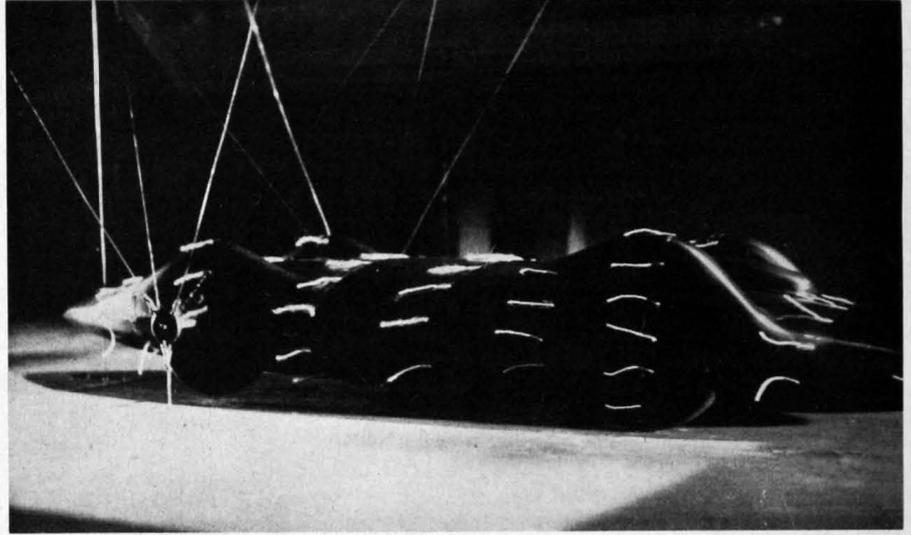


Land Speed Record Contender

A shaft-turbine-engined "Bluebird" designed to exceed 400 m.p.h. is being built for Mr. Donald Campbell to use in an attempt upon the world land speed record. The specifications and overall design were prepared by Norris Brothers, Ltd., and proved to be within the state of the art for all components except tyres.



IN September this year Mr. Donald Campbell intends to attack the world's land speed record at the Bonneville Salt Flats, Utah, U.S.A., with a new "Bluebird," the "C.N.7." The record was set at 394.196 m.p.h. in 1947 by the late John Cobb, and the "C.N.7" was projected by Norris Brothers, Ltd., the consulting engineers of whom Mr. Campbell is chairman, to have a maximum speed of 475 m.p.h. The evolution of light and powerful gas turbines has rendered the generation of sufficient power on a moving vehicle no longer a serious problem, and during the design of the car it proved that the one component whose capability limited the performance and dictated alterations to the design was the tyre. Weight saving and even drag reduction are prosecuted solely to lighten the duty of the tyres.

It should be made clear that the car has been designed to establish a record which will be recognised by the International Automobile Federation, whose regulations state that it must have at least four wheels, "not aligned," always in contact with the ground, at least two of the wheels steering and at least two driving. Thus, in principle, the car holding the I.A.F. record need not hold the absolute land speed record, which

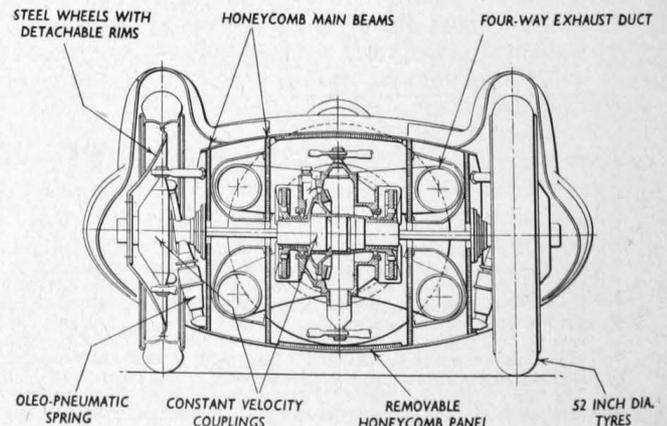
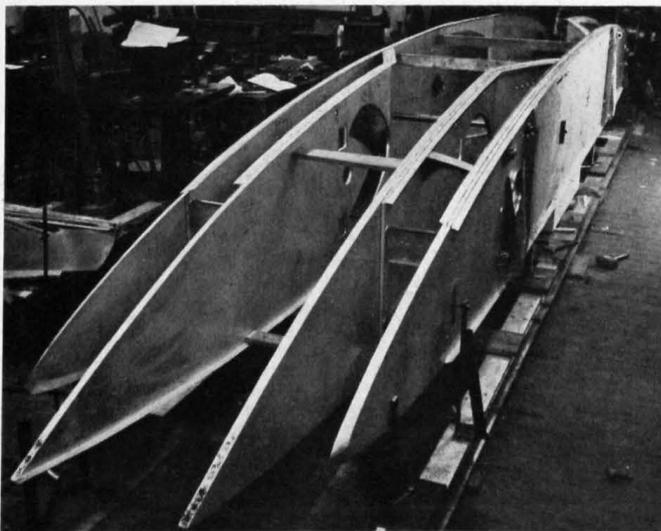
could belong to a motor cycle or to a vehicle with reaction propulsion. It need hardly be remarked that no wheeled vehicle can approach the speeds attained by rocket sleds in various research establishments.

