THE COLLEGE OF AERONAUTICS

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Swift Aquaplaning trials

1. INTRODUCTION

The object of the investigations at Cranfield is to investigate the effect of water depth, surface roughness - drainage characteristics and tyre pressure on aquaplaning and tyre ground friction.

Tests at Cranfield are full scale on the single main-wheel undercarriage of a Vickers Supermarine Swift F.7. operated through ponds of water on a test surface. The test area is a precision surface, level to an accuracy of 1/16" over its entire width. The levelled area is built into runway 22-04 and consists of six different surfaces of varying texture, three of concrete and three of asphalt, arranged as shown in fig. 1. The ponds are constructed of 1½" T section rubber strip affixed to the surfaces by suitable adhesives which were selected after a series of tests.

The Swift is fitted with an A.22 recorder giving traces of port and starboard wheel speeds, obtained by means of wheel speed generators, and airspeed. A modification is in hand to record oleo leg extension as a measure of wheel load and hydrodynamic force.

2. TEST AND MEASUREMENT TECHNIQUE

It is necessary before runs to await suitable weather conditions; strong and gusty winds cause rippling in the ponds rendering accurate depth measurement impossible. Furthermore, a headwind above about 10 knots causes heaping of the water at the downwind end of the pond so that a stable state of aquaplaning for any given depth is not attained. These conditions are of course in addition to the normal limitations for operating aircraft - weather then is an important factor in rate of progress. With the ponds filled with water to the required depth, say one inch, the depth of water is measured using a 20° wedge (fig. 2). Readings are taken at ten foot intervals over the whole length of the pond to ensure that a uniform depth exists. The Swift is flown on to the runway, the nosewheel held firmly down and the mainwheels directed through the ponds. The layout of the ponds allows the Swift to traverse two surfaces on one run, first concrete, then asphalt, recording values for two surfaces per run. In the course of its run a quantity of water is ejected

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from the ponds, this is accepted as the depth is required to be the variable parameter. Thus the Swift may make its next run as soon as measurements have been made, no time is then wasted on water pumping.

Aquaplaning depths are measured using a 10° wedge shaped board at right angles to the direction of travel. The wedge is coated with "plastic padding" which is marked by the tyre at a position which is determined by the height of the tyre above the runway surface (see fig. 3).

From the recorded trace of wheelspeed, ground speed is obtained, the trace also gives clear evidence of wheel spin down confirming that aquaplaning did occur. It is hoped that the oleo leg measurements will give a trace which, from the calibration curve already obtained can be used to give a measure of normal reaction or hydrodynamic force.

The range of aircraft ground speeds to be covered in subsequent trials is primarily fixed by considerations of flight safety. In the 3770 feet of runway remaining beyond the test area the pilot must be sure that, on the one hand he can complete a take off or alternatively that he can brake to a full stop. The decision made of course depends on the speed demanded at entry to the test area and on whether braked or free rolling conditions are under investigation. With the co-operation of the B.L.E.U. several take-off and landing runs were measured at R.A.E. Bedford to provide helpful aircraft performance data.

3. DISCUSSION OF RESULTS

Figure 4 shows the curves obtained for the trial runs, which were carried out at one tyre pressure at two ground speeds. The curve obtained by Gray at the R.A.E. Farnborough is also shown for comparison. As can be seen the curves are identical in shape, the difference in height is to be expected since Gray's runs were completed at 90 knots and 65 p.s.i. tyre pressure. It is however interesting to note that the relative distance between Gray's curve for 90 knots and that between the curves for 130 and 140 knots groundspeed obtained in the Swift appear to be of corresponding order.

Hydrodynamic force has been measured in a variety of experiments previously, as also has the critical aquaplaning speed for which a formula has been derived which agrees with

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experimental results. However very little effort has been expended on the significance of the aquaplaning depth i.e. the depth at which the aquaplaning tyre rides above the surface.

Presumably for a given wheel load, surface and ground speed a tyre will sink to an unique depth in any given depth of water. If the factors are such that the wheel sinks to the tips of the tallest asperities then a little friction is generated. As it sinks to meet an increasing number of asperities so the friction increases in a manner dependent upon the general shape and distribution of asperities. Now an element of tyre tread is in contact with the water film for a given length of time depending on tyre pressure (contact length) speed and wheel load, if in this short time the element can sink to the surface a certain amount of friction is achieved, otherwise the tyre will aquaplane. Thus it is apparent that the governing factor is the rate of sink of the tyre, this is known to vary with depth of water, normal pressure and surface drainage characteristics. In the U.S.A. a great deal of work to this end is being done by Moore, both theoretically and by observing the sinkage of flat plates through oil onto a surface of certain roughness.

