The Advantages and Problems of
Torque Converters
as Used on Logging Equipment
on the Pacific Coast
by
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INTRODUCTION

With all its inherent advantages and economies, mechanical engineers are usually willing to admit that the internal combustion engine lacks the smooth flexibility and high starting torque of the steam engine. This is due to the different torque characteristics of the two prime movers, easy to understand when one remembers that the impulses driving the crankshaft of the internal combustion engine come from a series of explosions rather than from the application of a vapor and a relatively constant pressure as in the case of steam. Thus, the internal combustion engine relies upon speed for the development of power and the overlapping of the rapid explosions for smooth performance. To compensate for its lack of lugging ability as increasing loads are imposed, the internal combustion engine requires a selective transmission between the crankshaft and final drive.

For years mechanical engineers have sought to provide an intermediary device that would enable the internal combustion engine to approach the torque characteristics of the steam engine. The ideal device must be simple; it must work without selection; and it must deliver rapid, smooth acceleration.

In attempting the solution, a great number of different transmissions have been developed with varying degrees of success. Many of them involve some application of air or oil controls. Few, if any, have succeeded in overcoming all the disadvantages common to these types of power transmission.
Among them are: Difficulty in making gear changes under load; the human element, involving the judgment of the operator as to the proper instant to change gears; and finally, sensitivity of such types of transmissions to heavy shock loads, frequently resulting in motor stalling. As a result of experience, operators generally want a wide margin of safety to overcome these limitations. The premium paid for that is the sacrifice of power efficiency.

Closest to the ideal of steam engine performance is the gasoline or diesel motor driving through the hydraulic torque converter of the Lysholm-Smith type now finding a wide range of services, splendidly adapted to the needs of the logging industry, where machines of high starting torque and smooth performance are factors of prime importance. This transmission, developed by the Twin Disc Clutch Company, of Racine, Wisconsin, provides an automatically variable torque speed range, which functions solely through the engine throttle, providing smooth, shockless acceleration, coupled with automatic speed adjustments. The drooping torque speed characteristics of this transmission device are especially advantageous for the starting and acceleration of heavy loads. The high initial torque is automatically reduced as the motor speed increases. Even if the output shaft of the converter is stalled due to extreme load conditions, the engine itself cannot be stalled but will continue to function at its normal speed. Under these conditions a maximum of five times the engine torque will be available on the output shaft of the converter.
Important advantages accruing to users of torque converters cannot fail to impress operators of logging machinery, whose equipment is constantly subjected to shock loads and variable speeds. The device is especially desirable on yarders and skidders, where every turn of logs presents a different problem in weight and starting torque. Another desirable feature of the torque converter on the yarder is the fact that high speed is available automatically on the haulback. The torque converter works extremely well on loaders where the operator can raise and lower his load by merely opening and closing the throttle. Other logical applications would include draglines, locomotive cranes, etc.

Equipment on which torque converters are installed will operate at a higher power factor, because the engine speed ratio is automatically adjusted to the work to be done, speeding up and slowing down as load conditions demand. Such engines in logging service, for example, will unquestionably run longer without expensive overhauls and definitely excel in the quantity of logs produced.

This introduction intends to give a brief summary of torque converters and their application to logging equipment.

The main part of this thesis which follows is an explanation of the principles of torque converters together with their application in the field with the benefits and disadvantages listed.

The largest part of this information was obtained from
the Twin Disc Clutch Company and some of the equipment manufacturers who use torque converters on their products. Mr. N. I. Matson, District Manager for the Twin Disc Clutch Company, and Mr. Don McNeil, Chief Engineer for the Willamette Hyster Company, supplied most of the material here assembled, as well as helping with interviews and letters on the subject.

Part I

PRINCIPLES AND DESIGN OF TORQUE CONVERTERS

Several years ago, the Twin Disc Clutch Company foresaw the need for hydraulic drives in connection with internal combustion engines for oil field, railroad, logging and dirt moving machinery, and general industrial service, and immediately began the development of both types: (1) The Hydraulic Torque Converter, under patents owned by Lysholm-Smith, and (2) The Hydraulic Clutch and Hydraulic Power Take-off.