The first tentative design used wheels 48in diameter over the tyre, but the Dunlop Rubber Company, Ltd., which has been and is responsible in all respects for the tyres, considered 50in the minimum at which centrifugal forces could be accepted and preferred 52in as offering prospects of even higher speeds. The 52in diameter appealed to the designers because it gave adequate ground clearance with the engine (a Bristol—now Bristol-Siddeley—"Proteus" was selected from the first) centre-line in the plane of the wheel centres*; it is interesting to note that the ground clearance remains positive with one tyre deflated, and that if the vehicle overturns it will be supported on the tops of the wheels. The use of a "Proteus" dictated other important characteristics of the design; since it has, in effect, a ring of air intakes around the centre section, a plenum

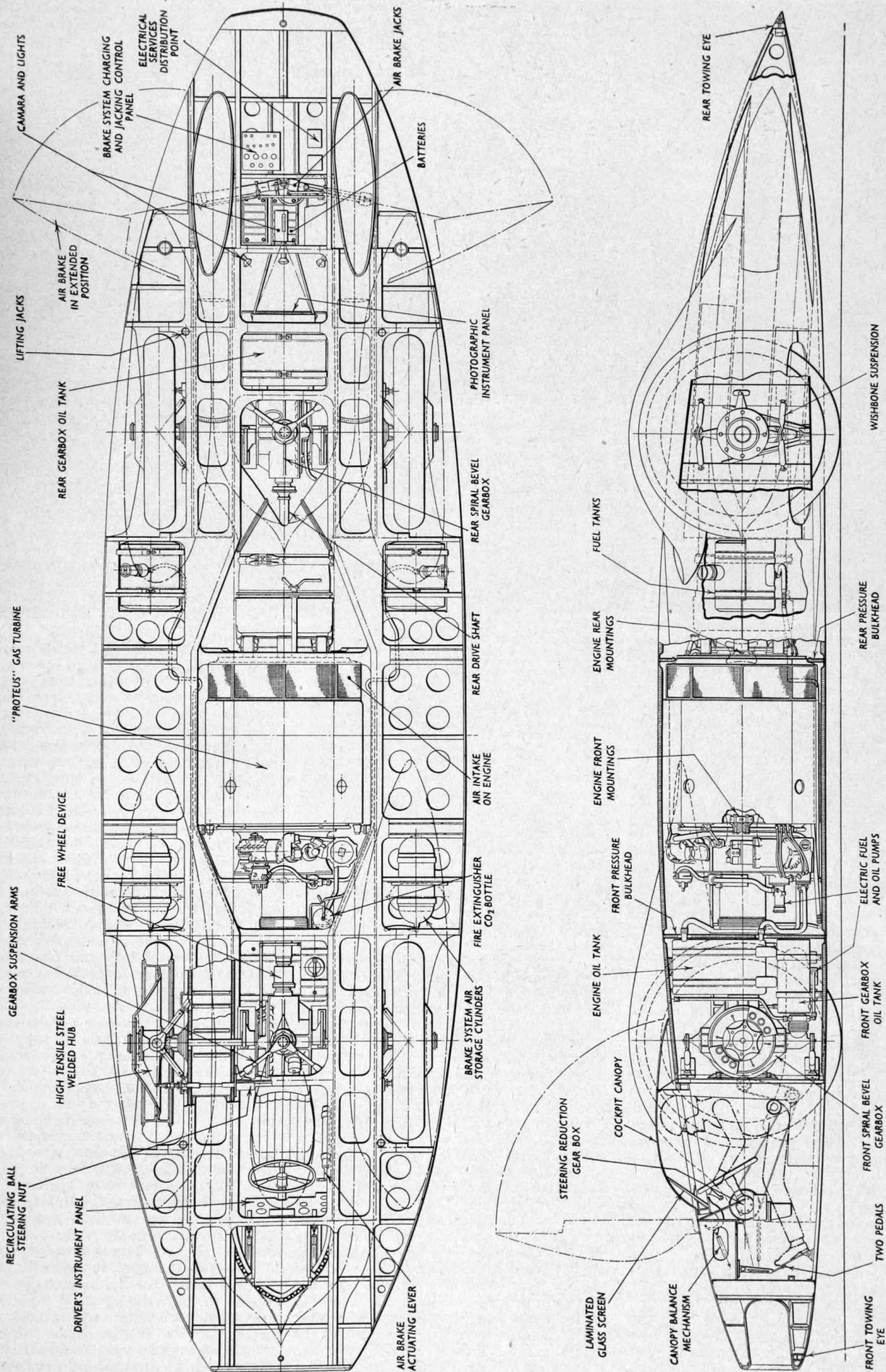
chamber installation was virtually mandatory, so that the steel-tube-frame construction of the Norris-designed "Bluebird" hydroplane was forsaken for an "egg-box" design in which the strength members are panels capable of supporting a pressure differential. Further, the large cross-section of the engine rendered unacceptable designs including a differential between front and rear wheels (the desirability of torque division will be discussed in detail below) and so the engine was modified to have a drive shaft leading back from behind the power turbine bearing. Since this implied that the rear final drive would have an input at turbine speed, the engine reduction gear at the compressor end was discarded, although the Allen-Stoekicht high-speed gearbox of a "Marine Proteus" was fitted for dynamometer testing. A very firm requirement in the specification was that full engine torque should not cause more than a 5 per cent variation in the ground reactions of the wheels, and the use of high-speed transmission shafts reduced the torsional stiffness necessary to satisfy this criterion.

The external shape of the car was, of course, dictated largely by aerodynamic considerations. For safety, it was decided that the pitching moment must be inadequate

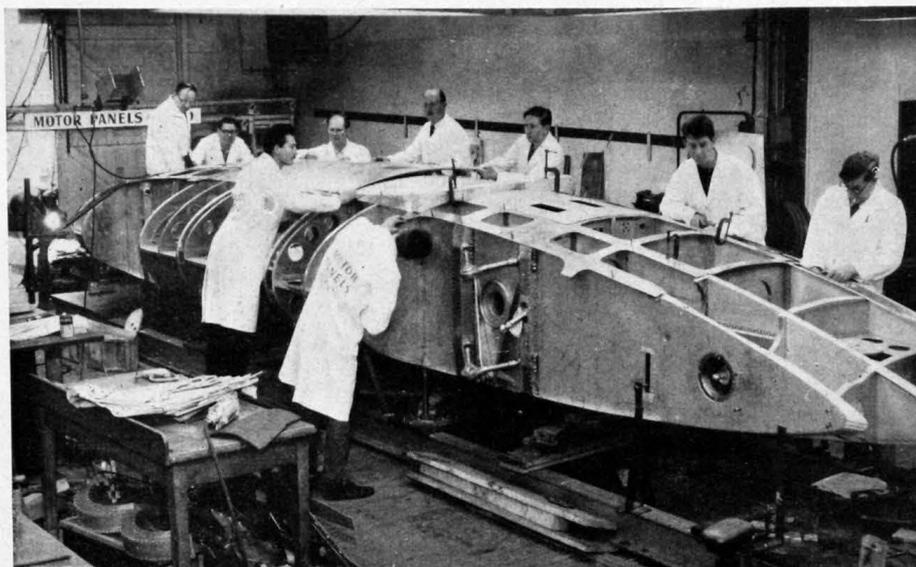
* From the references to the many forms of "Proteus" that have appeared in these pages, it will be recalled that, because of its reverse flow construction with an axial-centrifugal compressor, it is a relatively short and fat engine.



