1. INTRODUCTION

During the last decade, the hovercraft became one of the world's transportation systems. Thus it was demonstrated, once again, that history has a strange habit of repeating itself.

In 1903 the Wright brothers flew at Kittyhawk without a full understanding of subsonic aerodynamics; and again, in 1947 Chuck Yeager flew the X-1 research airplane at a speed greater than that of sound without a full understanding of supersonic aerodynamics. So it was in the 1960's that there existed a situation wherein a potentially viable commercial system was operating without a full understanding of the aerodynamics upon which that system was dependent.

While it is true that the theory of air-cushion support had been probed in considerable depth at a very early stage of hovercraft development, little or nothing had been done to study those aspects of subsonic aerodynamics upon which the handling qualities and control of hovercraft were so vitally dependent.

In late 1966, a feedback of operational experience was coming to hand from a first generation of amphibious hovercraft operating on a scheduled basis with revenue payloads on relatively-short over-water routes. On some of these routes, open-sea conditions prevailed. The feedback from these operations indicated the existance of certain problem areas, one of the most important being concerned with handling qualities.

As in the case of airplanes, the handling qualities of hovercraft depend heavily on their stability and control characteristics. In the case of hovercraft, however, the problem is rather more complex being dependent on aerodynamic, hydrodynamic, and air-cushion effects. There are also important interference effects at the aero-hydro-interface. Thus, in order to understand the overall handling problem, each of these contributory effects must be isolated from the others, so that individual study from a stability and control viewpoint can be attempted. The task of isolation is difficult. It does not fall within the scope of full-scale tests, neither is it amenable to analysis except possibly in the case of air-cushion effects where good progress has been made using mathematical analysis.

Faced with this situation, in early 1967 the then-responsible Ministry of Technology contracted with the former College of Aeronautics (now the Cranfield Institute of Technology) to explore on an experimental basis the effect of external aerodynamics on the handling and control qualities of hovercraft. This programme of research formed a natural complement to various programmes of hydrodynamic experimentation which were then proceeding, and still continue, at the facilities of the National Physical Laboratoty at Feltham.

The programme of aerodynamic experimentation at the Cranfield Institute was completed as recently as the end of 1970 and the subject matter of this paper has been drawn exclusively from this programme of research.

2. HANDLING QUALITIES OF AMPHIBIOUS HOVERCRAFT

Prerequisite to exploring the handling problem, it is necessary to examine the aerodynamic environment of the hovercraft. This is shown in Figure 1. We consider the hovercraft to be operating at a constant true speed in a wind which may have any bearing to the track of the hovercraft. It will be seen that dependent on wind direction, there can be substantial differences in cruising airspeeds. At low true speeds, airspeeds may even be negative; and operating sideslip angles may be anywhere between ±180°.

Longitudinal handling problems are illustrated in Figure 2. They may be summarized as -

(i) the effect of wind direction on longitudinal trimming in cruise conditions,
(ii) trim changes due to sudden changes of power setting, and,
(iii) the plough-in and stern breakaway prelude to the catastrophic roll-over.

Low speed lateral handling problems are shown in Figure 3. They may be summarized as -

(i) the questionable value of fins which provide high speed weathercock stability, and,
(ii) the problem of excessive drift when turning down-wind.

High speed lateral handling problems are shown in Figure 4 and may be summarized as -

(i) finding the means by which centripetal force can be generated to promote the turn, and,
(ii) the avoidance of adverse yawing moments due to transverse asymmetric skirt contact or clearance at the aero-hydro-interface.