The Bureau of Reclamation’s 1950 Mack LJSW-D

In 1940, the Mack Manufacturing Corporation introduced the “L” series of trucks, the LF, LH, LJ and LM. These trucks were built from 1940 to early 1942 until they were temporarily discontinued due to the war years. No “L” model trucks were manufactured during the war with production resuming after 1944. The LJ model was designed for heavier work and was available in a choice of truck (LJ), tractor (LJT) or 6 wheel versions (LJSW). The designations “SW” and “2D” were used interchangeably to indicate a 6 wheel truck. A variety of wheelbases, transmissions and gasoline and diesel engine options were also available. In 1950, Mack delivered 831 LJ2D model trucks with 621 or 74.7% equipped with diesel engines. A grand total of 13,931 LJ model trucks were built from 1940 to 1956 making it one of the most popular trucks in the Mack product offering.

The US Federal Government’s General Services Administration in Washington, DC ordered this LJSW model truck (serial number LJ2D-3352D) directly from the Mack Manufacturing Corporation (Purchase Order No: RR 51-5-1043) in late September, 1948 bypassing a Mack dealership. However, it was built on October 23, 1950 but not delivered until November 27, 1950 more than 2 years after it was originally ordered! It was shipped to an un-named government service department in Philadelphia, PA. The truck was ordered with the optional NHB Cummins engine developing 200 HP and 537 ft-lbs of torque at 2100 rpm (Fig. 1c, 188 certified net horsepower at 5000 feet altitude). This might seem unusual for a government vehicle to be equipped with a premium engine option but the truck was destined for a large construction project in the mountains of Colorado where net horsepower could decline by perhaps as much as 20% (altitude, temperature, barometric pressure and humidity dependent). The truck was Mack Yellow in color with optional Budd wheels all around which would be common for a western truck. Paint color options for Mack trucks in 1950 were Mack Green, Red, Yellow and Blue synthetic enamel. It was also equipped with the standard FA-25 front axle and SWD-451 rear axles (9.02 gear ratio recommended for dumpers and mixers) and with TR-150 five speed over gear transmission (ratios are 1st= 5.48, 2nd=3.11, 3rd=1.75, 4th=direct, 5th=0.77, rev.=5.53) and a Brown-Lipe 3 speed auxiliary transmission (ratios are 1st=2.59, 2nd=1.00 and 3rd=0.75). Other special options included a Luberfiner oil filter, air horn mounting arrangement and an engine compression release (for cold weather starting).

According to the “Truck Chassis Record” obtained from the Mack Museum, the truck was ordered with the longest wheel base available of 184.5 inches and a long platform of 240 inches (back of cab to the end of the frame). One can only conjecture as to the reason for the extra length and the delivery to Philadelphia but sometime between that delivery and it’s first service record available, the wheel base was shortened to 137.5 inches (standard wheelbase but the shortest available factory wheelbase for 5-speed transmissions with B-L auxiliary transmission was 158.5”), a pair of Elston Electric Sanders were added as well as a massive 60,000lb Garwood winch and a large rolling tail board (see also Fig 1a and b). Vertical exhaust was an option for 1950 but checking the part number on the chassis record with the Mack Museum, the truck had a factory installed vertical exhaust stack. There is a non-functioning fuel gauge on the dash but
rather than having sending units, the present 50 gallon fuel tanks manufactured by the American Steel Tank Co. have a dipstick and an anti-siphoning steel piece inserted just inside the fuel tank filling port. Fuel levels were likely checked daily by simply using the steel dipstick assembly on each tank. Interestingly, the truck was originally equipped with standard Mack factory 40 gallon side fuel tanks and fuel gauge. Also added was a very large after-market cab heater (double fan) manufactured by Hadees that occupies much of the space beneath the dash on the passenger’s side of the truck. Although the optional 17,000 BTU hot water heater was available from Mack, this was not ordered. Also not added at the Mack factory were directional signals and directional signal switch, ignition switch and ignition key (not required for Cummins diesel equipped), fifth wheel, the trailer brake connection and the hand control valve. Many of these options were furnished later at an unknown date. Perhaps the truck was destined to be something else like a dump truck or perhaps it was ordered as a simple chassis until a decision was made about its final configuration. Also note that all of the Bureau of Reclamation’s projects are west of the Mississippi so the delivery to Philadelphia remains a mystery.

The capacity of the Garwood winch could not be immediately confirmed but cleaning the identification tag on the top of the winch reveals a figure of 60,000 (see Fig. 3 third line). We have also been advised by a Garwood winch reseller that all 6M models have a capacity of 60,000 pounds (very conservative rating) thus one can assume that this large winch is a 30 ton unit used to pull various pieces of construction equipment onto a low boy trailer in situations where the piece of equipment could not be started. This would certainly be the case during the frigid winters in the Colorado Mountains where the truck eventually ended up in the summer of 1952.
Fig 1a: The first 2 pages of the original Operator’s Manual detailing options and serial numbers.