(Left). The main strength members, showing the location of the honeycomb-stabilised sandwich panels. The exhaust ducts pass through the large kidney-shaped holes in the inner aft panels
(Above). Cross section of C.N.7



Plan and elevation of C.N.7



A later stage in the construction of the shell, showing the suspension wishbones, the "steering" links, and the outer end of the drag flap ram. The side bays between the wheels are permanently skinned to form torsion boxes.

to support an incidence of 1 deg. if the front wheels were assumed to leave the ground, and that there must be only small movement of the centre of pressure with yaw. It may not be too early to remark that the final shape is expected to show a drag coefficient, referred to cross-sectional area, of only 0.16, but nevertheless the drag at design speed will be 30 per cent of the weight, i.e. 1½ tons.

Tyre considerations led to the body being designed to have no negative (or, of course, positive) lift; the programming of thrust and speed is discussed later. Wind tunnel testing started with two ellipsoidal bodies, one symmetrical, except, of course, for the wheels, their fairings, and the cockpit, and the other having a camber of magnitude equal to one-half the thickness/chord ratio. After the characteristics of these two shapes had been obtained, a model with a camber 16½ per cent of the thickness/chord ratio was tested, and the full scale body has been designed with camber 20 per cent thickness/chord; the camber line is a circular arc with a short straight section in the centre. The internal duct flow was investigated on another model with a butterfly throttle in place of the engine. Pressure tapping on the model shows that negative pressure exists, even as simple theory would suggest, all over the external surfaces, with the exceptions of the extreme front of the upper surface (before the cockpit cover) and the extreme rear of the lower surface (between and behind the bottom exhaust openings). One respect in which the "C.N.7" is conspicuously different from the designs of engineers specialising on automobiles is that it has no tail fins; negative aerodynamic stability in yaw is considered acceptable in view of the very high damping to be expected with the principal masses closely concentrated within the track and the wheelbase, and, of course, for drivers of very great ability. It may here be added—discussion of the handling characteristics will follow—that at high speed the very large angular momentum of the wheels causes the roll due to yaw to exert a significant stabilising steering correction (this is the same effect as that stabilising a motor-cycle, i.e. it varies as the rate of change of yawing velocity).

As has been indicated, an "egg-box" construction was selected to sustain the pressure differential of about 3 lb per square inch that is expected to be attained in the engine bay. The material chosen, for lightness, was aluminium alloy, and stiffness was

obtained by using "sandwich" panels with stabilising cores of "Aeroweb" honeycomb. The two main beams (26ft by 3ft) and four subsidiary beams (13ft by 3ft), which are seen in our illustration, use ¼in honeycomb

TABLE
Campbell Norris Project Seven "Bluebird"

Length overall ...	30ft
Breadth overall ...	8ft
Height overall ...	4ft 9in
Wheelbase ...	13ft 6in
Track ...	5ft 6in
All up weight ...	4 tons
Power unit ...	Single Bristol-Siddeley "Proteus" 705 developing 4250 h.p.
Tyres ...	Dunlop interwoven web ply 4; 32in diameter; 8.52in section
Brakes ...	Girling disc brakes and air brake flaps at each side of vehicle
Fuel ...	B.P. "Avtur," 25 gallons capacity

Development commenced January, 1956. Attempt on the land speed record expected to take place about September, 1960, at Bonneville Salt Flats, Utah.

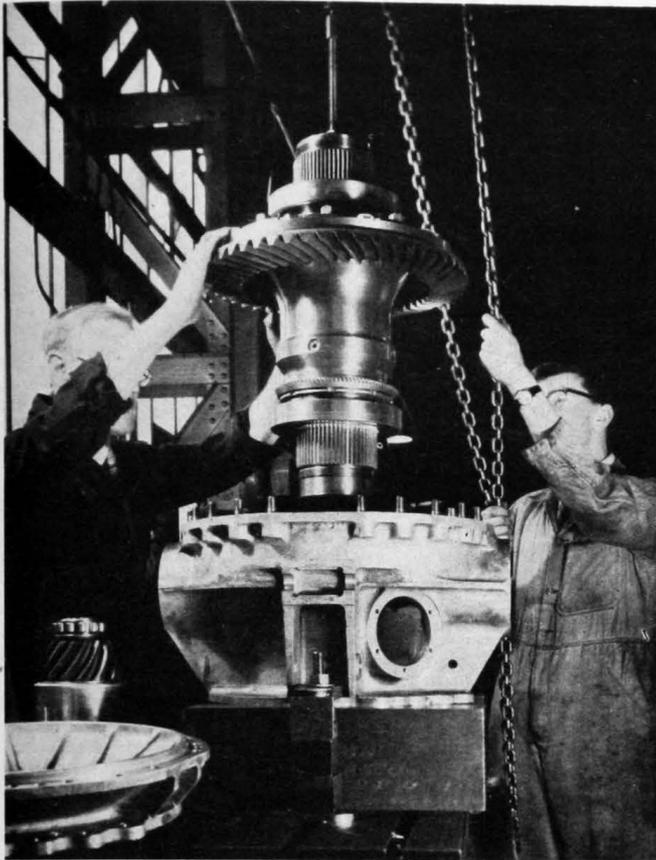
in 0.002in material, the core thickness being ¼in; the faces are 18 g aluminium alloy, bonded to the core with "Redux" or, in the vicinity of the hot exhaust ducts, "Hidux"—these panels were fabricated by CIBA (A.R.L.), Ltd. The "frame" of the car, by which is meant what remains when all detachable panels have been removed, is, as explained above, stiff enough virtually to isolate the suspension from the engine torque, but the removable panels are themselves made stiff, principally by honeycomb sandwich construction, and secured by stressed fastenings, so that the tyre-to-ground reactions will change by even less than the prescribed 5 per cent. The securing devices used are King shear fasteners but tests of these quick-release fittings in tension have shown that they may safely be used to retain panels against the depression outside and the compression inside the vehicle. It may be remarked that the consulting engineers responsible for the design experimented with sandwich panels stabilised with corrugated sheet in the manner associated, in this country, with Handley Page, Ltd., but since there was no cause to stress the core in compression in any direction parallel to the surface there was no advantage in this construction. The "frame" is permanently assembled by riveting and "Araldite" bonding; the side bays form very stiff torsion boxes, access to the fuel tanks being through the wheel wells.

