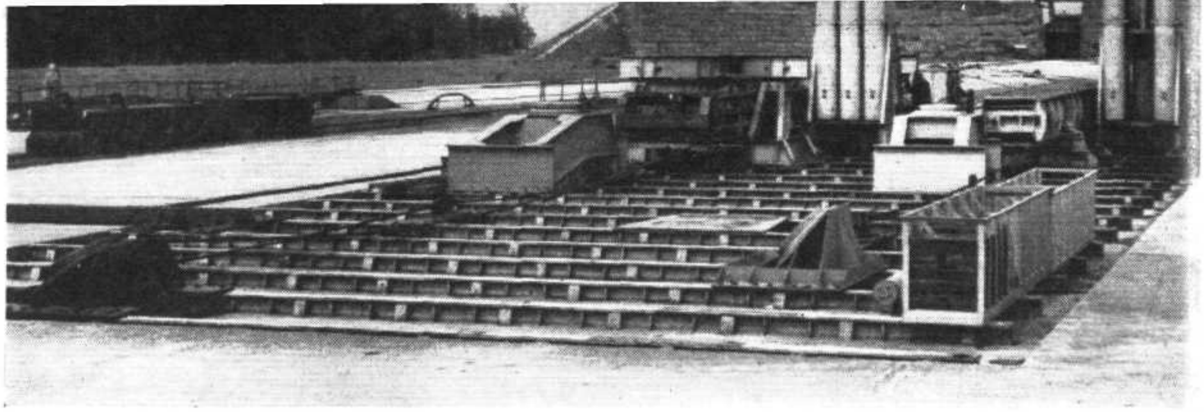

Part of the test equipment at the safety barrier and arrester gear proving base at Bedford

Arresting RN Aircraft . . .

danger of the main ram bottoming in the main cylinder, as even at the end of the spline barrel stroke some clearance orifice remains. If this happens and the aircraft still has way on, the aircraft/energy absorber link may part with disastrous consequences.

The Link

For all hydraulic gears the link between the aircraft and the gear is a steel wire rope stretched across the deck with an initial tension and raised above the deck by steel springs in the shape of a bow. In the ship case the bowsprings are retracted by power. The wire rope from the deck is led via a system of guide pulleys to one of the pulley blocks at either end of the main ram; it is then wrapped around the two crossheads missing every alternate pulley. A second wire rope from the deck is led to the other pulley block and wrapped around the two crossheads on the remaining pulleys in the opposite sense from the first rope. The reeving system is indicated in Fig 1. One unit therefore serves two centre-spans on the deck and each wire when rigged is a continuous length of 150 fathoms which serves opposite ends of two centre-spans. As the length across the deck is subject to heavy wear, means are provided for removal so that the centre span may be changed. The wire used in the system is of high quality and special construction determined by tests at NAD and at the manufacturers, British Ropes Ltd, Doncaster.

Basic Problems

The design requirement is the dissipation of a given amount of energy in a certain distance and within the strength of the aircraft and the limits of the human frame. The energy absorbed in a distance of just over 200ft is in excess of 15×10^6ft-lb and this gives rise to a retardation approaching 3g. The limits for the man are uncertain but they are probably of the order of 6g for a sustained load and appreciably higher for peak loads. The distance in which the aircraft has to be stopped is determined by the ship layout and is unlikely to alter appreciably. If uniform retardation were achieved throughout the stroke then higher entry speeds than those currently obtaining could be accepted. In practice the first part of the stroke is used in accelerating the moving parts of the system, of which the rope is a big proportion, up to the speed of the aircraft. These impact loads occasioned by inertia put high forces on the aircraft. Uniform deceleration is therefore not achieved, the ratio of maximum to mean retardation being about 1.5 for modern gears.