The programme at Cranfield aims initially at obtaining plots of sink rate with depth for various surfaces and tyre pressures under full scale conditions, with the aim of using this information to explain the phenomena of aquaplaning and low friction and to enable an accurate prediction of dangerous conditions. By varying water depth it is also hoped to measure the critical depths for aquaplaning and the variation of this parameter with speed, runway roughness and drainage qualities.

A numerical value for runway drainage quality is to be obtained by deriving the mean depth of the drainage channels by working a known volume of grease or sand into the channels over a known area of surface, this is in line with work being carried out at other establishments.

4. CONCLUSIONS

Although lack of performance data on the aeroplane has until recently limited runs to 140 knots indicated air speed an experimental technique has been evolved and measuring devices perfected. A series of runs has been made giving results which show great promise, both by their agreement with previous work by Gray and by their compliance with the accepted mechanisms of the phenomenon.

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With aircraft performance now known and experimental technique perfected, series of runs will be carried out at various combinations of speed, water depth, tyre pressures and surfaces, this should give a clearer understanding of tyre-water film - ground interaction. So far the runs have been free rolling but braked runs will commence in the near future. Thus it is hoped to collect extensive data on sink rates and critical depths which will give a clearer insight into the problem from a practical standpoint.

REFERENCES

1. 'Measurements of "Aquaplaning Height" on a Meteor aircraft, and photos of flow pattern under a model tyre'
W.E. Gray, D.F.C.
R.A.E. Technical Note No. Aero. 2855. November 1962.

2. "Drainage criteria for runway surface roughness"
D.F. Moore
Journal of The Royal Aeronautical Society. May, 1965.

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LAYOUT OF LEVEL TABLE FOR AQUAPLANING INVESTIGATIONS.

