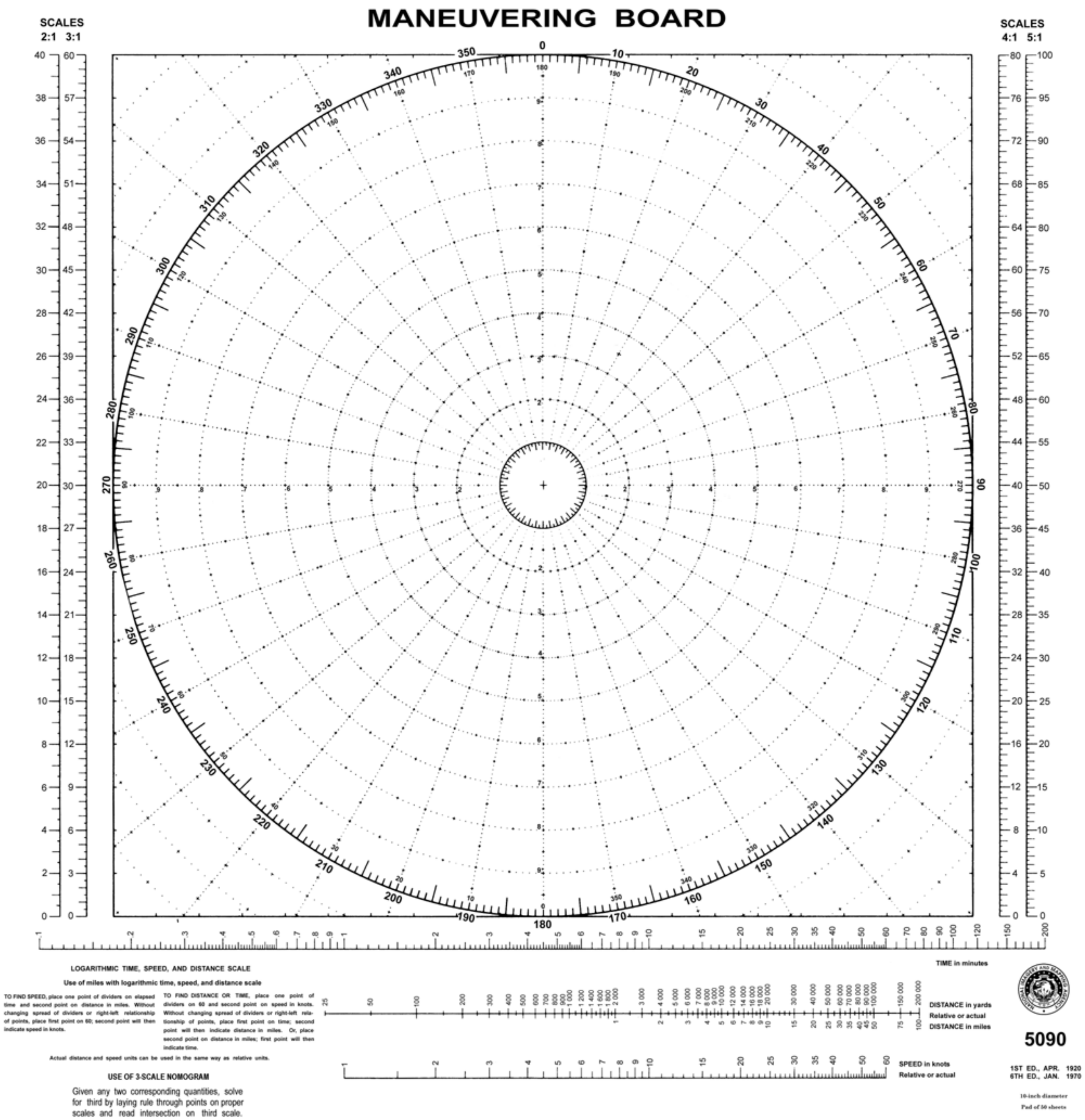
Situation:

Solution:

Required:

Answers:



Scale: Speed   :1;
Distance   :1 thousands of yds.