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800003

AMC Four Wheel Drive Eagle A New Dimension In Transportation

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American Motors Corporation

Congress and Exposition
Cobo Hall, Detroit
February 25-29, 1980

FREEDOM THROUGH MOBILITY 1905-1980 75th anniversary

SOCIETY OF AUTOMOTIVE ENGINEERS, INC.
400 COMMONWEALTH DRIVE
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ISSN 0148-7191

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INTRODUCTION

Figure 1 This picture shows the Jeffery Quad, with a 2-ton load of pig iron, forcing its way through a road with mud up to the axles.

The principle of four wheel drive was applied to a few vehicles before the turn of the century, but its development in the U.S. did not progress substantially until the Four Wheel Drive Company of Wisconsin was founded in 1910. This company built seven cars between 1911 and 1913 and then turned its attention to 4WD trucks, which received impetus of application in World War I and the Mexican War of 1916. By 1919, the Four Wheel Drive Company and its licensees had manufactured approximately 35,000 vehicles. These were used in Europe and Mexico, in addition to establishing a domestic market in the U.S.

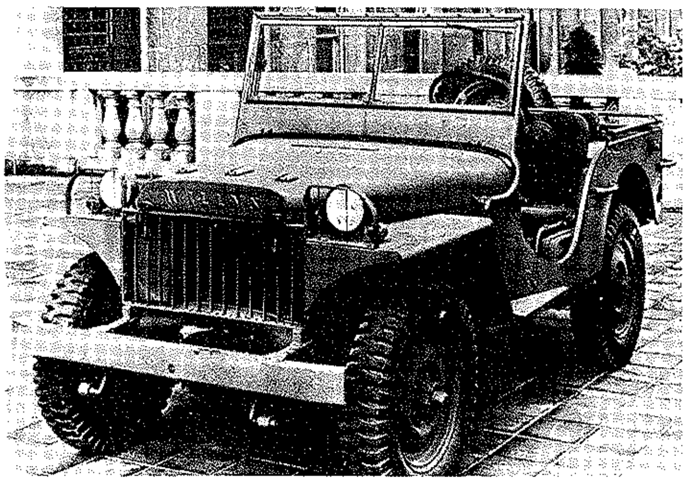

Figure 2 1941 Willys MA Model.

ABSTRACT

While demand for four-wheel-drive vehicles soared in the early 1970's, the available machinery accented off-road usage. American Motors Corporation was quick to respond to consumer interest in a new type vehicle combining the security of traditional 4WD with the comfort and convenience associated with 2WD passenger cars. The Eagle vehicle was first prototyped in 1972 and established package and design feasibility of a 4WD driveline applied to a unitized body. Four years later, with a new set of ingredients designed to overcome earlier problems of achieving NVH objectives, a concentrated development program was begun. The result, after several developmental phases, was the Eagle for the 1980 model year. The integration and application of AMC and Jeep engineering technologies that brought this project to fruition are herein described.

January 2, 1980

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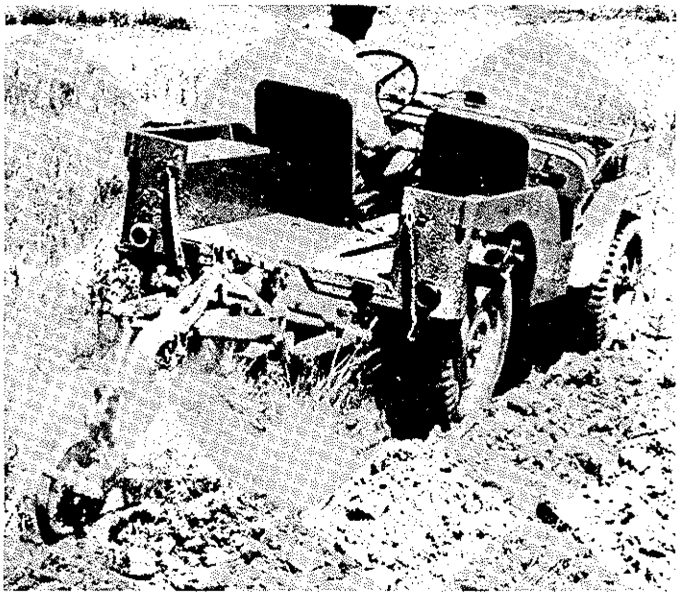

Figure 3 1946 Jeep CJ-2A — Production of a peacetime "Universal" Jeep began as soon as war ended. Thousands were sold to farmers for use as tractors.

In 1913 another 4WD product entry known as the Jeffries Quad was manufactured by the Jeffries Corporation of Kenosha, Wisconsin. This company became the Nash Corporation in 1916 and the product designation changed to the Nash Quad (Figure 1). Between 1913 and 1919, this company produced more than 30,000 units, the first 4WD vehicles in the AMC lineage.

Between the world wars, 4WD drivelines were mainly applied to medium to heavy trucks for specialized applications requiring high traction capability or auxiliary power take-offs. Four wheel drive received its second major impetus with World War II and the advent in 1941 of the famous Jeep vehicle (Figure 2).

More than 651,000 of these vehicles were produced between 1941 and 1945 and they firmly established the capability and reputation of 4WD as a superior means of transportation in adverse situations.

In the immediate post World War II period, commercial derivatives of the military Jeep vehicle found markets in a variety of applications, including service stations and farming, as well as extensive usage in worldwide markets where 4WD was the only practical answer to poor roads and adverse terrain (Figure 3). In this post-war period, although the usage of 4WD was almost totally utilitarian, a small section of the market was starting to emerge as multipurpose usage for both general transportation and a means of traveling to obscure places over difficult terrain for recreational enjoyment. This trend to such usage of 4WD vehicles in the U.S. has continued and today it far outweighs the original utilitarian application. The total 4WD segment of the market has grown rapidly in recent years and domestically is now approximately one million vehicles annually. In addition, the world market continues to increase and total worldwide yearly production is in the order of 1.3 million units.

The Jeep vehicle of World War II Jeep and other post-war civilian light 4WD trucks employed drivelines of the part-time variety. They used 2WD for hard pavement driving and required the manual engagement of 4WD when adverse terrain or low traction conditions were encountered (Figure 4). This arrangement rigidly interlocks the front and rear drivelines. With the exception of locking hubs in 1948 and the adaption of automatic transmissions in the early 1960's, basic driveline development was virtually dormant until 1973.

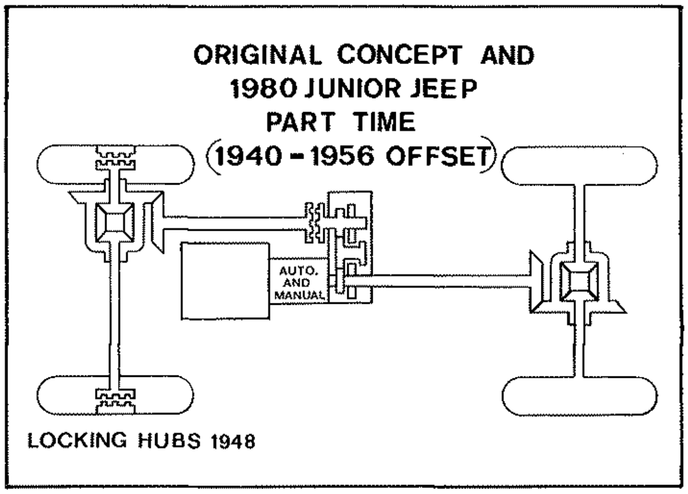

Figure 4

In the 1973 model year, Jeep Corporation and Chevrolet introduced full-time 4WD systems (Figure 5), which brought a whole new dimension of functional improvement to general highway driving while still retaining the off-road capabilities. The full-time 4WD was accomplished by adding a central differential to split the drive to front and rear without incurring driveline 'fight' which is inherent with part-time systems. This full-time concept, particularly combined with automatic transmissions, and the general trend toward recreational usage, helped to expand the domestic 4WD market to a much broader spectrum of users.