The main problems are therefore to use as little of the stroke as possible in accelerating and to secure as closely uniform an acceleration as possible. As far as the hydraulic system is concerned these two points are dependent upon the profile of the grooves in the spline barrel, i.e. at the beginning of the stroke the discharge orifice must be wide to enable speed to be built up rapidly and must then gradually reduce in an attempt to achieve uniform retardation. The hydraulic efficiency is high, for if the mean pressure for the stroke is calculated from the amount of energy absorbed by the unit and related to the maximum pressure produced the ratio is approximately 1.25. The difference between this figure and the overall maximum to mean retardations of 1.5 previously quoted is occasioned by tensions built up in the wire rope system by wave phenomena. This is at present the principal problem and the main obstacle to increased entry speed.

The major parameters which bear upon the problem of attempting to achieve uniform retardation within the strength limits of the aircraft, the wire rope, the main cylinder and the pulley bearings are listed in the next section. The variation of these parameters throughout the arrest is not amenable to calculation and they are therefore recorded from the unit under test conditions at Bedford. From these results, performance is established and improvements recommended. In the course of establishing the performance, mechanical faults occur and remedies are proposed. These improvements in performance and operation result from close co-operation between McTaggart Scott, DGS and NAD.

Main Parameters

The variables measured are rope tensions, main cylinder pressure, ram stroke and aircraft or deadload retardation.

Rope Tension. This is measured using a five sheave rope rider. The rope is deflected around a sheave mounted on a spindle which is supported through strain-gauged links. Under tension the rope attempts to straighten and the pulley support is loaded, thus causing an alteration in the gauges which is recorded and related to rope tension. This rope rider was developed in NAD and has proved extremely successful. Rope tensions are measured at the deck edge sheaves and just before and just after the gear. The difference in tension recorded at these positions is of the order of 10 tons for high energy shots and is caused by reflections and pulley and rope friction as the tension wave passes through the gear. A strain-gauged coupling can also be used to measure rope tension by recording the change caused by the elongation of a connection in the rope. This method suffers from the disadvantage that the connecting lead to the strain gauge is subjected to the same motion as the rope with an increased danger of failure. The measurement of the tensions in the centre span has not so far proved feasible. Attempts are now being made to determine the loads induced in the supporting structure, either of the hook in the aircraft case, or of the bollard in the deadload case, by strain-gauging the supporting members. Indications are that successful records will be achieved but the estimation of rope tensions at the engaging point from the loads in the supports involves a knowledge of the wire geometry at the hook throughout the arrest which is a fundamental property very difficult to assess, as the following brief explanation will indicate.

The behaviour of tension waves in a complicated wire system is imperfectly understood. The only detailed UK study of the problem* applies accepted theory to the arrester gear case over a limited range during the early stages just after impact. This application has not been systematically proved by controlled experiment although a test vehicle to do this has been part of NAD's programme for some time. It is the old story of day-to-day problems taking priority over the furtherance of fundamental knowledge. However, measured tensions accord reasonably well with theory for high entry speeds.

The facts fundamental to the study of tension wave phenomena are that the speed of propagation of a longitudinal stress wave is given by

$$K = \sqrt{\frac{Eg}{\rho}}$$

i.e., the speed of sound in the rope. The speed of propagation of a transverse disturbance is given by

$$c = \sqrt{\frac{Tg}{m}}$$

where E=elastic modulus, ρ=density, g=acceleration of gravity, T=tension, m=line density.

From these two fundamental formulae the following relationship can be deduced for transverse impact of the kind experienced in the arrester gear application

$$T = v^{\frac{4}{3}} \left(\frac{K}{2}\right)^{\frac{2}{3}} \frac{m}{g}$$

This expression is a first approximation and assumes no initial tension in the wire. It can be expanded to give a more rigorous treatment.

When the rope is struck a longitudinal tension wave is engendered which stretches the rope between the point of impact and the front of the stress wave and this stretch gives the slack for the formation of the transverse wave. The transverse wave is partially reflected and partly transmitted by impact with the centre span couplings and the deck-edge sheaves, and subsidiary longitudinal and transverse waves are set up, some of which return to the impact point until the whole system vibrates violently.

It can be shown that for the case of impact with the deck edge

* *Behaviour of Ropes under Longitudinal and Transverse Impact*, by J. Thomlinson. RAE Report No NA227.