CHRYSLER CORPORATION
ENGINEERING DIVISION

TECHNICAL REPORT

No. 4511.28

Issued By Product Development Laboratory

Dept. 854

SUBJECT

FUEL INJECTION

MODEL

"L" Series

DESCRIPTION

Bendix "Electrojector"

Development of Injector Valves

Reported by K. A. Graham

Approved by C. E. Bowlus DEPARTMENT HEAD

Approved by CHIEF ENGINEER

Prepared by

Technical Reports and Standards Department

Date October 1, 1959

18 (4/58)

PREFACE

The Bendix "Electrojector" is a new and novel approach in a fuel injection system for passenger car installation. As indicated by its name, it is electronically controlled and electrically actuated. This system has timed intake port injection, a low pressure (20 psi) common rail fuel supply and employs controls that are responsive to intake manifold pressure, engine speed, air pressure and temperature.

As in any fuel system, whether carburetor or fuel injection, the metering system must meet certain engine requirements; (1) optimum air to fuel ratio under varying loads and speeds for maximum economy, (2) starting enrichment which tapers off during warmup for good cold weather operation, (3) idling enrichment to compensate for exhaust gas dilution, (4) full throttle or load enrichment for maximum power, (5) acceleration enrichment to avoid momentary lean-out during this transient period, and (6) a fast idle during the warmup period to prevent engine stalling because of the added friction load during this period. In addition to these basic requirements, it is also highly desirable to cut off the fuel flow to the engine during deceleration to reduce the smog problem and to include automatic altitude compensation to extend the optimum operating range of the vehicle.

This project was initiated in order to laboratory test the "electrojector" electronic and electrical components to check on their design and reliability. A short time after a preliminary look at each component, the injector valve was singled out as unreliable mainly because of too slow operating time. Evidence then began to accumulate indicating that a dual channel "Electrojector" would have to be used in order to allow enough time for injector valve operation. This report covers only the work done by Department 854 in designing and testing various models of faster acting injector valves.

The major work done by Department 854 was on the trigger selector unit and is covered in a report being written by Departments 832 and 751.

10-20 (4/58)

CHRYSLER CORPORATION
ENGINEERING DIVISION
TECHNICAL REPORT

Report No. 4511.28
Date 10-1-59
Project or
Charge No. 8546102

SUBJECT: Fuel Injection - Bendix Electrojector - Development of Injector Valves

OBJECT: To test and study various components of the proposed Bendix "Electrojector" system to determine if the unit was basically sound and could be developed to function satisfactorily. This early work was primarily confined to the injector valve because it was found to be totally inadequate.

CONCLUSIONS: The investigation revealed immediately that the injector valves were not operating fast enough or accurately enough to allow a single channel system. Work was concentrated on designing a faster operating valve.

It was also found that extensive testing would be required on all electrical components to see if they could meet design requirements. Testing of the valves was only one phase of the investigation during this period.

Two valves were designed by the Product Development Laboratory (854) designated in this report as "A" and "B". Further development of these valves could have resulted in a vlave that would meet all requirements of the system. Development work was stopped when a valve and dual channel system designed by Bendix was received and preliminary tests indicated it would be satisfactory. Development time was then diverted to another major problem in the system, that of the trigger selector.

PROCEDURE AND RESULTS: The earliest version of the Bendix "Electrojector" fuel injection system consisted of the following units: A trigger selector, single channel modulator box, sensing units and injector valves. An electrical pulse, caused by breaker points closing, triggers a one shot multivibrator located in the modulator box. The breaker points were first located in a spacer ring placed between the engine's distributor body and cap. This spacer is called the trigger selector and has on its inside diameter, metal inserts which are electrically connected to each injector valve separately. A rotating brush supported on a distributor shaft extension contacts the spacer metal inserts for proper timed injection determined by the closing of the breaker points.

Later it was found that a dual channel system was necessary in order to allow enough time for injector valve operation. The trigger selector was then divorced from the ignition distributor and made a separate unit driven from a geared power take-off on the ignition distributor.

The multivibrator sets up a pulse the width of which is determined by the sensing units reflecting engine conditions. The sensing units are used for detecting engine temperature, manifold vacuum, altitude compensation, idle mixture and acceleration enrichment control. The determined pulse width is then amplified and through the selector portion of the trigger selector unit delivered to the valve. The valve is open for the duration of the pulse and fuel under 20 psi injected into the intake manifold. The fuel and air mixture then enters the cylinder through the intake valve and are compressed and ignited.

