RADAR PLOTTING

Ranger Hope © 2008

THE BASIC PLOT

CHANGED COURSE OR SPEED

Introduction

International Regulations for Preventing Collision at Sea

Rule 5 (Lookout) *"Every vessel shall at all times maintain a proper look-out by sight as well as by hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision".*

The rules require a vessel fitted with radar to make use of its detection capability for a full appraise by monitoring and radar plotting, especially in restricted visibility.

The bright image of vessels and coast that radar “paints” on its PPI (the radar screen) is valued by mariners at night, foul weather and in restricted visibility. Its use is a requirement of Rule 5, (Lookout). However, there are potential dangers for the unwary in interpreting the convincing map like image on the radar screen.

- The image you “see” on the radar screen is derived from radio wave echoes. A poorly tuned radar may detect only some of the picture or none at all. You could falsely assume nothing is there.

- On a small ship’s *unstabilised relative motion display* radar, the “movie you see” depicts your vessel as stationary and the coast streaming by, at your speed and in the opposite direction to your course. Similarly the targets painted are the resultant of their course and speed and your’s.

To judge if you will pass at a safe distance or collide with a target cannot be based on casual viewing, but requires the observation of change over a period of time (an interval) to extract the real motion from the relative. A larger vessel’s equipment, with automatic plotting aids (ARPA) can analyse developing collision risks, but smaller vessels must correctly interpret the display by:

- use of the *electronic bearing cursor* (EBL) to identify priority targets.

- systematic *plotting* of those priority targets until the danger is clear.

Use of the EBL to identify priority targets

In narrow seas there can be many vessels and consequently many targets painted on the screen, perhaps too many for a small vessel operator to plot.

The radar’s EBL facility allows a bearing line to be generated on a screen that can be pointed at any target displayed. By marking the targets with a pen, (either on the screen or on a transparent overlay) and comparing their positions after an interval of time, a prediction can be made of how they will continue to move.

The targets that cling to the EBL line (their relative angle remaining constant) indicate high risks of collision, always assuming that the course and speed of your own vessel and that of another vessel remain constant.

At 12:00 your own vessel steering 000º, (at the centre), detects targets 1, 2, 3 and 4 as dots. Each is marked on the screen and over the next 15 minutes the EBL cursor is used to monitor the targets' apparent movement.

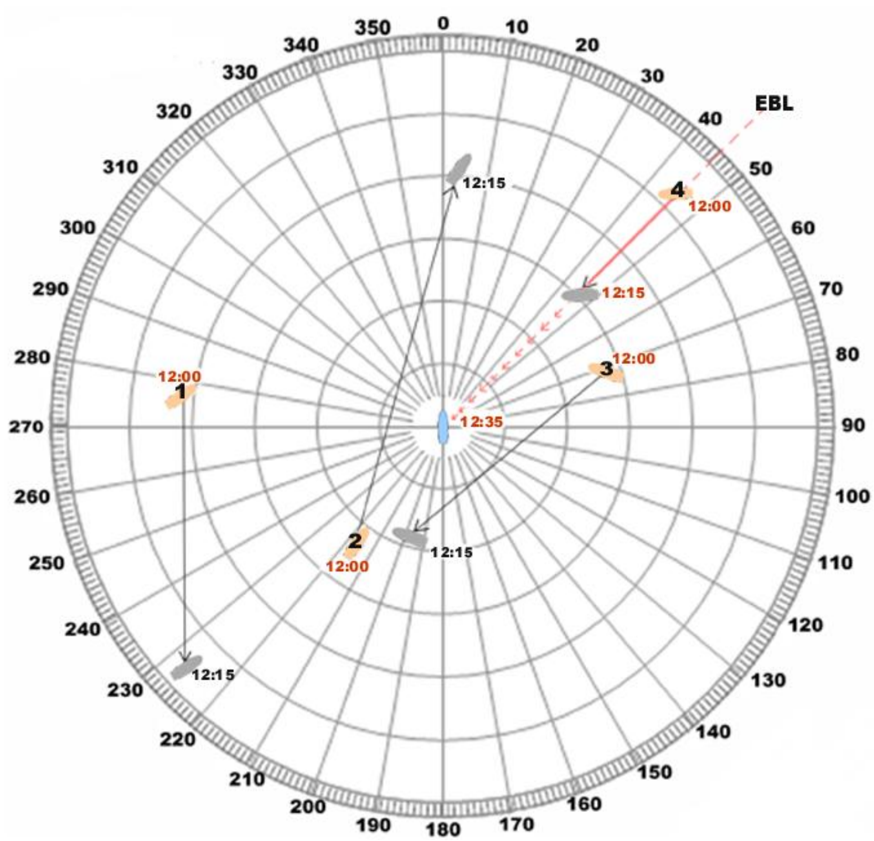
At 12:15:
Anchored target 1 has diverged from the EBL and is painted as moving in the opposite direction to your own vessels course. Its bearing draws aft from your course line (passes astern). Its range increases.

Overtaking target 2 diverges from the EBL and is painted moving faster than your vessel, to pass ahead. Its bearing draws forward. Its range increases.

Crossing target 3 diverges from the EBL and is painted moving slower than your vessel and passes astern. Its bearing draws aft. Its range decreases.

Crossing target 4 bearing is steady on the EBL, range decreased. Collision will occur without avoidance action. If the distance between 12:00 and 12:15 position is compared with the distance between 12:15 and the screen centre we can predict that collision will occur after 1.3 x the interval.

1.3 x 15' = 20' + 12:15 = 12:35



Proper use of radar

International Regulations for Preventing Collision at Sea specify radar usage:

Rules 6 (Safe Speed *extract*), *"every vessel shall at all times proceed at a safe speed so that she can take proper and effective action to avoid collision."*

Rule 7 (Risk of Collision *extract*) warns that *"assumptions shall not be made on the basis of…scanty radar information"*

Rule 19 (Restricted Visibility *extract*) requires that *"a vessel which detects by radar alone the presence of another vessel shall determine if a close-quarters situation is developing and/or risk of collision exists…she shall take avoiding action in ample time".*

While our EBL watch alerts us to a close-quarters situation or risk of collision it could provide insufficient detail to determine effective avoiding action. It is *scanty* information and we must use the process of a Radar Plotting in *ample time*.

Plotting terms and abbreviations

The application of simple geometry on a plotting sheet, a paper record of the radar display (PPI) over an interval of time, will enable you to determine the collision risk and safe action. The standard abbreviations drawn on a plotting sheet are:

C The centre of a radar plotting sheet.

O The position of an initial detection of a target on the PPI.

A The position of a subsequent detection after a timed interval.

P A point on extension of line OA passing closest & perpendicular to C.

CPA The predicted closest point of approach of the paint.

TCPA The predicted time of the closest point of approach.

WO Way of Own-a vector line representing your course and speed.

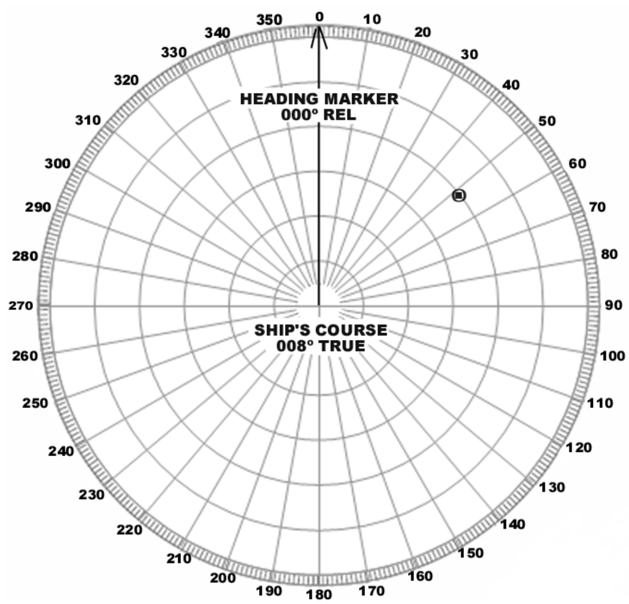
WA Way of Another-a vector line representing target's course and speed.

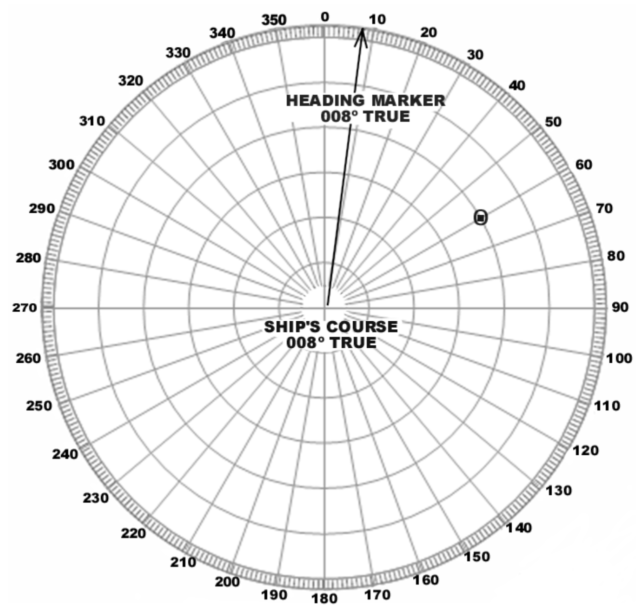
The radar display

There are two basic display systems, one with the heading marker fixed and pointing to the top of the screen (Ship's Head Up) and one with the heading marker moving with the vessel's course to align with the numbers marked on the display's bearing scale (North Head Up).

In both examples below our ship is on a course of course of 008ºT.

SHU Ship's Head Up	NHU North Head Up





A target is painted on the display bearing 052º Relative to the heading marker.
The bearing scale is degrees relative.

Target paint slews as the vessel yaws, creating bearing inaccuracy.

The same target is painted on the display bearing 060º True.

The bearing scale is degrees true.

The heading marker moves with vessel yaw, greater bearing inaccuracy.

The principles are the same for both radar displays. Relative target bearings should always be converted to true as the risk of collision is indicated by steady *compass* bearing and decreasing range. The following pages show examples.

The NHU plot, step by step.

Our aim is to find:

- the closest point of approach of the target (CPA) and its time (TCPA).
- the course and speed of another vessel (WA).
- the aspect (the vessel's lights/profile from our view) and avoidance action.

Our Own vessel is on a course of 008ºT at a speed of 15 kts.

Step 1: *Observation of the target over an interval of time.*

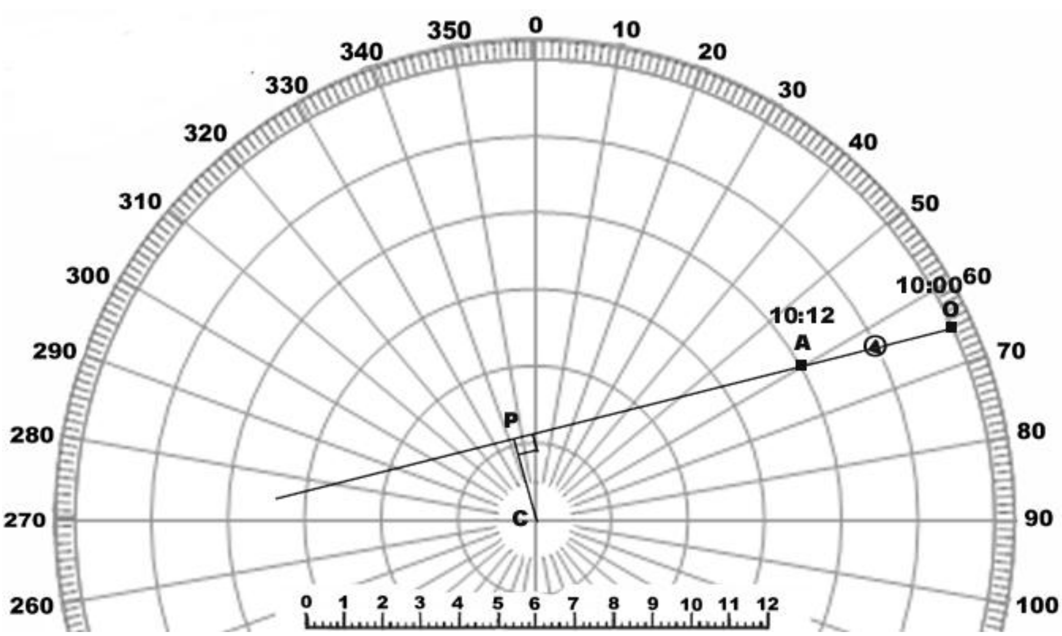
Using fractions of an hour will simplify later calculations, i.e. 3 mins, 6 mins, 12 mins, 15 mins, 20mins 30 mins.

1st report- at 10:00 target bearing 065ºT distance 12 nm

report- at 10:06 target bearing 063ºT, drawing forward, range decreasing.

Step 2: *Gathering the information required to find the CPA.*

report at 10:12 target bearing 060ºT, drawing fwd, range 8 nm decreasing.



The positions O and A are found from the first and final reports. A line is drawn from O through A to pass C. The line CP is drawn by dropping a perpendicular from the OA extension to C. **The length of CP (in this case 2.2nm) is the CPA**.

Step 3: ***Calculating the TCPA.***

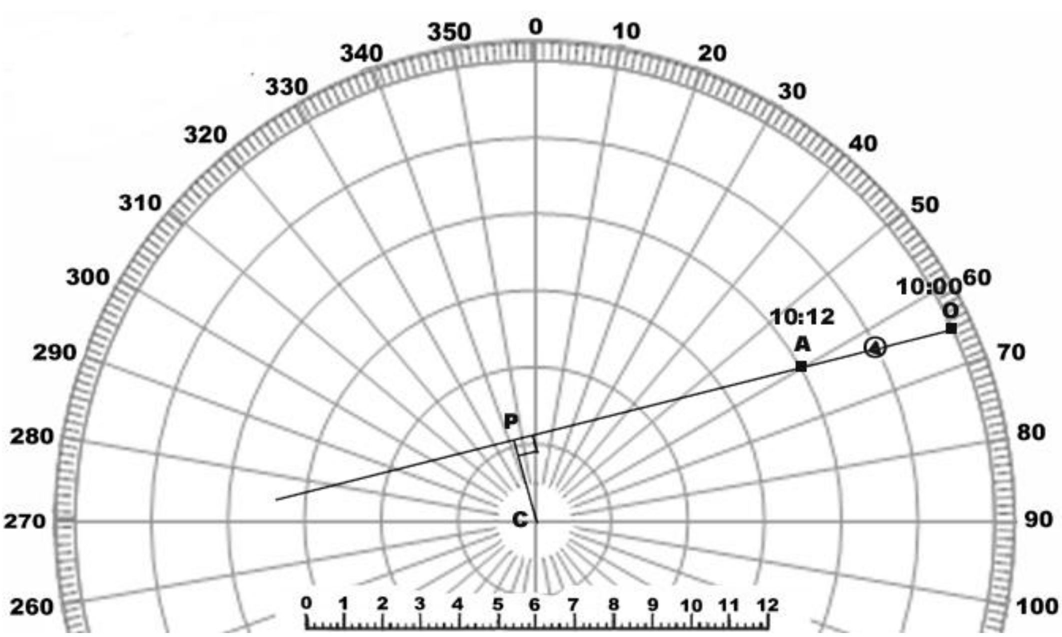
The line OA represents the relative movement of the target over 12 minutes (1/5 of an hour) and the extension AP is a prediction of its continuing movement (if both vessels courses and speed remain constant). A glance will tell you that if line OA represents 12 minutes and line AP is twice as long, then it represents roughly 24 minutes. However, this is “scant information” and a more elegant solution can be found in the formula:

Length AP / Length OA	**x**	**time of O to A**	**=**	**time of A to P**	**+**	**time at A**	**=**	**TCPA**

By measuring the length of the lines and using an interval of 12’

7.6nm / 4nm	**x**	**12’**				*(12’÷ 60 = 0.2 hrs)*		
1.9	**x**	**0.2 hrs**	**=**	**0.38 hrs**		*(0.38 x 60 =22.8’)*		
				22.8’	**+**	**10:12**	**=**	**10:34.8’**

Our TCPA is 10:34.8’



Step 4: *Resolving the plotting triangle.*

The OA is the resultant of the two vectors (components of the plotting triangle):

- WO our own movement over the interval and,
- WA another's movement over the interval. From our passage plan we know our course and speed.

