For an 84-minute system the servo loop gain for 'high' frequency signals is low because of the filtering action of the integrator in the loop. The feedback action is then not very marked and system behaviour is approximately that of simple double integration of acceleration. This is true for missile inertial systems with flight times of only a few minutes, not for aircraft flying for several hours.

This is all well known to the specialists in the inertial field, but not to the increasing number of people who will be coming into contact with such systems as users, maintenance technicians, &c. For their sakes I plead for use of a more accurate description of the basic principle. For most aircraft inertial navigators this is the principle of measuring the change in direction of the local vertical.

Calvert's Manœuvres and the Collision Regulations

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1. INTRODUCTION. The aim of this paper, which was presented to the last meeting of Icotas (London, 14 January), is to show how the manœuvres proposed by Calvert (*Journal* 13, 127) and by Hollingdale (*Journal* 14, 243) could be incorporated in the International Regulations for Preventing Collisions at Sea. Calvert's objective was, as Hollingdale points out, to establish a set of manœuvres whereby a collision situation may be converted into a 'miss' of specified magnitude. In particular:

(i) the rules of procedure are the same for both craft;
(ii) the manœuvres depend *only* on the direction of the relative bearing of the threat;
(iii) each craft makes an instantaneous turn (assumed sharp) *without* change of speed . . . but a 'measure of speed change when the threat is nearly abeam would provide an added safety margin.'

The manœuvres are set down in Section 2 in full as they might appear if included as one of the 'Rules of the Road'. Brief notes (which would not be included in the Rules) amplify or clarify certain details. The complete set of manœuvres need not necessarily be adopted in its entirety; for instance, the proposal to permit 'reverse manœuvres' might be omitted without prejudice to the rest. The new Rule would replace the present Rules 18, 19, 21, 22, 24 and paragraph 6 of the Annex. Since it is essential that Rules should be readily comprehended, Section 3 is an attempt to put the same concepts into more ordinary and seamanlike language. Because much change to the wording of the Regulations may be deemed inadvisable, an attempt is made in Section 4 to incorporate the maximum amount of Calvert's manœuvres with the minimum of change to the Rules. Section 5 discusses the application of Calvert's manœuvres to all, not only power-driven vessels.

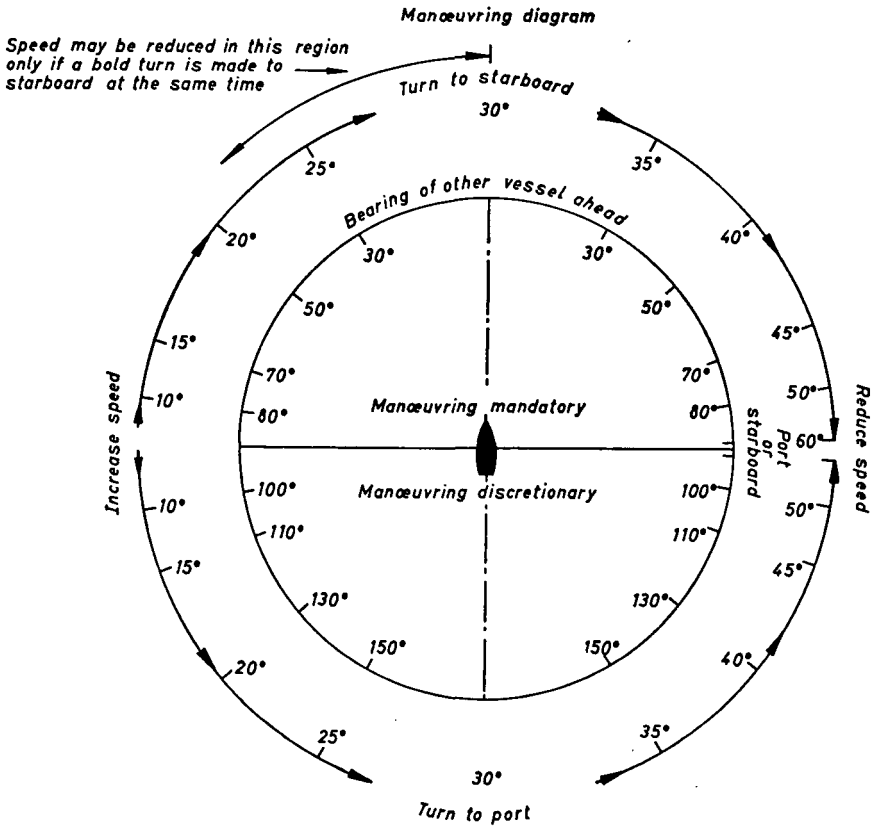

FIG. 1.