The centre of the body is occupied by the engine, a 705 "Proteus" giving 4100 h.p. at an output speed of 11,100 r.p.m.; it is not anticipated that the car will be power limited,

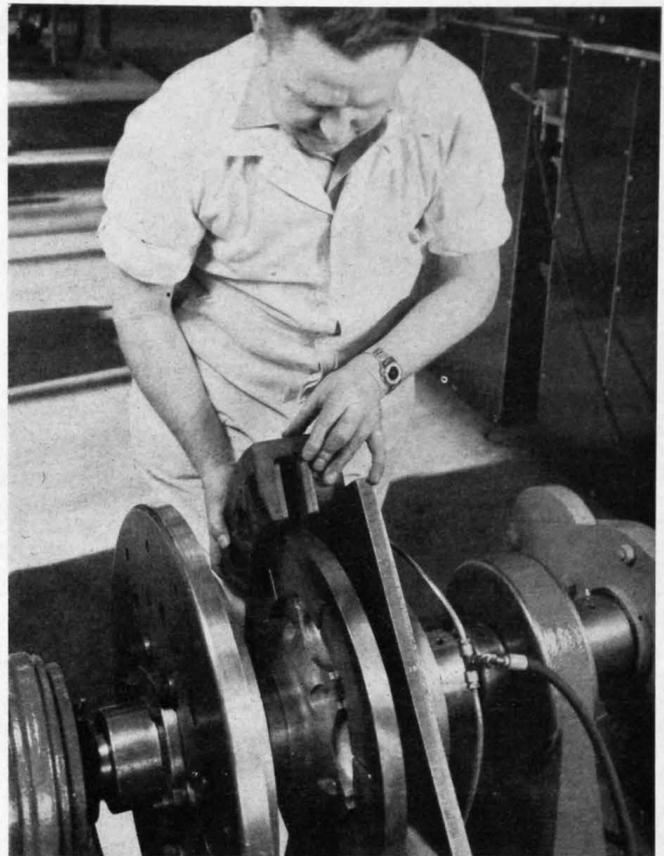
but in any case more power is available from later marks of engine. The drive from the compressor end of the l.p. turbine line can be either by a simple shaft or by a shaft leading into a Renold sprag clutch (factors affecting the choice will be outlined in the discussion of the tyres). The two final drive units have, as indicated above, both shafts in one plane, and employ spiral bevel gears with a ratio of 14:51 (3.64). A simple bevel differential is fitted with a locking pin movable only when the vehicle is at rest. The gears are of 3 D.P., 20 deg. pressure angle, 28 deg. 54 min. spiral angle, and 2½ face width; at standstill, loads may reach 4500 lb per inch face width. The duty of these gears is such that the gearboxes use the same enter-based lubricant as the engine, and additivity to improve the high-temperature qualities of the oil are necessary. A tank for lubricant adjoins the sump of each drive casing, and electric pumps circulate the oil independently of engine speed. The final drives are carried on large brackets on two bulkheads with provision for adjustment to align the input shafts with the engine; the torque reactions are taken into these bulkheads by pairs of inclined links at top and bottom.

The output from the differential goes to two large tubes with internal splines. Within these tubes run the inboard Rzeppa type constant velocity points of the Hardy Spicer propeller shafts; a conspicuous contrast with conventional practice is that any sliding imposed by the suspension geometry takes place outside the outer member of the universal joint and not inside the inner, thus greatly reducing the axial loads that can be evoked by friction on the splines.

On each side of each final drive are mounted disc brakes. The energy of the car at speed is 75×10^6 ft lb, and so to bring it to rest in one minute (which corresponds to little more than 0.3 g) involves degrading work to heat at over 2000 h.p. To dissipate this power in the atmosphere at any but the highest speeds is not feasible, but since the car is needed to make only isolated single runs (one hour may elapse between the runs in opposite directions for a record attempt) there is no objection in principle to the energy being retained on board the vehicle. As indicated earlier, at high speed the drag of even this streamlined car is a highly effective brake, and a pair of drag flaps are fitted which will, it is expected, add about 25 per cent to the air resistance. It may be interpolated that the drag increment due to air brakes is fairly sensitive to the detail design of the brakes, e.g. presence of upstanding or irregular edges, and so not easily determined in tests at unrealistic Reynolds numbers—should it prove desirable, the effectiveness of the drag flaps could probably be improved by trial-and-error techniques. It is envisaged that the normal stop will be made at roughly constant deceleration, the friction brakes being applied at 400 m.p.h. and loaded progressively as the drag falls off; this implies that half the kinetic energy is transferred directly to the airstream and half degraded to heat at the friction faces. (The free turbine engine does consume some energy if over-run, but this would be of the order of 10 per cent of the total energy dissipation in the normal friction-braked stop outlined above). The requirements drafted for the friction brakes were that the friction material should withstand at least two normal stops to avoid relining a hot brake in the middle of an attempt, and that the brake should survive, if not remain serviceable after, an emergency stop in which the friction brakes were left full on from full speed to rest. It proved possible to meet and indeed