So if we can remove our vector then that of another vessel will be revealed.

We can calculate that in *12'÷ 60 = 0.2 hrs* 2' we must have travelled:

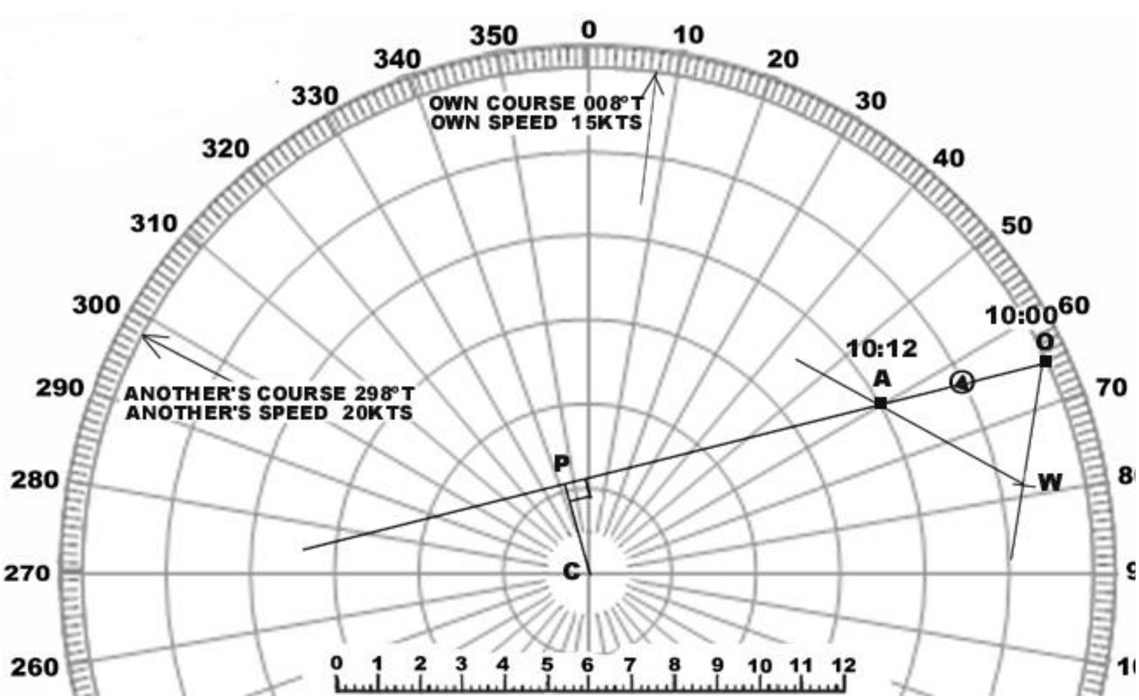
0.2 hrs x 15 kts = 3nm.

If we mark a position at a distance of 3 nm in the ***opposite*** direction to our course of 008ºT and call it W then we can create the vector WO, way of own. Effectively we have removed our vector from the line OA. If our vector is removed then that of the other vessel is revealed, the line WA, way of another.

Step 4: *Finding the course of another vessel.*

Note: as own course is from W towards O, so another's is from W towards A.

By transferring line WA to C we can read off the target vessel's course as 298ºT



Step 5: *Finding the speed of another vessel.*

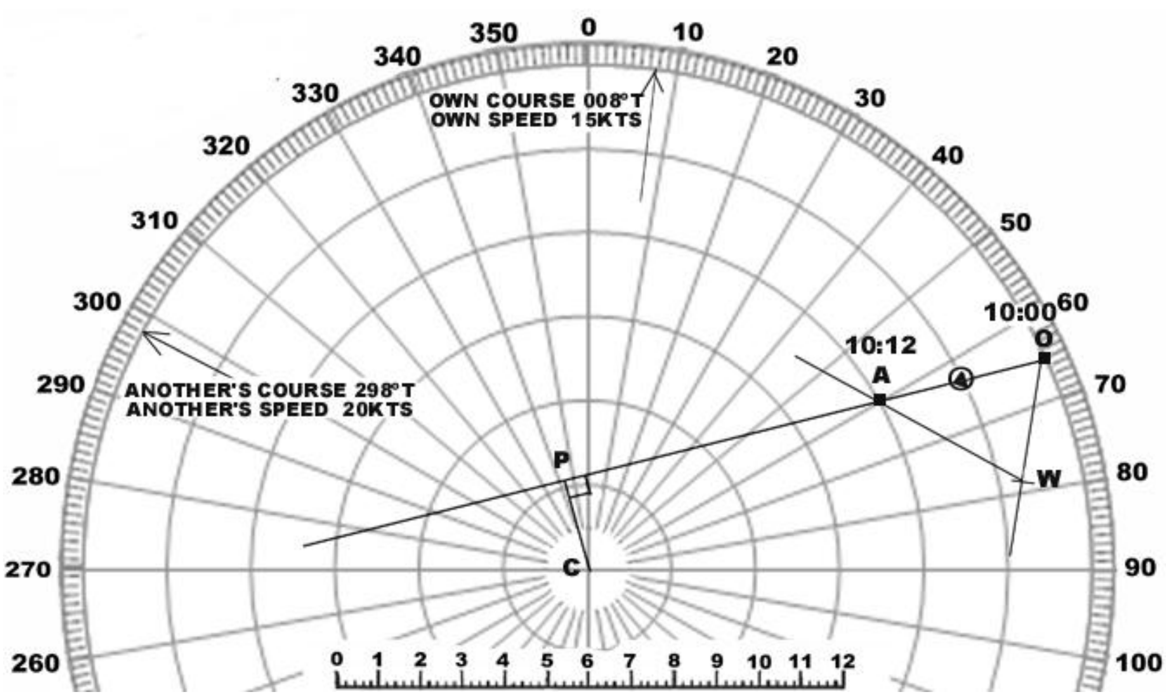
The distance that the target covered in the interval is shown by the length of the line WA. In this example we can measure this as 4 nm. Therefore, as it travelled 4 nm in 12' (0.2 hrs) then in 1 hr it would travel:

$$\frac{1}{0.2} \quad x \quad 4 \quad = \quad 20 \text{ kts}$$

Here it can be seen how selection of time interval can simplify later calculations

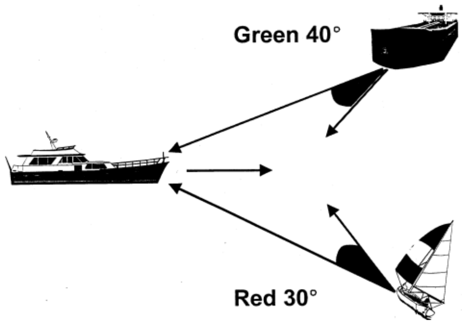
3 mins	6 mins	12 mins	15 mins	20mins	30 mins
1/20th hour	1/10th hour	1/5th hour	1/4th hour	1/3th hour	1/2th hour
0.05 hour	0.1 hour	0.2 hour	0.25 hour	0.33 hour	0.5 hour

In our example it travelled 4 nm in 1/5th hour, so WA = 5 x 4 = 20 kts



Step 6: **Finding the aspect of another vessel.**

Aspect is the relative bearing of your own vessel taken from the target vessel's fore and aft line. It is expressed red or green. Aspects derived from plots are approximate, but tell you roughly the target's profile from your viewpoint and what navigation lights you should look for at the time of the final report.



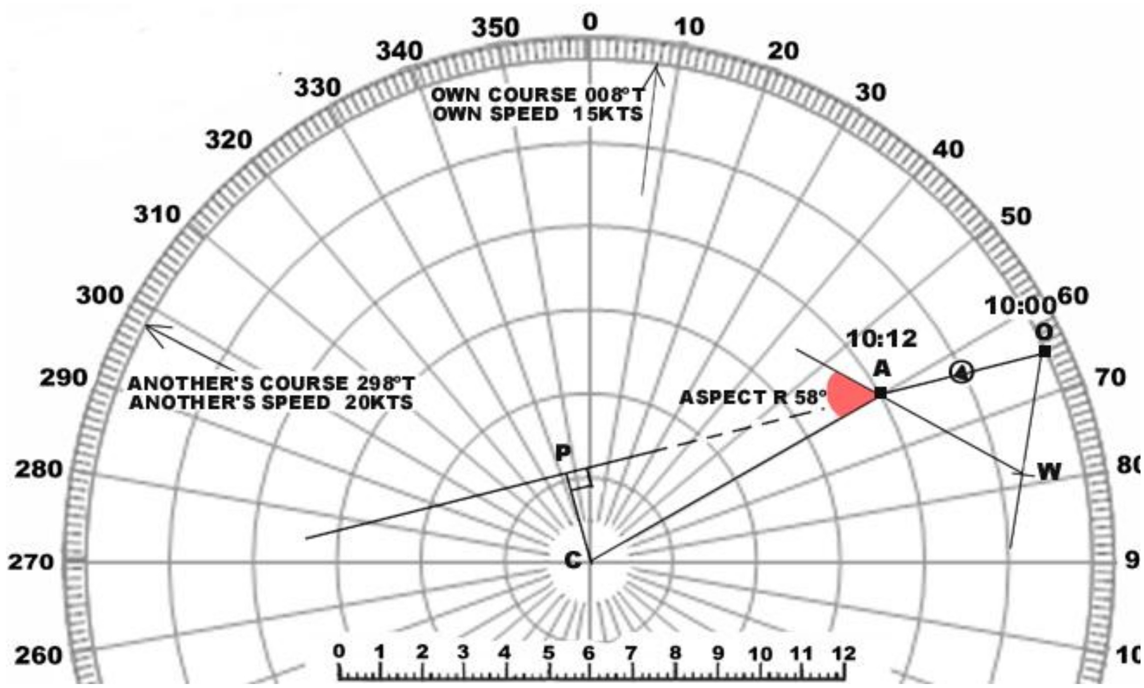
Note the use of bearing abbreviations

Relative	***040ºRel***	***330ºRel***
Aspect	***G 40º***	***R 30º***

Illustration courtesy of ANTA Publications

Aspect can be determined geometrically or mathematically

Geometrically:
A line from C to A is drawn; the angle between CA and the extension of WA is the aspect. This is easiest to measure by extending the line AC to cross the bearing scale on its far side, in this case at 240***º*** and counting the degrees up to WA's marked course line at 298ºT. Aspect in this case is R 58***º***.



Mathematically:
Aspect found by the reciprocal of the target's last bearing (its bearing of us, A to C) and the targets true course (WA).

Reciprocal of last bearing = 060° + 180° = 240°T.
Target's course = 298°T.
Lesser angle between the two = 298° - 240° = 058°.

The plot shows that we are on the port side of the target vessel so the target's **aspect is R 58°.**

While the vessels are not in sight of each other, to know aspect is not vital, but when the other vessel becomes visible, then the rules for vessels in sight of each other apply and suitable action will need to be taken depending on it being a head on vessel, a crossing vessel or an overtaking vessel.

Step 6: *The full report.*

The full report is the information found from the basic plot:

- the time of the last observation.
- the target's last bearing and how the bearing is changing (drawing forward/aft, steady).
- the target's last range and how the range is changing.
- the CPA and TCPA.
- the target's true course and speed.
- the aspect of the target.

Our full report at 10:12 would be as follows:

- **Time 10:12.**
- **Target bearing 060°T drawing forward.**
- **Target range 8.0 miles and closing.**
- **CPA 2.2 miles in 23 mins at 10:35.**
- **Target's course 298°T.**
- **Target's speed 20 knots.**
- **Aspect R58°.**
- **Action to avoid collision,** **go to Step 7.**

The SHU plot, step by step.

Our aim is to find:

- the closest point of approach of the target (CPA) and its time (TCPA).
- the course and speed of another vessel (WA).
- the aspect (the vessel's lights/profile from our view) and avoidance action.

Our Own vessel is on a course of 008ºT at a speed of 15 kts.

Step 1: *Observation of the target over an interval of time.*

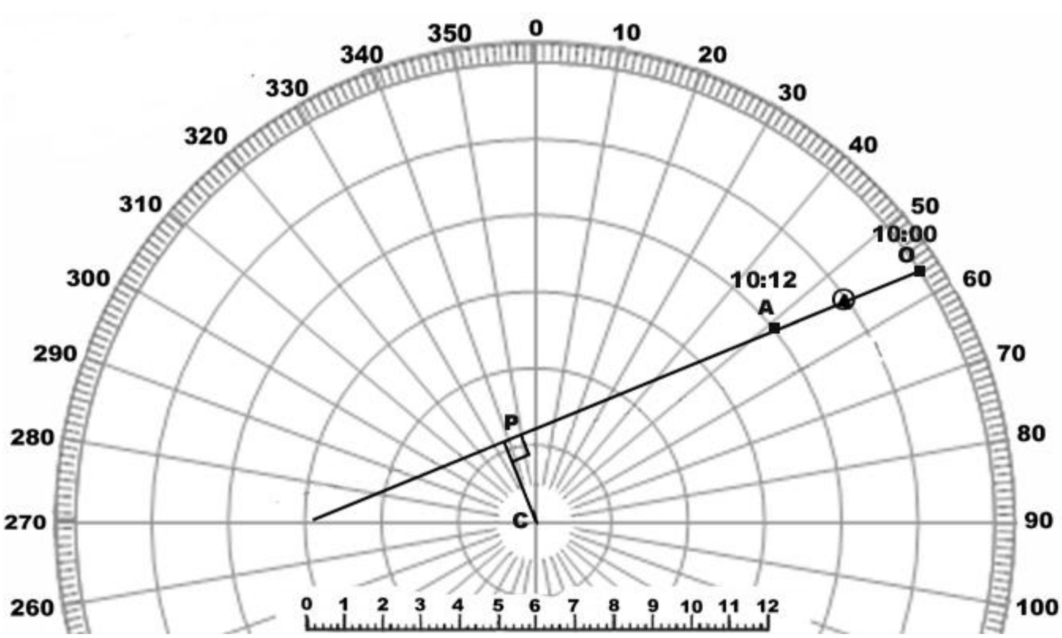
Using fractions of an hour will simplify later calculations, i.e. 3 mins, 6 mins, 12 mins, 15 mins, 20mins 30 mins.

1st report-   at 10:00 target bearing 057ºRel distance 12 nm

report- at 10:06 target bearing 055ºRel, drawing forward, range decreasing.

Step 2: *Gathering the information required to find the CPA.*

report at 10:12 target bearing 052ºRel, drawing fwd, range 8 nm decreasing.