2. Draft for a new Rule for power-driven vessels.[1]

(a) When two vessels are proceeding in such directions as to involve risk of collision a power-driven vessel which has the other vessel forward of her beam *shall* make alterations to course or speed or both in such a way that the combination of alterations would produce anti-clockwise rotation of the sight line[2] if the other vessel stood on. A power-driven vessel which has the other abaft her beam *may* alter course or speed or both to change[3] the sight line in an anti-clockwise direction.

(b) Alterations to course or speed or both to cause the sight line to rotate in a clockwise direction may *only* be made if both vessels have explicitly agreed that this shall be done by both of them.[4]

(c) The sight line can be rotated in an anti-clockwise direction by:

(i) altering course to starboard when the bearing of the other vessel is forward of the beam;

(ii) altering course to port when the bearing of the other vessel is abaft the beam;

(iii) reducing speed when the bearing of the other vessel is to starboard;

(iv) increasing speed when the bearing of the other vessel is to port.

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(d) When the other vessel is approaching from a direction which is nearly ahead or astern, an alteration of course is more effective than an alteration of speed. When the other vessel is approaching from a direction which is nearly abeam an alteration of speed is more effective than an alteration of course.

(e) If both vessels alter course as hereafter described the closest distance they will pass each other will be equal to half the distance at which they alter course. When the approaching vessel bears:

Red 80°/80° to port 80° on the port bow,[5] alter course 10° to starboard;
Red 70°, alter course 15° to starboard;
Red 50°, alter course 20° to starboard;
Red 30°, alter course 25° to starboard;
Ahead, alter course 30° to starboard;
Green 30°/30° to starboard 30° on the starboard bow, alter course 35° to starboard;
Green 50°, alter course 40° to starboard;
Green 70°, alter course 45° to starboard;
Green 80°, alter course 50° to starboard;
Green 90°, alter course 60° either to port or starboard.

(f) Paragraph (e) should be a guide to customary action, but it should be remembered that, in fog, a vessel may not be aware of the approach of others and so will not take avoiding action.

(g) When, from any cause,[6] such vessels find themselves so close that collision cannot be avoided by following the above manœuvres, they shall take such action as will best aid to avert collision. (See Rules 27 and 29.)

Notes. [1] The term 'power-driven vessel' is here used because it is employed throughout the present Rules; but it is not a very good choice since *all* moving vessels are driven by some power, sailing vessels by wind power. I would prefer the exact translation of the French 'mechanically propelled', or else 'engine-driven'.

[2] 'Sight line' or 'compass bearing'? The latter is more seamanlike. The words quoted are Calvert's.

[3] 'Rotate' or 'change'?

[4] Paragraph (b) of course assumes that efficient communication is possible and has been established between the two vessels. The only information required to be exchanged is that reverse manœuvres are to be employed.

[5] 'Red 80°' or '80° to port' or '80° on the port bow' are all synonymous; the two former expressions are more concise.

[6] Paragraph (g) is taken from Rule 21 and not from Calvert (who might repudiate it), but it seems necessary in view of Rules 27 and 29.

3. The same Rule expressed in more seamanlike language.

(a) When two vessels are proceeding in such directions as to involve risk of collision, a power-driven vessel which has another vessel forward of her beam *shall* keep out of the way by altering course to starboard.

A power-driven vessel which has another vessel abeam, or nearly abeam, to starboard, *shall* reduce speed.

A power-driven vessel which has another vessel abeam, or nearly abeam, to port, *may* increase speed.

A power-driven vessel which has another vessel abaft her beam *may* keep out of the way by altering course to port.

(b) Alterations of course or speed may be made in an opposite sense *only* if both vessels have explicitly agreed that this shall be done by both of them.

(c) (No change.) If both vessels alter course as hereafter described the closest distance they will pass each other will be equal to half the distance at which they alter course. When the approaching vessel bears:

80° to port, alter course 10° to starboard;
70° to port, alter course 15° to starboard;
50° to port, alter course 20° to starboard;
30° to port, alter course 25° to starboard;
Ahead, alter course 30° to starboard;
30° to starboard, alter course 35° to starboard;
50° to starboard, alter course 40° to starboard;
70° to starboard, alter course 45° to starboard;
80° to starboard, alter course 50° to starboard;
90° to starboard, alter course 60° to starboard or port.

(d) (No change.) Paragraph (c) should be a guide to customary action, but it should be remembered that, in fog, a vessel may not be aware of the approach of others and so will not take avoiding action.