Assembling one of the final drive units: at full power, the tooth loading will be 3450 lb per inch of face width. Sufficient oil is carried for it to be circulated only once in a $2\frac{1}{2}$ minute run



The cast magnesium brake caliper being offered up to the floating brake disc for test on a Ferodo dynamometer: the speed at commencement of braking is 2600 r.p.m.

exceed (friction pads are expected to last for four to five stops) these requirements with a conventional brake system. Since there was to be no attempt to dissipate much of the heat while the car was moving, there was every reason to bring the brakes inboard. For a heat sink, the disc is more attractive than a drum because it lends itself to kinematic design; while a disc driven from a shaft, rather than from a wheel, cannot easily be supported other than at the inner edge, this was not a limitation in an application where ample space was available. To impede the flow of heat from the sink into the transmission, a fixed caliper design with the disc riding on a six-pointed spider was adopted. Development in the Ferodo Test House showed that this duty did not demand any advanced concepts such as copper heat sinks, sintered metal facings, or ceramic friction materials. The final pads, which reach a surface temperature of 2200 deg. Fah., are of a moulded asbestos-based material evolved, interestingly enough, from that used in the drum brakes of the Gloster "Meteor"; this machine in its later marks was exceedingly heavy for the size of its wheel wells, and the Dunlop brakes frequently ran hot enough to rupture or ignite the air bags expanding the shoes. The "Bluebird" brake reaches 1600 deg. Fah. in a normal stop, and surface pressures of up to 200 lb per square inch are used; each pad is $6\frac{1}{2}$ square inches in area and $\frac{1}{4}$ in thick. The brakes themselves were manufactured by Girling, Ltd.; each disc is 16 in in diameter and weighs 33 lb 10 oz, while twelve pads at 5 oz each and two cast magnesium calipers bring the total weight of each assembly to 53 lb. The brakes are operated by compressed air, thus avoiding problems due to high fluid temperatures, and enough air for more

than thirty applications is carried in two reservoirs, one for the front brakes and one for the back; a third reservoir is subject to a hand control and applies all four brakes. The air brakes are also driven by compressed air, a fourth bottle being used to pressurise a hydraulic accumulator supplying the actuating rams; enough air for one and a half full and proportionately more partial extensions is carried.

Scoops bring cooling air into the vicinity of the brake discs while the car is moving, but the greater part, probably 90 per cent, of the heat generated in the friction brakes will be carried away by air pumped into these scoops after the car has stopped. The structure near the brake discs is protected from radiation by stainless steel cladding.

The suspension of the car is simple in appearance, having been designed predominantly to eliminate angular movements of the wheel axis which would generate precession couples. Each hub carrier is located by a wishbone at top and bottom and a track link at the end of the steering arm. Ackermann geometry is used. The "wishbones" are, in fact, pin-jointed frames, the length of each member being adjustable to vary camber, caster and "king-pin" inclination. The hub carriers, which are fabricated in steel, largely stainless FV520, are all four identical except for one dimension: the wheel axis is offset towards the steering arm in two and away from it in the other two; thus by inter-changing, say, the rear hub carriers from left to right, which involves inverting them, the angle of attack of the body can be altered 1 deg.

Springing is not a problem in the case of a car operating on the Salt Flats, since the surface is effectively plane—although it is worth bearing in mind that at the design speed

of the "C.N.7," a curvature of 2 in in 100 yards imposes 1 g. One problem that did arise was that of selecting a design case that would prevent the car being unrealistically flimsy, and that adopted was proposed by Mr. Reid Railton; the car should withstand being dropped 6 in. A rather hard suspension was desirable to minimise the precession torques arising as the vehicle rolls when lateral acceleration is applied or discarded, and there was chosen a suspension frequency of 120 c/s with a total wheel movement of 4 in. Since the mere release of the power lever when nearing maximum speed causes an abrupt transition from 0.3 g forward to 0.3 g backward, damping was designed to be high, no single disturbance causing the sprung mass to pass through the equilibrium position more than once. The suspension units, designed in principle by Norris Brothers, Ltd., and in detail by Girling, Ltd., are oleo units combining spring, damper and rebound buffer. They consist basically of a cylinder filled with oil and closed by a piston, the combination being loaded in tension (the piston-rod passes through a gland in the head of the cylinder). An increase in applied load causes oil to be forced through an orifice in the piston into the hollow piston rod; this displacement is resisted by a charge of compressed nitrogen in the piston-rod, separated from the oil by a freely moving plunger. The movement of oil from the cylinder into and out of the piston rod is damped by various orifices controlled by ball valves. Apart from carrying its load in tension, the spring and damper unit is similar to many aircraft springs and the Dowty motor-cycle suspensions; it was not considered necessary to vary the damping with displacement in the manner of some telescopic hydraulically-damped suspensions. The



Friction pads are retained in the caliper by press studs: the pad is moulded to fit into the caliper or braking plate. Quick *in situ* replacement is not a requirement

spring is rendered progressive in the bump direction by the natural characteristic of an air (or gas) suspension and in the rebound direction by a series of rubber rings surrounding the cylinder which abut against a flange on the piston-rod. The cylinder is extended upwards to the top of the hub carrier by a tubular tie, fabricated by Accles and Pollock, Ltd., through which there passes the propeller shaft. The weight of each suspension unit is 12 lb.

The hub carrier, including the cylinder of the suspension unit, turns for steering about the wishbone pivots. A travel of 5 deg. either way is provided; the front wheels are steered by a recirculating ball screw driven by sprocket chain from a bevel box in front of the driver. It is intended that no correction during a run should call for the driver's grip to be moved round the wheel rim, nor for loads in excess of 5 lb; the mechanism is designed to possess a minimum of friction. As the drawings make clear, the "king-pin" axis passes vertically through the contact area, so that there is no self-centre at zero speed. The turning circle is 300 ft.