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Step 3: ***Calculating the TCPA.***

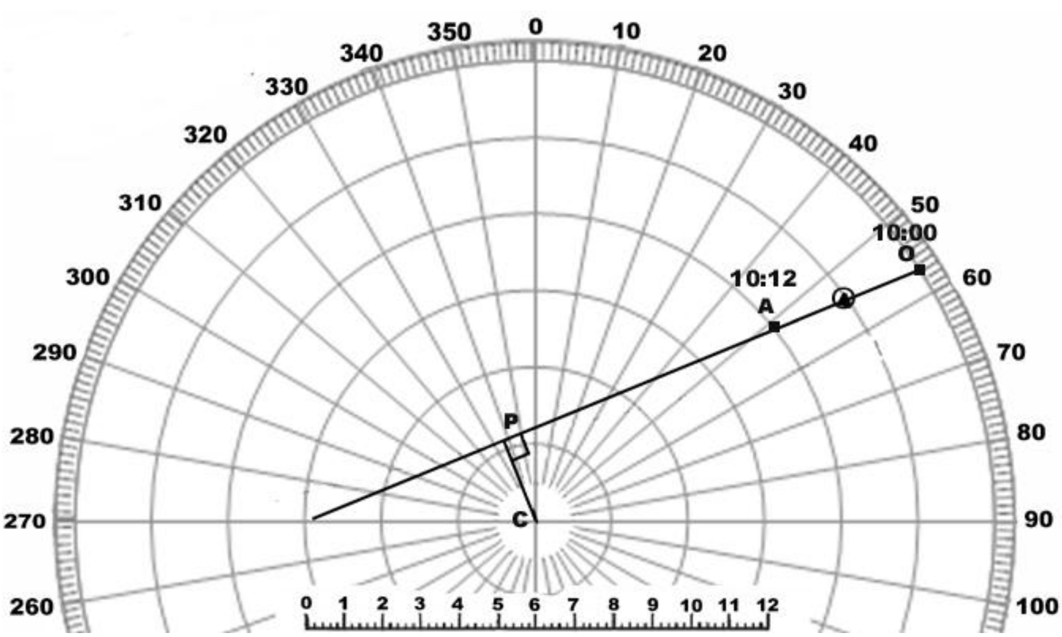
The line OA represents the relative movement of the target over 12 minutes (1/5 of an hour) and the extension AP is a prediction of its continuing movement (if both vessels courses and speed remain constant). A glance will tell you that if line OA represents 12 minutes and line AP is twice as long, then it represents roughly 24 minutes. However, this is "scant information" and a more elegant solution can be found in the formula:

Length AP / Length OA	**x**	**time of O to A**	**=**	**time of A to P**	**+**	**time at A**	**=**	**TCPA**

By measuring the length of the lines and using an interval of 12'

7.6nm / 4nm	**x**	**12'**				*(12'÷ 60 = 0.2 hrs)*		
1.9	**x**	**0.2 hrs**	**=**	**0.38 hrs**		*(0.38 x 60 =22.8')*		
				22.8'	**+**	**10:12**	**=**	**10:34.8'**

Our TCPA is 10:34.8'



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- WA another's movement over the interval. From our passage plan we know our course and speed.

So if we can remove our vector then that of another vessel will be revealed.

We can calculate that in *12'÷ 60 = 0.2 hrs* 2' we must have travelled:

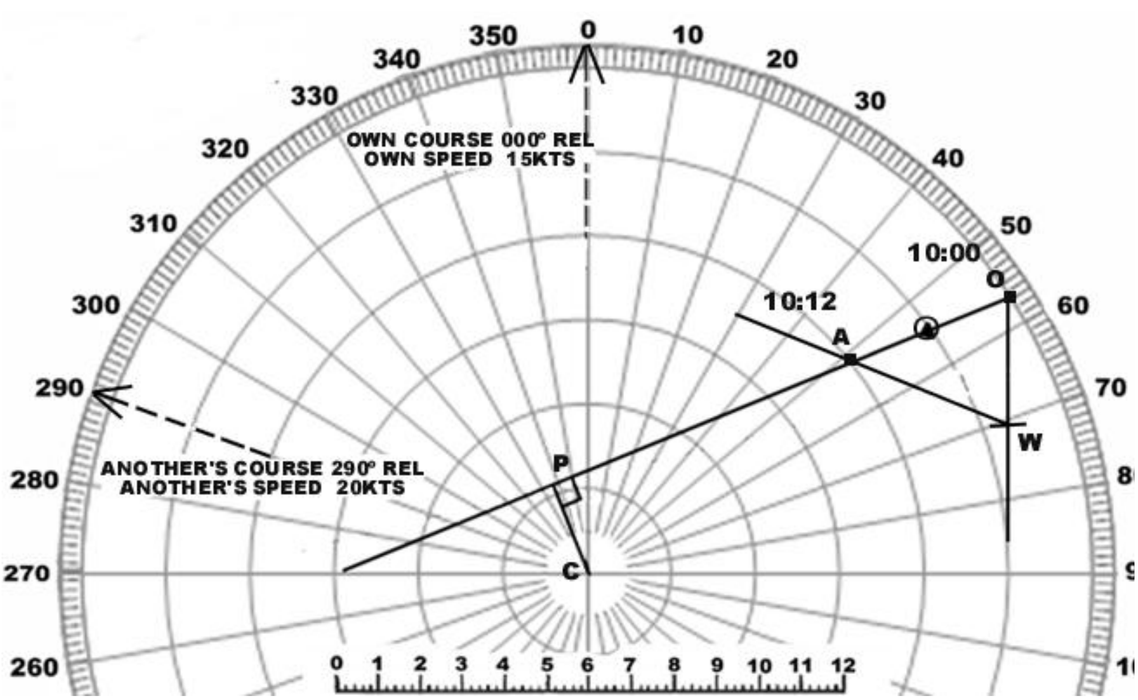
0.2 hrs x 15 kts = 3nm.

If we mark a position at a distance of 3 nm in the ***opposite*** direction to our course of 000ºRel and call it W then we can create the vector WO, way of own. Effectively we have removed our vector from the line OA. If our vector is removed then that of the other vessel is revealed, the line WA, way of another.

Step 4: ***Finding the course of another vessel.***

Note: as own course is from W towards O, so another's is from W towards A.

By transferring line WA to C we read off the target vessel's course as 290º Rel.



Step 5: ***Finding the speed of another vessel.***

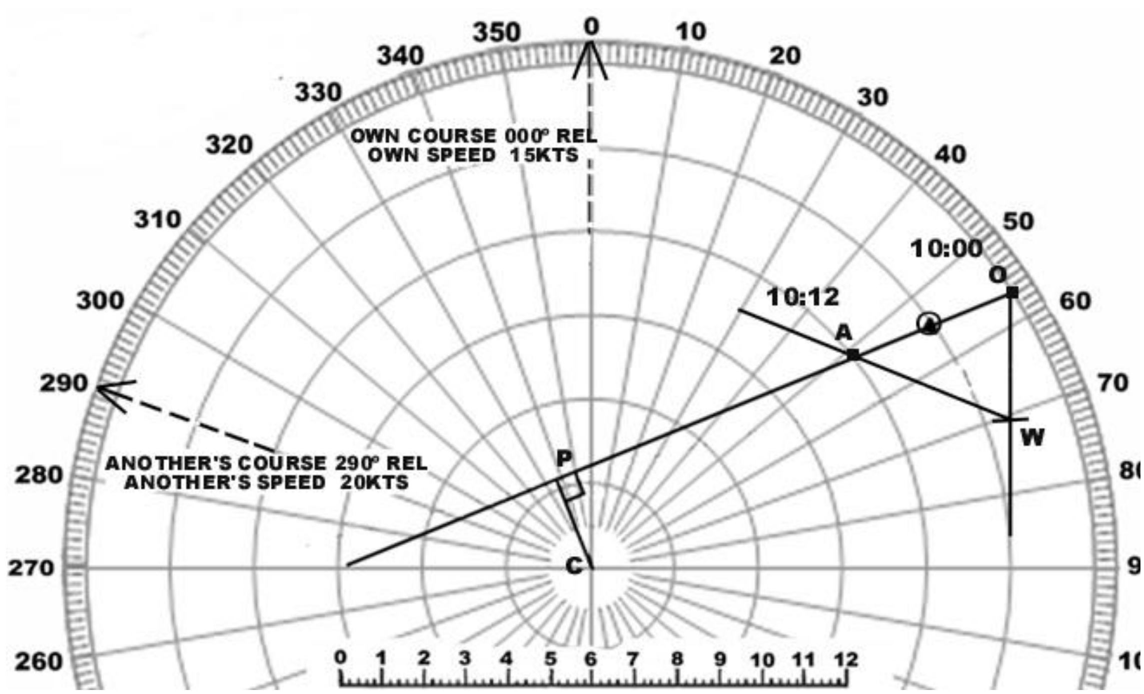
The distance that the target covered in the interval is shown by the length of the line WA. In this example we can measure this as 4 nm. Therefore, as it travelled 4 nm in 12’ (0.2 hrs) then in 1 hr it would travel:

$$\frac{1}{0.2} \times 4 = 20 \text{ kts}$$

Here it can be seen how selection of time interval can simplify later calculations

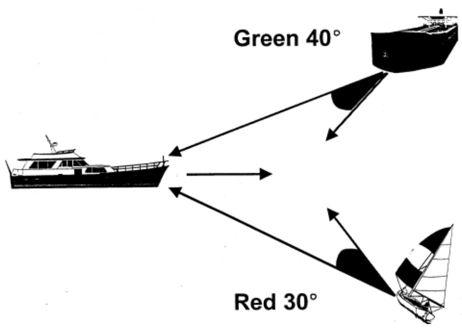
3 mins	6 mins	12 mins	15 mins	20mins	30 mins
$1/20^{th}$ hour	$1/10^{th}$ hour	$1/5^{th}$ hour	$1/4^{th}$ hour	$1/3^{th}$ hour	$1/2^{th}$ hour
0.05 hour	0.1 hour	0.2 hour	0.25 hour	0.33 hour	0.5 hour

In our example it travelled 4 nm in $1/5^{th}$ hour, so WA = 5 x 4 = 20 kts



Step 6: Finding the aspect of another vessel.

Aspect is the relative bearing of your own vessel taken from the target vessel's fore and aft line. It is expressed red or green. Aspects derived from plots are approximate, but tell you roughly the target's profile from your viewpoint and what navigation lights you should look for at the time of the final report.



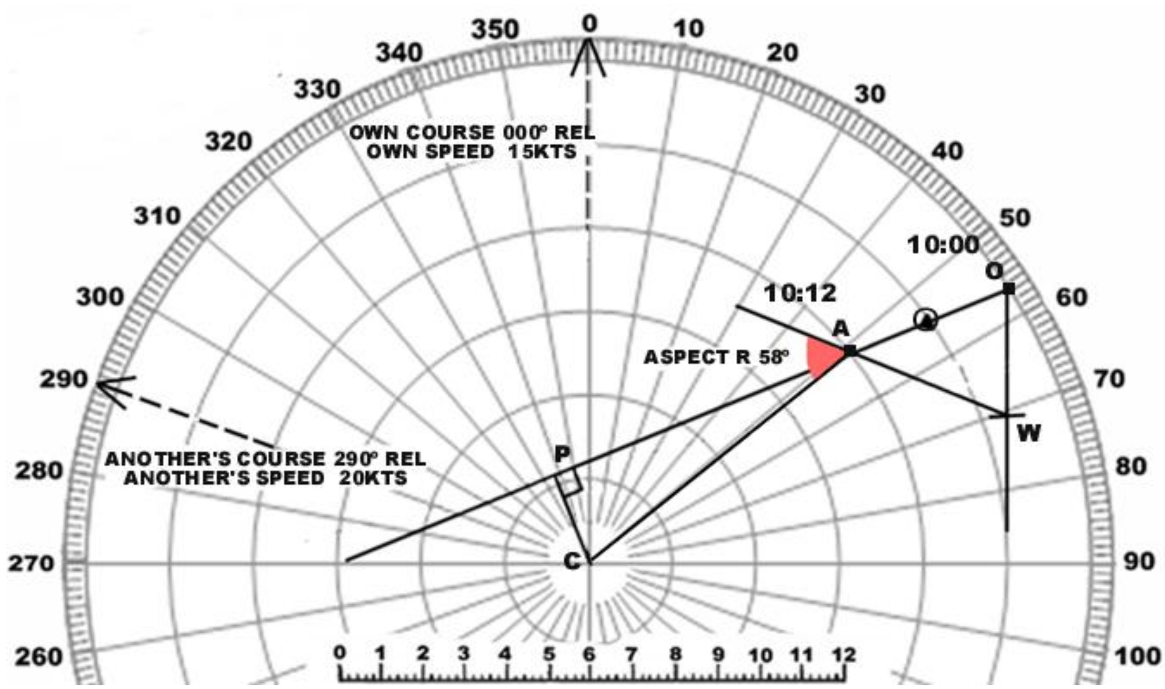
Note the use of bearing abbreviations

Relative	***040ºRel***	***330ºRel***
Aspect	***G 40º***	***R 30º***

Illustration courtesy of ANTA Publications

Aspect can be determined geometrically or mathematically

Geometrically:
A line from C to A is drawn; the angle between CA and the extension of WA is the aspect. This is easiest to measure by extending the line AC to cross the bearing scale's far side, in this case at 232***º*** and counting the degrees up to WA's marked course line at 290º Rel. Aspect in this case is R 58***º***.



Mathematically:
Aspect found by the reciprocal of the target's last bearing (its bearing of us, A to C) and the targets true course (WA).

Reciprocal of last bearing = 052° + 180° = 232°Rel.
Target's course = 290°Rel.
Lesser angle between the two = 290° - 232° = 058°.

The plot shows that we are on the port side of the target vessel so the target's **aspect is R 58°.**

While the vessels are not in sight of each other, to know aspect is not vital, but when the other vessel becomes visible, then the rules for vessels in sight of each other apply and suitable action will need to be taken depending on it being a head on vessel, a crossing vessel or an overtaking vessel.

Step 6: ***The full report.***

The full report is the information found from the basic plot:

- the time of the last observation.
- the target's last bearing and how the bearing is changing (drawing forward/aft, steady).
- the target's last range and how the range is changing.
- the CPA and TCPA.
- the target's true course and speed.
- the aspect of the target.

Our full report at 10:12 would be as follows:

- **Time 10:12.**
- **Target bearing 052° Rel. drawing fwd. (008°T + 052°Rel = 060°T)**
- **Target range 8.0 miles and closing.**
- **CPA 2.2 miles in 23 mins at 10:35.**
- **Target's course 290° Rel. (290° Rel + 008°T = 298°T)**
- **Target's speed 20 knots.**
- **Aspect R58°,**
- **Action to avoid collision, go to Step 7.**

Action to avoid collision

In the previous example the CPA was just over 2 nm, a reasonable clearance for small vessels, but less than the stopping distance of a very large vessel. Once again, the prediction from the plot relies on the course and speed of both vessels not changing.

If there is a collision risk, or a close-quarters situation is developing, then you must take avoiding action. The other vessel might not have radar or be disabled and unable to avoid collision. International Regulations for Preventing Collision at Sea specify the general actions to avoid collision in any state of visibility:

Rule 8 (Action to Avoid Collision *extract*), "…action taken to avoid collision shall… be positive, made in ample time… be large enough to be readily apparent to another vessel observing visually or by radar… a succession of small alterations of course and/or speed shall be avoided."

However, there are situations of being in *sight of one another* and being *in or near restricted visibility* where specific rules come into play.

Section II - Conduct of Vessels in Sight of One Another. These rules for vessel that can see each other should be familiar to readers. Go to the end of this book if you are unsure.

Section III - Conduct of Vessels in Restricted Visibility. In or near restricted visibility these differing steering instructions apply. Rule 19 (d) does not tell you what action to take, but what actions to avoid taking.

Rule 19 (d) (Conduct of Vessels in Restricted Visibility *extract*). "A vessel which detects by radar alone…another vessel "…
Shall avoid:

"(i) An alteration of course to port for a vessel forward of the beam, other than for a vessel being overtaken"

"(ii) An alteration of course toward a vessel abeam or abaft the beam."

Rule 19 (e) "…every vessel …which cannot avoid a close-quarters situation with another vessel forward of her beam, shall reduce her speed to be the minimum at which she can be kept on her course…."

In deciding the proper action to take to avoid collision in our previous examples of the SHU and NHU plot, we were steering 008° T, the target was bearing around 060° T and we might consider the range decreasing and a predicted CPA of 2.2 nm to be too close for comfort in restricted visibility.

Rule 19 (d) (i) states that you should avoid an alteration of course to port for a vessel forward of the beam. This target is forward of your starboard beam.