As anticipated, the demand for hydraulic drives has steadily increased. This is conclusively shown by the present widespread use of Hydraulic Torque Converters and Hydraulic Clutches in a wide variety of applications, ranging from drilling rigs in the oil fields of Trinidad to loaders and yarder in the logging camps of the Pacific Coast; in railcar and marine service, in locomotive and construction cranes, and many others.

The process of perfecting the hydraulic drives, like the development of any other essential piece of machinery, was necessarily slow. The field was new and comparatively
undeveloped, and there were few guiding precedents or established practices to follow. Research and development were further impeded by the fact that there was no test equipment or laboratory facilities available to meet the needs imposed by the job to be done. It was necessary, therefore, to develop both the methods for testing and the apparatus with which to make the tests, and to equip special laboratories for the necessary research, and to build up a personnel familiar with this type of work. Once these facilities were provided, the many problems of production still remained to be solved. Because each part was new to the production line, special machinery---dies, tools, guages, jigs, fixtures---had to be designed to produce the various units in sufficient numbers to meet the anticipated demand, as well as to assure ease of assembly, proper maintenance in the field, and the complete interchangeability of parts.

All of these obstacles were ultimately hurdles, however, and in December, 1938, the first of the Twin Disc Hydraulic Drives, a torque converter, was shipped to the oil fields for application to a cable tool drilling rig. The torque converter's advantages were soon recognized by the drilling industry and, as additional units were shipped to this and other fields, of industry, the desirability and superior performance of hydraulic drives was soon established.2

Before attempting to consider the design of the torque converters or to compare the power and torque characteristics of steam and internal combustion engines, it is necessary to understand the relation of torque and speed to horsepower.
Torque can be defined, briefly, as the effort producing or attempting to produce, rotation or torsion. Torque may be broken down into the product of two components: (1) force usually measured in pounds; and (2) lever arm distance, usually measured in feet. In other words, assume that a line is pulled from a drum one foot in diameter by a force of 100 pounds. The force of 100 pounds is exerted at the end of a lever arm of 0.5 feet (drum radius), thus producing a torque of \(100 \times 0.5\) or 50 ft. lbs. which is the effort tending to rotate the drum.

![Figure 1.](image)

Further, assume that the above torque on the drum is sufficient to rotate the drum (Figure 1.) at a given number of revolutions per minute. When torque is delivered at a given rate of speed, horsepower is developed and, within the elapsed time, work is accomplished. The relation of horsepower to torque and speed is such that for a given amount of horsepower an increase in torque will be compensated by a decrease in speed.

An automatically-variable, torque-speed type transmission will, without any help or guesswork on the part of the
operator, provide an automatic increase in torque to compensate for the slower speed while permitting the internal combustion engine to run at a constant speed. The Hydraulic Torque Converter comes as close to this ideal as any other transmission unit produced to date.

The operation of the Torque Converter depends upon the circulatory movement of a fluid to transmit power from the input to the output shaft. The Lysholm-Smith type of Torque Converter, which the Twin Disc Clutch Company manufactures, consists of four major parts: (1) Fluid; (2) Pump; (3) Turbine; and (4) Stationary housing. Its functioning may be described as follows: (Figure 2.)

![Diagram of Torque Converter](image)

**Figure 2.**

The pump, which is coupled to the engine, circulates the fluid, and the fluid, through the velocity imparted to it by the pump, becomes the transmission medium for the power delivered by the engine. As the fluid is forced against the
turbine blades and the blades mounted to the stationary housing, it releases its energy in the form of torque and speed. As a result of the fluid reacting upon the turbine and stationary blades, the input or engine torque is increasingly multiplied, as the speed of the output shaft is slowed down.