It will have appeared in the preceding paragraphs that the design is in many respects dominated by the tyres, and much importance attaches to the wheels and tyres. Each hub runs on two angular-contact ball bearings and carries a steel disc wheel, sharply dished, devoid of any lightening holes or other stress-raisers.

The wheel has been stressed to remain undamaged if the car rolls over sideways, corresponding to a side load on two wheels 15 per cent greater than the weight of the car. The 7 in by 4 1/2 in tyre is mounted on detachable rims retained by a ring of nuts; a bead spacer gives a positive grip on the tyre. The tyre itself consists of four plies of "Fortisan" rayon cord and has an outer coating of 0.02 in natural rubber; it is of a very shallow wide-base section to minimise growth with speed, which is expected to amount to a 1/4 in increase in radius. The tyre and tube, also natural rubber, weigh 50 lb, and the complete assembly of wheel and tyre is balanced to an accuracy corresponding to 1/4 oz at the periphery. The tyre will be inflated with nitrogen to a pressure exceeding 100 lb per square inch; stationary, it deflects roughly 3/8 in under load. Since the spring-loaded Schrader valve will be opened by the acceleration at high speeds, the gas is retained by the valve cap.

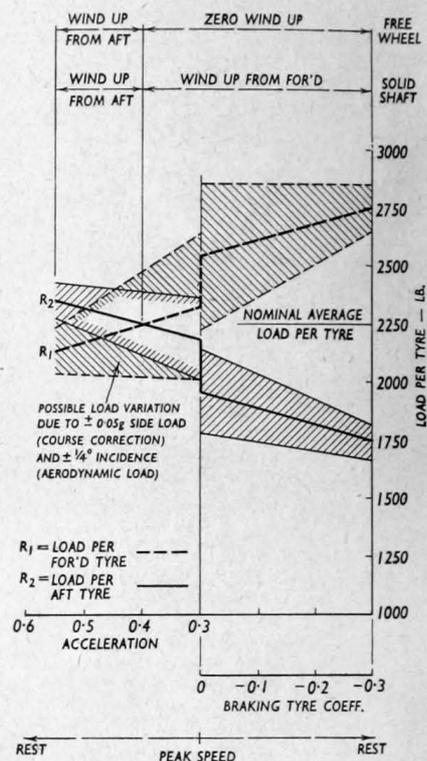
The duties imposed upon this tyre are

manifold. One that is not exacting, however, is endurance; a run will last little more than a minute, of which only a fraction will be spent at high speed, and there is no objection to changing tyres after each run — this will, in fact, be routine, since it avoids inspecting for accidental damage a tyre that will be too hot to touch. The fact that tyre life can be sacrificed to speed of development and consistency in manufacture may explain the use of cords of rayon rather than higher strength materials such as nylon or steel.

A study of the effect of tyre performance on the vehicle can well begin with the accompanying graph, showing the variation in tyre loads throughout a run up to speed and back to rest, for one c.g. position.

Since the Salt Flats allow little more than 10 miles for a course, a 475 m.p.h. run would have no constant speed sector at all. The plots show not lines but bands, since tyre loads will vary if there is any side force or if the angle of attack varies, as it must due to change in rolling height with load. The run starts with acceleration at 0.6g, diminishing to 0.3g at peak speed—it will be recalled that drag is capable of imposing 0.3g, so that this is, or may be made, a constant thrust acceleration — followed by deceleration — for this plot the friction brakes are assumed to be applied at full speed — at a close to constant rate (the figures on the graph show only that component of the deceleration affected by the friction brakes). Bearing in mind that applying the brakes drives the angle of attack negative, so that the tyre loads will tend to the upper part of the bands illustrated, it immediately becomes clear that the critical case for the tyre is the front wheel in the high-speed decelerating regime; hence the use of aerodynamic drag in the 500-400 m.p.h. range. It will, of course, be questioned whether the c.g. forward position must be used, since it causes the rear tyres to be more lightly loaded except under high acceleration. The discussion of handling is left till later; but this weight distribution is explained by the fact that, since these tyres are not of rigid breaker construction, there will be a distinct change in the revolutions-per-mile dimension as the load is varied. Under power, the rear wheels will effectively be smaller than the front, and so the engine power will be taken predominantly by the front wheels; if torque was transmitted by the tyres without slip, as it cannot be, the rear wheels would at the start of the run be recirculating power into the engine — "Wind up from aft." No quantitative information on the slip due to traction or the change in rolling radius with speed and load is available for these tyres, so no estimate of the magnitude of the maldistribution of torque is possible, but it is now clear why a constant-thrust run-up is preferred to the high-initial-thrust acceleration that a turbine would tend to provide. It appears that even in the case shown, the front wheels may be transmitting a thrust equal to or even exceeding the normal reaction if 0.6g is attained.

It may be remarked that, in the 475-500 m.p.h. band, the deflection under load has become virtually nil (the tread is experiencing 8000g) and so this problem may be less onerous in future extreme-performance wheeled vehicles! The opposite effect obtrudes when braking; and the free-wheel in the forward shaft avoids power being passed from the rear wheels to the front brakes, as well as allowing the car to turn without stressing the transmission. As was mentioned earlier, the tyre designer found that the design was dictated by the load to be carried rather than by the friction forces to be generated, which may perhaps be paraphrased by saying that