Fig. 1b: Cover of the original Operator’s Manual
<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>1950</td>
</tr>
<tr>
<td>Net vehicle weight</td>
<td>743</td>
</tr>
<tr>
<td>Main transmission speed</td>
<td>5 speed Mack</td>
</tr>
<tr>
<td>Tires</td>
<td>11.00 x 22 12 ply</td>
</tr>
<tr>
<td>Fifth wheel 2&quot; Holland Safety</td>
<td>150-c</td>
</tr>
<tr>
<td>Motor</td>
<td>Cummins Diesel</td>
</tr>
<tr>
<td>Chassis No.</td>
<td>LJD2D3352D</td>
</tr>
<tr>
<td>Motor No.</td>
<td>NH8-84851</td>
</tr>
<tr>
<td>Transmission</td>
<td>Brown Type - Model 9037-C</td>
</tr>
<tr>
<td>Purchase Order</td>
<td>RR 51.5 - 1043</td>
</tr>
<tr>
<td>Certified Net Horse Power</td>
<td>1880 @ 2100 RPM 200 @ 2100 RPM Endo level</td>
</tr>
<tr>
<td>Power Take Off</td>
<td>Ser # 7902</td>
</tr>
<tr>
<td>Winch</td>
<td>Ser # C77923</td>
</tr>
<tr>
<td>Transmission</td>
<td>Ser # 11KBA5130AP9-TR150</td>
</tr>
<tr>
<td>Rear End</td>
<td>Ser # 10FA5205 DP 4</td>
</tr>
<tr>
<td>Wheel Base</td>
<td>13 7/8 inches</td>
</tr>
</tbody>
</table>

Fig. 1c: A plasticized information card of unknown age with various details of the truck written by hand and firmly posted somewhere inside the cab. It was most likely produced as a reference document to be used by various government drivers.
Fig 2: Numbered parts diagram for the Garwood winch. Note hand writing in red in the upper left corner (“For Mack truck, I-29986-1950”). This notation would suggest that the winch was added after being licensed in Colorado.
The truck was eventually shipped (or driven?) to Loveland, Colorado to move various pieces of construction equipment working on the large Colorado-Big Thompson construction project.

**The Colorado-Big Thompson Construction Project**

The Bureau of Reclamation is an agency under the US Department of the Interior and oversees water resource management, specifically as it applies to the oversight and operation of numerous water diversion, delivery, storage and hydroelectric power generation projects it has built throughout the western US.

The Bureau of Reclamation was responsible for the Colorado-Big Thompson project which spreads over approximately 250 miles in the State of Colorado. This very large project was designed to store, regulate, and divert water from the Colorado River on the western slope of the Continental Divide to the eastern slope of the Rocky Mountains providing supplemental water for irrigation to approximately 720,000 acres of land, for municipal and industrial use, hydroelectric power and water-oriented recreation opportunities including several man-made lakes. Major features of the project include dams, dikes, reservoirs, power plants, pumping plants, pipelines, tunnels, transmission lines, substations and other associated structures. The project diverts approximately
260,000 acre-feet of water annually from the Colorado River headwaters on the western slope to the Big Thompson River for distribution to project lands and communities. The Northern Colorado Water Conservancy District apportions the water used for irrigation to more than 120 canals and 60 reservoirs. Eleven communities receive municipal and industrial water from the project and electric power is produced by six power plants.

In 1870, before statehood was achieved by the Colorado Territory, cooperative irrigation in the South Platte River Valley began which marked the start of an era in which irrigation became important in the economic development of northeastern Colorado. By 1900 the streams were over appropriated and attention was given to developing the plains reservoirs to store the spring floods. By 1910, most of the better reservoir sites were used and few possibilities were apparent, except costly transmountain diversion. During these years, the increasing demand for agricultural products for a growing population and the tendency to prepare as large an irrigation system as possible to spread the cost of the construction resulted in over-expansion, especially in years of high and adequate runoff. Water shortages continually plagued the irrigators. The idea of transmountain water diversions had been in existence since 1889, when the Colorado legislature appropriated money to investigate such a proposal. In 1922 after several legislative steps, the signing of the Colorado River Compact was completed which apportioned the Colorado River water between the upper and lower basin states.