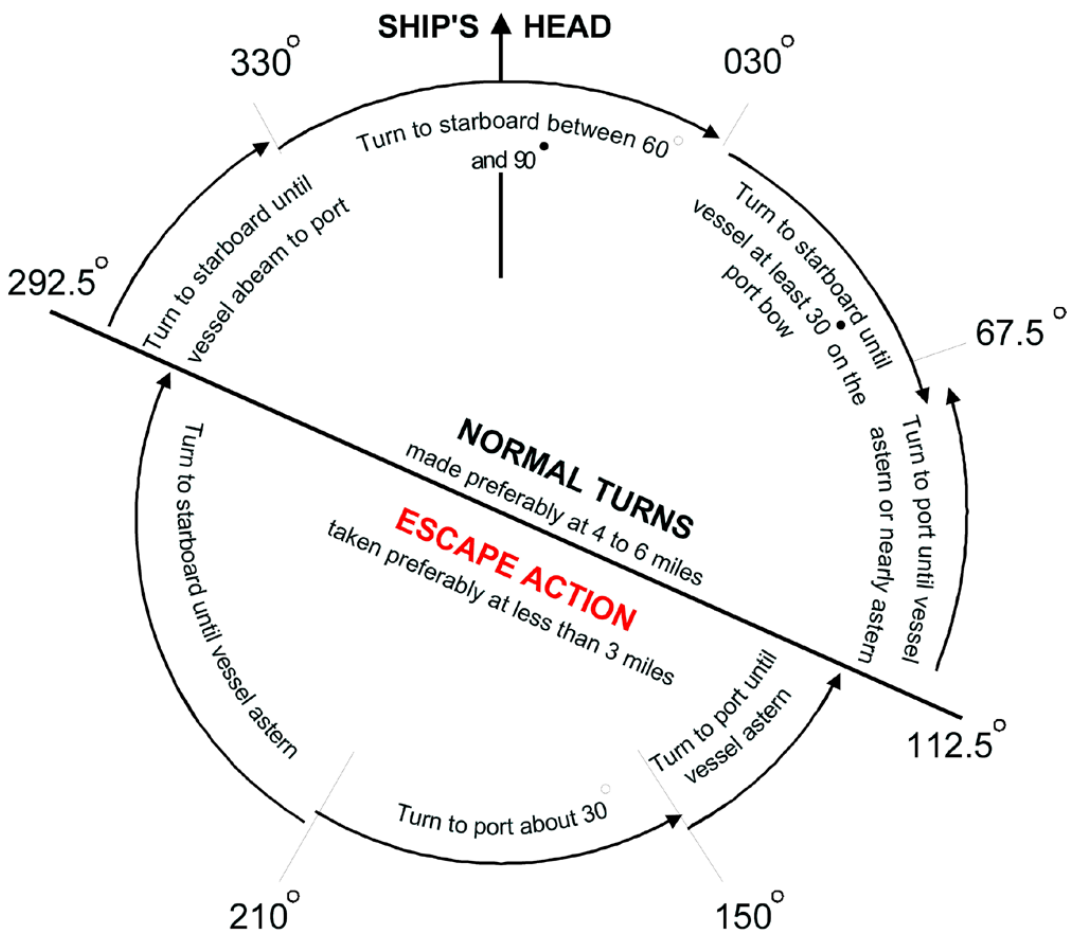


Diagram courtesy of ANTA publications

Step 7- *Avoiding action (SHU & NHU example plot)*

Consulting the diagram above, there are two alternatives:

- alter course a substantial amount to starboard (30° -60°).
- reduce speed or stop until the danger is clear.

Check your progress

In the following situations, complete a plot and final report. Check your answers later.

Plot 1. Your vessel is steering 030° T at a speed of 20 knots. The following observations of a target on the radar are made.

Time	***Bearing***	***Range***
1203	070° T	6.0 miles
1206	069° T	5.0 miles
1209	068° T	4.0 miles

Plot 2. Your vessel is steering 280° T at a speed of 15 knots. The following observations of a target on the radar are made.

Time	***Bearing***	***Range***
0900	290° T	12.0 miles
0906	291° T	10.0 miles
0912	292° T	8.0 miles

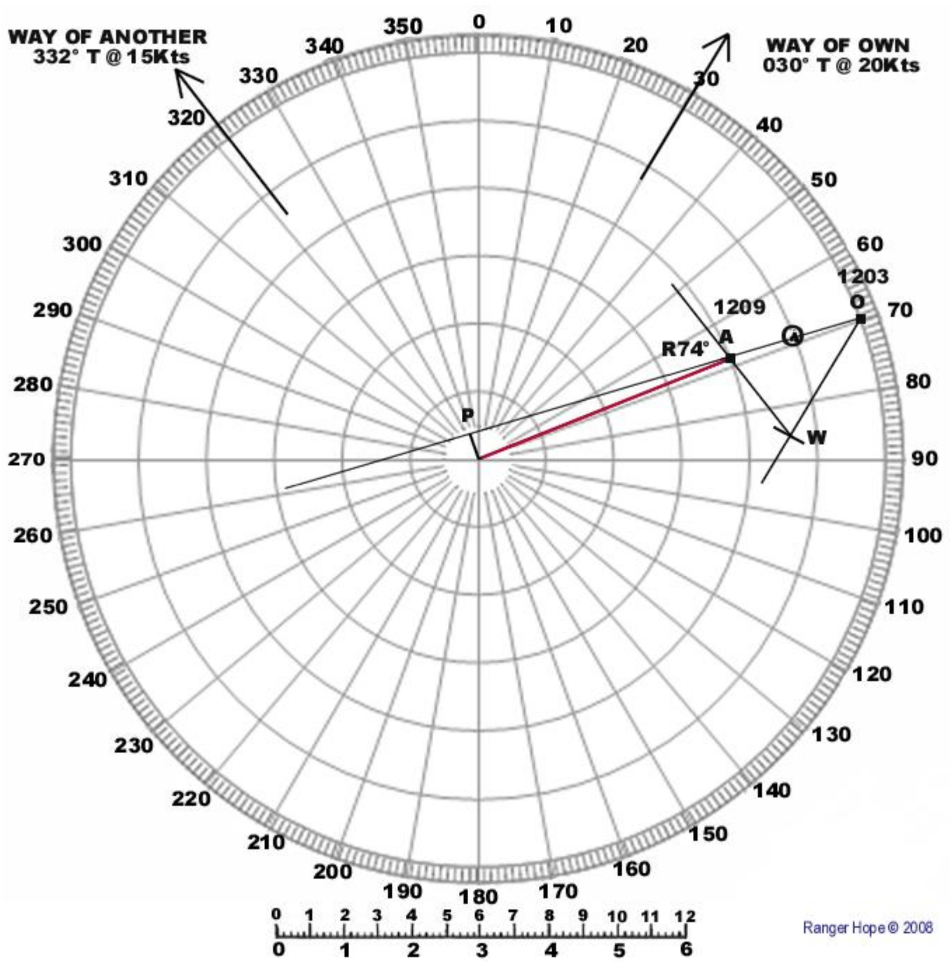
Plot 3. Your vessel is steering 090° T at a speed of 12 knots. The following observations of a target on the radar are made.

Time	***Bearing***	***Range***
1430	130° Rel	4.5 miles
1435	130° Rel	3.5 miles
1440	130° Rel	2.5 miles

Answers to check your progress

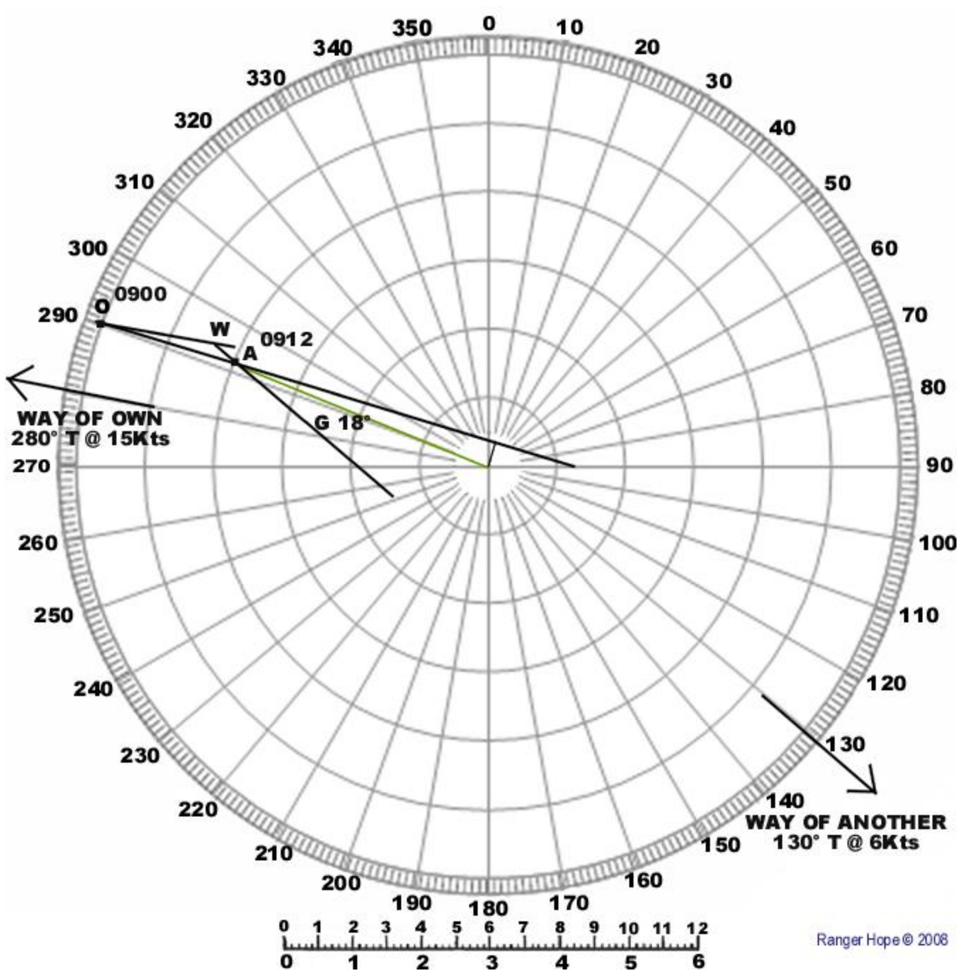
Plot 1. Our full report at 12:09 would be as follows:

- Time 12:09.
- Target bearing 068° T. drawing forward.
- Target range 4.0 miles and closing.
- CPA 0.5 miles in 12 mins at 12:21.
- Target's course 322° T.
- Target's speed 15 knots.
- Aspect R74°. Action - A substantial turn to starboard until the vessel is at least 030° on our port bow.



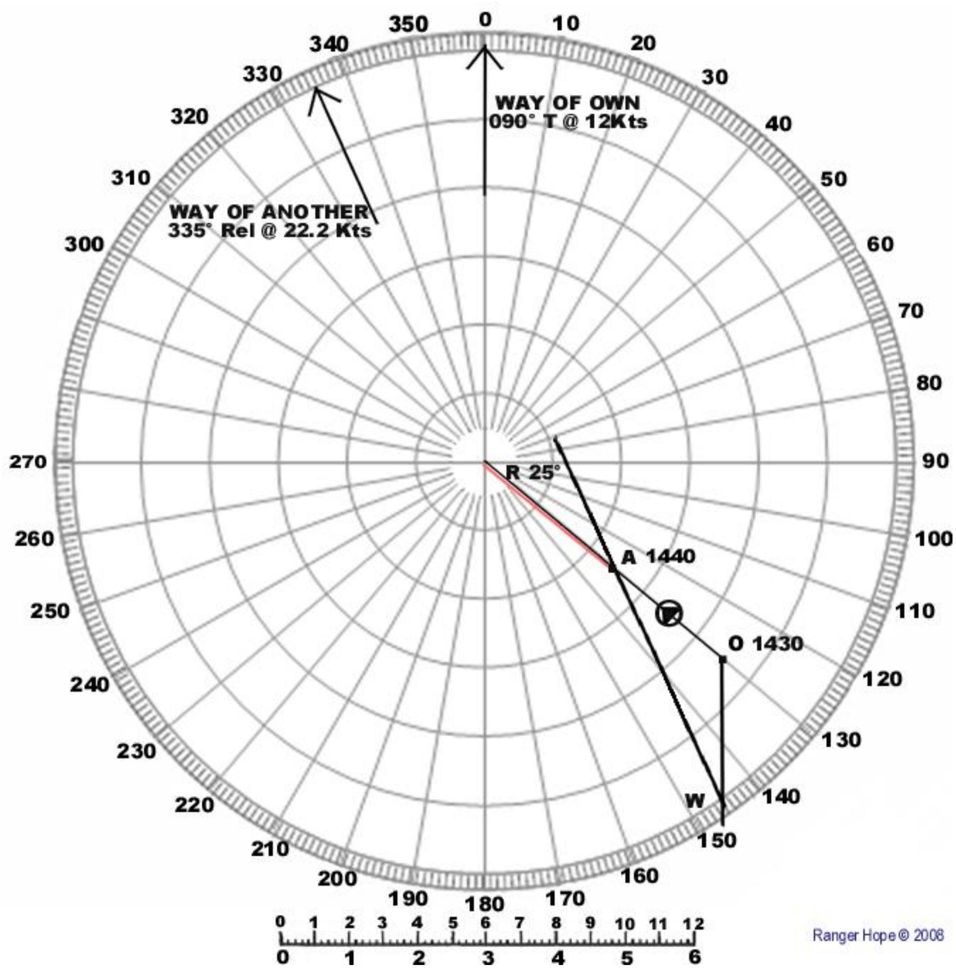
Plot 2. Our full report at 09:12 would be as follows:

- Time 09:12.
- Target bearing 292° T. drawing forward.
- Target range 8.0 miles and closing.
- CPA 0.8 miles in 24.6 mins at 09:36.6.
- Target's course 130° T.
- Target's speed 6 knots.
- Aspect G18°. Action - A substantial turn to starboard between 060° and 090°.



Plot 3. Our full report at 14:40 would be as follows:

- Time 14:40.
- Target bearing 130° Rel. steady. 130° + 090°= 220° T
- Target range 2.5 miles and closing.
- CPA collision in 12 mins at 14:53.
- Target's course 335° Rel.   335° + 090°= 425°- 360°= 065° T
- Target's speed 22.2 kts knots.
- Aspect R25°. Action – Turn to port until vessel is astern.



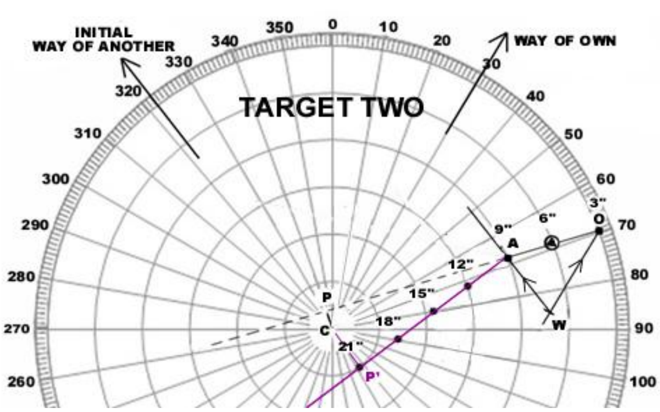
Another vessel’s change in course or speed.

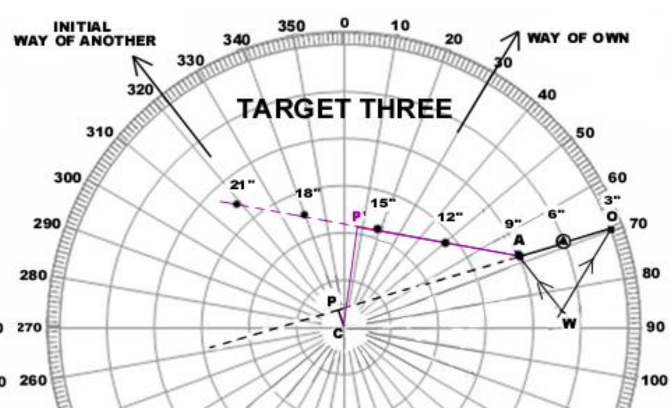
Detecting and interpreting change in target’s motion:

Targets detected at close quarters were plotted below to find their initial OAP line, predicted CPA, course/speeds and aspects (all Red 75º). Following best practice, the targets were subsequently monitored and deviations from the predicted OAP lines were detected.

Caution is required to ensure target “wander” is not a changing relative view due to our own vessel’s yaw. An additional consideration is that larger craft can take ten minutes or more to settle on a new course and even longer to reach a higher speed. In our decisions the Collision Regulations, *Risk of Collision Rule 7c*, must be considered - *Assumptions shall not be made on the basis of scanty information, especially scanty radar information.*

In this case however, at successive 3 minute intervals the targets consistently lined up as new AP¹ lines, coincidentally originating from A as the moment of target behaviour change. The OA line is the resultant of the vectors of course & speed of own vessel (WO) and course & speed of another vessel (WA). As our vessel maintained constant course & speed (no leeway/current were present) this target behaviour must have been due to the other vessel’s changes in course, or speed or both.