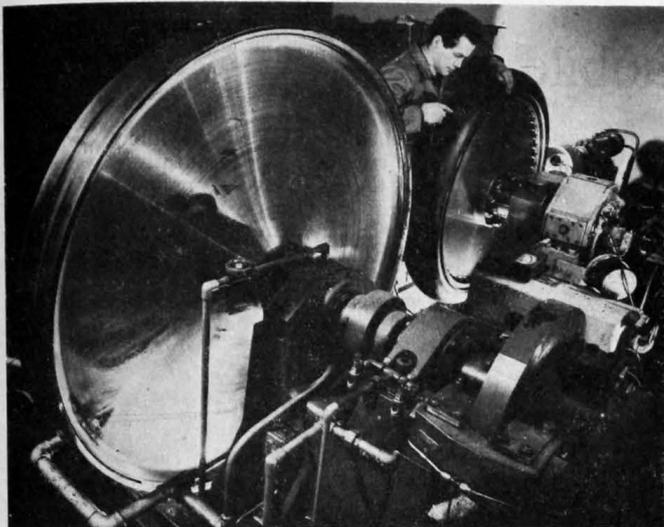


Tyre load variation during run. C.G. 10.4 in forward of mid wheel position

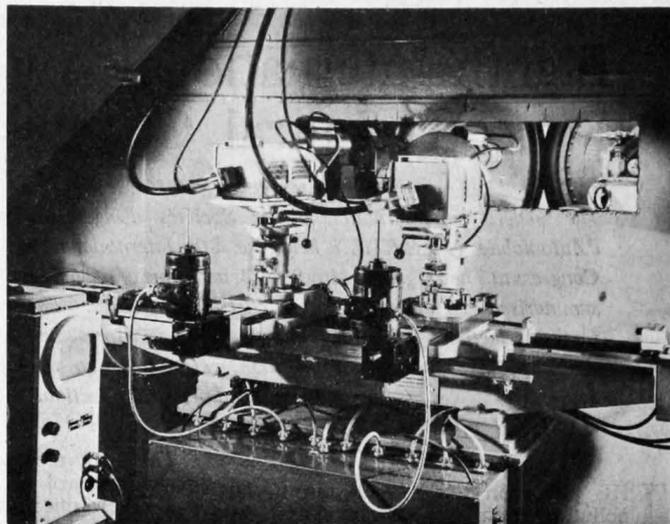
at low speeds the car is significantly over-tyred.

Considerations such as these show that the handling properties of the car may present problems of some interest. It is clear that the c.g. position cannot be regarded as a variable in a high-power run, and it is anticipated that the tyres will be too sensitive for the static margin to be adjusted by varying the tyre pressures. From the description given of the suspension geometry, it will be recalled that the attitudes of the wheels can be adjusted; however, the roll centre heights will in all cases be very close to zero, so that the only deviations that can be controlled will be those depending on roll angle. The suspension stiffness can be varied by putting less oil and more nitrogen, or vice versa, in the springs, and this would allow different roll stiffnesses to be obtained at front and back. It should be emphasised that it is at this stage not known what problems will be met in the field of handling, since Dunlop tyres are not supplied with quantitative cornering force characteristics and so no stability assessments can be made.

It will be appreciated that driving the car may be by no means straightforward. The driver has an armoured glass panel in front of him, and on to this is projected the presentation of a Kelvin Hughes accelerometer. This is a "demand" instrument, the presentation showing a scale with two indices, one denoting the required and the other the achieved acceleration. A speed-sensing computer drives the demand index to execute the diminishing acceleration/constant deceleration programme outlined earlier. The conventional instrument panel has the instruments needed to check on the serviceability of the vehicle. It may be observed that the driver wears a mask and breathes air from a bottle; this lessens the problems of ventilating the cockpit and in particular of preventing the glass and "Perspex" misting up, while in any case the driver would have to wear a microphone for his radio link with the support crew.



A thermocouple probe is introduced into the tyre casing after a test run. Notice the very heavy disc brake on the drum shaft and the automobile brake on the wheel shaft. Beyond the wheel is the loading ram



The tests are observed by closed circuit television. The cameras are mounted on a remotely controlled optical bench, so that they can be used to make measurements of tyre deflections.

At the opposite end to the cockpit, behind the rear final drive, an automatic observer is installed. The "serviceability" instruments, the speedometer and a galvanometer indicating suspension deflection (to provide information, not available when the suspension was designed, as to how truly flat the surface is) are photographed by a camera. Since the film cannot be processed and scrutinised in the interval between runs, it is intended to install a system of radio telemetry (see page 236, February 5, 1960) to allow the instruments to be monitored continuously by the support crew; this will have the advantage that the driver could be warned of some classes of failure in time to limit the damage resulting. The instruments, together with the oil and fuel pumps, are energised from 24V batteries; lead acid cells have been chosen, since, in an aluminium car, acid is less aggressive than alkali, but because there is no starter motor draw to meet the batteries are much lighter than normal equipment.

It will be noticed that, apart from the propulsion, all energy demands are met from accumulator of one kind or another; this was virtually inevitable since discarding the reduction gear deprived the "Proteus" of its auxiliaries. The one take-off is a tachometer generator drive on the front transmission.

TYRE TESTING

It will be appreciated that the performance of the car is vitally dependent on the tyres, and that for there to be any reasonable prospects of success tyres that are reliable at the intended speeds must be available. The Dunlop test plant on which the tyres of previous British record-breaking cars were developed has reached the limit of its development at 420 m.p.h., and so a new test plant was undertaken. Construction began in January, 1958, but not until September, 1959, was one of the tyres for the "C.N.7" tested—it will be clear that, since a large number of tyres must be on hand before the attempt, twelve months is no long time for development and manufacture of a tyre such as has never before been made in this country. The new test plant is noteworthy in particular for having the wheel under test supported on a bed that floats on an air bearing, affording extreme accuracy in load measurement.

The facility is designed to allow the loads experienced in bringing a vehicle to rest to be simulated, and this involves storing very large amounts of kinetic energy. The test

room was therefore built underground, and 350 tons of concrete were employed in the construction of the cell structure. The test plant consists of a drum, driven through a torque-meter by a 450 h.p. electric motor, and a tyre drive unit. The test wheel, mounted on a bed which is supported on air bearings so that the load applied to the tyre can be accurately measured, is coupled through a universally jointed shaft to the tyre drive unit, which includes a 250 h.p. electric motor and a "Dynamatic" brake. The tyre drive unit weighs about 12 tons with its baseplate, and it is moved backwards and forwards as the wheel moves in order to keep deflections in the universal joints to a minimum. This is important because the torque-meter is on the tyre drive unit and any errors introduced by the joints cannot be eliminated.