Engineering studies of the Colorado-Big Thompson Project began in 1933, a favorable report was presented in 1934 and in January 1935, the Bureau of Reclamation was allotted funds by the Public Works Administration to make a new study. Project construction was contingent upon the formation of a conservancy district to contract with the United States Government. Accordingly, the Colorado Water Conservancy Law was passed by the Colorado legislature in 1937. First construction funds were provided in the Interior Department Appropriation Act of August 9, 1937. The Secretary’s finding of feasibility was approved by the President on December 21, 1937. Construction of the project began at Green Mountain Dam during November 1938. The first power was generated at the Green Mountain Power plant in May 1943; all construction of the dam and power plant was completed in October 1943. Construction of Granby Dam started in 1941 and of the Alva B. Adams Tunnel in the summer of 1940 (this tunnel is 9.75 ft in diameter, 13 miles long and extends under the Continental Divide to a point 4.5 miles east of Estes Park.) Work was curtailed during World War II, but at the end of the war, the pace of construction increased considerably. During 1956, all major features were essentially completed except the Big Thompson Power plant, which was completed in 1959.

This government Mack truck was serviced at the Bureau of Reclamation’s Loveland Garage every 500 miles and had a complete service and maintenance check every 5000 miles or 90 days, whichever came first. The first service record available is dated June 23, 1952 with total miles at 14,513 and 627 hours. The whereabouts of the truck up to this point in time is unknown. There are, in fact, more than 100 pages of Bureau of Reclamation “Shop Job Orders” and “Motor Vehicle Inspection Reports” from June 23, 1952 until 1980. The last job orders are undated and show a jump in recorded mileage from 98,814 to 108,753. The latter figure is likely an error and does not concur with the
average yearly mileage dating from 1952 which averaged approximately from 1000 to 2000 miles. In one example, the truck sat from June 13, 1963 to September 20, 1963 having been driven only 65 miles in that period. There are no dated service records for 1980 to account for the 10,000 miles that accumulated in just one year (present mileage showing is 1946 miles). Some examples of Shop Job Orders and Motor Vehicle Inspection Reports are shown in Figs 4 and 5.

Fig 4: Shop job order dated June 29, 1953. Note mechanic’s helper’s hourly wage ($1.53)
Fig 5: A Motor Vehicle Inspection Report done every 5000 miles or 90 days, dated June 16, 1953.
Although the truck was purchased to haul several pieces of construction equipment to and from the many different construction sites that comprised the Colorado-Big Thompson project, it also hauled 6 inch pipe (see Fig. 6a and b).

Fig 6a: Special Transport Permit given to the Bureau of Reclamation for hauling 6 inch pipe from Loveland to Grand Lake dated July 6, 1965.
Fig 6b: Reverse side of the Special Transport Permit showing maximum weights, widths and lengths plus location exceptions which were railroad underpasses. Figures in pencil presumably are determinations by various drivers trying to establish a legal maximum weight.
P245-704-5266 Loveland Service Area—Old Garage—Colorado—Big Thompson Project, Colorado. The back and south sides of the building are shown in this view. Work by Jones and Hazlrop, under Specifications No. 704C-208.

R. E. Holdsworth Photo, July 9, 1952.
Fig 7a and b: Photos of the Loveland Garage where the Mack truck was serviced. Photos were obtained from the National Archives and Records Administration, Denver, CO. Interestingly, the Loveland Garage was completed on June 23, 1952 which is also the date of the first surviving service record for the truck.

![Image]

Fig 8: General view of the Bald Mountain Tunnel Inlet Channel after the placing of Riprap dated Oct. 28, 1953. Note the low bed trailer/truck combo in the background. Make of the truck is unknown (Sterling?). Photos were obtained from the National Archives and Records Management, Denver, CO.

In reviewing the many service records for the truck, there are several interesting entries as follows:

**March 29, 1956.** From a Shop Job Order, “Wash truck and motor, 500 mile check, drain oil and change filter cartridge, complete service after being in a dust storm, repair hood, N/C.”

**June 19, 1956.** The truck and motor were washed and the 6 injectors were replaced after having been rebuilt earlier that same month by Cummins Diesel Sales of Colorado. A compression test (42,378 miles) at the same time gave the following values: No.1=400lbs, No.2=400lbs, No. 3=410lbs, No.4=390lbs, No.5=400lbs and No.6=400lbs.
June 22, 1956. The truck was driven to Cummins Diesel Sales in Denver for a dynamometer test. All test values and other engine data are shown in Fig. 9. Horsepower determinations for each rpm and road speed would seem to be rather low considering that very early certified test data showed 188 HP at 5000ft elevation.