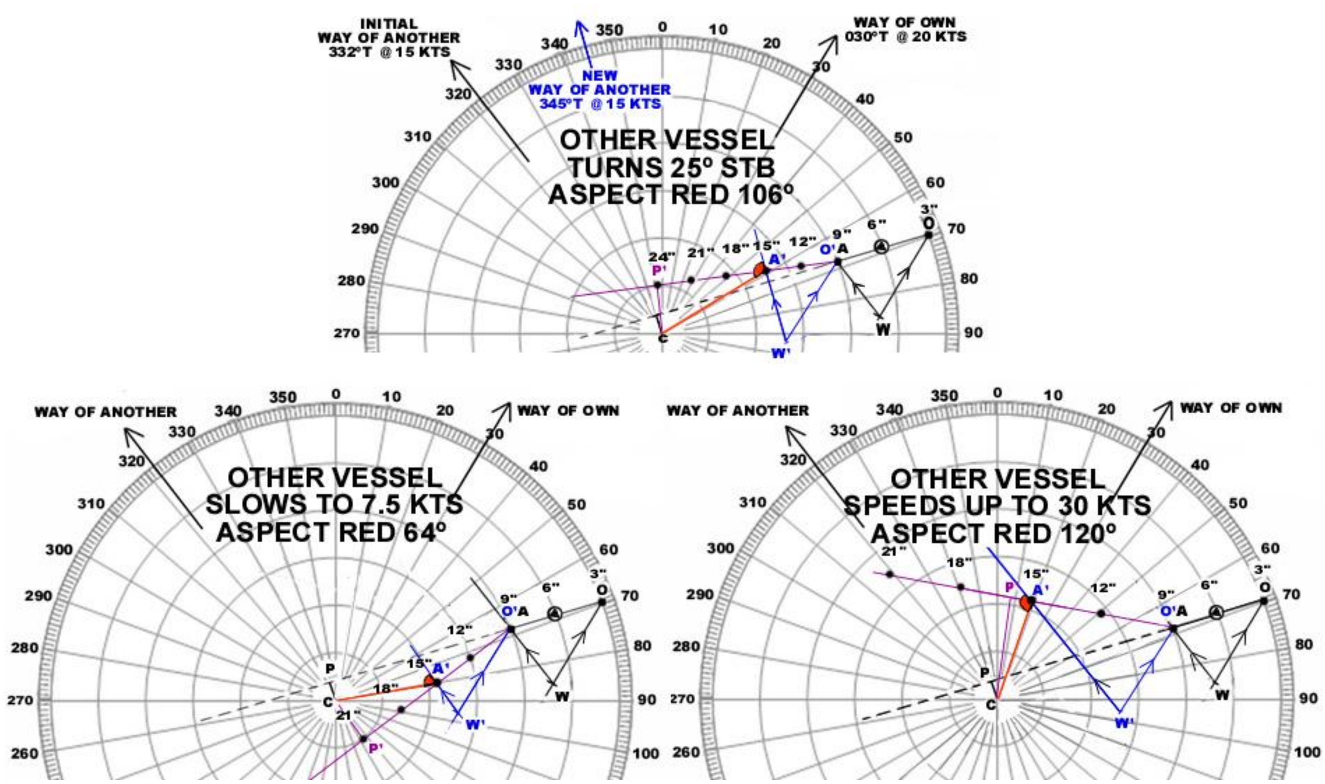
Targets 1-3 initially being aspect Red 75º are crossing situations making us the give way vessel (*Rule 15*). The obligation for avoidance action rests with us, but as the other vessel took action *Rule 8d Action to Avoid Collision* comes into play *(action taken to avoid collision ... shall... result in passing at a safe distance. The effectiveness ... checked until the other vessel is finally past and clear).*

Only Target 1 positively identified itself by radio to notify its 25º to starboard altered course, maintained speed and intention to pass ahead. A recommended substantial course change (30º to 60º) would have increased their aspect to Red 111º or more, close to or becoming an overtaking give way vessel. Hence the radio message to ensure we understood its actions. However, while Targets 2 and 3's new CP^1A's are displayed, the course/speed/aspect require re-plotting with new $O^1A^1W^1$ vector triangles as shown below.

Aspects of all other vessels must be monitored and re-assessed in order to visually identify them, allowing that they may not have detected us and their changed behaviour may not be avoidance action but an operational manoeuvre.

Changing of course, slowing down or speeding up:

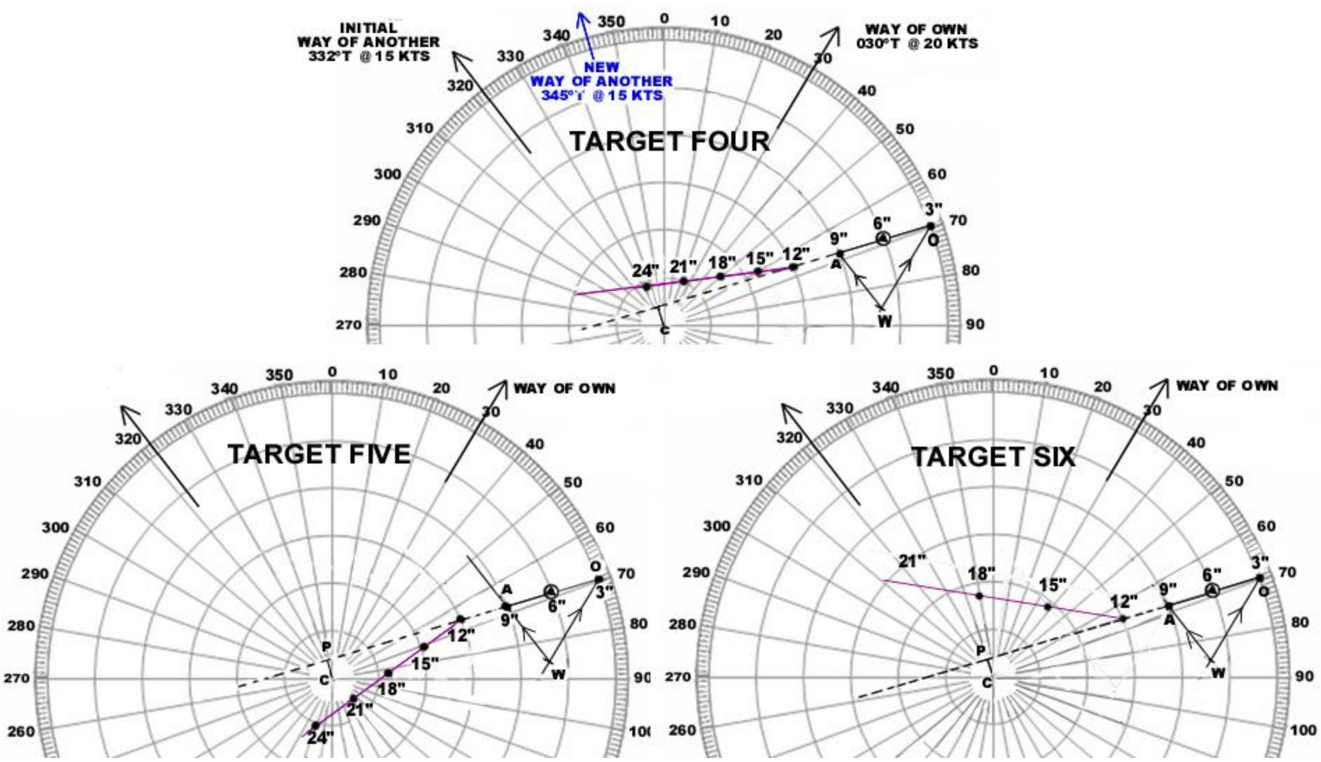
The new $O^1A^1W^1$ plots can be constructed by transferring the 6 minutes (9"- 3") constant OW vector from the point A when target motion changed, (in the example below called O^1). Position A^1 is at the target detection at the repeat 6 minute interval. The direction and length of W^1A^1 enable the other's course, speed and aspect to be determined.



Note that a modest change in course was as effective as halving speed in increasing CP^1A^1 to 1 mile but additionally delayed the TCP^1A^1 to 24”. Also, Target Three’s remarkable ability to double its speed to 30 knots increased CP^1A^1 admirably but also slashed the TCPA to just over 15”.

Changing of course, slowing down or speeding up after a delay:

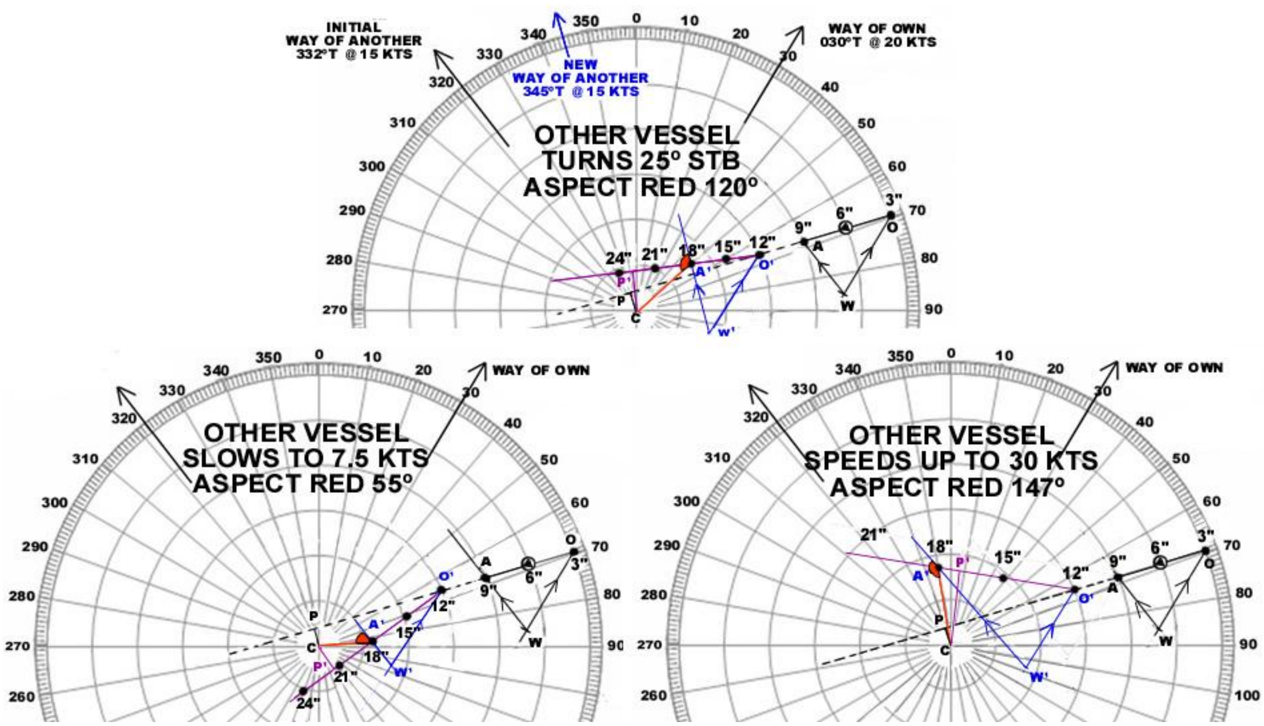
For the purpose of simplifying the explanation of constructing a proving plot, in the previous examples we selected position A as the moment that the behaviour of the targets 1-3 changed. In reality, the more likely scenario is that at some time after position A the change will occur. Below are detections of another set of targets 4-6 that in these examples changed their behaviour after a 3 minute delay from when position A was detected and the initial plot constructed.



Again, at successive 3 minute intervals the target detections consistently lined up as new AP^1 lines, but this time originating at 3 minutes after position A as the moment of target behaviour change. The OA line is the resultant of the vectors of course & speed of own vessel (WO) and course & speed of another vessel (WA). As our vessel maintained constant course & speed this target behaviour must have been due to the other vessel’s changes in course, or speed or both.

Changing of course, slowing down or speeding up after a delay:

As with the previous examples of the $O^1A^1W^1$ plots can be constructed by transferring the initial 6 minutes (9”- 3”) and constant OW vector from the point of target motion change, called O^1. But in the case of this 3 minutes delay not at position A, but from the point that the newly lined up target detections cross the initial OA line extension. Position A^1 is found at the target detection point at the repeat 6 minute interval. The direction and length of W^1A^1 enable the other’s course, speed and aspect to be determined.



Note that in practice it is very difficult to determine the precise moment that the other vessel changes its motion. Caution is required to rule out target “wander” caused by our own vessel’s yaw. Rule 7i Risk of Collision specifies *Such risk shall be deemed to exist if the compass bearing of an approaching vessel does not appreciably change.* An additional consideration is that larger craft can take ten minutes or more to settle on a new course and even longer to reach a higher speed. In our decisions Rule 7c, must also be considered - *Assumptions shall not be made on the basis of scanty information, especially scanty radar information.*

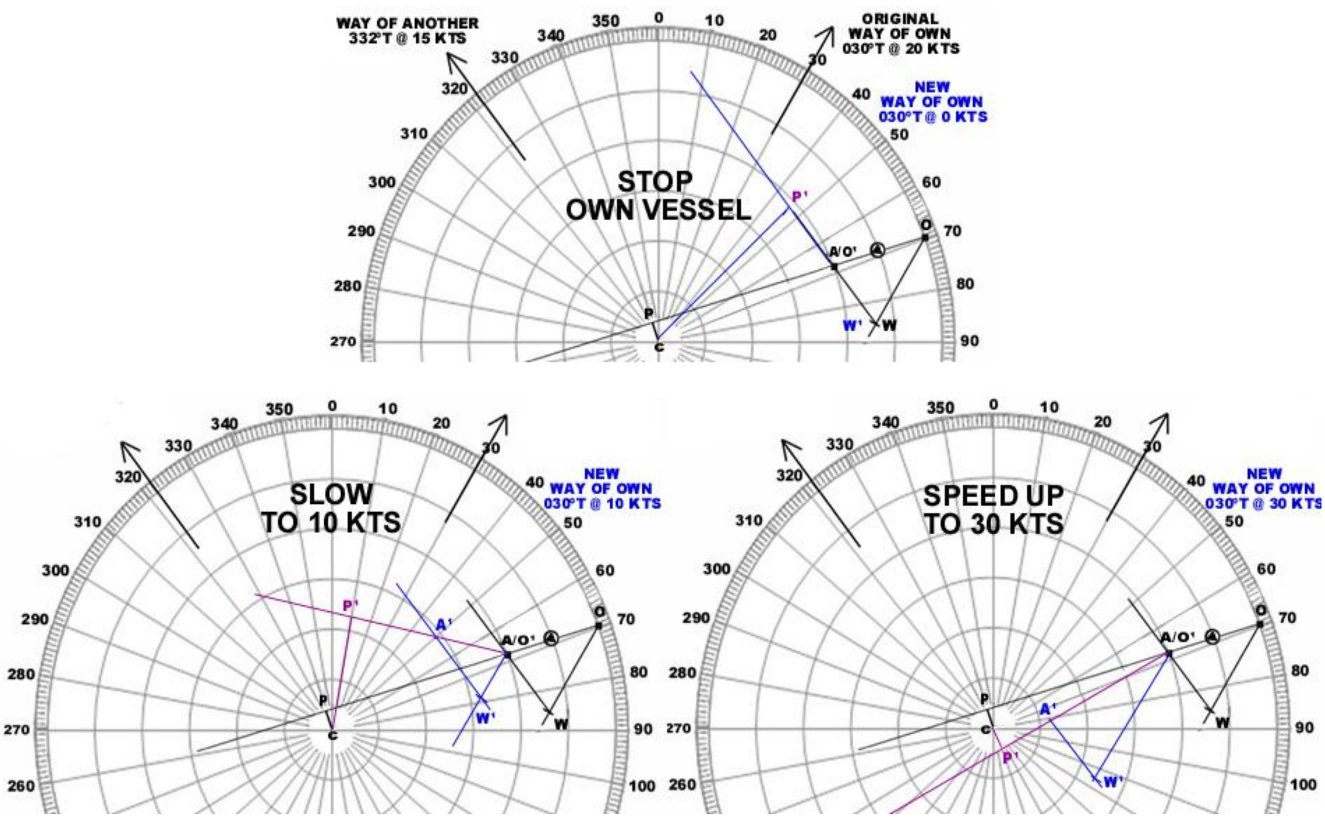
In summary, some time is required for the target line to settle down. Note that Target Six’s remarkable ability to double its speed to 30 knots increased CP^1A^1 but also slashed the TCPA to just over 15”. In fact, by the time we were able to determine the new aspect it had already overtaken us and was finally past and clear.

