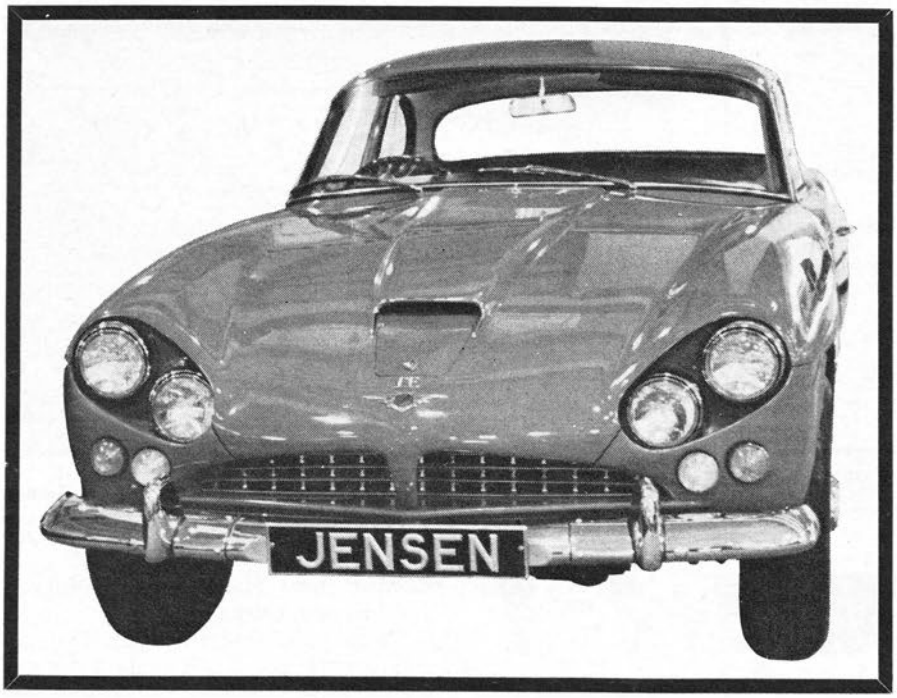


JENSEN-FERGUSON: 2+2=4

The Super-Stability Formula Is a Unique Gearbox, Braking Control

BY JOSEPH LOWREY

FOR TRACTION and controllable stability on wet, slippery road surfaces, what can beat an Oldsmobile Toronado that has 60% of its weight on driven front wheels? Ford fans may cite the rear-engined GT-40 coupe as raced at Le Mans. The GT-40's weight transfer during acceleration adds to the 55% static loading which it has on its driven rear wheels. Well ahead of either, however, is the Jensen FF sports sedan, built in England around a Chrysler 383-cu. in. V-8 engine and TorqueFlite transmission. The FF puts 100% of its weight on four driven wheels.

Other vehicles have 4-wheel drive for use off paved highway, but these 4-wheel drives must be shifted into 2-wheel drive when run on smooth surfaces, if they are not to shred their tires. The Jensen FF (initials stand for Ferguson Formula) is a high-speed car designed solely for use on roads and has no provision for disengagement of its 4wd system, primary objectives of which are to provide better braking from high speeds, faster acceleration and more precise cornering.

Two teams of engineers have worked together to produce this 4-wheel drive sports sedan. Jensen Motors Ltd., with a factory in the Birmingham suburb of West Bromwich, works mainly behind the scenes of Britain's auto industry. Jensen sub-contracts assembly of Austin-Healey, MG and Sunbeam Tiger sports cars for companies whose mass-production assembly lines are not geared to build 2-seaters in smaller numbers. For pleasure, prestige and, they hope, profit, the Jensen company for more than 30 years also has built small numbers of rather expensive sporting cars under its own name. Proprietary engines often have come from Ford, Nash or Chrysler.