The pump, which is of the centrifugal type, imparts the power developed by the engine to the fluid in the form of fluid velocity, thus giving the fluid capacity to perform work. When the fluid leaves the pump, it flows directly into the first stage of a three-stage turbine.

The principle of the Torque Converter is the resistance of fluid in motion to any change in the direction and speed of its flow.

The simple use of a three-stage turbine would not provide an increase in the output torque. The result would be simply a hydraulic clutch or coupling. But, by re-directing the flow of the fluid, taking advantage of its resistance to change, the torque supplied by the engine is built up or multiplied. To do this, two sets of stationary blades are located between the turbine stages. (Figure 2.) These are mounted to the turbine housing.
Figure 3 shows the schematic diagram of fluid circulation in the Hydraulic Torque Converter.

When the reactionary blades are mounted in the stationary housing and the housing assembled to the engine or to a solid base, these blades cannot move when the fluid is forced against them, so the fluid flow is re-directed and the fluid's resistance to this change results in torque multiplication. Were it not for these stationary blades, there would be no torque multiplication and the output torque would be equal to that put into the unit by the engine. Due to the fact, however, that the stationary blades, be re-directing the fluid flow, do multiply the torque delivered by the motor, the unit becomes a torque converter.

![Graph showing performance characteristics of a torque converter](image)

Figure 4.

Before attempting a successful application of the Torque Converter, it is necessary to consider certain performance characteristics which can be presented best in graphic form. (Figure 4.) A typical performance curve is shown above.
it applies to a standard, plain Torque Converter. The curve indicated output torque obtained with an engine delivering 500 foot pounds of torque at 1800 RPM, which is the full throttle speed of the engine. No partial throttle characteristics are shown. The top efficiency is a broad, practically flat curve with a peak of approximately 85 per cent. As the output shaft speed approaches two-thirds of the engine's speed, the engine and converter torques become equal.

Viewed solely from the theoretical standpoint, the Torque Converter does not appear to be as efficient a unit as it is in actual operation.

To appreciate its true efficiency, in the full practical sense of the word, it is necessary to observe the Torque Converter at work on the job, because its performance in the field --- the all-important factor to the operator --- far outstrips the performance indicated by the efficiency curve.

The Torque Converter's efficiency characteristic is not the most important consideration in making an application. It is far more important to analyze carefully the job the converter is expected to do. Once this is done, and the converter is then applied so that it will be able to do most of the work within its best operating range, maximum efficiency, as interpreted in terms of work done, is assured. By taking these precautionary steps, the efficiency and torque-speed characteristics of the converter can be tailored to the work requirements of the job to be done.

Consider, for example, the case of a tractor equipped with
a four speed transmission. The horsepower available in each gear plotted against the respective speed in MPH is represented by curves in Figure 5. Even with the ablest operator shifting gears at the most opportune times, it is evident that the average work that can be performed under varying load conditions cannot exceed the shaded area shown in Figure 5.

If a hydraulic transmission of the torque converter type were applied, the horsepower available plotted against the speed in MPH would result in the curves shown in Figure 6.
At first glance, it appears that the lower peak efficiency of the hydraulic unit is overshadowed by a more favorable performance of the gear transmission. This comparison is incorrect because all four speeds of the transmission are being compared collectively.

In actual service, gear shifts usually cannot be made without coming to a complete standstill; therefore, in order to measure the amount of work done, the conditions in each of the four speeds must be compared separately with the corresponding conditions prevailing in the hydraulic drive. Such a comparison is shown in Figure 7. This comparison brings out clearly that the gear transmission permits the delivery of a higher peak output in each speed. In actual operation, however, it is very seldom possible to make use of this peak output because of the very narrow range of the peak during which it is available in each case.

A thorough analysis of the conditions under which a transmission-equipped unit is operated shows that the power factor
is generally between 50 and 60 per cent. In other words, it is necessary to run at partial loads with the engine operating against the governor in order to have a certain amount of power reserve available for contingent increases of load.