In the late 60's and early 70's, the demand for 4WD multipurpose vehicles escalated at a phenomenal

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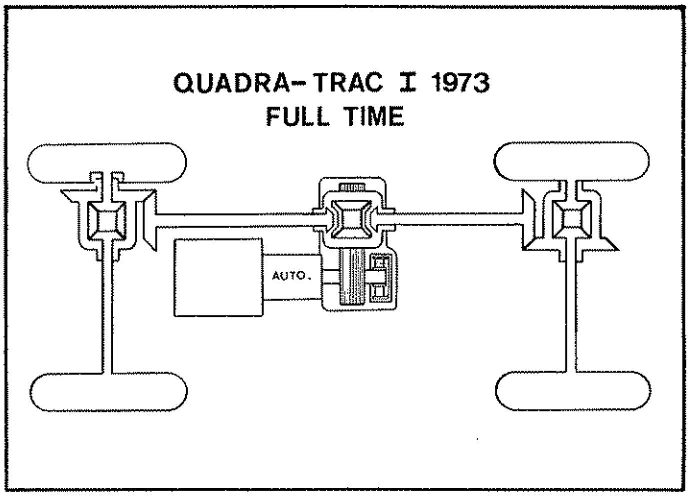

Figure 5

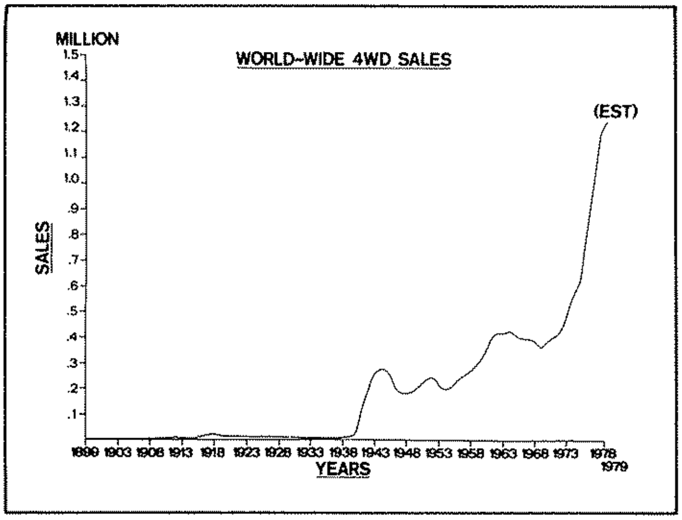

Figure 6

rate, which raised conjecture of their usage (Figure 6). It was evident that many consumers coming from the 2WD segments were buying the vehicles for the security they offered for on-highway driving, although the only vehicles available were accented to off-road usage. They employed separate frame constructions, solid axle suspensions and mostly large utilitarian bodies (Figure 7). This out-of-context purchase, particularly in high volumes, raised the question of whether there was a need for a new type of vehicle with a different balance of compromise accented to highway usage. This line of reasoning, coupled with the need for more fuel efficient vehicles, led to the 'Eagle' vehicle concept. The program was planned to combine Jeep vehicle 4WD and AMC passenger car technologies to meet three basic objectives:

1) To generate a vehicle having the security of Jeep 4WD, but with a body with the comforts and conveniences associated with a passenger car.

2) To develop the desired package combination with NVH ride and handling to refinement levels associated with 2WD passenger cars.

3) To design the 4WD system to operate full time and react automatically to situations and circumstances without any input from the driver.

The Eagle vehicle, as it is now designated, was first prototyped in 1972. This vehicle established package and design feasibility of a 4WD driveline applied to a unitized body, but also demonstrated the problem of meeting two wheel drive NVH objectives with the multiplicity of machinery involved.

The subject was revisited in late 1976 when a new set of ingredients was selected and embodied into a concentrated development program. This second attempt, after several development phases, culminated in the evolution of the Eagle for the start of the 1980 model year.

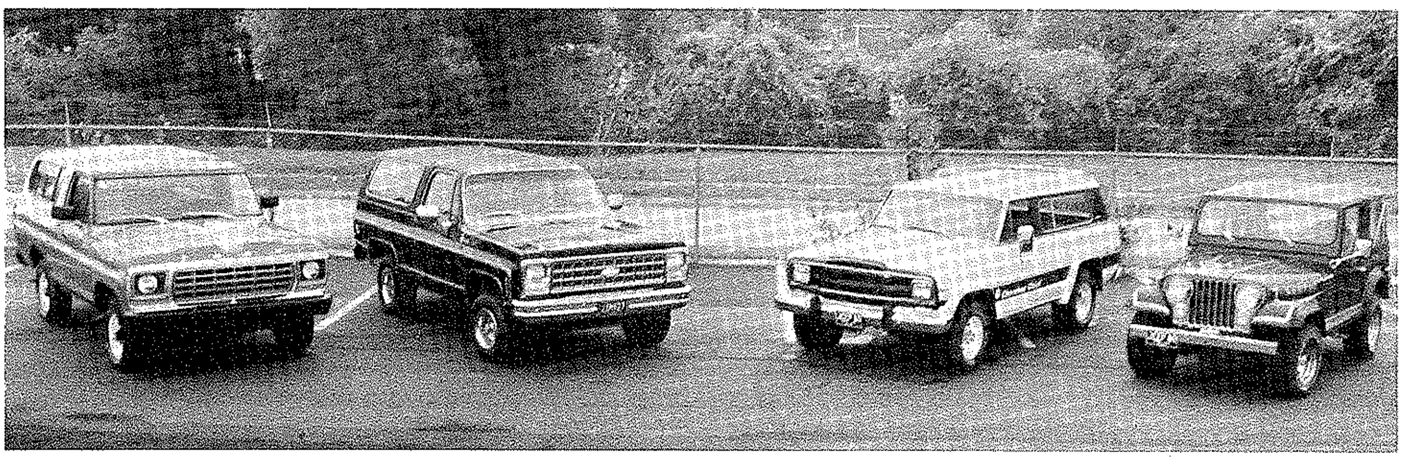

Figure 7

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PACKAGE DEVELOPMENT

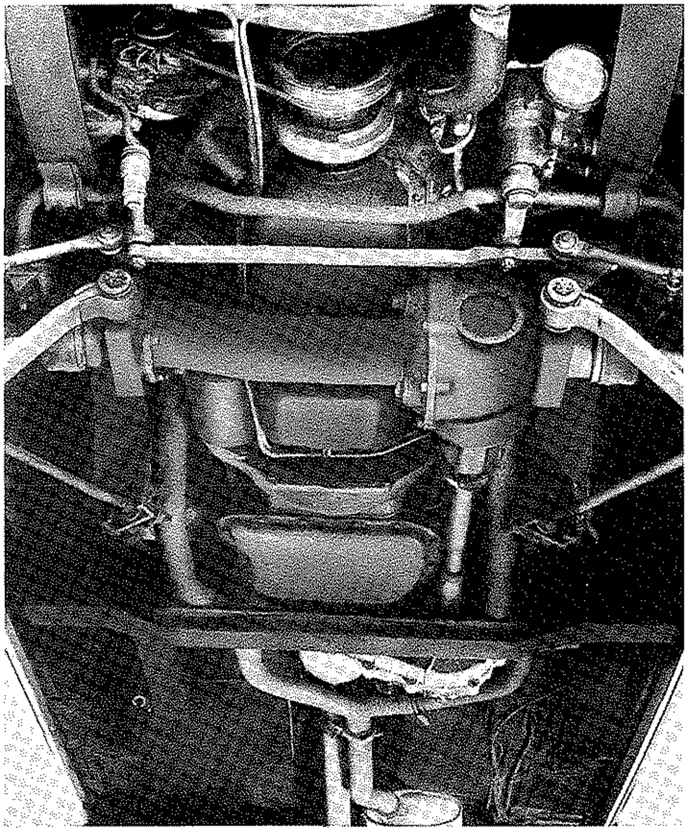

Figure 8

In the original 1972 study, a special Jeep vehicle driveline was packaged under a Hornet Sportabout (Figure 8). The body and driveline were surprisingly compatible since the passenger car version of the body used a spring over upper arm and employed forward steering. Both of these ingredients were essential factors in the successful marriage of the units.