Not many miles away, at Coventry, Harry Ferguson Research Ltd. is developing and trying to sell ideas about 4-wheel drive which were originated by the late Harry Ferguson, an Irishman who made a fortune out of lightweight farm tractors. Headed by former racing driver Maj. Tony Rolt, and with Claude Hill, previously an Aston Martin chassis designer, in charge of engineering detail, the team which continued its work after Harry Ferguson's death in 1960 has been primarily concerned with preparing designs for all-purpose cars. Ferguson, however, also has been seeking every possible application for the 4wd system, which centers around a unique limited-slip differential, used to share engine torque between front and rear wheels. Alone and in partnership with others, Ferguson engineers have tested their ideas on both front- and rear-engined single-seat racing cars, using BRM, Coventry Climax and Novi engines.

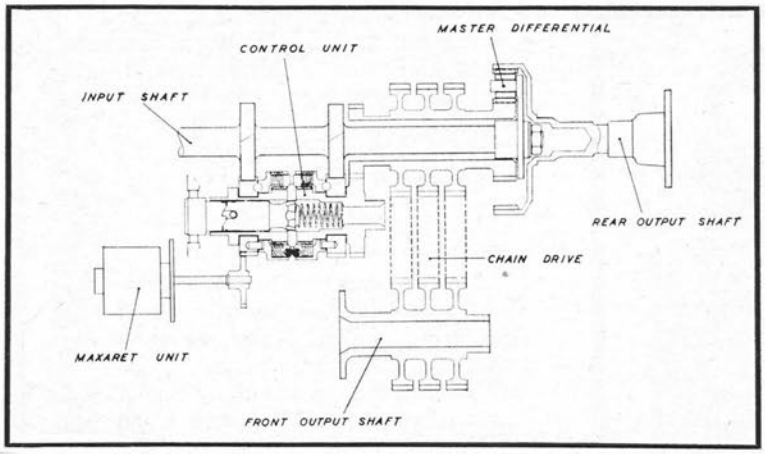
FIRST FRUITS of collaboration between Jensen and Ferguson engineers, which started secretly about three years ago, the Jensen FF is in some ways a compromise car. It inherits body moldings and many chassis details from the C-V8 sports sedan with Chrysler 383-cu. in. engine, which has been listed in progressively improving forms since the 1963 season. Despite some limitations imposed by features handed down from a proven model, this 4wd luxury sedan with a top speed exceeding 130 mph may be the trend-setter for other future high-performance cars.

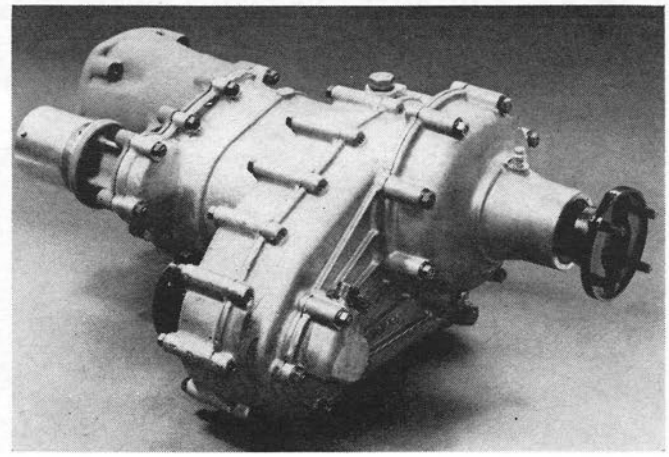
From the exterior, the Ferguson Formula 4wd layout appears deceptively similar to most other 4wd installations, as used on Jeeps and other go-anywhere vehicles. There is a transfer box behind the transmission, from which a propeller shaft runs forward alongside the engine to drive the front wheels, in addition to a conventional shaft driving the rear wheels.