Some interest attaches to the method of measuring torque. In the drives to wheel and drum there are included calibrated torsion springs, at each end of which are toothed wheels. Each wheel is scanned by a photoelectric detector, and the phase difference between the two signals, which represents the twist in the torsion spring, is derived electronically. These high-frequency signals have another use: in high-speed testing, drum and wheel are run up to speed separately so that windage and bearing losses can be measured and subtracted from the power consumption when the tyre is loaded on to the wheel—tyre and drum are synchronised by counting pulses on a "Dekatron" display and establishing shaft speeds in the inverse ratio of the peripheries.

The exact diameter of the running tyre is of importance to the designer as well as the tester, and it is measured by providing the television camera that monitors the tests with a close-up lens and a graticule electronically imposed on the image; the growth of the tyre as it is accelerated can be observed on the graticule to 0.001in. It is also desired to measure the deflection of the tyre under the applied load, and this is achieved by using two cameras, one focused on the rim of the drum and the other on the rim of the wheel, and observing the distance between the cameras; such a system demands that the cameras be moved while maintaining exact alignment, and they are therefore mounted on an optical bench. In addition, the small depth of focus associated with the close-up lens means that the centre of the tread and the side of the wheel cannot both be in focus, so provision

for moving the camera along the line of sight is also installed.

In the development of the land speed record tyre, as has been mentioned, testing has concentrated on establishing load-carrying ability at high speeds. However, the facility can also test tyres under braking, the "Dynamatic" brake bringing tyre and drum to rest under a programme of speed and torque selected beforehand. A further mode of testing is to spin up a tyre out of contact with the drum, and in this mode speeds of 675 m.p.h. can be reached. The speed available in drum testing is 500 m.p.h. and the contact load $1\frac{1}{2}$ tons: the machine will accept tyres up to 12in wide and 54in diameter. The tyres for the "C.N.7," which are 52in in diameter, have as yet been tested to 24 cwt.

CONTRIBUTORS OF COMPONENTS AND SERVICES

Accles and Pollock, Ltd., steel tubes and tubular fabrications; Anderton Springs, Ltd., circlips; Andre Rubber Company, Ltd., engine mounting eccentrics; Automotive Products Company, Ltd., self-sealing couplings; Aviation Development Corporation, Ltd., Chobert rivets and pin pins; B.B. Chemical Company, Ltd., "Bostik" compounds; Bluemel Brothers, Ltd., steering wheel; Bowden (Engineers), Ltd., Bowden control to canopy mechanism; Bristol-Siddeley Engines, Ltd., engine; The British Aluminium Company, Ltd., aluminium; The British Petroleum Company, Ltd., fuel and lubricants; The British Refrasi Company, Ltd., exhaust insulating blanket; Davids Brown Companies, transmissions, gearboxes; Brown Bayley Steel, Ltd., steel forgings; Burman and Sons, Ltd., steering gear; The Chesterfield Tube Company, Ltd., air bottles; CIBA (A.R.L.), Ltd., honeycomb and bonding; Crane Packing, Ltd., mechanical seals and P.T.F.E. bushes and gasketing; Dowty Rotol, Ltd., machining of drive shafts, couplings, &c., dynamic balancing; Dowty Seals, Ltd., moulded rubber components; Dunlop Rim and Wheel Company, Ltd., wheels; Dunlop Rubber Company, Ltd., tyres; Dunlop Rubber Company, Hose Division, flexible hose and fittings; Electro-Hydraulics, Ltd., air brake jacks and systems, mechanical brake control system and vehicle jacks; English Electric Company, Ltd., air brake mechanism; The English Steel Corporation, half-shafts and steel bar; Exactor, Ltd., hydraulic control systems; Ferodo, Ltd., brake linings and "Sindaryo" rings; Thos. Firth and John Brown, Ltd., steel forgings and sheet; Firth-Vickers Stainless Steel, Ltd., stainless and heat-resisting steel sheet and bar; Girling, Ltd., brakes, suspension leg, wheel and gearbox suspension wishbones; Hardy Spicer, Ltd., Birfield constant velocity couplings; The Henderson Safety Tank Company, Ltd., tanks; Hertfordshire Rubber Company, Ltd., rubber sheet and rubber sections; High Pressure Components Company, charging valves for pneumatic system; The Hughes-Johnson Stampings, Ltd., steel forgings; I. V. Pressure Controllers, Ltd., stop cocks and pressure reducing valves; King Aircraft Corporation, quick release fasteners and filler caps; Light Metal Forgings, Ltd., light metal forgings; Joseph Lucas, Ltd., electrical equipment, fuel pump and control systems; William Mills, Ltd., light metal castings; Motor Panels (Coventry), Ltd., body structure and assembly of vehicle; Rubery Owen and Co., Ltd., special bolts, standard nuts, bolts, &c.; Pioneer Oilsealing and Moulding Company, Ltd., oil seals and "O" rings; The Plessey Company, Ltd., plugs and sockets; The Power Flexible Tubing Company, Ltd., flexible metal bellows; Pye, Ltd., Switch Division, micro-switches; The Pyrene Company, Ltd., fire extinguishing equipment; Ransome and Marles Bearing Company, Ltd., ball and roller bearings; Renold Chains, Ltd., sprag clutch, chain and sprockets; The Rymatic Engineering Company, Ltd., solenoid valves; L. Robinson and Company (Gillingham), Ltd., Jubilee clips; Rose Brothers, Ltd., spherical bearings; The S.P.E. Company, Ltd., oil pumps and fuel pumps; Simmonds Aeroaccessories, Ltd., "Nyloc" self-locking nuts and FRAM separator filter; Sons Industrial Instruments, Ltd., motor instruments; Star Aluminium, aluminium foil lagging; Tecalemit, Ltd., lubricating equipment, filters; United Springs, Ltd., tension and compression springs; W. E. Sykes, Ltd., barrelling of drive shaft teeth; Triplex Safety Glass Company, Ltd., canopy-screen; Vickers Armstrong (Engineers), Ltd., hubs, steering arms; W. Vinten, Ltd., cameras; Arthur Woollacott and Rappings, Ltd., aluminium foil.