The Hornet independent front suspension upper arms and springs were left in place, but all other components in the steering and suspension were unique together with crossmembers and engine mounts. The front axle was mounted directly to the front body extensions and the floor structure was modified to accommodate packaging the transfer case and driveline. The transfer case was a modified Quandra Trac unit with a direct through drive to the rear and a left side offset drive to the front. The transfer case was of the full-time variety and employed a friction modulated biasing limited slip differential.

The initial design and the subsequent prototype development established package and design feasibility of the arrangement, but the vehicle did not meet the program objective criteria. The ride and handling of the vehicle were acceptable, but the NVH factors greatly exceeded the desired level of passenger car standards.

In the late 1976 renewed approach to the problem, a key factor was a full-time transfer case with a viscous biasing differential. The viscous unit had been invented and developed by FF Developments Ltd. of Coventry, England. They had sold the manufacturing rights to GKN Ltd., which arranged a prototype development with the FF Company. This initial development was again based on a Hornet body, employed the FF viscous biasing case, Salisbury front axle, GKN half shafts and an engine mounted axle similar to front wheel drive systems such as the GM Toronado or the current East West units. The prototype was completed in May, 1977 and, after initial development and further design studies, resulted in a production proposal in July, 1977 that aimed at the 1980 model year.

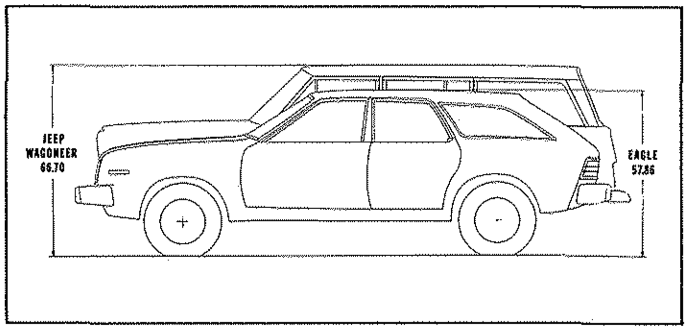

Figure 9

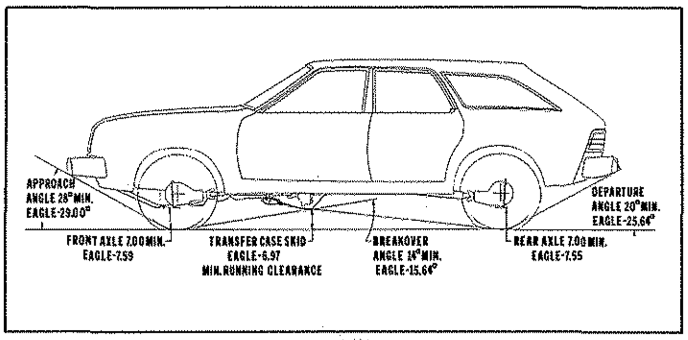

Figure 10

Design development of the package, using a modified Concord body, resulted in a vehicle that was some three inches higher than its 2WD bodied counterpart, but nearly eleven inches lower than a Jeep Wagoneer (Figure 9). The overall package design and functional criteria met multipurpose vehicle safety standards and light truck emissions and fuel economy requirements (Figure 10). A second set of concept prototypes established full functional feasibility in keeping with the objectives and, based on these results, final production approval was given late in 1977.

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VEHICLE CONFIGURATION & SYSTEMS

Overall Package

The sophisticated 4 x 4 Jeep vehicle driveline was developed in conjunction with a body derived from the AMC line of Concord passenger cars (Figure 11). The arrangement provided a direct drive to the rear axle and an offset drive on the left hand side to the engine mounted front axle (Figure 12).

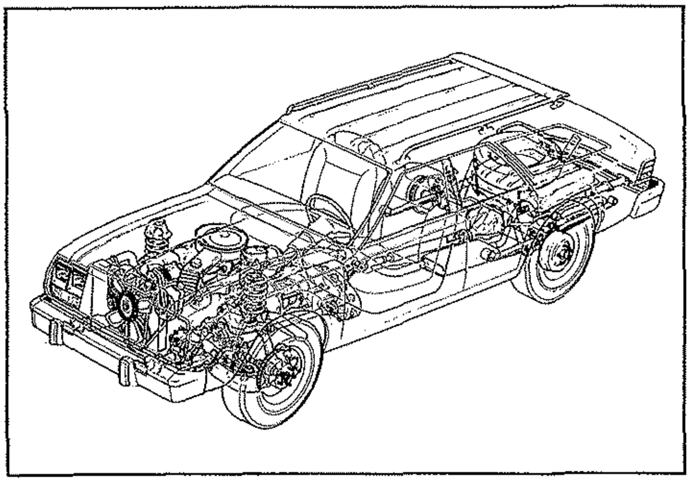

Figure 11

Powertrain

To minimize the spectrum of development, a single combination of driveline was chosen. It inluded the 258 CID 6-cylinder engine, Chrysler 998 3-speed automatic transmission, power steering and power brakes. The basic units were light truck systems developed in conjunction with the 1980 Jeep CJ vehicles. The basic componentry required little or no modifications except for the addition of two bosses on the engine block to accommodate the front axle mounting and a new oil pan to provide close coupled packaging of the front axle assembly.

Transfer Case

A full-time system of 4WD was selected to meet the requirements with its associated central distributing differential. Previous developments with friction modulated biasing differentials had proven unacceptable in unitized structured vehicles because of NVH from slip-stick factors. Open differential transfer cases had also been the subject of development and had demonstrated the need for a dampening medium to keep the noise factors within acceptable limits. The interplay of power distribution between front and rear axles and the resulting chatter was deemed unacceptable, particularly with the unit body design.