Inside the transfer box, however, this 4-wheel-drive system differs fundamentally from those designed solely for off-the-road use. The traditional 4wd does not have a central "third differential" to share torque between front and rear propeller shafts, because, if just one of the vehicle's four wheels lost traction, its spin could then take all tractive effort away from the remaining three wheels. Instead, the usual 4-wd system couples the front and rear drive-lines positively together. For highway driving, where slight inequalities of tire diameter exist or the front wheels go farther than do rear wheels on acute turns, which could cause severe tire scrub, the driver is advised to disengage the conventional front-wheel drive completely.

In the Ferguson system, which seeks the advantages of 4-wheel drive without the disadvantages that require disengagement of front wheels during highway driving, a differential gear is used between the front and rear propeller shafts to permit small speed variations and to eliminate destructive, power-wasting tire scrub. This third differential is, however, a highly sophisticated spin-limiting design which does positively what high-friction differentials such as the ZF or the Powr-lok do approximately.

In addition to the main front-wheel drive gearing in a Ferguson transfer box there are two extra gear sets, one ▶





HEART OF THE Jensen FF is a limited-slip "third" differential which shares torque between front and rear wheels. Coupled with a Dunlop Maxaret control system, the unit also prevents wheel lockup in braking.

JENSEN-FERGUSON: 2+2=4

with a slightly higher ratio than the main gearing and the other with a slightly lower ratio. These gears fix the amount by which a differential allows the front driving shaft to turn more slowly or more rapidly than the rear driving shaft. Each of these secondary transfer drives has a one-way clutch (or freewheel) in it, and in normal driving, when the central differential is almost inactive, these oppositely-handed one-way clutches slip freely. If, however, either a front or a rear wheel starts to spin, so the difference between front and rear propeller shaft speeds reaches a maximum determined by the secondary drive gearing, one or the other of the one-way clutches takes up the load. The transmission then provides solid drive to both axles at slightly unequal speeds.

Possibly the greatest advantage of this positively-limited-slip central differential is that it works during braking as well as during acceleration. With the Ferguson 4wd system, if either the front or the rear wheels of a car start to lock prematurely, the appropriate one-way clutch solidifies the central differential, and braking effort is then transferred through the driveshafts to the end of the car which is providing too little braking effort. This ability to transfer braking effort from front to rear wheels, or vice versa as conditions require, is very valuable, it being impossible ever to choose a front-to-rear distribution of braking effort which suits both light and heavy loads, on both dry and wet or ice-covered roads.

Beside letting all of a car's laden weight be used effectively for braking adhesion in emergencies, without premature lock-up of either front or rear wheels destroying directional control, the Ferguson transmission offers an additional advantage. Equipping a car with one of the anti-locking control systems which are widely used on aircraft wheel brakes becomes much less expensive, because instead of four control units being needed on the four wheels, one control unit driven from the transmission can limit brake hydraulic line pressure to that ideal maximum which, with the available wheel grip, just starts all four wheels locking.

Applying these principles to the Jensen FF has involved redesign of a well-proven chassis, especially of that part forward of the firewall. Mountings for the Chrysler engine have been moved 2 in. toward the right side of the car, leaving room for a driveshaft to run along the left side of the engine from the transfer casing to the off-center front differential. Extra length at the front of the chassis, which increases the wheelbase from 105 in. to 109 in., leaves room for the frame-mounted differential ahead and to the left of the engine nose. Aft of the firewall, the frame is widened to full perimeter shape. Steel pressings link two large-diameter tubular side-rails which function as sealed vacuum reservoirs for the power-assisted brakes.

REDESIGN OF the Jensen's short and long arm front suspension linkage, necessary to accommodate universally-jointed driving shafts, also has provided the slightly greater swing axle effect which seems best suited to a 4-wheel driven car. Tubular construction is used for the outer part of each lower suspension arm, which carries the main horizontal loads of both acceleration and braking. The upper arms are of much lighter construction. Instead of the customary one spring and one damper per front wheel, the Jensen has two coil springs per front wheel, mounted on Girling telescopic damper struts placed one ahead and one behind the driving shaft.