Fig. 9: Dynamometer test data dated June 22, 1956.
January 29, 1957. "5000 mile inspection, wash mud and ice off truck, checked all gear boxes, removed floor boards and transmission cover, made new gaskets and installed cover on transmission, replaced floor boards, repaired winch lever (loose), checked batteries, (gravity test between 1175 and 1200). Batteries were put on charger and charged at 10 amps for 7 hrs and no gravity rise occurred. Batteries are over 3 years old and are sulfated to the point that they won’t take any higher charge. Made and started to install rear hood center hold down.” These are written comments by Lawrence Karst who spent 17 hours working on the truck. Total miles noted were 46,284. It is believed that Mack LJ and A models were the last trucks built that had wooden floor boards. Mack introduced the famous “B” model in 1953 which came with sheet metal flooring.

May 22, 1957. “Service call to Briggsdale, Colorado on State Highway 14 that wheel had locked on the Mack truck. Pole trailer and poles raised and blocked so that tractor could be unhooked, Sterling tractor hooked to trailer. Left rear wheel of Mack jacked up off road and chained into carrying position. Axle shaft removed, unit towed back to Loveland Garage. Rear wheel pulled and broken cone and rollers cut off housing with cutting torch.”-Delbert R. Herald, Heavy Duty Mechanic.

June 7, 1957. “The following costs were incurring in repairing water damage to the above equipment (Mack truck and trailer) resulting from crossing of the Colorado River about one mile west of Parshall, Colorado. The tractor and trailer were being used to deliver material for the erection of the Williams Fork Substation, Account No. 145-255/75.” Repairs required the following: the Mack’s fuel pump was removed and taken to the local Cummins Diesel service center in Denver for a complete overhaul and recalibration. Additional supplies for the repair included a wheel bearing for the trailer, 100 pounds of gear oil, 1 filter cartridge and 1 oil seal. Delbert L. Herald was the Heavy Duty Mechanic ($2.50/hr), Lawrence W. Karst was the Mechanic’s Helper at $1.94/hr and J. H. Wiley was the Low Boy Driver who was paid $2.28/hr. Government per diem rates at that time were a flat $10 per day.

June 6, 1960. The Bureau of Reclamation spent $1171.51 “to place Mack Tractor in first class operating condition.” Looking at figures 10 and 11, the Cummins engine was overhauled and completely rebuilt at 57,445 miles by the Cummins Diesel shop in Denver at the end of May, 1960. The truck was delivered to the shop on Monday, May 16 and the work was completed on Friday, May 27, 1960. J. H. Wiley was dispatched to the Cummins shop in Denver to pick up the truck (4 hrs at $2.88/hr.).

Service records from the 1970’s up to 1980 were very scant and did not contain much detail. Below in figures 11 and 12 are the last special permits issued to the Bureau of Reclamation for the Mack truck/trailer combination for hauling a crawler tractor for one month in the spring of 1979 and 1980.

The truck, after almost 30 years (to the day) of government service, was sold at a government auction to a local construction company, the Ed Loloff Construction Company in Kersey, CO. It was purchased from the General Services Administration on November 21, 1980 but not re-licensed until July 7, 1981 (see Fig. 15). The Loloff Company used the truck to move various pieces of their construction equipment.
including a Cat dozer, loader, drag line and a trencher. They also used it to move a conveyor that they used with their crusher. It was used sparingly and there were no mechanical problems with the truck.

On June 20, 1997, the truck was sold to Gene Marlin of Marlin Crane Inc. of Indianapolis, IN. Gene had seen the truck parked outside the Loloff yard with a “for sale” sign on it and since he had driven a truck just like this when he was a young man, Gene decided to purchase the truck from the Loloff company where he started a general restoration. The truck was painted in a dull military gray with no markings when Gene purchased the truck (see Figs 14a, b and c). He sandblasted the entire truck with charcoal since this was used in the aircraft industry and was a technique that Gene was familiar. The uniform size of the particles does little outward damage to metal surfaces unlike sand with its wide range of particle sizes. Since Gene always wanted a red and green truck, he hired a summer student to paint the entire frame and winch a kind of forest green. The truck was then taken to the local Freightliner dealership for some restoration work on the inside of the cab and to paint the outside of the cab a bright red (attempted to match Mack Red). Much of the restoration work was done from February 2, 1999 to January 12, 2001. The truck was kept in Gene’s aircraft hanger for several years when he decided to sell the truck in 2008 (see photos in Figs. 16-18).

The truck was purchased and hauled back to the Pfahl restoration shop in Bethlehem, CT. Some engine repairs were completed immediately after arrival (blown head gasket between cylinders 5 and 6) but serious restoration could not be started until the fall of 2010. The single disk injector pump was particularly troublesome and had to be removed and repaired 3 times before finally getting it to function correctly. It contains some elements of a carburetor (float bowl, float, needle and seat) and details of this have been outlined in Appendix C. During the operation of the truck in the mountains of Colorado, no adjustments were made to the fuel system to accommodate for the increase in elevation since the fuel system would have been set at the factory for operation at sea level (see Appendix C). The exhaust likely smoked because the engine would have been starved for air at the 5000 ft. elevation.