The FF Development Ltd. viscous biasing design was selected because it not only provided smooth torque distribution and dampening, but also offered the added feature that is the equivalent of automatic lock-up. The design incorporates a series of plates alternately anchored to either side of the mechanical differential and running in a special silicone fluid which maintains viscosity over a wide range of temperatures. The viscous unit provides sufficient dam-

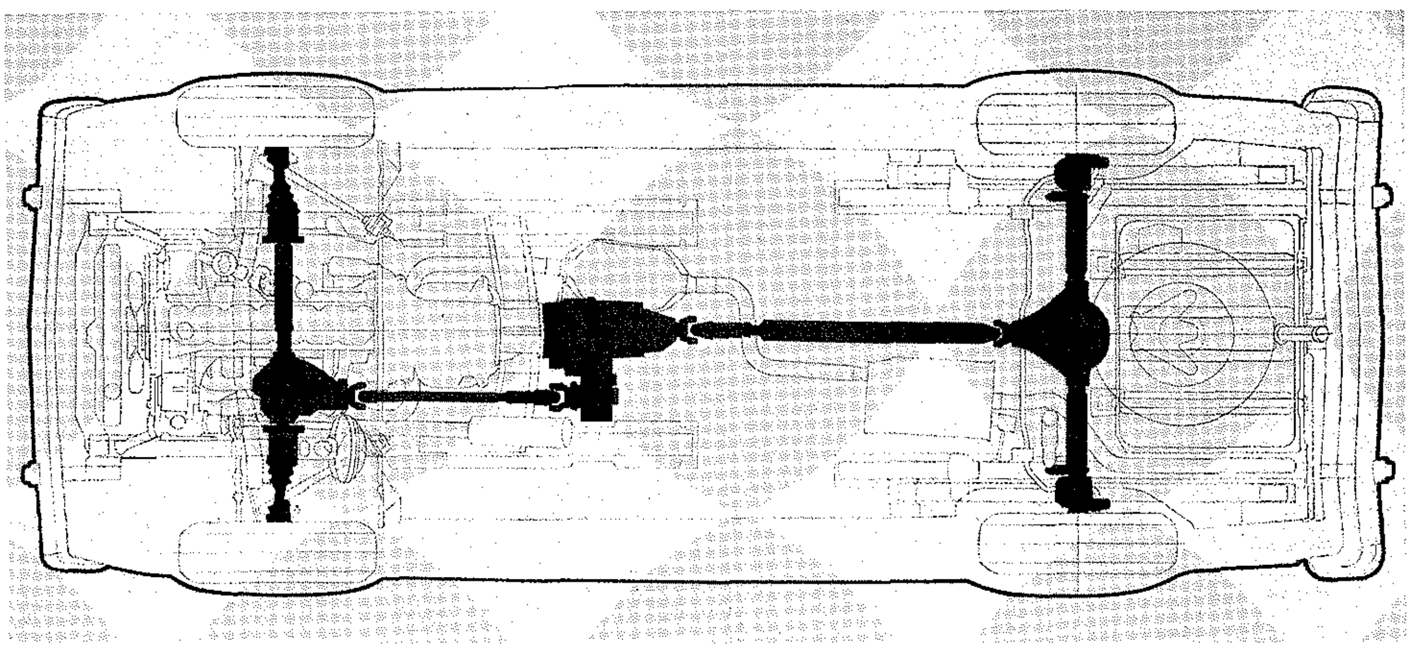

Figure 12

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pening action to quell interplay and work done for biasing increases with speed of differentiating. The system works to the degree that the vehicle can even be driven with a front or rear propeller shaft removed (not recommended practice).

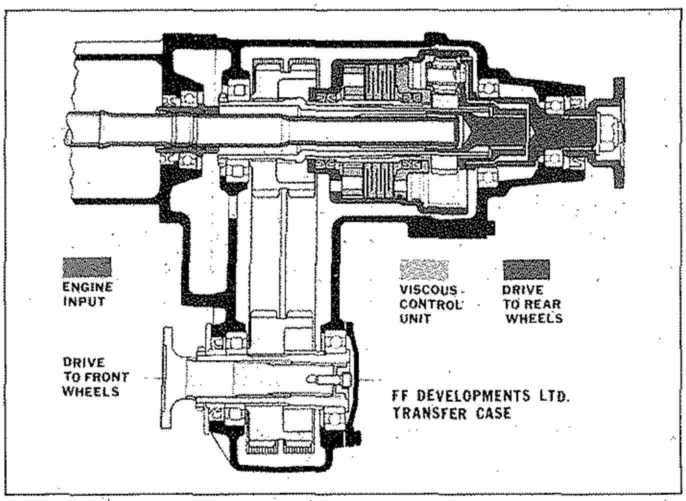

Figure 13

Initial prototypes were fitted with transfer cases made by FF Developments, the inventors of the viscous biasing differential. These units employed a Morse Hy Vo chain drive to the front axle and used an epicyclic differential (Figure 13). They had a resulting distribution of torque of 30 percent front and 70 percent rear. These experimental units worked extremely well, but were not available in production quantities. Second generation units were selected to be common with those being developed for the 1980 Senior Jeep range of vehicles (Figure 14). These units were developed by New Process Gear, which had become the North American licensee for the viscous units from GKN Ltd. which in turn had purchased the rights to the unit from FF Developments Ltd. These second generation units were designated the 219 series for Jeep vehicle off-road usage with high and low range and 119 for Eagle, which has single range only. These units employ direct drive to the rear axle and offset via a conventional differential and a Morse Hy Vo chain to the front of the vehicle (Figure 15). The biasing unit with 43 plates is packaged as a self contained annulus on the outside of the mechanical differential and contains special silicone fluid. A final selection of 15,000 centistokes viscosity was made based on empirical development. Lubrication of the main case is with 10W 30 engine oil.

Front Driveshafts

The front driveshaft couples the drive from the transfer case to the engine mounted front axle. A conventional propeller shaft was selected with single cardan joints and a slip spline. The slip spline is mainly for neutralizing assembly tolerances and vibrating movement in the powertrain. The packaging of the shaft was limited by diameter and proximity to the transmission as shown in Figure 16. Care was also taken to approximately equalize the break over angles within acceptable limits as shown in Figure 17.

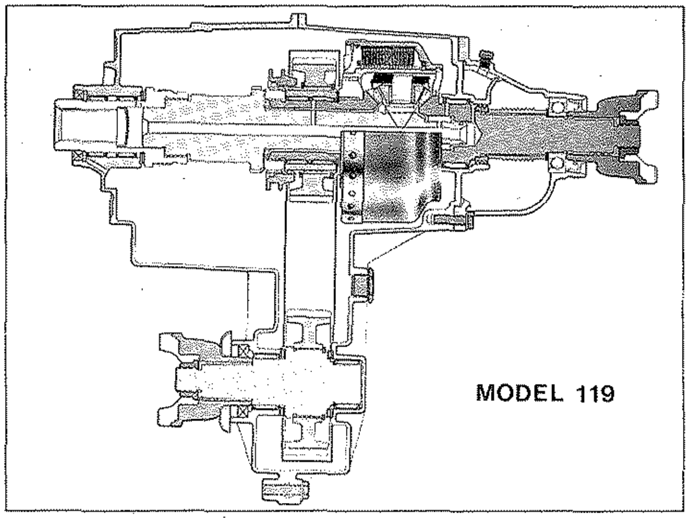

Figure 14

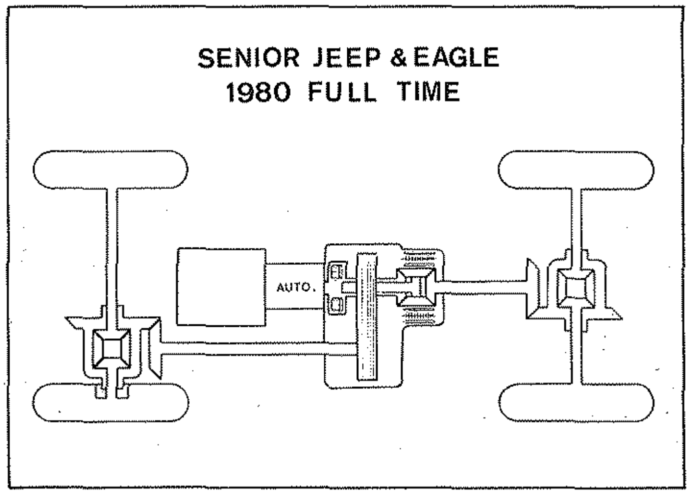

Figure 15

Front Axle

The original concept vehicle employed a specially constructed Salisbury axle using an aluminum case. This unit offered weight and optimum package advantage, but would have required unique tooling and development. Subsequent prototypes were constructed with modified Dana Type 30 units of cast iron case construction. Bosses were added to the case for mounting to the engine and the short coupled side revised to include the outer bearing support directly in the case. Special output flanges were designed to