A converter-equipped unit will be operated at necessity at "Unity Power Factor" because it will always operate at the highest speed at which the load can be pulled, automatically slowing down and speeding up as the load varies.

From the above analysis, it is evident that the Torque Converter-equipped unit will produce slightly lower output peaks, but at the end of a working period in actual service, it will have excelled in the amount of work done.

An actual proof of the above statements is substantiated by the test results tabulated below which were obtained with a standard tractor and one of the same model equipped with a Torque Converter operating under the same conditions.4

Table 1

<table>
<thead>
<tr>
<th>Hourly mileage for equivalent loads.</th>
<th>Standard Tractor</th>
<th>Torque Converter Tractor</th>
<th>Per Cent Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.16</td>
<td>2.85</td>
<td>3.95</td>
<td>16</td>
</tr>
<tr>
<td>3.52</td>
<td>4.95</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>4.40</td>
<td>5.35</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>
Illustrations of Torque Converters:

The Direct Drive Converter (Figure 8). This type of converter is intended for applications such as rail cars and other similar equipment where the hydraulic drive is used during the acceleration period and the direct drive during the normal full speed operation. With this combination it is possible, by merely shifting the clutch, to provide for the high starting torque developed in hydraulic drive and required for quick, smooth acceleration, and also to take advantage of the additional speed range and maximum efficiency in direct drive for normal propulsion and high speed operation.

The Plain Converter (Figure 9). This type of converter is intended for industrial installations where a continuous hydraulic drive is desirable. The drooping torque characteristics and automatic torque-speed adjustment render these models particularly adaptable to any service where heavy loads have to be continuously started and accelerated (hoists, cranes, switching locomotives, oil field and logging equipment, etc.).
Figure 8.
Sectional Drawing of Direct Drive Converter -- Model DF
Figure 9.
Sectional Drawing of the
Plain Converter -- Model F
Due to the diesel engine's limited speed range, the problem of providing a satisfactory operating speed range in industrial service is more acute than any previously encountered in gas or gasoline engine applications. Therefore, a power transmission that will permit the operation of an engine at its normal and most efficient operating range, regardless of the speed of the driven machinery, is an advantage and an asset which is now more commonly appreciated than ever before.

It is a conceded fact that in many types of industrial installations, engines are being installed which are larger than would normally be required to carry the average operating load. This is done solely for the purpose of providing a means to take care of momentary overload conditions. However, by using a Torque Converter in connection with an internal combustion engine it is possible in most cases to use a smaller engine operating at somewhat higher speeds to do the same work which normally would require a larger, heavier, slow-speed engine.

In addition to new machinery equipped with the Torque Converter, there is a tremendous field for Torque Converters in machinery which has been designed for operation with steam engines. For example, by providing an internal combustion engine with the characteristics of a steam engine, direct replacement of the steam engine can be accomplished without
any major changes in the balance of the machinery.

Log Loaders:

In this type of application, the Torque Converter is the sole power transmitting unit, supplying power to the jackshaft from which all operations originate.

Regardless of the size of the log, the machine will handle it at the fastest speed possible. The operator has only to open and close the throttle to raise and lower the load. This ability to control the load with the throttle makes good brakes less important and gives the loader all the advantages of a steam loading machine.

Yarding Machines:

Applied to this type of equipment, the Torque Converter has rendered invaluable service on many of the Northwest's logging operations, particularly where the yarding job is complicated by excessive undergrowth, stumps, and other obstacles. On shows of this type, operators have been quick to recognize the converter's no-stall and shock-cushioning characteristics as important factors in maintaining a high rate of production and extending the life of allied equipment.

For example, on a British Columbia show where two twin engine yarders, powered with identical engines, one using a standard gear-type transmission, and the other equipped with a Torque Converter, daily production figures showed an advantage of 17 to 20 per cent in favor of the converter-equipped unit.