Bolted rigidly to the main chassis, a removable sub-frame at the front of the car carries the front suspension, the steering gear and the rubber-mounted final drive unit. A new power-assisted rack-and-pinion steering gear has been designed for this car by Engineering Productions Ltd. of Clevedon. The unit draws hydraulic power from the usual engine-driven pump. Steering arms run directly from each end of the transverse rack to a front hub-carrier.

Inherited from the preceding C-V8 model, which uses a similar engine with rear-wheel drive only, rear suspension on the Jensen FF is by a rigid axle with half-elliptic leaf springs of two-rate design. A Panhard rod (track bar) from the left side of the chassis to a bracket just above the right hand end of the rear axle provides positive lateral location and a very high roll axis. Drive and braking reactions are taken through the leaf springs. Settings for the Armstrong telescopic rear suspension dampers are regulated from a 4-position switch between the front seats.

Apart from trivial alterations to suit available space, no changes are made in the stock 383-cu. in. Chrysler engine or in its TorqueFlite 3-speed automatic transmission. With 10:1 compression ratio and one Carter 4-barrel carburetor, the engine is rated at 330 bhp, and has the same 3.07 axle gearing with which the rear-driven Jensen achieves 135 mph at about 5200 rpm engine speed. There is enough space around the power unit to suggest that any owner who so desires may fit headers and multiple carburetors. The Salisbury final drive units can accommodate 2.93 or 3.54 ring gear and pinion combinations.

Directly behind the TorqueFlite transmission, the Ferguson transfer case is installed as part of the rubber-mounted power unit. The input shaft

drives the planet wheel carrier of a simple epicyclic differential gear, the annulus of which drives the rear propeller shaft directly. The sun wheel of the set drives through triple Morse internal-tooth chains to the front propeller shaft. Quite deliberately, this epicyclic differential delivers unequal shares of the input torque to the front and rear of the car. Equal forces from the teeth on free-rotating planet gears are applied at unequal radii to generate torques on the sun gear and the annulus.

For best handling characteristics on turns, the designers chose to apply 37% of the power unit's output torque to the front wheels and 63% of the torque to the rear wheels. With this distribution of effort, turning power on or off has only a slight effect upon the car's turning radius, and this effect is in the sense to which owners of rear-wheel-driven sports cars are accustomed. Once enough power is used to start either set of wheels spinning, the control system takes over from the differential, usually to transfer surplus tractive effort from the rear to the front wheels, though if necessary it can do just the opposite.

Spin-limiting control over the epicyclic central differential is by a pair of gear sets coupling the input shaft to one-way clutches on a layshaft which is geared solidly back to the differential's front output shaft, as shown in the accompanying diagram. From long years of experimenting with systems of this kind, on everything from station wagons to single-seat Grand Prix racing cars, Ferguson engineers have chosen differential control gearing which only permits the rear wheels to turn 5.5% faster than the front wheels before a one-way clutch solidifies. To accommodate sharp turns at low speeds, the other one-way clutch is geared to allow the front wheels to turn at up to 16.5% above the speed of the rear wheels before the differential is solidified. The two one-way clutches are of multi-plate design, lightly preloaded by springs against balls in tapered recesses of their end-plates. Slight drag, when a clutch slips in its free-wheeling direction, develops no extra engagement force, but any drag in the opposite lock-up direction makes the balls roll up their ramps to force the clutch plates into non-slip engagement. An interlock is provided in the system to keep the differential control clutches from locking up when the car is being reversed.

FROM THE transfer case layshaft on which these two differential control clutches are mounted, the tiny control flywheel of a Dunlop Maxaret anti-skid brake control system is driven by gears. There is what amounts to a screw thread on the driving spindle of this small flywheel, pre-loaded axially by a spring so maximum deceleration generated by braking on a dry road does not quite rotate the flywheel on this screw thread. Any greater deceleration, such as occurs suddenly if one or more of the car's wheels starts to lock, makes flywheel inertia compress the pre-load spring, moving the flywheel along its threaded spindle to operate an electrical contact which, through a solenoid, operates air valves to reduce the output force from the brake vacuum servo.