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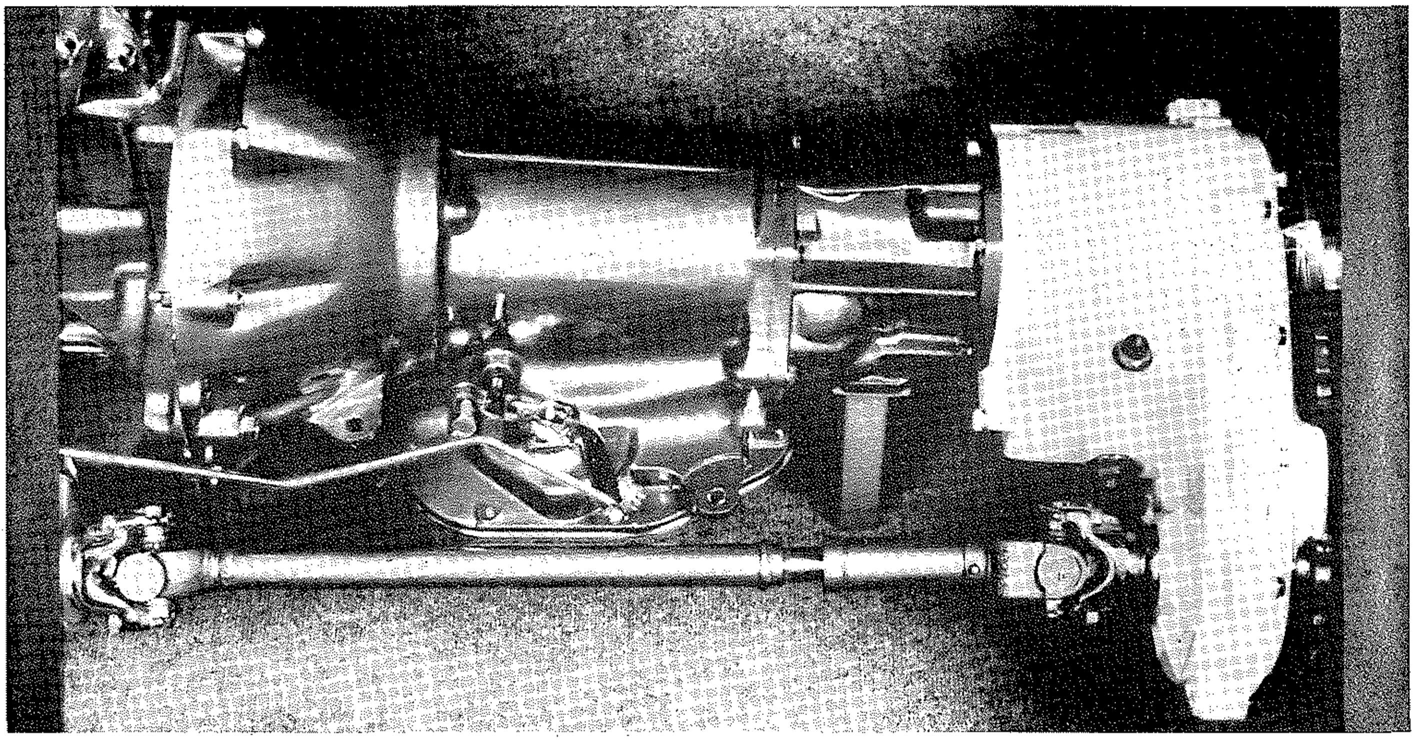

Figure 16

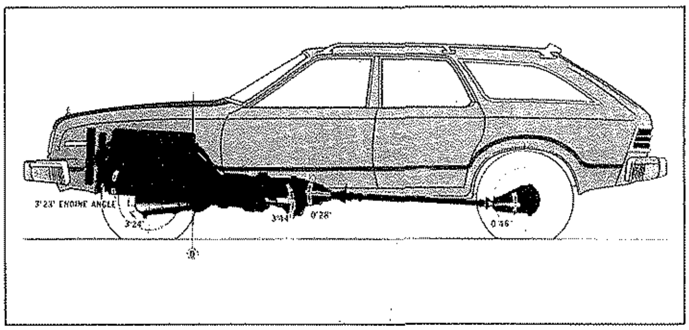

Figure 17

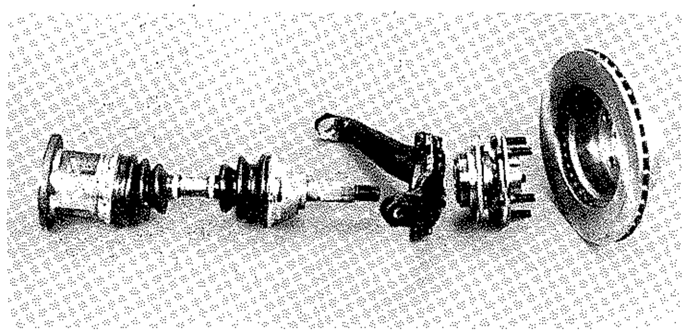

Figure 18

couple with the half shafts and the whole unit is three point mounted to the engine.

Half Shafts

Both Saginaw and GKN units were used in the various stages of development and in the production phase. The Saginaw units employed are essentially identical to those used on the GM 'E' cars, while the GKN units are adapted from a combination of European applications. The inboard end units are tripot plunge joints with CV characteristics and the outboard joints are CV Rzeppa units (Figure 18).

The inboard units are required to allow plunge action as a result of suspension and steering action, together with compensating for relative engine to suspension movement as a result of the engine mounted front axle.

Front Hub, Yoke, Brakes and Wheels

The front hub was evolved from the GM 'E' car design with a live spindle and New Departure unit bearing. An alternative design using pre-set Timken units (Figure 19) has also been developed.

The yoke was initially designed as a one-piece right and left hand casting which included the steering arm. This design was eventually abandoned in favor of a non-handed forged unit with separate steering arms.

2.6" Bendix calipers were selected for the front end braking together with an 11" diameter rotor. This combination resulted in a 1.6" positive offset of the 15" diameter wheel. This diameter was not only necessitated by the front hub package requirements, but also chosen electively in keeping with traction, ground clearance and general packaging factors.

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Front Suspension and Steering

As noted previously, the upper 'A' arm and its associated spring and shock absorber were basically retained from the passenger car independent front suspension application. The yoke was packaged in conjunction with the 15" diameter 6" wide rimmed wheels and related to half shaft jounce and rebound limitations. This resulted in a King Pin inclination of 11° and a front tread of 59.6" (Figure 20). Bottom arms and struts are unique together with their mounting, including the front suspension crossmember, which also combines the engine mounts and jounce stops.