Own vessel's change in speed.

To minimize collision risk by increasing CPA a vessel could stop, slow down or (often less achievable) speed up. In seeking this improved CPA a new vector plot is first drawn. In the examples below we altered speed at A, so this is effectively also a new position O^1. The W^1A (our speed) is the vector that changes while the W^1A^1 vector (another's speed) stays constant.

Stopping, slowing down or speeding up:

Plots for our vessel on initial course 030ºT and speed 20 kts plots with 0.5 mile CPA and the consequence of altering speed are shown below. If our vessel stops WO vector stops increasing while the W^1A vector keeps going to extend past the new CP^1A (3.8 miles). In this case relative motion and true motion are identical as only one changing vector is in play, the other vessel.



In the examples above we changed speed at A, so this is also a new position O^1 for the new vector plot. If our 20 knots vessel slows to10 knots or speeds up 30 knots, the W^1O^1 own speed vector is drawn proportionally shorter or longer but in the same direction of the initial WO vector. After finding W^1 the constant WA length and direction can be repeated as W^1A^1, thus providing the line A/O^1 A^1 and its extension to CP^1A (2.3 miles ahead and 0.5 miles behind).

Plotting own vessel's change in speed.

Plot 1a. Own vessel's slows its speed.

Our vessel while on a course of 030°T at a speed of 20 kts plots a target ahead with 0.5 miles predicted CPA requiring avoidance speed change.

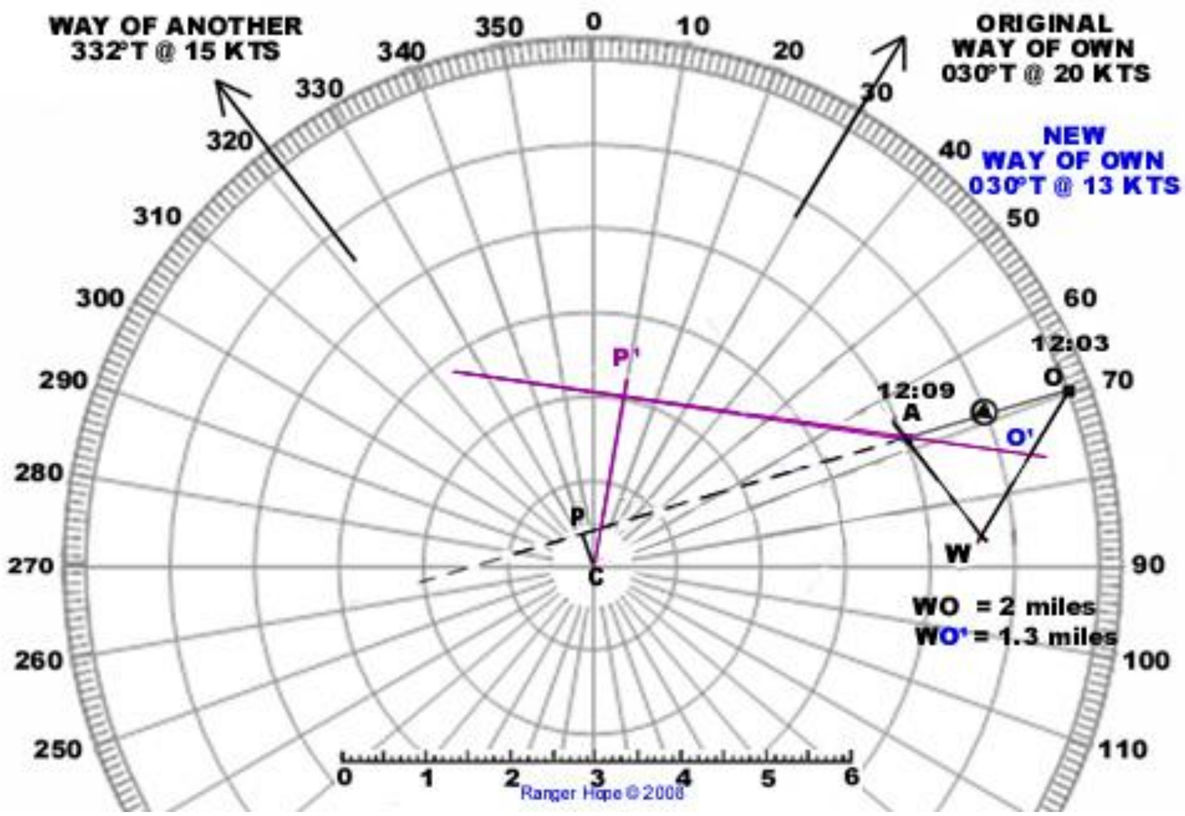
Finding the CP^1A resultant on decreased speed to13 knots:

Calculate the new speed vector of 13 knots x 6" interval (1/10th hour) =1.3 nm. Draw this shorter speed vector line from W to a new position O^1. A new O^1 line extended through and past A will provide the new CP^1A.

Finding speed change required to increase CPA from 0.5 to 2 miles:

Draw a line from P^1 (the chosen 2 miles CP^1A^1) to A (the 2:09 position) and extend it to cross the initial WO line at new position O^1. From this vector WO^1 the required speed can be calculated from the length times the interval period:

Measured 1.3 nm x 10 = 13 kts



See geometric explanation of Plot 1a on Page 33.

Plot 1b. Own vessel's change in speed after a delay.

Our vessel while on a course of 030°T at a speed of 20 kts plots a target ahead with 0.5 miles predicted CPA requiring avoidance speed change.

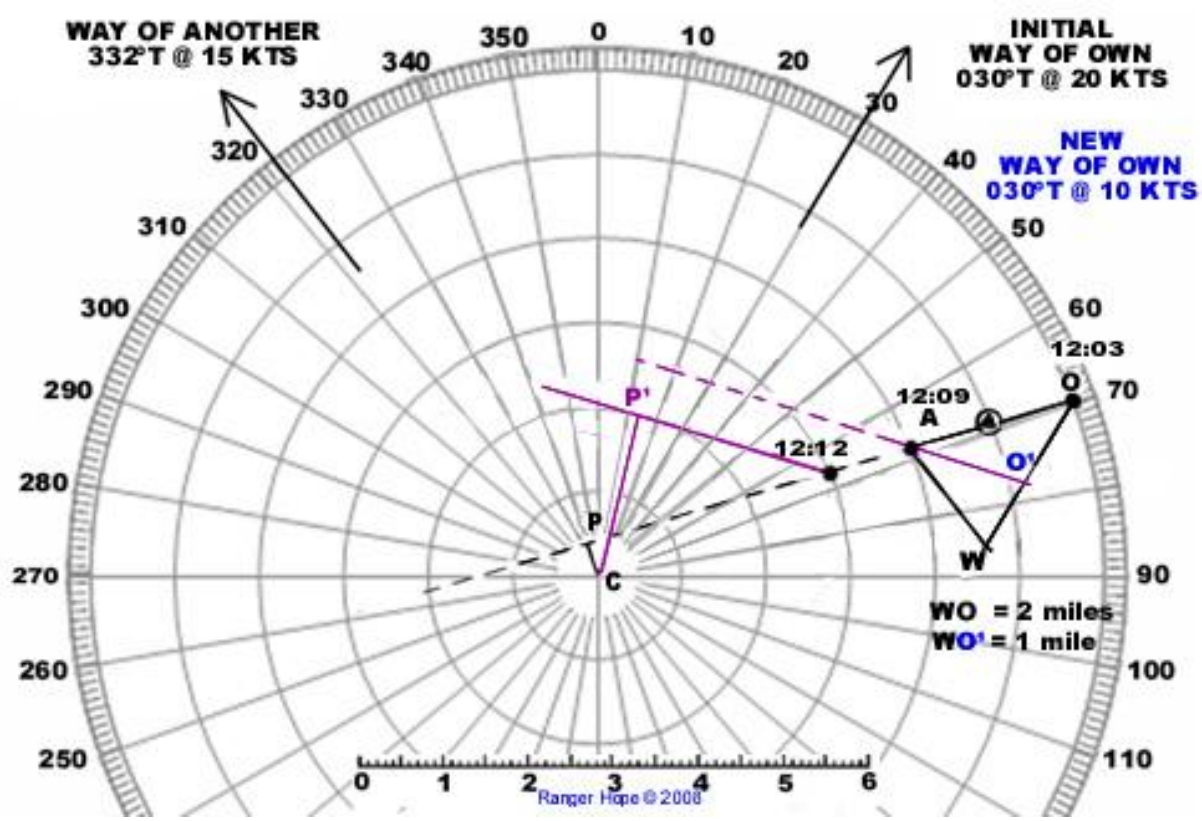
Finding speed change required to increase CP^1A^1 from 0.5 to 2 miles.

From the (current) target position after the delay, in this case 12:12 draw a line to P^1 as the required 2 miles CP^1A. Transfer a line parallel to this extending through A to cross the initial WO to find O^1. Measure the new WO^1 to find our vessel's travel over the initial between 12:30 -12:09 interval. Calculate the speed from the multiples of this distance that would be covered in 60 minutes, in this case:

Measured 1 nm x 10 (6 mins) = 10 kts

Finding the CP^1A resultant on slowing to 10 knots.

Calculate the distance that would be covered in 6 minutes at ten knots, in this case, 1 nm. Mark this distance from the initial W to find the new WO^1 vector. From O^1 draw a line through A and extend towards the centre. Transfer a line parallel to this from the current target position (12:12). Where this line passes closest to the centre is the new CP^1A.



See geometric explanation of Plot 1b on Page 34.

Plotting own vessel's change in course.

Plot 2a. Own vessel's change in course.

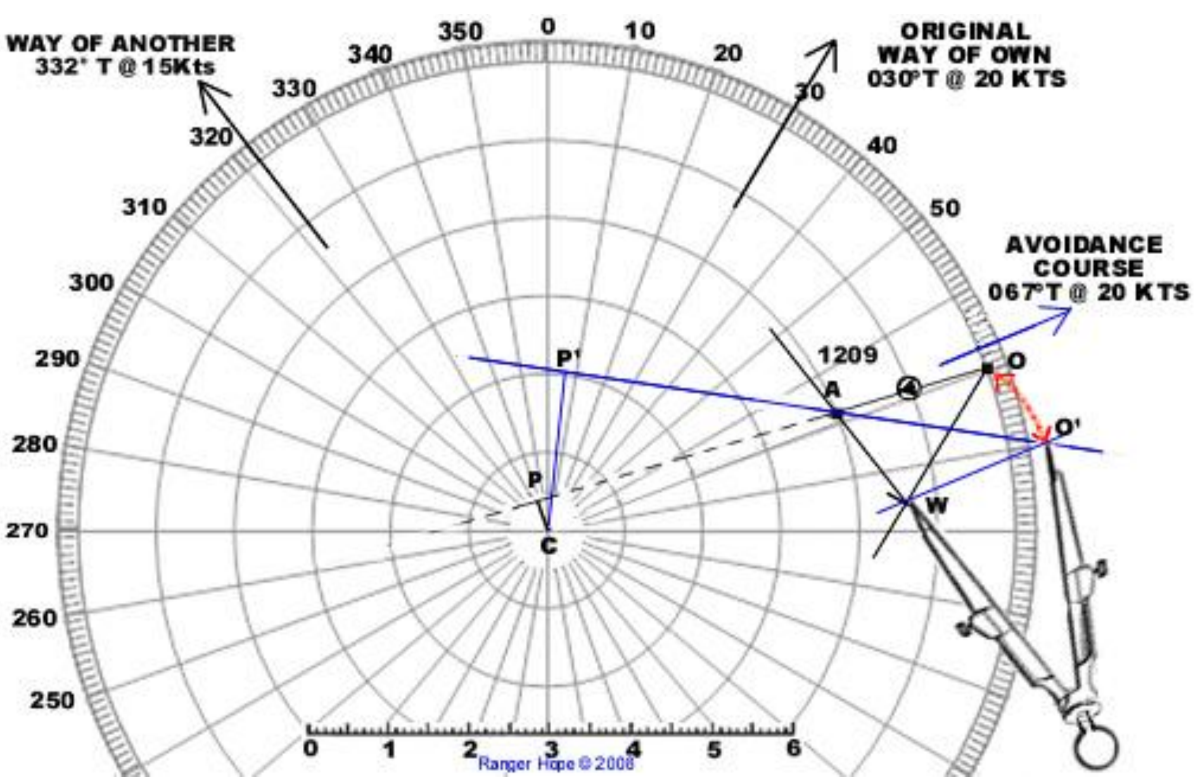
Our vessel while on a course of 030ºT at a speed of 20 kts plots a target ahead with 0.5 miles predicted CPA requiring avoidance course change.

Finding the CP¹A resulting from chosen 37º to Stb course change.

Transfer the avoidance course (030ºT + 37º Stb = 067ºT) from the outer bearing scale and draw as a line from W extending in the avoidance course direction. With dividers spanning WO, swing arc from O to cross the avoidance course line. Call the crossing point O¹. Draw a line from O¹ back through A and extend past the centre. A perpendicular from the centre crosses at P¹, the new CP¹A.

Finding course required to increase the 0.5 miles CP¹A to 2 miles.

Draw line from P¹ (new 2 miles CP¹A) through A (the 2:09 position) and extend. With dividers spanning line WO, swing an arc from O to new position where the extended P¹A line is crossed. Call this O¹. Draw line WO¹ and transfer it to the outer bearing scale to read off the avoidance course, in this case 067ºT.



See geometric explanation of Plot 2a on Page 35.

Plot 2b. Own vessel's change in course after a delay.

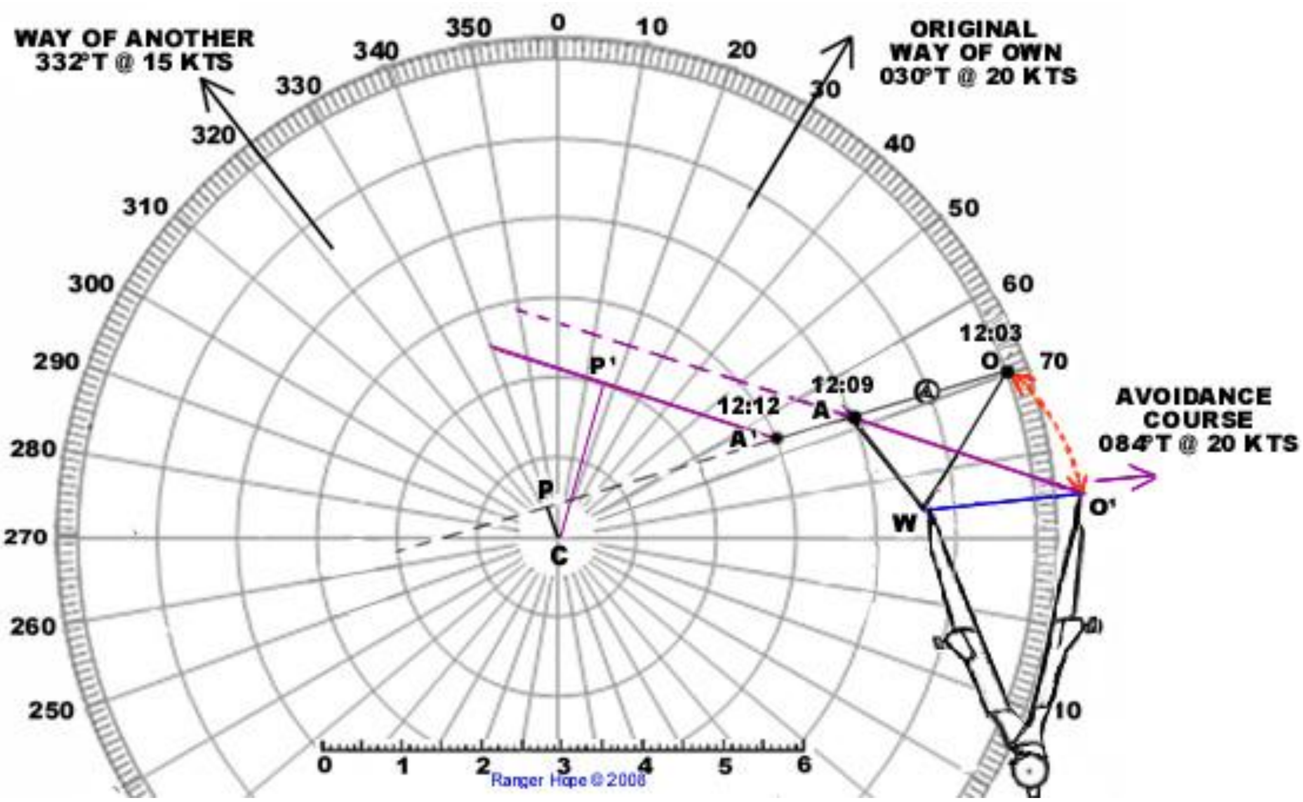
Our vessel on 030°T and speed 20 kts plots a target ahead with 0.5 mile CPA requiring avoidance course change actioned after 3 minutes delay.