WORKING IN a very rapid series of on-off brake pressure cycles, this Maxaret control system effectively prevents wheel locking during crash stops, even on very slippery roads. Departures from the normal design of brake servo motors were needed. An additional vacuum diaphragm prevents feedback of vibration to the pedal when the anti-skid control operates and insures that panic pressure by a driver on the brake pedal can be counteracted by the vacuum servo if such becomes necessary.

To test this Maxaret control system for keeping braking effort just on the borderline of wheel locking, this writer drove a conventional car on an artificially-watered airfield runway and measured small, but in some circumstances vital, improvements in the best attainable straight-line stopping distances. Tests simulating the need to swerve while braking showed a very large advantage with the Maxaret system, which eased off the brakes just sufficiently to keep the wheels turning and the car steerable all the time, instead of permitting it to slide uncontrollably with two locked wheels.

On the Jensen FF the Maxaret controls four brakes located actually on the road wheel hubs. Solid discs of 11.25-in. diameter inside pierced-disc wheels carry 6.70-15 Dunlop Road Speed tires. The vacuum servo unit operates between the brake pedal and a tandem master cylinder. Any hydraulic failure leaves two brakes working and the controlled 4-wheel-drive transmission permits these two brakes to operate on all four wheels. Separate pads on the rear discs are operated by the mechanical parking brake which, like the main hydraulic braking system, is self-adjusting for lining wear.

To suit the Jensen FF chassis, which has a 56.875-in. front and rear wheel tread, the short drive from the transfer case to the front differential has been divided. First is a solid shaft supported on the power unit, fitting very close against the torque converter casing. Next is a tubular shaft to the front differential, with two universal joints to allow for flexible power unit mountings. The short propeller shaft to the rear axle is of conventional open tubular design, with a telescopic coupling enclosing the front universal joint. As each axle transmits only a part of the engine's power, it has been found satisfactory to use normal bevel-gear differentials instead of Powr-lok units in the Salisbury final drives at each end of the car.

Beneath a distinctively-styled exterior, the molded fiberglass and plastic Jensen coachwork encloses just four armchair seats. As befits the high price, it is furnished in the tradition of European luxury sports sedans with leather upholstery and pile carpets. A polished wood panel carries instruments, including an ammeter, tachometer and an oil pressure gauge. Roof pillars are slender, but steel framing provides strong anchorages for safety harness which combines lap straps with shoulder straps. Rugged enough to shield its occupants in major accidents, and rigidly mounted on the perimeter frame, the Jensen body can be repaired after minor city traffic bumps by bonding-in new pre-fabricated sections to the one-piece body shell.

Conversion of the Jensen C-V8 from 2- to 4-wheel drive has brought some penalties as well as some real advantages. Cost of this hand-crafted car rises to nearly $12,000 at the British factory (without local sales tax) whereas the equivalent rear-drive sedan remains available at about $9750. Weight also goes up, according to factory figures, from about 3500 to 3700 lb. Driven front wheels and an extra 4 in. of wheelbase length widen the turning circle slightly, from 38 ft. to 39 ft. diameter. Mechanism occupies a little more space. The transfer box enlarges the transmission cover toward the left side of the car, though adequate foot width remains. Keeping transmission noise out of the body is a tough problem.

ON THE CREDIT side of the balance sheet, this car should be capable of quite exceptionally fast acceleration from rest and, on wet or icy surfaces, its advantage will persist up to quite high speeds before extra weight and power losses in a second driven axle begin to exact a slight penalty. Cornering should be unusually good on dry surfaces and even more notable on slippery roads. Braking power should be above average in the best conditions and uniquely good when conditions are treacherous or a swerve must be combined with a crash stop. This is the first 4-wheel-driven car to be listed for fast highway driving, but not by any means the ultimate. If it succeeds, as its sponsors hope it will, the Jensen FF could be the trend-setter for 1970 and beyond. ■