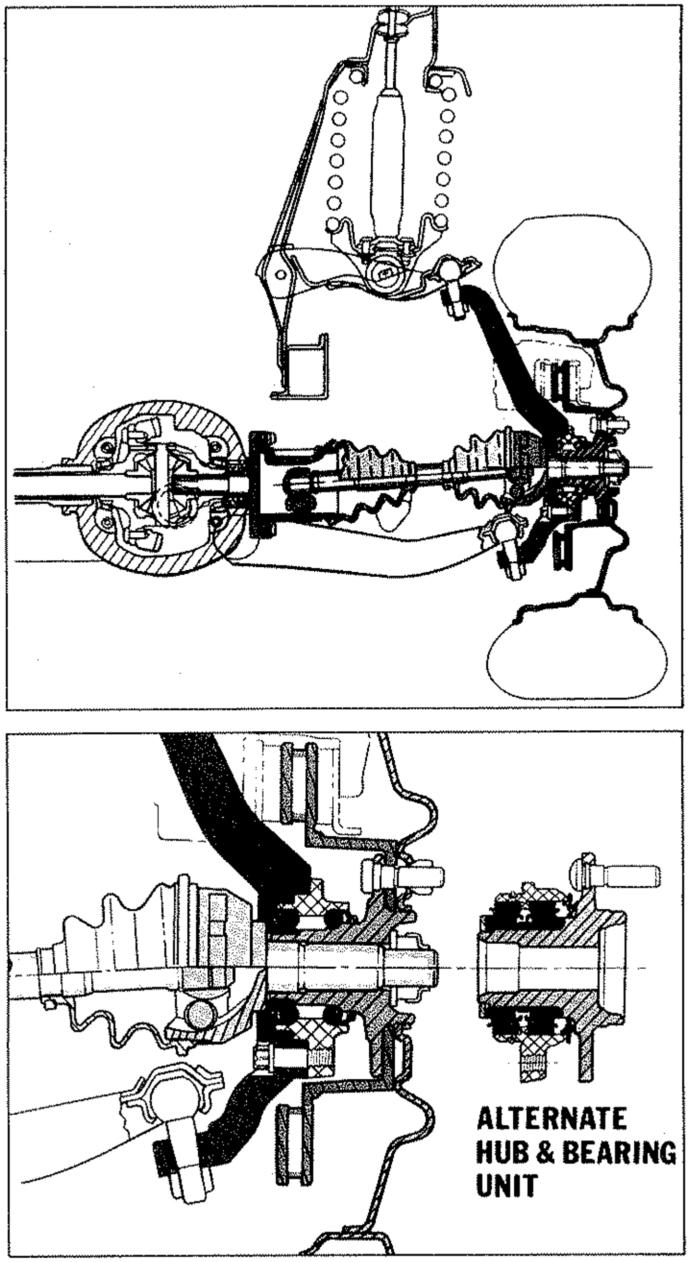

Figure 19

The steering system retains the passenger car steering box with a modified mounting position, while all linkages are new. The system comprises a center cross link, an idler arm and two adjustable articulated links. The resulting geometry allows for a turning circle of 35.4 feet. A steering damper was added to eliminate the possibility of wheel shimmy. A front anti-sway bar packaged forward of the axle completes the front suspension and steering assembly (Figure 21).

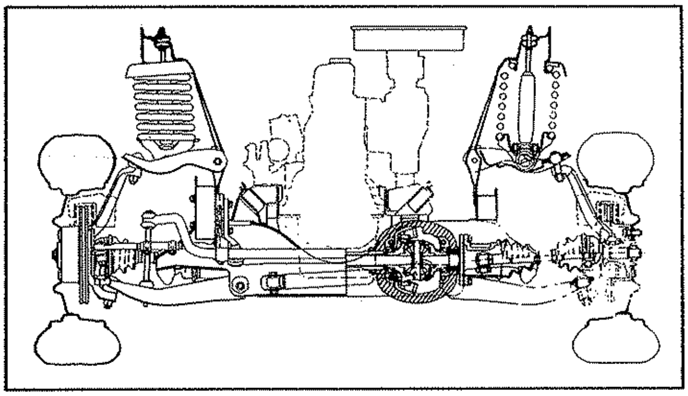

Figure 20

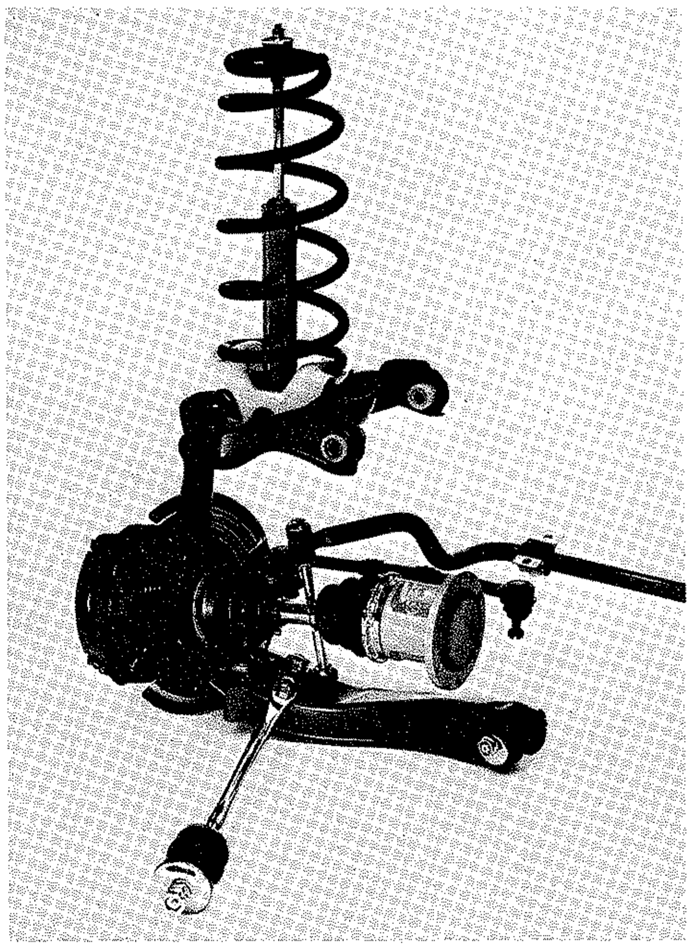

Figure 21

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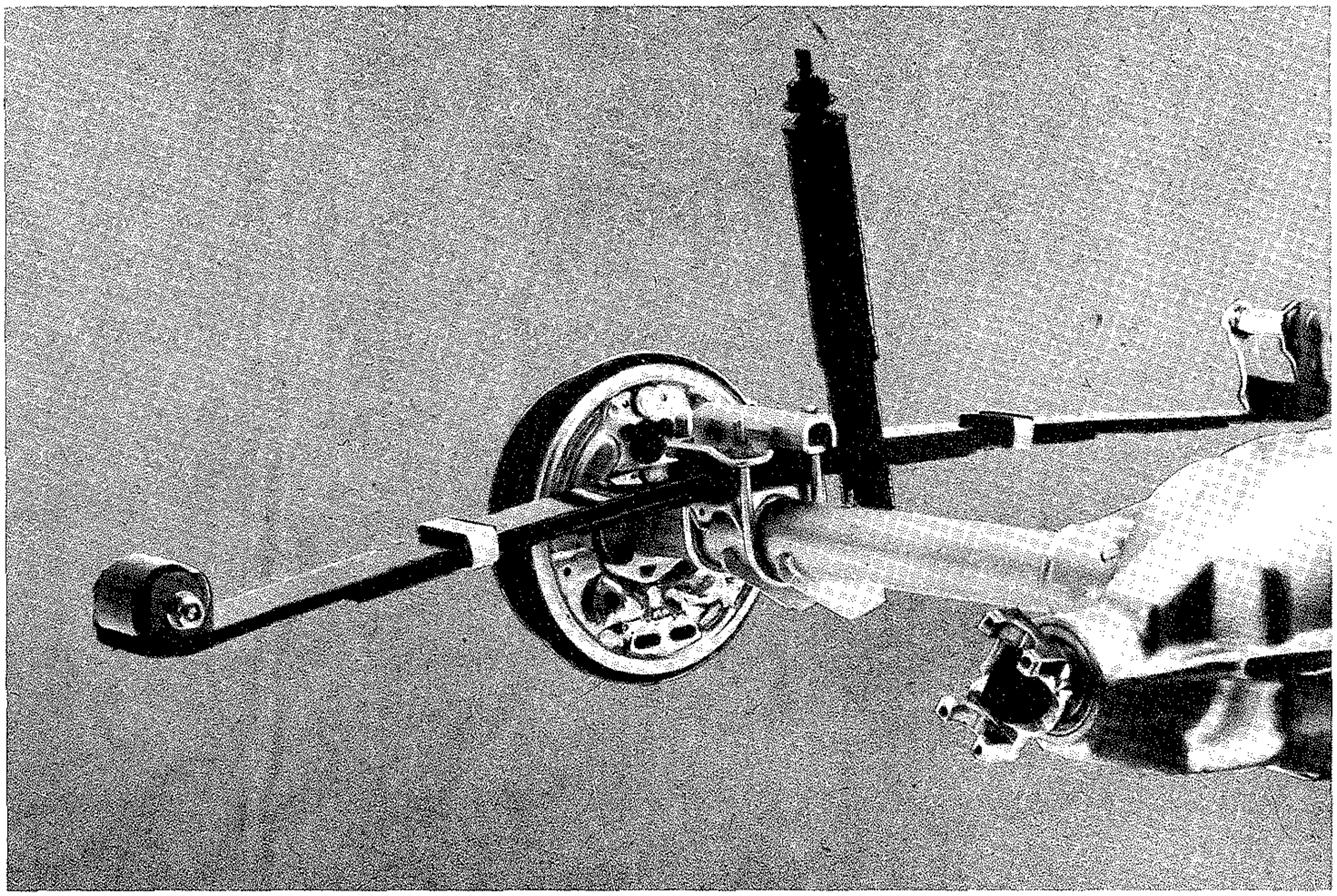