The duration of the pulse could be varied from 1.0 to 4.5 msec. with the dual channel, depending on the engine requirements at that instant. The control on the amount of fuel is partly determined by the speed of the valve opening and closing. The original investigations on the opening and the closing of the valve revealed that the valve was held open from 6 to 10 milliseconds after completion of the electric pulse. Tests were started to try and reduce the closing time from an average of 8 msec. to an average of 0.8 msec.

The first Bendix sample valves were solenoid type. It was made up of the following parts: 175 turn coil mounted on a stainless steel tube with two steel ends, plunger with a nylon tip, seat for the plunger, spring and a pole piece which controlled the movement of the plunger. When the coil was energized, the plunger would move up against the pole piece opening the seat for fuel to enter. When the pulse was completed, the spring would move the plunger back into position with the nylon tip closing in the seat and cutting off the fuel supply.

In order to determine the closing and opening of the valve with relation to the oscilloscope pattern, a circuit was set up whereby the movement of the plunger was traced on the oscilloscope by use of a linear movement transducer. Using a dual channel oscilloscope enabled the valve electrical pulse and the plunger movement to be studied in relation to each other. Figure 1 shows the two patterns and what conclusions were made from this test. Interest in the total closing time for the valve was the main issue of this investigation.

The difficulty of the valve closing was attributed mainly to eddy currents set up in the magnetic circuit of the valve. Two methods of approach were used to determine what could be done for shortening the closing time. One was to rework the valve by interchanging parts, effectively increasing the air gap and slotting the components of the valve. This was done in a step by step method to see which one had the greatest effect on the eddy current losses. The other was to design a valve that would meet the requirements specified.

Nine sample valves were received from Bendix. The average closing time for these valves was 9.0 msec. with one valve having a low of 3.0 msec. This valve was selected as the one that would be used as a test sample. The plunger, spring and pole piece were interchanged with other valves. No noticeable difference was observed.

The next step was to reduce the metal to metal contact of the plunger with the pole piece. Two types of insulation were used to achieve this on the contact surface of the plunger. A small disc of mylar (.001 thick) was cemented on the plunger surface. This effectively changed the average closing time to 5.0 msec. A silicon compound D.C. 804 was also tried on the plunger. This proved successful from the standpoint of reducing the closing time but the material itself could not take the pounding.

The outside housing of the valve was also changed to see what effect this would have on the valve. Two changes were tried, one was using brass and the other a canvas base phenolic housing. The closing time was reduced but the valve operation was affected by any magnetic metal in contact with its surface. This metal would change the opening and the closing time. The results were not too satisfactory.

Although some of the above tests helped to reduce the closing time on one valve, on another valve the same alteration would not be as effective. It was decided that a new designed valve should be tried. This valve would incorporate what was helping to decrease the closing time in other tests and also include the use of different metals for its component parts. All the metals used would be those having a high resistance to eddy currents.