In general, our restoration work involved mostly cleaning, grinding, sanding, repainting and detailing the interior and exterior to get it close to its original color and condition. Tires were replaced but much of the mechanical details of the truck were in very good condition. The channel type front bumper had too many bends and dents in it to be economically straightened so an exact duplicate of the front bumper was made. The original bumper was saved as a pattern for future restoration work. The pintle hook on the rear of the truck had been badly bent some time in the past. It appears as though a cable was lashed to the hook and the truck was pulled sideways. It has been left in its present configuration for posterity. Some restoration photos are shown in Figs. 19-22.

Attempting to obtain historical information from a large government department is both time consuming and frustrating, but with luck and persistence, some information was found. The main problem was not a lack of photos; but rather, very few photos of the construction equipment and trucks used to complete the Colorado-Big Thompson project (see Appendix A). Even the resident historian was unable to help. One can only assume that there are likely no photos of the truck or the people that drove and serviced the vehicle while in government service. It is also likely that the people that were associated with the vehicle and the Bureau of Reclamation during the time frame described have
long since passed away. Finally, the Loveland Garage also no longer exists. Its fate remains unknown. All that remains is this 1950 Mack LJSW-D that is a testament to an interesting piece of Colorado history and of course, antique truck history.

**Acknowledgements**

I am indebted to the Mack Museum staff for providing very valuable material and assistance. I want to thank Ms. Kara Lamb, Public Involvement Specialist and Mr. James Judd, Management Analyst of the Bureau of Reclamation for their help and assistance. Thanks to Ms. Marlene Baker of the National Archives and Records Administration in Denver for organizing various materials related to the Colorado-Big Thompson project and for help in obtaining my “researcher” status. Thanks also to Don Loloff and Gene Marlin for valuable material and information. As always, a special thank you goes to the Matt Pfahl restoration team for a job well done.
Fig. 10: Job No. D-27232 for Mack Cummins diesel engine overhaul dated May 27, 1960.
Fig. 11: Invoice No. 4-1646 for the Mack Cummins engine overhaul dated May 27, 1960.
Fig. 12: Special Transport Permit issued to the Bureau of Reclamation for moving a Crawler Tractor from 3/26/79 to 4/26/79.
Fig 13: Special Transport Permit issued to the Bureau of Reclamation for moving a Crawler Tractor from 4/7/80 to 5/7/80.
Figs 14 a, b and c. The truck is parked in the front of the Loloff Construction yard with a “For Sale” sign in the front window circa 1997.
Fig. 15: Registration and Ownership Details dated November 21, 1980 but the truck was not licensed until July 7, 1981. Note the list price of $17,000.

Fig. 16: Red and green 1950 Mack LJSW in Gene Marlin’s aircraft hanger.
Fig. 17: Red and green 1950 Mack LJSW in Gene Marlin’s aircraft hanger.

Fig. 18: Getting ready to load and move the truck to the restoration shop.
Fig. 19: Restoration photos. Note damage to radiator fins accumulated over the many years of service in the Colorado Mountains.

Fig. 20: Restoration photo of the Garwood winch.
Fig. 21: Truck interior undergoing some minor restoration and detailing.

Fig. 22: Restoration photo of the rear of truck.
Appendix A-Bureau of Reclamation Trucks, 1930’s-1950’s
TIME DOES TELL... PLENTY!

The Mack trucks you see on the road today are of all descriptions. But there's one thing they have in common. Being Macks, they're built to last! That's a basic Mack advantage, doubly important in wartime when replacements are hard to get. Seven out of every ten Macks built ten years ago are still on the job. For forty-eight years Mack trucks have established a record for long life that is still gaining on house room and battle room alike. The expression "Built like a Mack truck" was not coined by us, but by those who watch Mack trucks at work.


If you've got a Mack, you're lucky...if you plan to get one, you're wise!
the hardest work looks easy when MACKS come on the job

Many Mack users say that two Mack trucks easily haul a full capacity load up the steepest grades—and you can rely on the strength of their rugged Mack-built engines, frames, gears, axles and transmissions. Facts like these explain why almost half the diesel trucks sold in the U.S.A. last year were Mack—the No. 1 sales record. Available from 125 to 200 horsepower, all models are famous for economy, power and performance. And Mack gasoline trucks have the same outstanding reputation.

Macks are unrivalled as the longest lasting trucks you can buy. That’s because Mack makes sure of building the finest trucks in the world. They make more of their own parts than other manufacturers and to the highest automotive standards.

These are a few of the reasons for Mack’s superiority in heavy-duty trucks. See your Mack representative for the best advice on your hauling needs.