Figure 22

Rear Drive and Rear Suspension

The drive to the rear axle is straight through the transfer case and by a normal single cardan drive shaft with a slip spline. The rear axle is an AMC unit with a 7-1/2" diameter ring gear and cast center case and tube construction. The rear brakes are 10" x 1.75" drums with integral hubs and tapered spline attachment to the drive shafts. The rear suspension (Figure 22) is normal half elliptical springs which are mounted over the axle. Rear shock absorbers are staggered to help eliminate torque tramp and an anti-sway bar is provided as an optional feature. Another optional feature is a rear automatic leveling system, which is of the electric pump pneumatic variety and is activated by a height sensing switch.

Body Systems and Structure

It was originally intended to only adapt the Concord Wagon body for the Eagle. As development proceeded, the two and four-door sedans were added to the body availability. All three body styles use basically the same underbody structure and changes required for adapting the 4WD system were largely common. They included a new front floor panel and crossmembers to clear the transfer case located under the driver's seat, rear floor pan changes to accommodate the larger spare tire and strengthening front and rear suspension attachments. Appropriate reinforcements were added to the front body extension for mounting the front suspension and crossmember.

The body was raised 3 inches and the tread increased over two inches to accommodate the driveline. This created a wheel enclosure and stone pecking problem in addition to undesirable appearance factors. To resolve these issues, Krayton (SBR modified with polypropylene) wheel flares and rocker protectors were added. These actions overcame the functional problems, added a degree of all-around protection and gave the vehicle a unique, aesthetic appearance.

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TESTING AND DEVELOPMENT

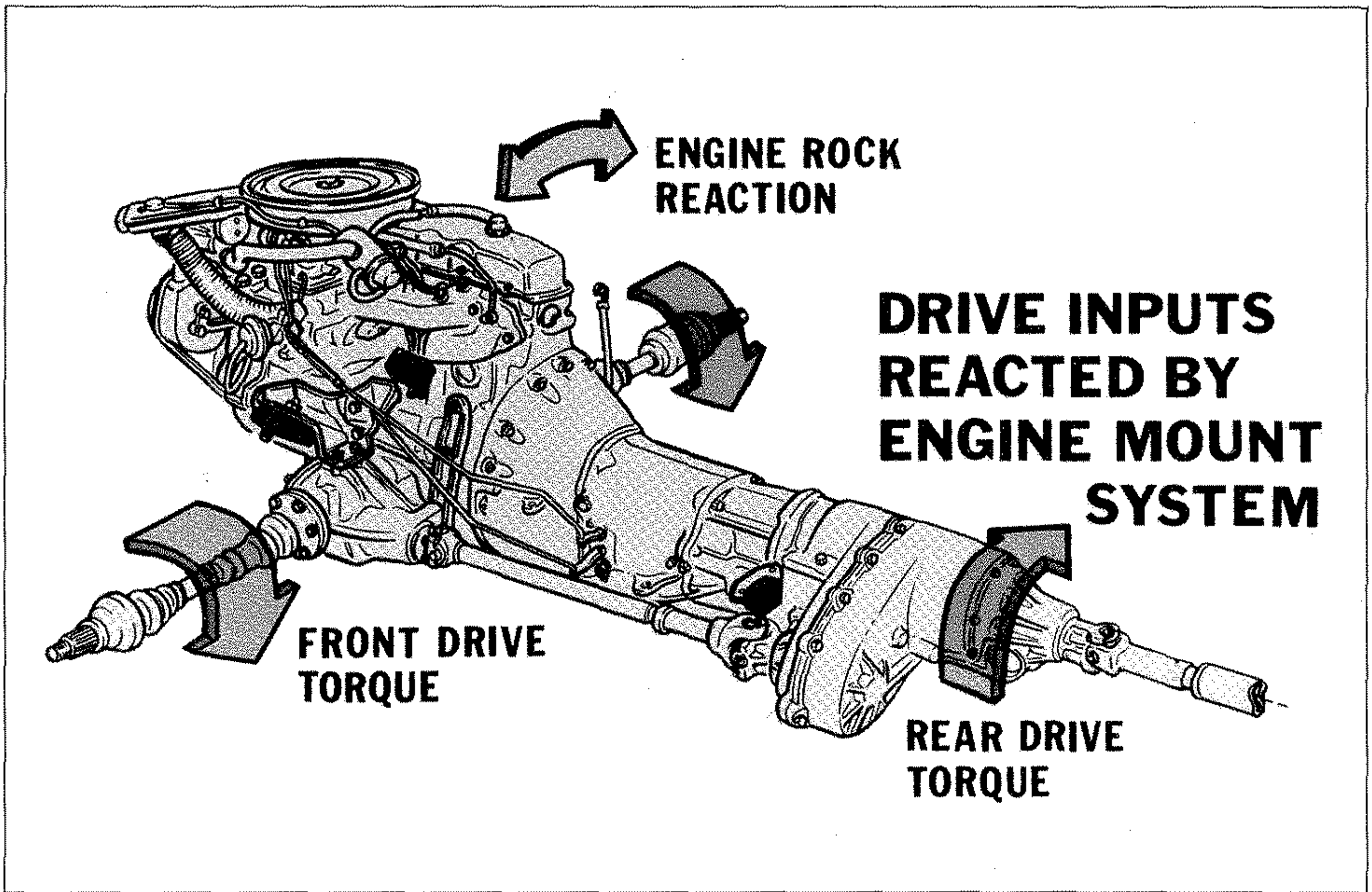

Figure 23

Development of the production phase prototypes commenced in the fall of 1977 in conjunction with refinement of the design to meet manufacturing requirements. Considerable time and effort went into tailoring engine mounts to bring NVH to objective levels. The nature of the configuration, with the front axle mounted to the engine, made this task considerably more complex than either 2WD, normal 4WD or even FWD. The engine idle factors are around the plane of the crankshaft, similar to a normal 2WD vehicle but when power is applied to the wheels, a complex set of forces comes into play. The drive to the rear sets up a reaction around the crankshaft centerline, while a second set of forces around the front half shaft is brought into action (Figure 23). The transition from idle to drive creates a final set of multi variables. Another factor in mount development was the subject of 'static torque' created when the vehicle is at rest and the engine is idling with resulting drag from the torque converter. In this condition, the rock of the engine around the plane of the crank induces lateral movement in the inner half shaft joints. A combination of idle torque and the degree of side movement of the engine relative to the half shafts can produce an undesirable degree of rumble at rest or in initial acceleration. The final balance of compromise in mount selection was accomplished with carefully tailored, but basically conventional type engine mounts.