Another time study was recently made for purposes of
camparing a four-speed three-drum yarber with a converter-equipped yarber. The results of this study, as shown in Table II below, reveal that besides the converter-yarder bring in more logs in less time, the rig also showed a 58.5% increase in line speed when yarding over a 30% greater distance.

Table II

<table>
<thead>
<tr>
<th>Log No.</th>
<th>Size (Feet)</th>
<th>Total Time (Min.)</th>
<th>Hang-up Time (Min.)</th>
<th>Distance (Feet)</th>
<th>Rate (Ft./Min.)</th>
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<tr>
<td>1</td>
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<td>11 1/2</td>
<td>2</td>
<td>700</td>
<td>74</td>
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<tr>
<td>2</td>
<td>500</td>
<td>2 1/2</td>
<td>0</td>
<td>750</td>
<td>300</td>
</tr>
<tr>
<td>3</td>
<td>1,000</td>
<td>9 3/4</td>
<td>3</td>
<td>700</td>
<td>104</td>
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<tr>
<td>4</td>
<td>1,000</td>
<td>6 3/4</td>
<td>3</td>
<td>750</td>
<td>200</td>
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<tr>
<td>5</td>
<td>2,500</td>
<td>16 1/2</td>
<td>9</td>
<td>750</td>
<td>79</td>
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<tr>
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<td>800</td>
<td>4 1/2</td>
<td>0</td>
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<td>178</td>
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<td>800</td>
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<td>750</td>
<td>214</td>
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<td>4 1/2</td>
<td>0</td>
<td>750</td>
<td>124</td>
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<tr>
<td>Total</td>
<td>25,000</td>
<td>79 1/2</td>
<td>18</td>
<td>8,800</td>
<td>1,694</td>
</tr>
</tbody>
</table>

Twin Disc Torque Converter Equipped Yarber

<table>
<thead>
<tr>
<th>Log No.</th>
<th>Size (Feet)</th>
<th>Total Time (Min.)</th>
<th>Hang-up Time (Min.)</th>
<th>Distance (Feet)</th>
<th>Rate (Ft./Min.)</th>
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<td>900</td>
<td>163</td>
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<tr>
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<td>2,250</td>
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<td>160</td>
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<td>3,400</td>
<td>8</td>
<td>0</td>
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<tr>
<td>4</td>
<td>1,000</td>
<td>2 1/2</td>
<td>0</td>
<td>900</td>
<td>260</td>
</tr>
<tr>
<td>5</td>
<td>2,000</td>
<td>4 1/2</td>
<td>0</td>
<td>900</td>
<td>200</td>
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<tr>
<td>6</td>
<td>3,000</td>
<td>6</td>
<td>0</td>
<td>900</td>
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<td>0</td>
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<tr>
<td>8</td>
<td>1,300</td>
<td>4 3/4</td>
<td>0</td>
<td>900</td>
<td>190</td>
</tr>
<tr>
<td>9</td>
<td>2,000</td>
<td>11 1/2</td>
<td>5</td>
<td>900</td>
<td>139</td>
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<tr>
<td>10</td>
<td>1,000</td>
<td>2 1/4</td>
<td>0</td>
<td>900</td>
<td>400</td>
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<td>11</td>
<td>1,500</td>
<td>3 3/4</td>
<td>1</td>
<td>900</td>
<td>327</td>
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<tr>
<td>12</td>
<td>2,000</td>
<td>5 1/2</td>
<td>0</td>
<td>900</td>
<td>164</td>
</tr>
<tr>
<td>Total</td>
<td>22,525</td>
<td>62 1/4</td>
<td>8</td>
<td>10,800</td>
<td>2,686</td>
</tr>
</tbody>
</table>

Percentage gained by Converter-Yarder 27.6 200 30 58.5
Applied to twin engine yarders, the Torque Converter gives that added advantage of providing for proper distribution of the load and preventing one engine from fighting the other. Two-speed drums are sometimes used to increase the operating range.