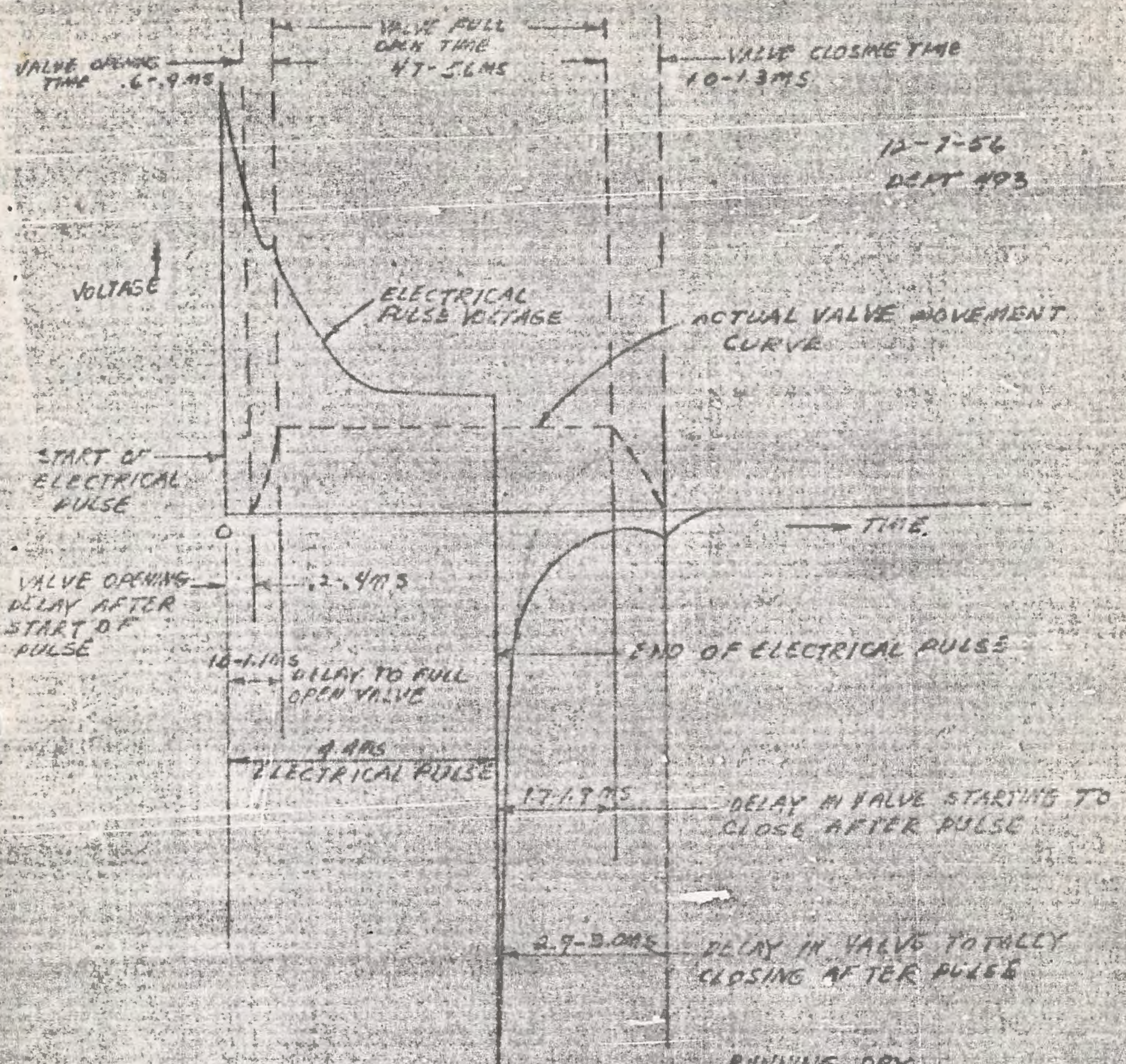
Four valves were designed and tried in order to see their effectiveness on the closing time. Diagrams of the valves are shown in Figures 2, 3, 4 and 5. The first design, Fig. 2, used the plunger, spring, seat and pole piece from the original Bendix valve. The magnetic circuit was laminated from silicon steel washers for the purpose of reducing the magnetic field losses. The second design changed the pole piece and used a disc type pluger, See Fig. 3. The basic design was the same as that of Fig. 2. The design of Fig. 4 was based on using a different magnetic iron and a cylindrical magnetic circuit. It used a disc type plunger. Fig. 5 was the same basic design but the magnetic iron was changed to a horseshoe type and a different spring design.

The magnetic circuit of this first design, 854-1, was made of laminated silicon for the purpose of reducing eddy currents. Results indicated an average closing time of 1.3 msec. which still was too high. Further testing and design changes would be required.

The second design, 854-2, reworked the pole piece and used a disc type plunger. The results of this test were not too definite since the spring used was too light and excessive bounce was experienced. The disc type plunger did reduce the closing time to an average of .6 msec. This fell within the limits required but a new and heavier disc would have to be tried. This was achieved by redesigning the entire valve.

The third design was designated "A" and is shown by Fig. 4 and calculations "A". This valve used a cylindrical type magnetic circuit with a disc type plunger having a hemispherical seal. The fourth design was similar to "A" and is shown in Fig. 5 and calculations "B". It used the same plunger but had a horseshoe type magnetic circuit. The metals used for the magnetic circuit of these valves was Permalloy, Hypernik, Silicon and Armco.

The results from these tests were very significant. The closing and opening time fell within the range that was required. Further development for this valve would give a satisfactory production version for the system. Tests were concluded after a production version of a Bendix designed valve was tested and preliminary tests were satisfactory. Attention was also required on another component of the system that was in trouble - the trigger selector.



DUAL CHANNEL OSCILLAGRAPH TRACES OF TYPICAL TEST VALVE

RUNNING DRY
PRI. VOLTS – 13.8 D.C.
DIST. RPM – 270
PULSE RESISTANCE – 1/2 K

WITH AN ELECTRICAL PULSE 4.4MS THE VALVE IS FULL OPEN FOR 4.7 TO 5.6 MS AND OPEN FOR 6.9 TO 7.2 MS WITH A .2 – .4 MS DELAY IN VALVE OPENING AFTER START OF PULSE

FIG. 1