the light condition its draught may well be halved, resulting in a being reduced by a possible 40 per cent, producing a 70 per cent increase in β.

The argument in case 3(c) is not easy to follow. Presumably the contention is that two vessels whose centre-lines are exactly parallel will in fact be on courses converging by an angle of $0^\circ.5$. If the ships are so close that this is going to make a difference their masters will no doubt be using other more sensitive variables than ship's heading to decide the possibility of collision.

There remains the 1 kt docking case in example 3(b). The value of β is likely, now, to be outside the linear range. This can be dealt with by rewriting (3) to give

$$Y^{-1}(\beta) = \frac{4C_B B\omega \sin\phi}{V} \tag{6}$$

Putting in the numbers, $Y^{-1}(\beta) = 0.031$ for this case, Martin gives results for a ship of $L/H = 12.74$ and $B/H = 1.85$ at a Froude Number of 0.16 which is close to the characteristics of our ship. Entering a value of the lateral force function into this curve gives a value of $\beta = 6^\circ.9$, or a drift speed of 0.12 kt which corresponds well with Anneveld's figure.

The picture changes, however, if we consider the light ship case. In round figures, L/H will be doubled. Martin has results for $L/H = 25.42$ and $B/H = 2.92$. This is a narrower vessel, but the effect of beam is not great at this low aspect ratio. Using this curve $Y'(\beta) = 0.031$ corresponds with a value of $\beta = 10^\circ$. The resulting drift speed is 0.18 kt—just the critical value quoted by Anneveld. Alternatively, if the ship is brought alongside a quay with no drift, one end of the 440 m vessel will be 77 m further out than the other. This is going to make life interesting for the terminal operators.

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Terrain Clearance During Descent and Approach

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INTRODUCTION. The purpose of the descent and approach is to move the aircraft from the cruise to final approach while keeping within the proper envelopes of speed, acceleration, rate of descent, adherence to A.T.C. clearances, avoidance of bad weather and clearance from terrain and obstructions and other visible aircraft. Man carries out this task, at least until the ILS glide slope is captured. The methods used are not as thorough as the programme an electronic computer

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would need for this task. Perhaps men prefer to use common sense, but perhaps a high level of safety can only be achieved with thorough rules.

PROFILES. The characteristics of the aeroplane and of the atmosphere make one profile theoretically the most economical. Whether or not this is the pilot's preferred profile, he has in his repertoire one or two preferred profiles for use when possible. He therefore starts descent when possible at the appropriate time or distance from destination: if he correctly judged the wind and other factors, he will arrive, without unusual use of thrust or of drag-increasing devices or of height-losing orbits, at final approach at proper speed and height. The normal profile of a jet aircraft is such that only at a few airports does the terrain constrain the descent.

Starting the descent too late may result in arriving overhead the destination too high, necessitating time-consuming circling to lose height, since it may not be possible to steepen the descent much even if the need is recognized. Therefore descents are usually started too soon—too soon that is in relation to the optimum. When it becomes certain that the aircraft is below the desired profile, descent can easily be reduced by increasing thrust. But true airspeed decreases on the descent, from cruising speed or more to about half that speed. Therefore a too early start of descent results in reaching low altitude a long way out followed by a long drag in at low altitude. This is risky unless terrain clearance can easily be checked. It is also more time consuming and uneconomical than descending too late; for each minute the descent is started too early at least one extra minute will be added to the flight time because true airspeed at low altitude is half cruising speed or less. On the other hand, starting the descent too late and arriving overhead too high may often be absorbed with little penalty by steepening the descent near the airfield at low speed with the help of speed-brakes, undercarriage and/or flaps or by continuing the descent on to a long downwind leg. A steep descent for the last few thousand of feet is certainly safer with respect to terrain.

AIR TRAFFIC CONTROL (THROUGHOUT THE WORLD). The effect of A.T.C. is often to bring the aircraft below the optimum profile; the controller likes to get aircraft down too early rather than too late because too late may entail descent in holding patterns which takes up extra airspace and disrupts sequencing. He can more easily deal with horizontal aircraft occupying only a single level than with aircraft descending in a band of levels and liable to be anywhere in the band at any time. And conflicts, for which horizontal flight is desirable, are more likely to occur close in than far out. Incidentally there is now a move to keep jets high above uncontrolled traffic, to descend in special areas near the airport; but this affects only the lower part of the descent.

Once the start of descent has been decided and fixed there may be a tendency to continue descent in the usual way, on the assumption that the desired profile is being achieved. In fact, due to unexpected winds on the cruise and/or descent, the descent may have been started at the wrong point. During the descent clues to deviations from the desired profile may arise from navaids, from pinpoints or from sighting of the ground or airfield. In the absence of such clues, descent may be continued down to the cleared altitude, and that altitude, although safe near the destination may not be safe further out. There is a tendency in both pilots and controllers to believe that E.T.A.s and descent profiles are correct. A.T.C. should accept more responsibility for terrain clearance. A.T.C. should never give a clearance to an altitude which is unsafe for a sector which it is not certain an aircraft has left.