MACK TRUCKS, INC., Plainfield, New Jersey. Makers of world-famous trucks, buses and fire apparatus, gasoline or diesel. Distributors in all principal cities of the world.

MACK first name for TRUCKS
WHERE STEEL IS KING!

There's an especially appropriate point to this picture of a Mack in a big steel mill. In the world of durable materials, steel is king. Steel for strength. Steel for durability. And in the world of trucks, Mack reigns on these same two counts. It is Mack for strength. It is Mack for durability. For the very backbone of Mack construction is Mack's lavish use of heat-treated alloy steels. "Built like a Mack Truck" means built to work hard... to stay on the job longer... and to do the job at lowest cost.


IF YOU'VE GOT A MACK, YOU'RE LUCKY... IF YOU PLAN TO GET ONE, YOU'RE WISE!
Appendix C

Cummins Fuel Injection Systems, 1932-1960

Introduction

Diesel engines emerged as a competitive power plant technology in the 1930’s due in large part to their superior fuel economy over gasoline engines. Between 1946 and 1958, the number of trucks registered nationally nearly doubled from fewer than 6 million to more than 11 million units due, in part, to the very ambitious highway construction program initiated during the Eisenhower era (Federal-Aid Highway Act of 1956). As the trucking industry began its conversion from standard gasoline to diesel, transmissions and other components also evolved with improved highway construction. Many of these trucks were equipped with both naturally aspirated and turbocharged diesel engines and many of these engines were sold by the Cummins Engine Company. From the earliest days in 1932 when Cummins introduced the H model diesel engine, fuel injection had been the key technological challenge. Compared with gasoline carburetors, diesel injection systems were large, heavy and considerably more expensive. They were also a major factor limiting engine performance.

In general, a diesel fuel injection system has the following requirements:

(1) A fuel pump to draw fuel from the fuel tank and deliver it to the individual injectors for each cylinder.

(2) A means of controlling the pressure of the fuel being delivered by the fuel pump to the injectors so the individual cylinders will receive the right amount of fuel for the engine power required.

(3) Fuel passages of the proper size and type so that the fuel will be distributed to all injectors and cylinders with equal pressure under all speed and load conditions.

(4) Injectors to receive either low or high pressure fuel from the fuel pump and deliver it into the individual combustion chambers at the right time, in equal quantity and in the proper condition to ignite and burn efficiently.

Truck manufacturers of diesel engines typically have used four basic injection systems as follows: Distributor Type, Multiple Plunger Type, Common Rail Type and Unit Injector Type. The main focus of this article will be the Single Disk (SD), Double Disk (DD) and Pressure-Time or PT injection systems developed and manufactured by the Cummins Engine Company. The early injection systems (SD and DD) used a metering system that resembled the distributor-spark plug arrangement of gasoline engines. Interestingly, they also used float bowls, floats and check valves which would also commonly be found on the carburetor of gasoline engines.
Fig. 1: Various Diesel Engine Applications.
The Single Disk Fuel Injection System

The Single Disk (SD) injection pump has been used on Cummins high speed diesel engines since they were first commercially introduced in 1932. The pump was mounted on the camshaft side of the engine and consisted of five distinct units (see Fig 2): governor, metering pump, distributor, pressure and suction pumps and the float chamber. It was driven either directly or through an auxiliary drive from the camshaft gear. The fuel pump main shaft on the Cummins H and NH engines was designed to turn at engine speed.

Fig. 2: SD Fuel Pump Sub-Assembly Units
Each of the fuel pump units is driven by the main shaft which extends through the governor housing and into the main housing (see Fig. 3 above). The main shaft is driven by a drive gear that meshes with the engine camshaft gear. The governor is mounted on the main shaft while the distributor is driven by a bevel gear that meshes with the main shaft and turns at half engine speed.

The gear pump housing contains two gear pumps which are driven by a drive shaft coupled to the fuel pump main shaft. When the float chamber is filled, the raised position of the float closes a valve regulating the fuel level in the chamber. The pump discharge pressure created by the closed valve opens a spring-loaded by-pass valve permitting recirculation of the fuel back to the pump suction. When the height of the fuel in the float chamber falls sufficiently to allow the float to open, the by-pass valve automatically closes and fuel is discharged into the float chamber. The No. 2 pump draws fuel from the float chamber and delivers it under pressure through a check valve, screen and tube to the fuel distributor. When sufficient pressure is built up in the lines above the gear pump, the ported piston valve is forced down against the spring pressure until the ports open allowing the discharge from the pump to recirculate to the pump suction. The air pressure chamber helps to keep a constant pressure against the fuel at all times which helps prevent excessive wear and chattering of the gears. When enough fuel is used to decrease the pressure against the regulator, the spring pushes it upward, thus shutting off the
flow of fuel through the bypass. A conical screen helps clean the fuel before it goes to the distributor. The check valve assembly above the conical screen prevents the return flow of fuel after the engine has been shut down. The emergency control valve can be used in an emergency to bring the speed of the engine under control.