That the Torque Converter is firmly entrenched as essential equipment in the logging industry is plainly indicated by the comments of both operators and manufacturers, three of whom are quoted at random as follows:

A British Columbia logger says, "This machine will pull as large a log out of a bad hole as she formerly would as a steam unit. When running in the haulback line and the strawline, tachometer tests on the crankshaft showed that this machine is running 12 per cent faster on the light pulls than when she was a steam unit. We stalled the output shaft of the converter against a stump for a full minute. The engines were then idled for thirty seconds and the stalling pull again exerted for a full minute. This operation was continued three times and we found it was impossible to raise the temperature in the converter or engines over 160 degrees."

A Washington logger says, "In 36 days, averaging 70M a day, we wore out—didn't break—three cable chokers, using a converter-equipped gas yarder. With a geared transmission yarder, we would have broken at least a choker a day—would have spent $1,170 for chokers against the $97.50 actually spent. Furthermore, we didn't lose any time for broken rigging—all the crew's time was productive time."

A yarder manufacturer says, "There seems to be an ever increasing appreciation of the value of the Torque Converter in the logging machinery field. Constant motor speed and freedom from gear changing give the Torque Converter all the advantages of steam with many added economies—we see great possibilities for the Torque Converter in logging applications."
CONCLUSION

Although, in the brief space of a few years, the use of hydraulic drives has effected startling improvements in many different applications, it is conceded among the men who are familiar with this new development in transmissions that the gains already made are nothing as compared with those in store for the future.

This generally-held belief is based on the fact that, up until the present time, hydraulic drives have been applied almost exclusively on already existing equipment, as an afterthought. In most cases, they have been attached to a prime mover---normally an internal combustion engine---which was designed to accommodate an entirely different type of transmission. Due to this fact, it has usually been necessary to make compromises and sacrifices which made it impossible to obtain the best results and optimum performance characteristics from the hydraulic units.

A survey of the development work now going on among many manufacturers, however, indicated that this period of make-shift installations is nearing an end and that in the near future, hydraulic drives will be given a real opportunity to show what they can do. With the new designs now on the drafting boards, taking into consideration the performance characteristics of hydraulic drives, it will soon be possible to put matched units into the field; units which have been designed and engineered throughout to complement all the desirable features of the other.
The future of hydraulic drives is further brightened by the fact that the Twin Disc Clutch Company's facilities for research, design, and production are being constantly improved and enlarged as additional operating data from the field becomes available.

In addition, both manufacturers of allied equipment and the men who will operate that equipment on the job are steadily gaining a wider knowledge of the operation and care of hydraulic drives and this, too, will be a factor conducive to improved performance.

In view of all these facts, it can be reasonably assumed that hydraulic drives will be the means of effecting greatly improved performance of any machine or any job of which they are a part, from the standpoint of more work done, at a lower cost, in less time, with less wear and tear on the equipment.
Figure 10.

Willametter Hyster three-drum yarder equipped with Twin Disc Hydraulic Torque Converter owned by C. D. Johnson at Toledo, Oregon.
Figure 11.
Close-up of Willamette-Hyster three-drum yarder with Torque Converter

Figure 12.
Hydraulic Power Take-off as installed in a Lorain Shovel
Figure 13.
One of two Gunderson Brothers twin engined yarders built for the C. D. Ray Logging Company, Fairview, Oregon. Units are powered with GM Diesels equipped with Twin Disc Torque Converters.

Figure 14.

2. Hydraulic Drives,
3. Twin Disc Clutch Company, Racine, Wisconsin.

4. The Story About Work Done, Hydraulic Department, Twin Disc Clutch Company, Racine, Wisconsin.


6. Hydraulic Drives,
7. Twin Disc Clutch Company,
8. Racine, Wisconsin.

Anyone desiring further information on this topic will find Mr. N. I. Matson, District Manager, Twin Disc Clutch Company, 539 First Avenue, South, Seattle, Washington, very friendly and cooperative in supplying information.