The viscosity level and percent fill of the viscous biasing unit were also areas of empirical development. The original prototype development of the NP 119 unit used 60,000 centistoke viscosity oil, but this was progressively reduced to 15,000 centistoke at 70 percent fill for initial production to minimize the chance of normal variations in front to rear rolling radiuses bringing in the biasing action unnecessarily. The final selection of the viscosity level was also influenced by the Jeep vehicle usage, which has the added implication of non-constant velocity drive joints with solid axle.

Although the 15,000 centistoke units perform satisfactorily, empirical evaluation with other levels is still in progress for consideration on future models. Torque values for the various viscosity levels are shown in Figure 24 against RPM of the unit.

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Suspension and steering refinement followed normal lines of development. Front suspension static settings of the 1/16" toe out were found to provide the best handling characteristics in keeping with 4WD or FWD practice. A steering damper was added as a precaution against wheel shimmy which could possibly occur with excessively worn tires. Although the Eagle is not intended for the same type of off-road usage as a Jeep vehicle, it was subjected to considerable unpaved and trail-type testing. Special subjective testing included snow-plowing, which again demonstrated the vehicle's tractive capabilities (Figure 25).

Braking system tailoring in conjunction with transfer case biasing, clearly demonstrated improvements in deceleration over a 2WD configuration. This was particularly true in heavy braking situations incurring or approaching wheel slippage conditions. Increasing the centistoke levels in the viscous unit fluid resulted in increasing braking response.

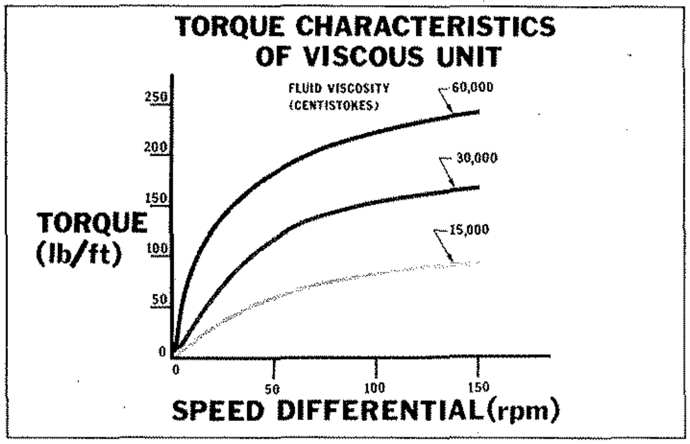

Figure 24

Fuel economy and emissions development were made against 49-state and California requirements for light trucks. Safety requirements were executed against multipurpose vehicle regulations, although the vehicle does meet all safety standards for passenger cars with the exception of bumpers.

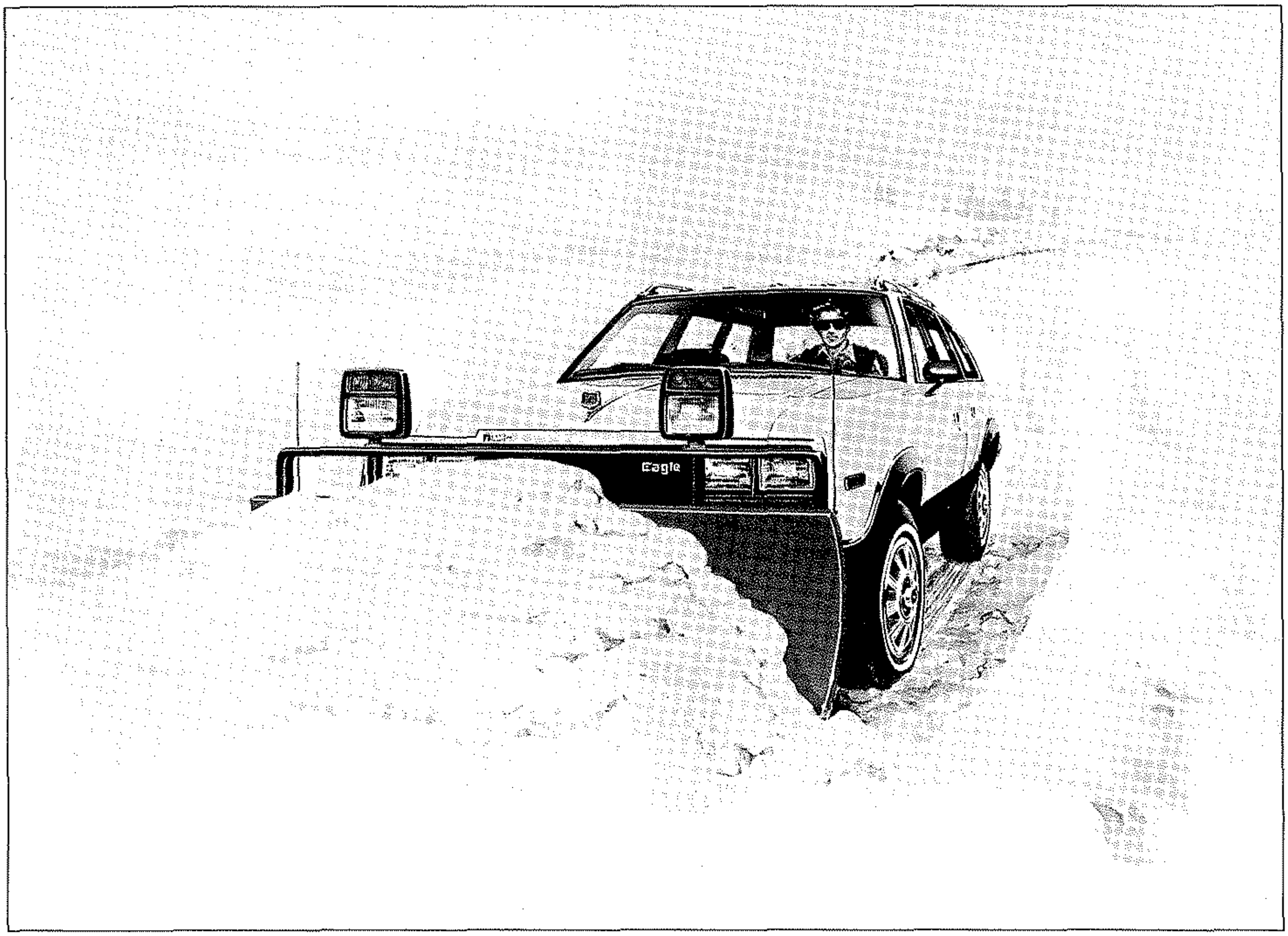

Figure 25

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SUMMARY

Creating a new vehicle has always been a challenging and rewarding experience. This is even more so today with the implicit technology required to meet the prevailing multi-faceted legislation.

The Eagle was brought to fruition by personal effort on the part of dedicated engineers and combining capabilities and technology from a variety of sources. Within the company, the inputs were an integration of Jeep vehicle and AMC passenger car activities. In addition, the contributions of a wide spectrum of vendors and suppliers played a major role in the design and development of many components and systems.

The 1980 Eagle project set out to advance the art of 4WD and to create a unique segment in the market. It is hoped that it has met these objectives and that it will be a new dimension in transportation.

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