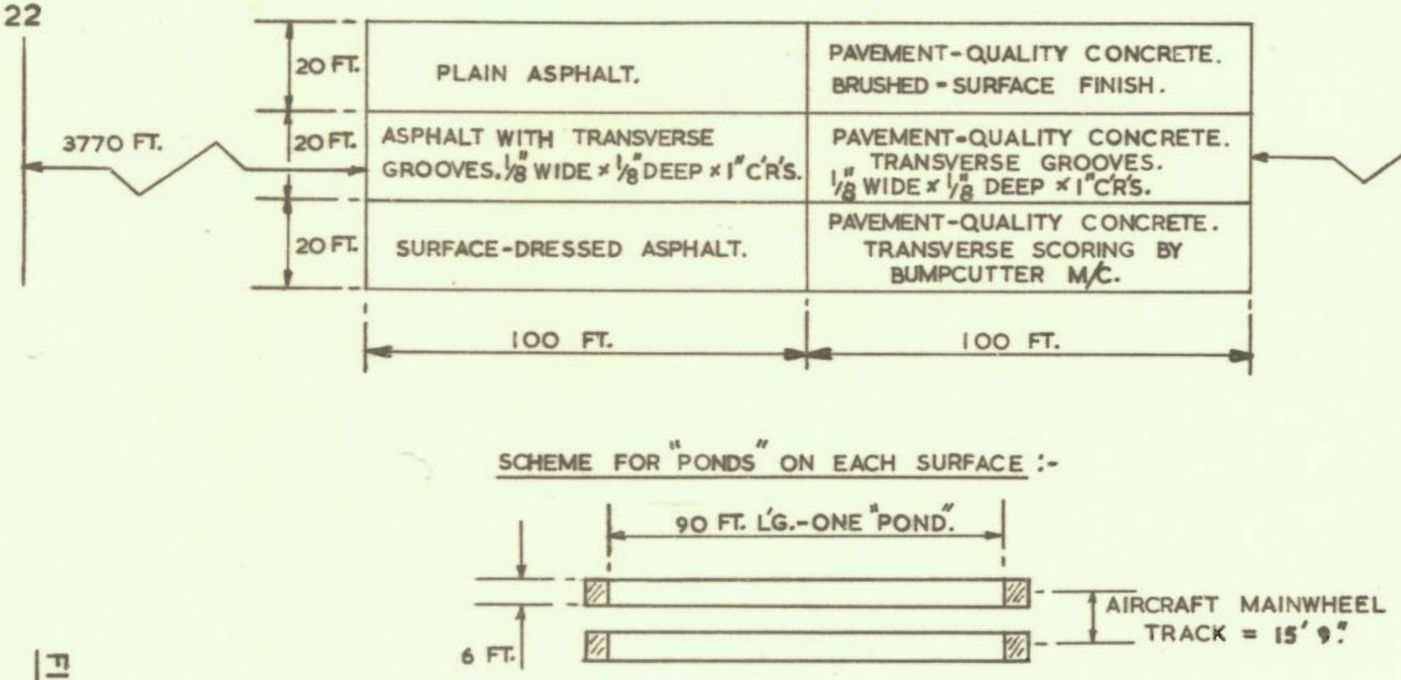

FIG. 1.