Finding the CP¹A¹ with delayed 54º to Stb course change:

Calculate the new avoidance course from the current course plus or minus the turn away from it (in the example, 030ºT + 54º Stb = 084ºT). From initial W to O¹. draw this directional vector the same length as initial WO. From O¹ draw a line back through A and past the centre. Transfer a line parallel to this to pass through A¹ (the 12:12 position) and past the centre. This gives the new CP¹A¹ of 2 miles.

Finding course required to increase 0.5 miles CPA to 2 miles after delay:

Draw a line from P¹ (the chosen new 2 miles CP¹A¹) to A¹ (the 12:12 position). Draw a line parallel to this and extend through the initial A to well past the initial WO line. With dividers spanning the initial WO line, sweep an arc from W to find new position O¹ where the previously drawn line is crossed. Line WO¹ is the new avoidance course, in this case 084ºT.



See geometric explanation of Plot 2b on Page 36.

Geometry of plots

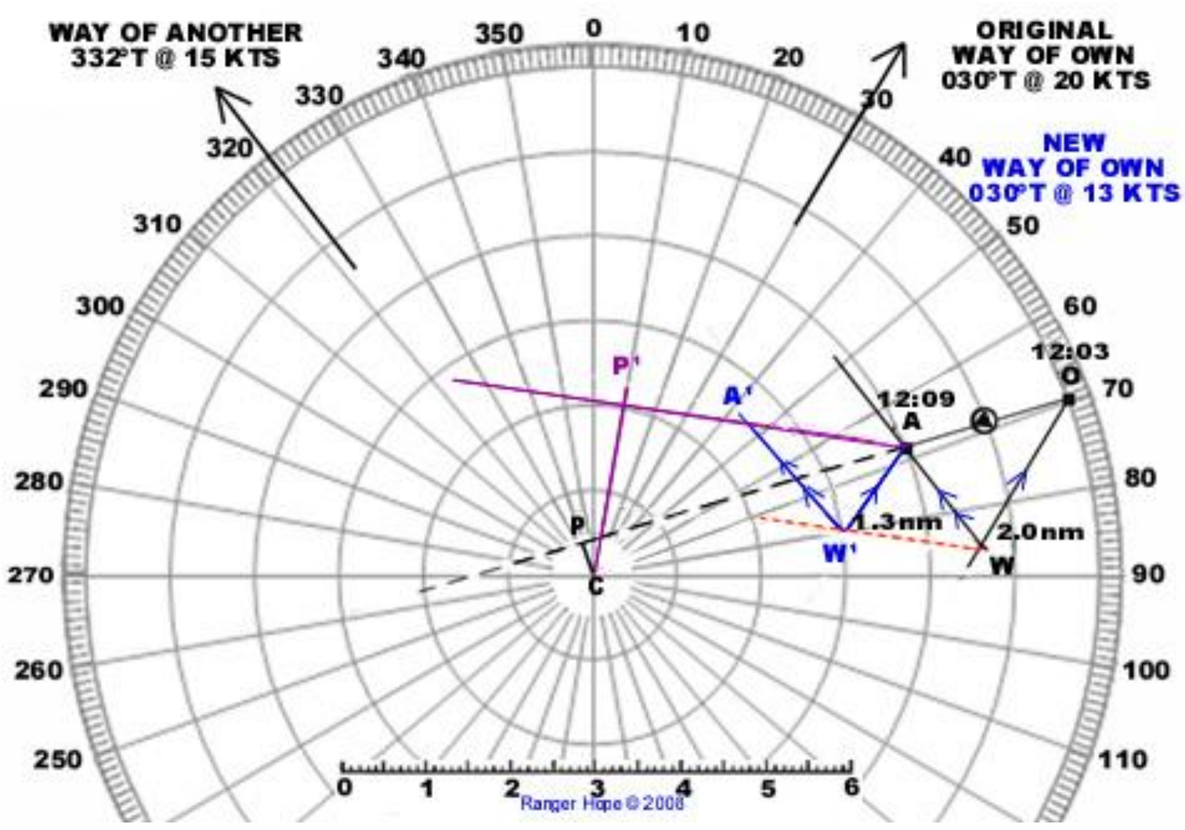
Explanation of Plot 1a from Page 29:

The underpinning geometry of the previous simplified plot can be seen below, showing how the in both cases the solution essentially re-plotted a new $O^1A^1W^1$ vector triangle. For example:

Finding the CP^1A^1 resultant on decreased speed to13 knots:
Calculate the new speed vector of 13 knots x 6" interval (1/10th hour) =1.3 nm. Draw this shorter line from A in the same direction of the initial WO to new position W^1. Transfer a repeat WA vector to become the new W^1A^1. The positions A through A^1 can be extended to find P^1 and the new CP^1A^1.

Finding speed change required to increase CPA from 0.5 to 2 miles:
Draw a line from P^1 (the chosen 2 miles CP^1A^1) to A (the 2:09 position). From W transfer a line parallel to P^1A. If then a new WO vector is drawn from A in the same direction of the initial, the position W^1 is found. From this vector W^1O the required speed can be calculated from the length times the interval period:

Measured 1.3 nm x 10 = 13 kts



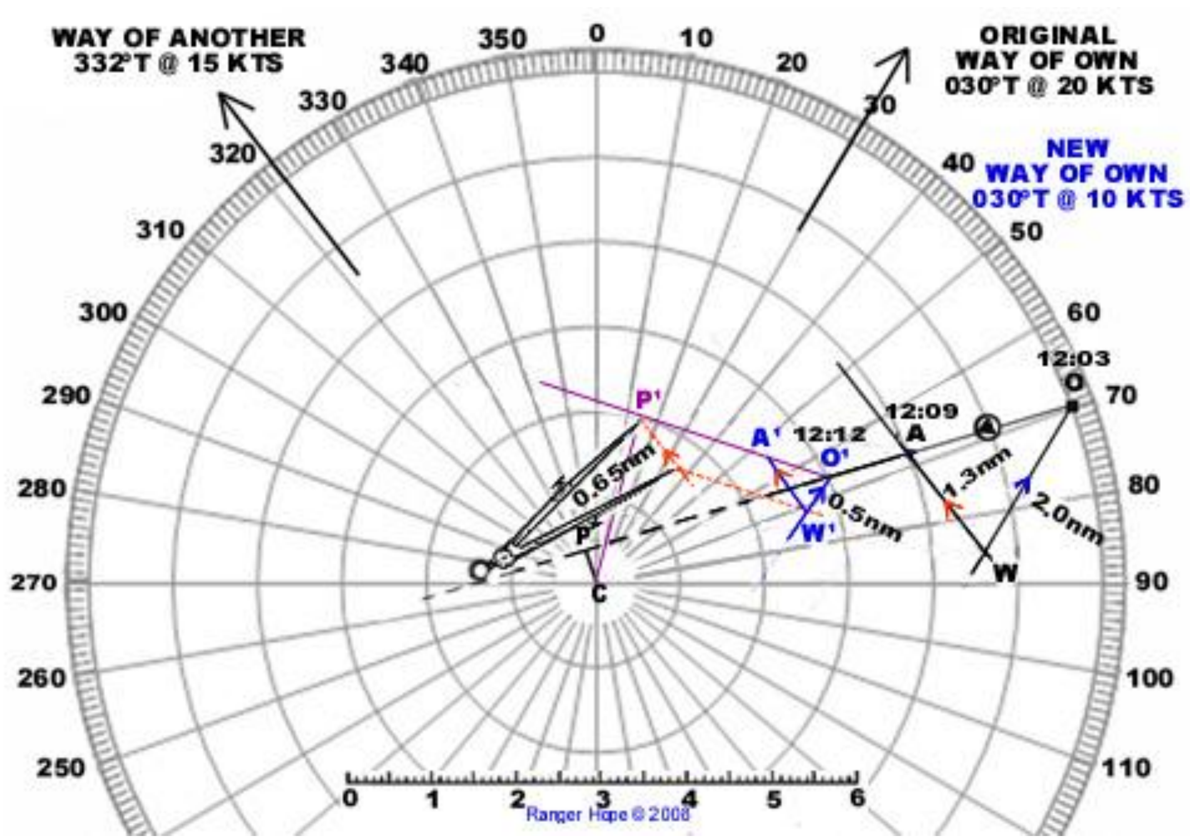
Explanation of Plot 1b from Page 30.

The underpinning geometry of the previous simplified plot can be seen below, showing how the in both cases the solution essentially re-plotted a new $O^1A^1W^1$ vector triangle. For example:

Finding speed change required to increase CP^1A^1 from 0.5 to 2 miles.
Find the O^1 on the initial OAP line representing the delay period, in this case 3 minutes after A. Draw a line from P^1O^1 (the chosen 2 miles CP^1A^1). From O^1 transfer a line parallel to the initial OW. Calculate the other vessel's travel over the delay period (1.3 x 3/6 mins = 0.65 miles) then transfer the initial WA vector to P^1 and mark off the 0.65 miles. From that position a line parallel with P^1O^1 will find W^1 and the length W^1O^1 provides the required speed, in this case:

Measured 0.5 nm x $3/60^{th}$ hour (3 mins) = 10 kts

Finding the CP^1A^1 resultant on slowing to10 knots.
Calculate the distances travelled during the delay from A to O^1. Draw a new $O^1A^1W^1$ vector plot to find the new CP^1A^1.



Explanation of Plot 2a. from Page 31.

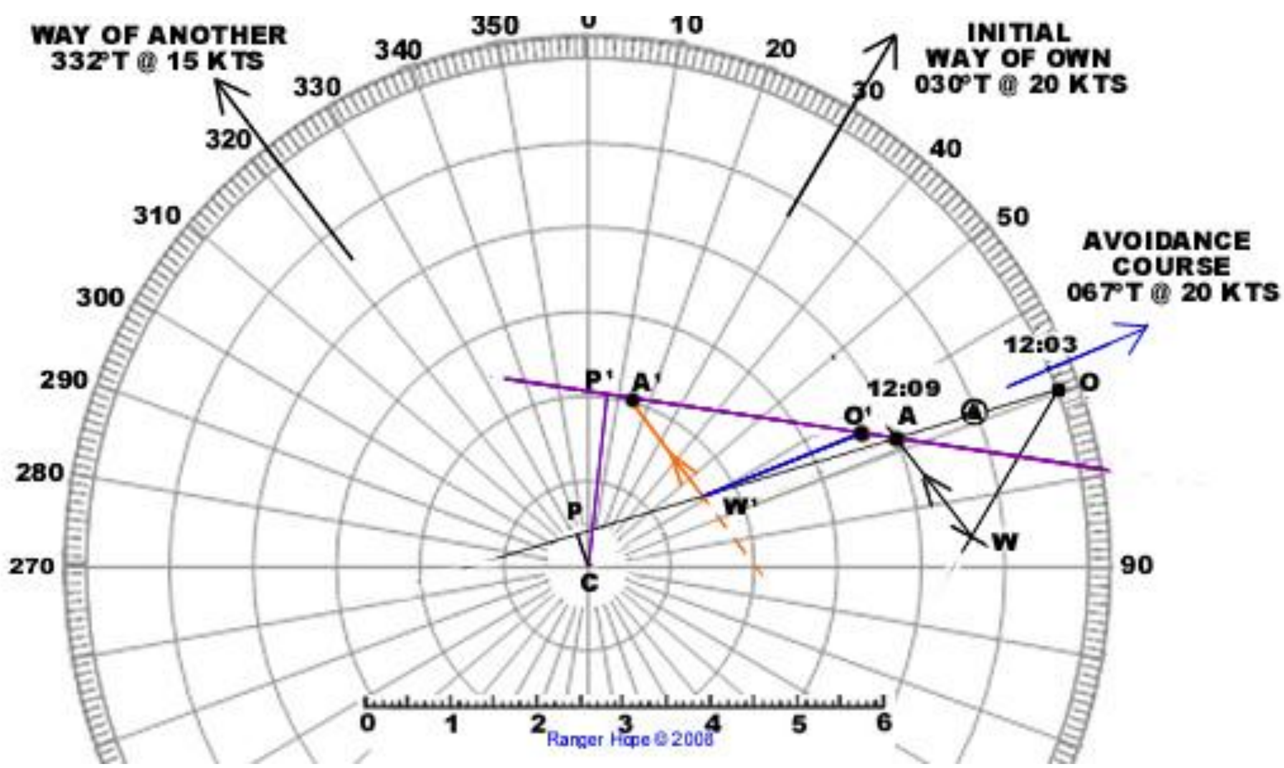
The underpinning geometry of the previous simplified plot can be seen below, showing how the in both cases the solution essentially re-plotted a new $O^1A^1W^1$ vector triangle. For example:

Finding the CP^1A resulting from chosen 37º to Stb course change.

A new WO vector in the avoidance course direction (030ºT + 37º Stb = 067ºT) can be drawn from position A (at 12:09) or the last target position O^1 (as below). Marking the length of our unchanging speed (the initial WO length) on this line finds a point W^1. Transferring the initial and unchanged vector WA from W^1 finds a point A^1. A line joining A to $A^1$and extended past the centre finds the new CP^1A.

Finding course required to increase the 0.5 miles CP^1A to 2 miles.

Draw line from P^1 (new 2 miles CP^1A) through A (the 2:09 position) and extend. A parallel line to the unchanging WA vector can be drawn anywhere from a point on this line that we call W^1A^1. With dividers, sweeping the length of our unchanging speed (the initial WO length) finds a point O^1. Thus W^1O^1 must be the changed vector and its direction can be read off the scale.