The distributor mechanism at the top of the pump assembly has two functions. First, it allows the fuel from the fuel supply line to pass to the metering pump as the plunger is on its downward stroke (see Figs 3 and 4). Second, the distributor provides another passage from the metering pump to the injector next in firing order. This is accomplished by means of a rotating distributor disk and the stationary distributor cover to which the fuel lines to the individual injectors are connected. The distributor works on exactly the same principle as a rotary distributor on a gasoline engine, except that passages are used instead of wires to provide a path for fuel instead of electrical voltage. The mating surfaces of the disc and cover are finely machined to make an oil-tight joint and accordingly, fuel cannot leak between the surfaces from one hole to another. The drilled holes in the disc and cover act as fuel passages when the holes in the disc are rotated to align with the corresponding holes in the cover. Fuel cannot pass through the distributor when the holes are not properly indexed. All fuel lines remain full of fuel at all times. Fuel received by the metering pump from the gear pumps and discharged from the metering pump through the distributor to the injectors is under low pressure at approximately 120 to 160 psi.

The single disk fuel pump has one metering pump which measures and forces fuel to all injectors and delivers an equal amount of fuel to all cylinders (see Fig. 4). The plunger of the metering pump is forced upward by the lobes of the fuel cam. On the upstroke, the plunger forces fuel through the indexed passage to the proper injector. As the fuel cam turns, the spring above the plunger pushes the plunger down and more fuel enters from the gear pump through the distributor by a newly indexed passage. Control of engine speed and load is accomplished by varying the stroke of the metering pump plunger either by the governor or operator control. A long stroke of the plunger sends a heavy charge of fuel to the injector and a short stroke sends a correspondingly smaller fuel charge. This is accomplished by moving the vertical lever and roller either towards the fulcrum (small fuel charge) or outwards from the fulcrum increasing the pump stroke and delivering a larger fuel charge.

The hand priming pump draws fuel from a connection just below the fuel inlet check valve and delivers it to a connection following No. 2 pressure pump and by-passing the gear pumps. Fuel can be forced to the injector when the priming valve is open. The purpose of the priming valve is to bleed all fuel lines of air or to provide a solid column of fuel from the fuel tank to the injector. It is located on the side of the distributor housing and provides a passage for fuel during priming operations without the use of the metering pump. The priming valve must be closed at all times when the engine is running; otherwise, an excessive charge of fuel will be delivered to the injectors and the engine will run at an uncontrolled speed.
Fig. 4: Fuel Flow from Tank to Distributor, SD System
Fig. 5: Fuel Flow through the Single Disk Distributor
Fig 6a and 6b: Compressor-Type Single Disk Pump on a 1950 Mack LJSW with 200 HP Model NH Cummins Diesel Engine
The governors used on the fuel pump may be either mechanical or hydraulic depending on the engine application. Hydraulic governors are used on stationary power applications where a constant speed must be maintained with varying loads. Alternatively, mechanical governors are used on engines where throttle control and flexibility between idling and maximum speeds is required.

Mechanical governors control both the idling speed (500-525 rpm) and prevent overspeeding of the engine beyond its maximum speed rating. This is accomplished by a flyball-type governor acting on an idling spring and a maximum speed spring. When the engine is started and brought up to idling speed, the governor weights work against the small idling spring. As the throttle is opened and the engine speed exceeds 525 rpm, the small idling spring becomes inactive and acts as a solid sleeve. Engine speed is now controlled by the accelerator which is connected by links to the vertical lever (see Fig. 3 and Fig. 5). As the engine reaches maximum speed, the large governor spring takes control limiting the revolutions to the maximum rated speed of the engine.

**The Double Disk Fuel Injection System**

Design and development of the double disk pump began sometime in the early 1940’s and by the summer of 1946, several hand-built prototypes were being tested. While essentially very similar to the single disk pump, the double disk pump employed two rotating disks and covers instead of one to distribute and inject fuel. One disk was dedicated to incoming fuel while the other handled fuel discharge to the injectors (Fig 7 and 8).