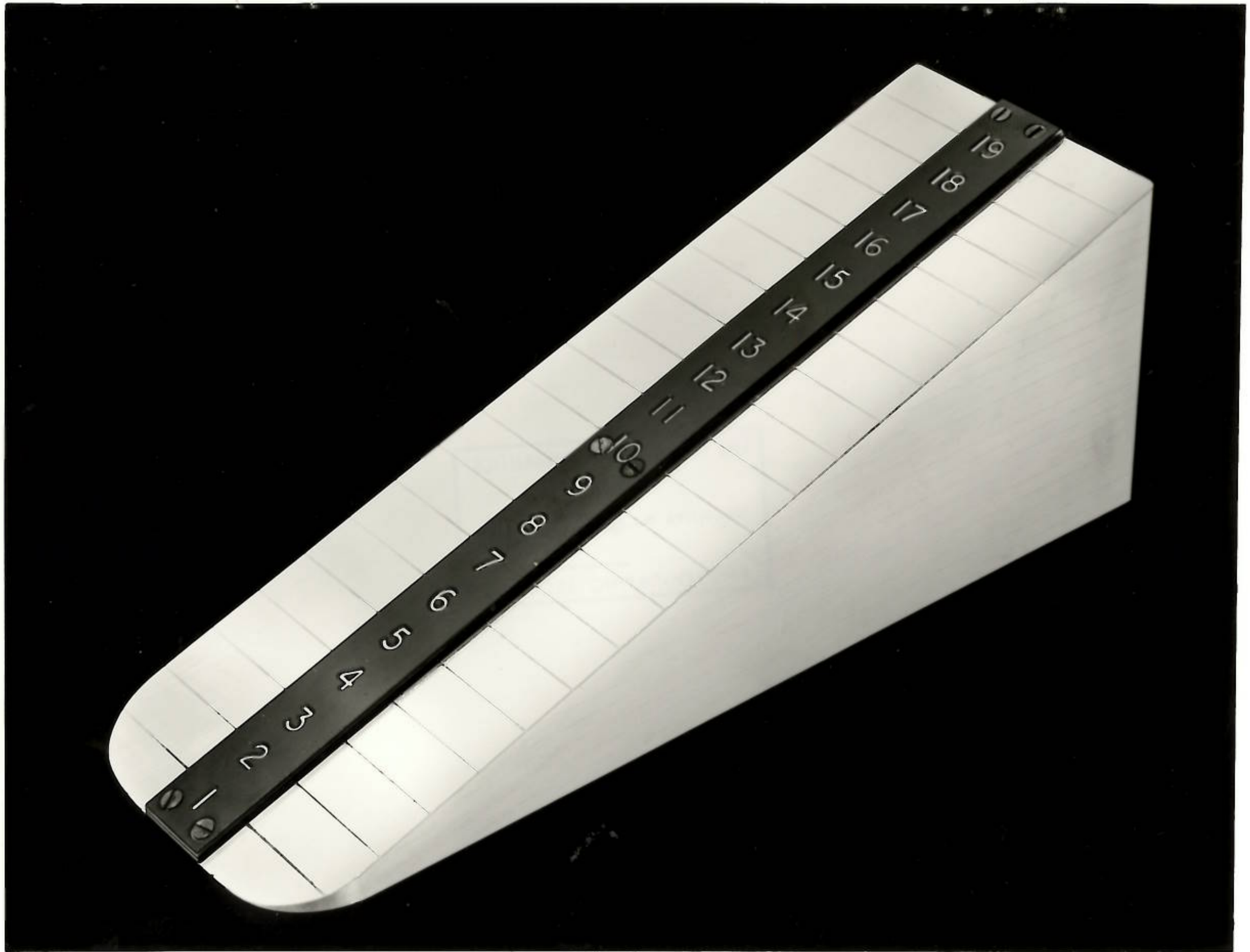

FIG. 2

FIG. 3

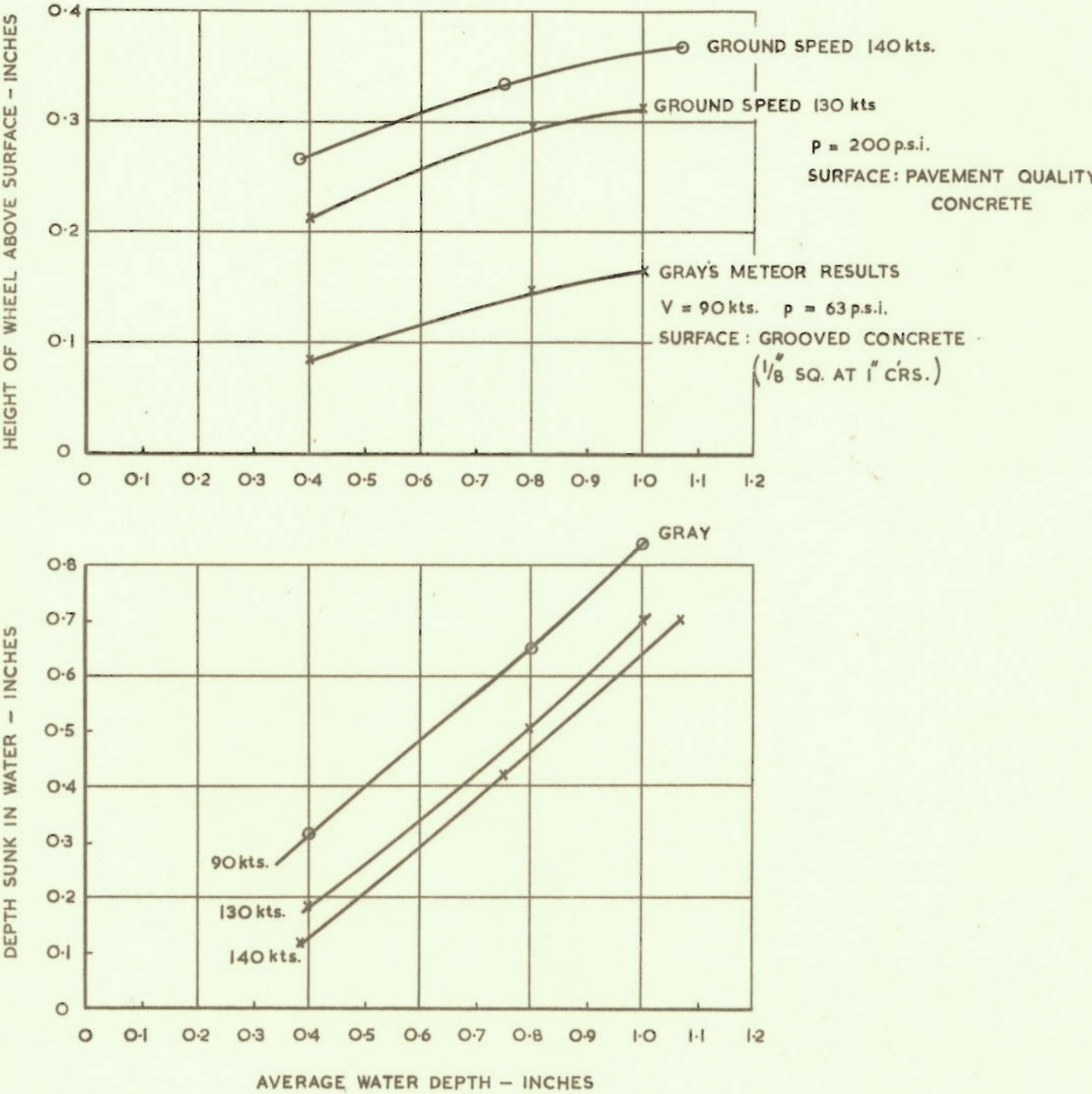

FIG. 4. AQUAPLANING OF A FREE-ROLLING WHEEL