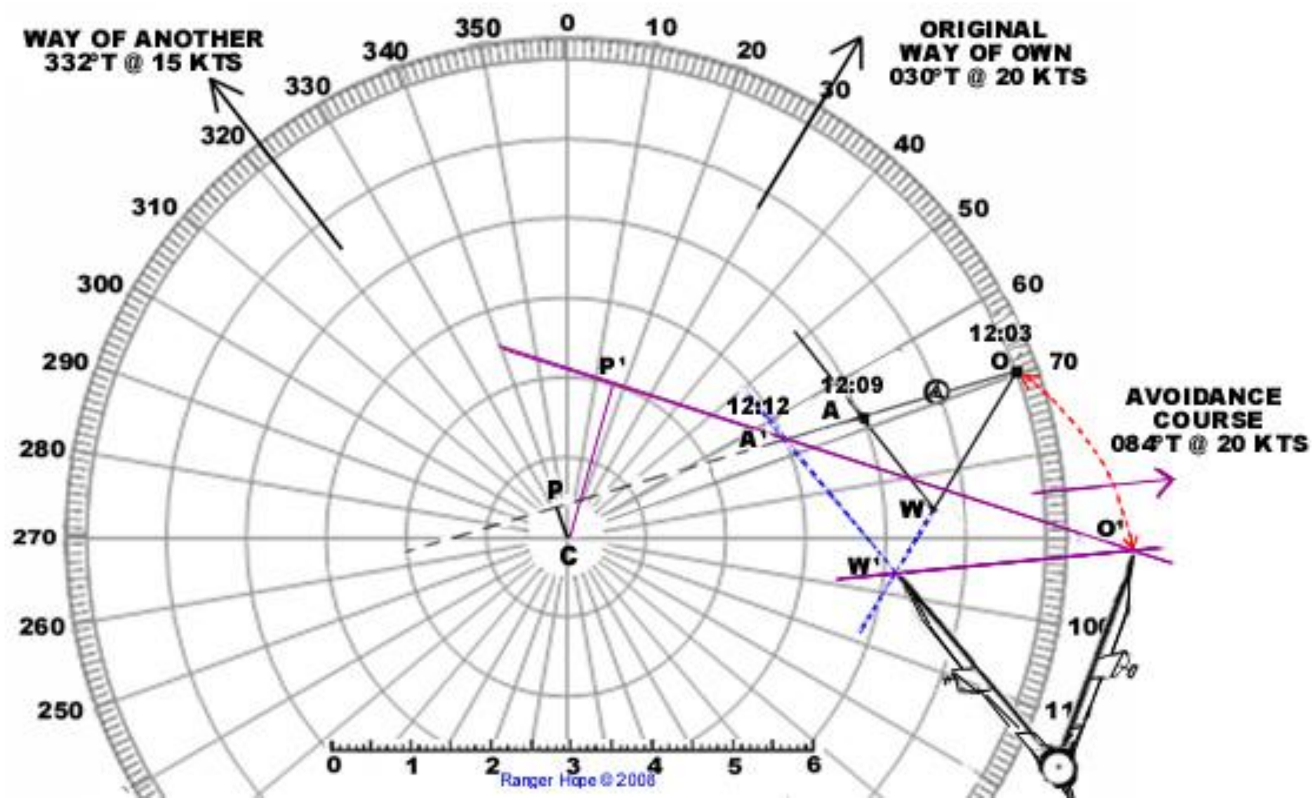


Explanation of Plot 2b. from Page 32.

The underpinning geometry of the previous simplified plot can be seen below, showing how the in both cases the solution essentially re-plotted a new $O^1A^1W^1$ vector triangle. For example:

Finding the CP^1A^1 with delayed 54º to Stb course change:
Extend the vector lines WO and AO lines by 3 minute to the points W^1 and A^1. Transfer the avoidance course (030ºT + 54º Stb = 084ºT) from the outer bearing scale and draw as a line from W^1 extending in the avoidance course direction. With dividers spanning WO, swing arc from O to cross the avoidance course line. Call the crossing point O^1. Draw a line from O^1 back through A and extend past the centre. A perpendicular from the centre crosses this at P^1, the new CP^1A^1.

Finding course required to increase 0.5 miles CPA to 2 miles after delay:
Extend the vector lines WO and AO lines by 3 minute to the points W^1 and A^1. Draw line from P^1 (new 2 miles CP^1A^1) through A (the 2:12 position) and extend. With dividers spanning line WO, swing an arc from O to new position where the extended P^1A line is crossed. Call this O^1. Draw line WO^1 and transfer it to the outer bearing scale to read off the avoidance course, in this case 084ºT.



Extracts for radar from the International Regulations for Preventing Collision at Sea
1972

Part A – General

Rule 2 Responsibility

(a) Nothing in these Rules shall exonerate any vessel, or the owner, master, or crew thereof, from the consequences of any neglect to comply with these Rules or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case.

Rule 3 General Definitions
For the purpose of these Rules, except where the context otherwise requires:
(i) The word "underway" means a vessel is not at anchor, or made fast to the shore, or aground.
(k) Vessels shall be deemed to be in sight of one another only when one can be observed visually from the other.
(l) The term "restricted visibility" means any condition in which visibility is restricted by fog mist, falling snow, heavy rainstorms, sandstorms and any other similar causes.,

Part B - Steering and Sailing Rules
Section I - Conduct of Vessels in any Condition of Visibility

Rule 4 Application
Rules in this section apply to any condition of visibility.

Rule 5 Look-out
Every vessel shall at all times maintain a proper look-out by sight as well as by hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision.

Rule 6 Safe Speed
Every vessel shall at all times proceed at a safe speed so that she can take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstances and conditions.
In determining a safe speed the following factors shall be among those taken into account:
(b) Additionally, by vessels with operational radar:
(i) The characteristics, efficiency and limitations of the radar equipment;

(ii) Any constrains imposed by the radar range scale in use;
(iii) The effect on radar detection of the sea state, weather and other sources of interference;
(iv) The possibility that small vessels, ice and other floating objects may not be detected by radar at an adequate range;
(v) The number location and movement of vessels detected by radar;
(vi) The more exact assessment of the visibility that may be possible when radar is used to determine the range of vessels or other objects in the vicinity.

Rule 7 Risk of Collision
(a) Every vessel shall use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists. If there is any doubt such risk shall be deemed to exist.
(b) Proper use shall be made of radar equipment if fitted and operational, including long-range scanning to obtain early warning of risk of collision and radar plotting or equivalent systematic observation of detected objects.
(c) Assumptions shall not be made on the basis of scanty information, especially scanty radar information.
(d) In determining if risk of collision exists the following considerations shall be among those taken into account:
(i) Such risk shall be deemed to exist if the compass bearing of an approaching vessel does not appreciably change;
(ii) Such risk may sometimes exist even when an appreciable bearing change is evident, particularly when approaching a very large vessel or a tow or when approaching a vessel at close range.

Rule 8 Action to Avoid Collision
(a) Any action taken to avoid collision shall, if the circumstances of the case admit, be positive, made in ample time and with due regard to the observance of good seamanship.
(b) Any alteration of course and/or speed to avoid collision shall, if the circumstances of the case admit be large enough to be readily apparent to another vessel observing visually or by radar;
a succession of small alterations of course and/or speed shall be avoided.
(c) If there is sufficient sea room, alteration of course alone may be the most effective action to avoid a close-quarters situation provided that it is made in good time, is substantial and does not result in another close-quarters situation.
(d) Action taken to avoid collision with another vessel shall be such as to result in passing at a safe distance. The effectiveness of the action shall be carefully checked until the other vessel is finally past and clear.
(e) If necessary to avoid collision or allow more time to assess the situation, a vessel may slacken her speed or take all way off by stopping or reversing her means of propulsion.
(f)(i) A vessel which, by any of these rules, is required not to impede the passage or safe passage of another vessel shall when required by the circumstances of

the case, take early action to allow sufficient sea room for the safe passage of the other vessel.
(ii) A vessel required not to impede the passage or safe passage of another vessel is not relieved of this obligation if approaching the other vessel so as to involve risk of collision and shall, when taking action, have full regard to the action which may be required by the rules of this part.
(iii) A vessel the passage of which is not to be impeded remains fully obliged to comply with the rules of this part when the two vessels are approaching one another so as to involve risk of collision.

Section II - Conduct of Vessels in Sight of One Another

Rule 11 Application
Rules in this section apply to vessels in sight of one another.

Rule 13 Overtaking
(a) Notwithstanding anything contained in the Rules of Part B, Sections I and II, any vessel overtaking any other shall keep out of the way of the vessel being overtaken.
(b) A vessel shall be deemed to be overtaking when coming up with a another vessel from a direction more than 22.5 degrees abaft her beam, that is, in such a position with reference to the vessel she is overtaking, that at night she would be able to see only the sternlight of that vessel but neither of her sidelights.
(c) When a vessel is in any doubt as to whether she is overtaking another, she shall assume that this is the case and act accordingly.
(d) Any subsequent alteration of the bearing between the two vessels shall not make the overtaking vessel a crossing vessel within the meaning of these Rules or relieve her of the duty of keeping clear of the overtaken vessel until she is finally past and clear.

Rule 14 Head-on Situation
(a) When two power-driven vessels are meeting on reciprocal or nearly reciprocal courses so as to involve risk of collision each shall alter her course to starboard so that each shall pass on the port side of the other.
(b) Such a situation shall be deemed to exist when a vessel sees the other ahead or nearly ahead and by night she could see the masthead lights in line or nearly in line and/or both sidelights and by day she observes the corresponding aspect of the other vessel.
(c) When a vessel is in any doubt as to whether such a situation exists she shall assume that it does exist and act accordingly.

Rule 15 Crossing Situation
When two power-driven vessels are crossing so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way and shall, if the circumstances of the case admit, avoid crossing ahead of the other vessel.

Rule 16 Action by Give-way Vessel
Every vessel which is directed to keep out of the way of another vessel shall, so far as possible, take early and substantial action to keep well clear.

Rule 17 Action by Stand-on Vessel

(a)

(i) Where one of two vessels is to keep out of the way of the other shall keep her course and speed.

(ii) The latter vessel may however take action to avoid collision by her manoeuvre alone, as soon as it becomes apparent to her that the vessel required to keep out of the way is not taking appropriate action in accordance with these Rules.

(b) When, from any cause, the vessel required to keep her course and speed finds herself so close that collision cannot be avoided by the action of the give-way vessel alone, she shall take such action as will best aid to avoid collision.

(c) A power-driven vessel which takes action in a crossing situation in accordance with subparagraph (a)(ii) of this Rule to avoid collision with another power-driven vessel shall, if the circumstances of the case admit, not alter course to port for a vessel on her own port side.

(d) This Rule does not relieve the give-way vessel of her obligation to keep out of the way.

Section III - Conduct of Vessels in Restricted Visibility

Rule 19 Conduct of Vessels in Restricted Visibility

(a) This rule applies to vessels not in sight of one another when navigating in or near an area of restricted visibility.

(b) Every vessel shall proceed at a safe speed adapted to the prevailing circumstances and condition of restricted visibility. A power-driven vessel shall have her engines ready for immediate manoeuvre.

(c) Every vessel shall have due regard to the prevailing circumstances and conditions of restricted visibility when complying with the Rules of Section I of this Part.

(d) A vessel which detects by radar alone the presence of another vessel shall determine if a close-quarters situation is developing and/or risk of collision exists. If so, she shall take avoiding action in ample time, provided that when such action consists of an alteration in course, so far as possible the following shall be avoided:

(i) An alteration of course to port for a vessel forward of the beam, other than for a vessel being overtaken;

(ii) An alteration of course toward a vessel abeam or abaft the beam.

(e) Except where it has been determined that a risk of collision does not exist, every vessel which hears apparently forward of her beam the fog signal of another vessel, or which cannot avoid a close-quarters situation with another vessel forward of her beam, shall reduce her speed to be the minimum at which she can be kept on her course. She shall if necessary take all her way off and in any event navigate with extreme caution until danger of collision is over.

Rule 21 Definitions

(a)"Masthead light" means a white light placed over the fore and aft centreline of the vessel showing an unbroken light over an arc of horizon of 225 degrees and so fixed as to show the light from right ahead to 22.5 degrees abaft the beam on either side of the vessel.

(b) "Sidelights" means a green light on the starboard side and a red light on the port side each showing an unbroken light over an arc of horizon of 112.5 degrees and so fixed as to show the light from right ahead to 22.5 degrees abaft the beam on the respective side. In a vessel of less than 20 meters in length the sidelights may be combined in one lantern carried on the fore and aft centreline of the vessel.

(c) "Sternlight", means a white light placed as nearly as practicable at the stern showing an unbroken light over an arc of horizon of 135 degrees and so fixed as to show the light 67.5 degrees from right aft on each side of the vessel.

(d) "Towing light" means a yellow light having the same characteristics as the "sternlight" defined in paragraph (c) of this Rule.

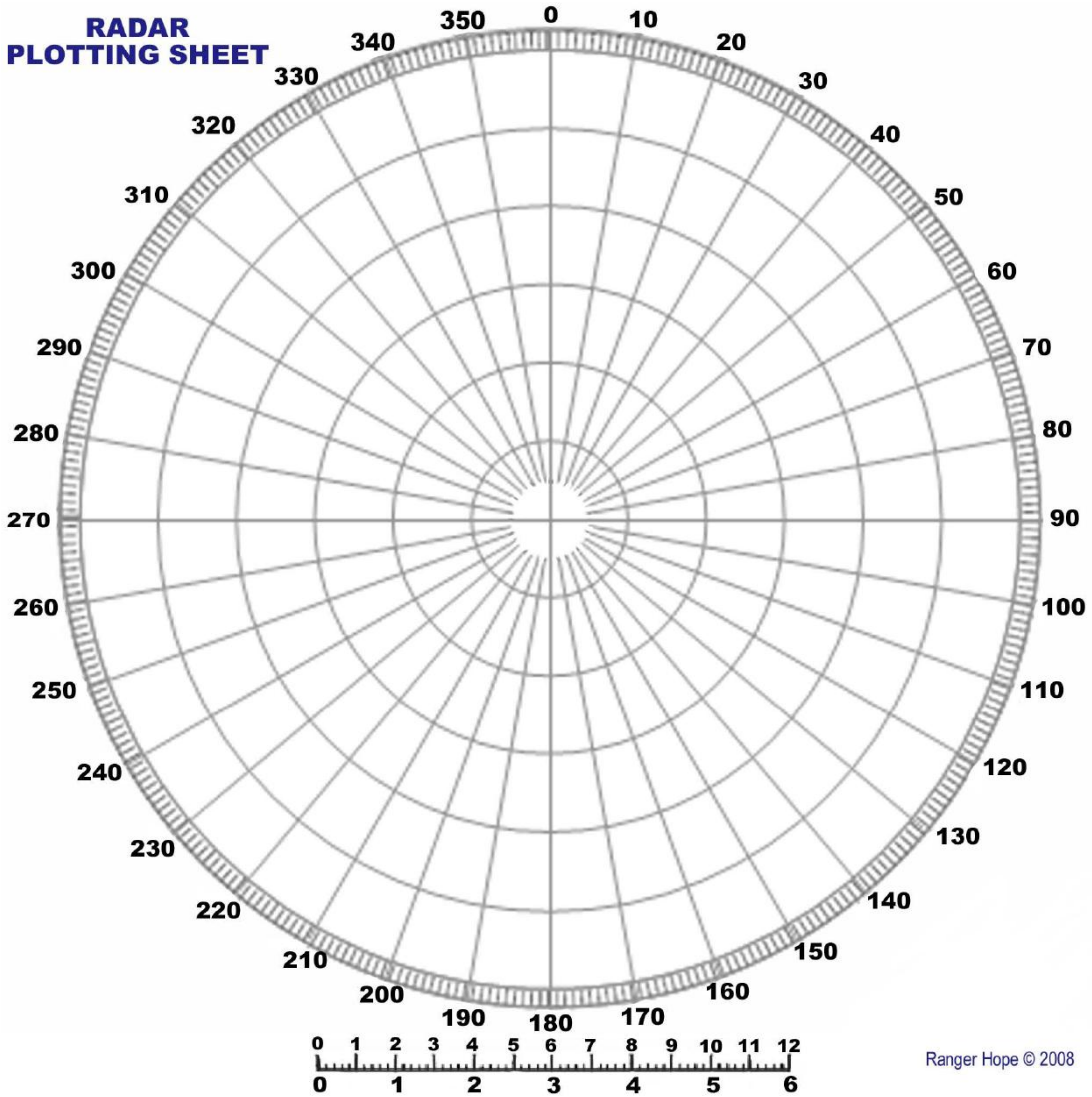
(e) "All round light" means a light showing an unbroken light over an arc of horizon of 360 degrees.

(f) "Flashing light" means a light flashing at regular intervals at a frequency of 120 flashes or more per minute.

References and Acknowledgements:

IMO - International Regulations for Preventing Collision at Sea

W. Burger - Radar Observers Handbook for Merchant Navy Officers


RADAR
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