Fig 7: Fuel Distribution of the DD Pump
The suction disk and plate each have six holes. Three of the holes in the plate are connected to the fuel passage from the No. 2 gear pump; the other three holes are connected to the fuel passage which leads to the metering pump. All six holes in the disc are interconnected. While the metering plunger is on its down stroke, the six interconnected holes in the disc transfer fuel from one side of the plate to the other side thereby completing a fuel passage from the No. 2 gear pump to the metering pump. Holes in the discharge disc and cover align during the delivery stroke thus delivering metered charges of fuel to the proper injector in time for the power stroke. Like the SD pump, the DD fuel pump has one metering pump which measures and forces fuel to all injectors which receive an equal amount of fuel. As in the SD system, the plunger of
the metering pump is forced upward by the lobes of the fuel cam. On the upstroke, the plunger forces fuel through the indexed passage to the proper injector. As the fuel cam turns, the spring above the plunger pushes the plunger down and more fuel enters from the gear pump through the distributor by a newly indexed passage (see Figs 5 and 7). Control of engine speed and load is accomplished by varying the stroke of the metering pump plunger as in the SD fuel pump.

Injectors

The fuel injector is mounted in the cylinder head above each cylinder and is an integral part of the fuel system. As such, a brief review is warranted. The injector is mechanically operated from the camshaft through rocker levers and a push rod (see Fig. 9). The length of the stroke of the injector plunger remains constant at all speeds. The injector cup is mounted on the end of the injector. During the compression stroke, the fuel metering pump forces a charge of fuel of the exact amount for the load and speed of the engine into the injector cup.

Fig. 9: Fuel Injector Cross Section

After the piston starts upward on the compression stroke, hot air is forced through the small spray holes in the injector cup. The fuel in the cup is exposed to intense heat and pressure and thus is preheated and completely dispersed. A few degrees before top dead center, the plunger is forced down and the preheated fuel charge is forced out through the six (seven in the NH)
small holes of the injector cup into the cylinder (Fig. 10). These holes are only a few thousands of an inch in diameter and the fuel is completely broken up and distributed as a spray through the compressed air at the top of the cylinder. Air temperatures here reach approximately 1000°F. and the highly combustible fuel charge ignites and forces the piston downward on its power stroke. The injector plunger continues it’s down stroke during the first part of the power stroke and remains in the lowest position until the start of the exhaust stroke. A small check valve is located in the lower end of the fuel passage in the injector body to prevent fuel from being blown back and filling the fuel lines with air.

Fig. 10: Fuel Injection Cycle

The double disk pump was lighter than its single disk predecessor but was extremely complicated and very expensive to manufacture. Both material and manufacturing costs were well above those of the single disk pump. It was also claimed to be easier to maintain based on its new design which incorporated a unit-replaceable pressure pump, governor assembly and distributor disks. By early 1950, Cummins was offering the double disk pump as standard equipment on several models. Unfortunately, the pump was plagued with mechanical problems including chronic leakage.

The disk based fuel systems served the Cummins Company very well from the 1930’s to the early 1950’s. However, these disk-based systems shared a fundamental mechanical limitation in that neither could operate at very high speeds under high pressure (200 psi was max for the DD pump). This tended to limit rpm and horsepower. By the end of the 1954 model year, double disk pump manufacturing was discontinued.
**The PT Fuel System**

The invention and commercialization of the double disk pump system overlapped with the development of an alternative fuel system and injection technology known as the PT or pressure-time system. Whereas the double disk system was patterned after the single disk system, the PT system was a radical departure (see Fig. 11-14). The principle of the PT system was based on the fact that by changing the pressure of a liquid flowing through a pipe, the amount of liquid coming out of the open end could also be changed. Increasing the pressure increases the flow or the amount of liquid delivered and vice versa. The PT fuel pump supplied fuel at low pressure to a common rail where it was distributed uniformly to all cylinders and then injected at high pressure by a small mechanically driven plunger within each cylinder head.

Fig. 11: PT Fuel Pump Cross Section with Mechanical Governor
Fig 12: PT Fuel Pump Units

Fig. 13: Fuel Flow Diagram for Pressure-Regulated PT Fuel Pump
This new PT pump was a lot smaller and much simpler than its much heavier and more complex predecessors. It was also more producible, predictable and practical than the earlier SD and DD fuel pumps. This breakthrough in fuel pump design and performance had really advanced the state of the art and could not have come at a better time for Cummins considering some of the problems that had plagued earlier fuel systems. It was also considerably cheaper to manufacture because of its mechanical simplicity. The PT pump had only 148 parts compared to 415 parts for the SD and 448 parts for the DD pump. Manufacturing costs averaged $143 per PT pump while the SD pump was $268 to produce and the DD pump cost $325 per unit (Cruikshank and Sicilia, 1997). By the end of 1953, more than 400 units had been manufactured. Another great advantage of the PT pump was that it could be retrofitted on every Cummins engine manufactured since 1932. Not surprisingly, the PT pump quickly emerged as one of the most popular and successful diesel engine components in many years.

References