IN VARIOUS DEPTHS OF WATER

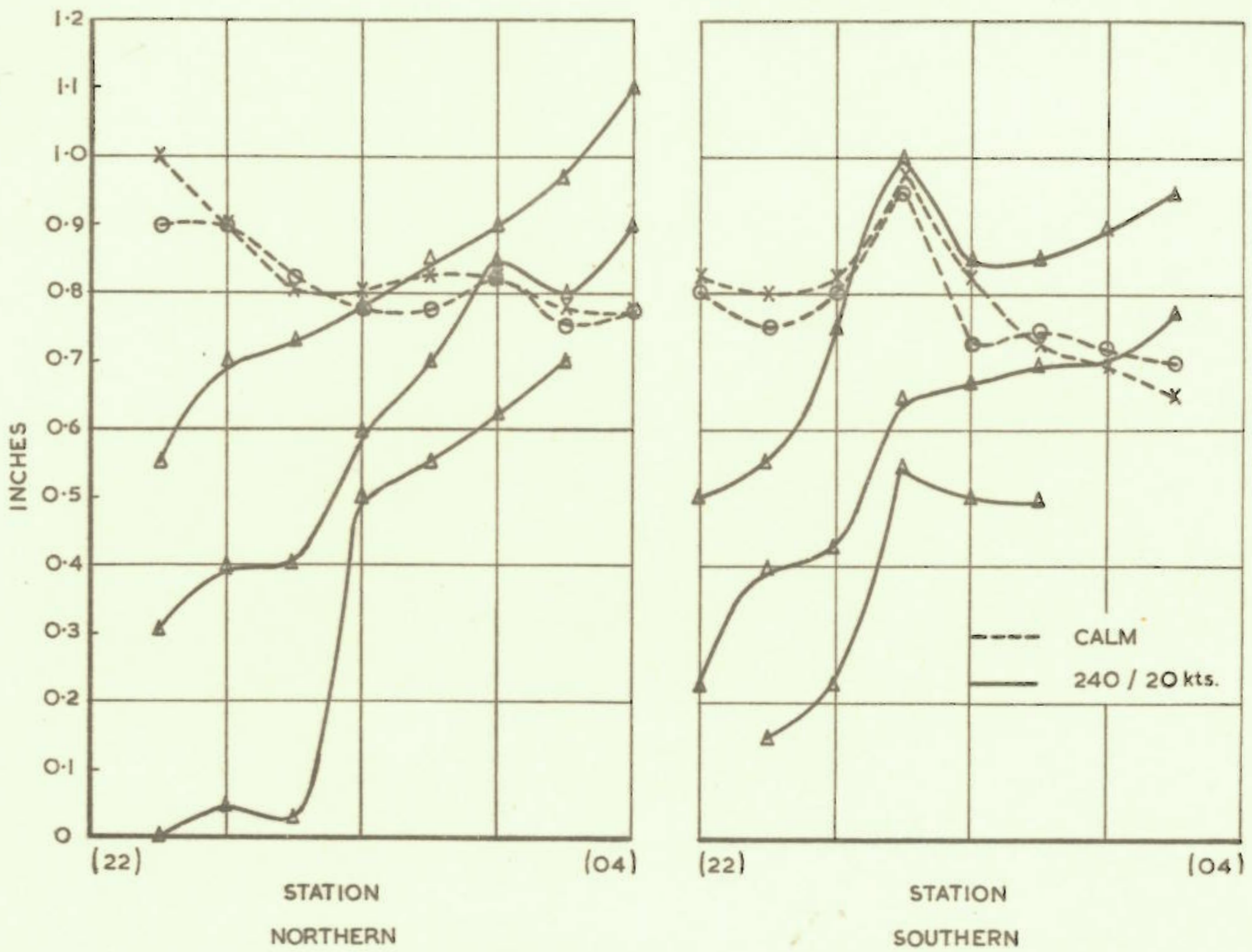

FIG. 5. TYPICAL DEPTH MEASUREMENTS, PONDS ON PAVEMENT QUALITY CONCRETE