A.T.C. constraints may control the time and therefore the position of the start of descent. They may also delay descent below certain altitudes until certain events occur; these events may be position reports or they may be changeover altitudes at which control of the aircraft is handed over from one controller to another. Loss of terrain clearance may occur if position reports are faulty, which may be due to poor navaids, or if A.T.C. does not work to the following rule: clear aircraft only to altitudes which are safe for the sector in which the aircraft is now as well as for later sectors.

NAVAIDS. The only navaids currently available which provide continuous reliable clues to the pilot for judging his descent profile are those which indicate miles to go, such as DME, doppler with computer and inertial with computer; moving map displays are excellent for terrain clearance. Incidentally Australian A.T.C. even has a descent procedure which uses a schedule of altitudes and DME distances. Perhaps the following measures should be taken: provision of DME at every public transport airport and provision of one of the navaids mentioned above in every public transport aircraft.

RULES. Rules for pilots for safety heights should be clarified. The rules specify safety heights for

(a) a sector, that is the route between two points,
(b) angular sectors around the airport navaid,
(c) the position overhead the navaid (to be used for instrument approach),
(d) procedure turn,
(e) position passing the outer marker on final approach,
(f) position passing the middle marker on final approach.

But the permitted conditions for changing from one safety height to the next are seldom stated, especially for transitions from (a) to (b) and from (b) to (c). Many safety heights are provided for the pilots, but the decision to change from one safety height to the next is left to his common sense and judgment. Some accidents have shown this is not always good enough. Perhaps rules should be developed sufficiently precise for use to programme a computer, then they would certainly be precise enough for human use. Airline safety heights are perhaps only useful in the cruise and as a reminder to pilots of high ground. Their specification is too vague for more thorough use. Since complex rules are difficult to apply quickly, perhaps one unoccupied crew member or a computer should, in large aircraft, continuously monitor terrain clearance. Monitoring by both A.T.C. and aircraft is necessary to guard against mistakes, for instance mistakes of navigation or radar identification.

Information on areas and safe heights where aircraft are descended under radar control should be provided to pilots and navigators. The areas should be defined by lines easily discerned by aircrew, for instance VOR radials or DME distances. While following radar instructions they could then easily check terrain clearance.

VISUAL FLIGHT. Rules about safety heights should apply day or night in all weather except perhaps when all the following conditions are satisfied:

(a) ground visibility is reported better than 5 kilometres,
(b) in-flight visibility is better than 5 kilometres,
(c) speed is low,
(d) sufficient ground pattern, perhaps including the runway, is visible.

One dangerous optical illusion is worth mentioning because of the way A.T.C. encourages pilots to call 'field in sight' and because of the tendency for pilots to relax once the field is in sight, be it ever so distant—and the distance is notoriously hard to estimate visually especially at night.

As Fig. 1 shows, danger exists if poor visibility or cloud or darkness hides the nearby high ground when the gradient of descent (B) exceeds the gradient of the sight-line (A) from the pilots' eyes to the nearest part of the ground pattern

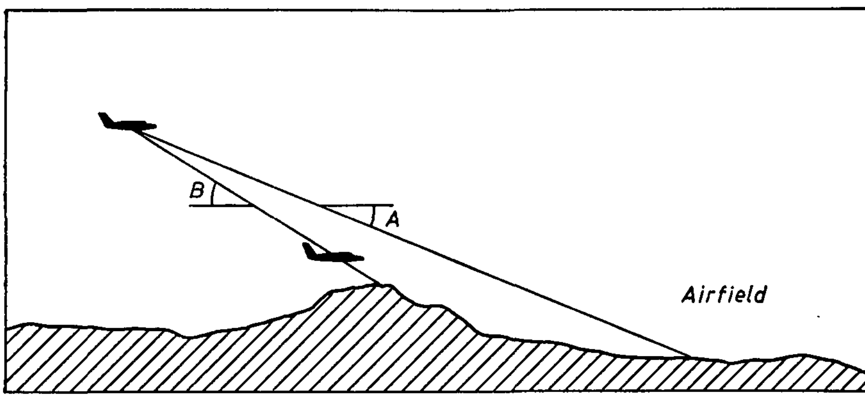

FIG. 1. The gradient of descent and gradient of sight-line

visible ahead. Some information on B is given by indicated rate of descent and airspeed or groundspeed. If ground pattern fills a big enough part of the field of view in the right direction, direct vision may establish B through showing the point towards which the aircraft is moving. Direct vision is good for establishing horizontal directions from points on the ground, but it establishes vertical direction and distance only approximately; therefore (A–B) has to be perceived as big before it's safe to assume it's not negative. The figure shows how an aircraft can strike high ground while having the field in sight almost to the last moment.

Unless it is known that there is no high ground in the area, at night areas of ground pattern without lights must be assumed to be on high ground, which incidentally often has fewer lights than low ground. If ground pattern is visible by day, ground texture is generally visible and this enables direct perception of height above terrain; by night generally only lights are visible and direct perception of height depends on perception of angular motion of the ground pattern. Even when direct vision is good, the experienced pilot also uses such information as elevation and position of high ground, indicated altitude and position as given by navaids to establish position; he then manœuvres the aircraft in the horizontal plane often by reference to the ground pattern, especially the runway; but he manœuvres the aircraft in the vertical dimension rather by reference to his instruments.