(e) (No change.) When, from any cause, such vessels find themselves so close that collision cannot be avoided by following the above manœuvres, they shall take such action as will best aid to avert collision. (See Rules 27 and 29.)

4. The introduction of Calvert's manœuvres to the Rules of the Road with as little change to the Rules as possible. The basic concept of Calvert's manœuvres is that the manœuvre should be such that the sight line rotates in an anti-clockwise direction (unless, by mutual agreement, the reverse direction is agreed upon by the two vessels concerned). This anti-clockwise rotation of the sight-line manœuvre is already required in clear weather of both vessels when two power-driven vessels are meeting end-on or nearly end-on; of one of two vessels when two are crossing, and, in thick weather, of vessels generally, by the rather weak advice in paragraph (6) of the Annex. In clear weather there is thus little or no need of change and in thick weather when vessels are not in sight of one another, and there is therefore no 'stand-on' vessel, a short addition, preferably to Rule 16(c), should suffice.

Rule 16 (c) would then read (the additional words being in italics): 'Rule 16 (c). A power-driven vessel which detects the presence of another vessel forward of her beam before hearing her fog signal or sighting her visually may take early and substantial action to avoid a close-quarters situation, *but she shall not alter course to port to do so*.

'If a close-quarter situation cannot be avoided, she shall, so far as the circumstances of the case admit, stop her engines in proper time to avoid collision and then navigate with caution until danger of collision is over.'

Notes. This prohibition of an alteration of course to port has been put into Rule 16 rather than into the Annex as being more authoritative here, but it could be relegated to the Annex, leaving Rule 16 unchanged.

A vessel not allowed to alter course to port and unable for any reason to alter to starboard might wish to slow down. If the threat is on the port bow, a reduc-

tion of speed alone will cause the sight line to rotate clockwise; this is covered in the Annex amendment which follows.

The Annex would need some alteration. No change is necessary until paragraph (4) whose last sentence should be omitted. (5) remains unchanged. (6) is new:

(6) If both vessels alter course as hereafter described, the closest distance they will pass each other will be equal to half the distance at which they alter course. When the approaching vessel bears:

80° to port, alter course 10° to starboard;
70° to port, alter course 15° to starboard;
50° to port, alter course 20° to starboard;
30° to port, alter course 25° to starboard;
Ahead, alter course 30° to starboard;
30° to starboard, alter course 35° to starboard;
50° to starboard, alter course 40° to starboard;
70° to starboard, alter course 45° to starboard;
80° to starboard, alter course 50° to starboard;
90° to starboard, alter course 60° either to port or starboard.

This should be a guide to customary action, but it should be remembered that in fog a vessel may not be aware of the approach of others and so will not take avoiding action.

(7) (Partly new.) When the other vessel is abeam or nearly abeam to starboard speed *shall* be reduced. When the other vessel is abeam or nearly abeam to port, speed *may* be increased. When the other vessel is on the port bow, speed may be reduced only if a bold turn to starboard is made at the same time. A reduction of speed should be substantial. A number of small alterations of speed should be avoided.

(8) Unchanged.

5. SAILING VESSELS. In Calvert's original paper he refers to 'craft'. So far the manœuvres have been applied to power-driven vessels only, but they could be followed by all vessels, irrespective of their means of propulsion. This would avoid the necessity for navigators of sailing vessels applying one set of Rules when sailing and another set of Rules when motoring. (Yacht-racing tactics, built up round the present Rules, need not be affected, as special rules used only when racing could still be formulated as they have been in the past.) It would remove the risk of a vessel under sail, but also using her engine, though not displaying the cone point down, required by Rule 14, from being taken for a 'sailing vessel'.

If the new Rule applied to sailing vessels as well as to power-driven vessels, Rule 17 becomes redundant, but Rule 20 could stand almost unchanged. The principle that 'steam gives way to sail' is, in general, still valid, though already qualified by sailing vessels giving way to power-driven vessels engaged in fishing; to all other craft when overtaking them; to large power-driven vessels in narrow waters and, of course, to vessels unable to manœuvre as required by the Rules.

Rule 20 (a) would then read: 'Notwithstanding Rule x (the new Rule) when a power-driven vessel and a sailing vessel are proceeding in such directions as to involve risk of collision, except as provided for in Rule 26, the power-driven vessel shall keep out of the way of the sailing vessel.'

In the drafts proposed in Sections 2 and 3 'power-driven vessels' should then be read as 'vessels'.