STUDEBAKER-PACKARD CORPORATION
~~PACKARD~~ ENGINEERING DIVISION
Advanced

Advanced Engineering

Project No. 354

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DYNAMIC STUDIES OF INJECTION NOZZLES

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DYNAMIC STUDIES OF INJECTION NOZZLES

Object:

To give results of flow bench tests of fuel injection nozzles.

Introduction:

During engine dynamometer tests with the American Bosch fuel injection system, erratic engine operation was experienced. This was manifested by firing in the intake manifold and unsteady operation under numerous operating conditions even though a wide range of fuel-air ratios was used. This condition led to the belief that the amount of fuel injected from cycle to cycle was not constant.

Flow bench tests were suggested in an endeavor to support this belief.

Flow bench test equipment:

A half-inch length of an enlarged diameter (.375 in. O.D.) thin-wall (.010 in.) tube was fitted into a normal .1875 in. diameter injection line. A strain gage was cemented along the circumference of the enlarged tube. This arrangement made it possible to measure the change in expansion of the tube as it was subjected to varying injection line pressures.

The output of the strain gage was fed to an amplifier and then to an oscilloscope upon which the instantaneous pressure changes in the injection line could be observed and studied. A camera was fitted to the oscilloscope making possible a permanent record of the oscilloscope trace.

The nozzle under test was installed in a flow box such that the nozzle could be seen. A high-intensity, short-duration light arrangement, which was synchronized to the injection pump, made possible visual study of the spray pattern as the fuel emerged from the nozzle.

The nozzle under observation and also the remaining seven were connected to an American Bosch fuel injection pump in the manner normally used to check pump calibration and distribution.

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Discussion:

A study was made of the following nozzles: 1) American Bosch automotive; 2) American Bosch (Ex-Cell-O) aircraft; 3) Packard design; 4) drilled jet; and 5) swirl jet. The first three contained spring loaded valves with opening pressures of 100 and 60 psi. Nozzles 4) and 5) were of the open jet type; nozzle 4) had a .013 in. drilled hole as an orifice; and nozzle 5) was adapted from the Ex-Cell-O nozzle by having the spring and valve removed, leaving only the swirl arrangement for the jet.

Well defined oscilloscope traces were obtained during the tests. Consistent pressure patterns were noted when the open jet nozzles 4) and 5) were installed. See Figures 1 and 2. The pattern remained consistent throughout the entire speed and output range. However, the traces of the American Bosch automotive and the Packard nozzles were inconsistent. The primary and also secondary peak pressures varied greatly in magnitude and, at times, a very low pressure was noted. See Figures 3 and 4. The inconsistencies were noted over a wide speed and injection rate. It was more serious at the higher speeds.

A distinct difference between the various nozzles was noted in the oscilloscope patterns. Whereas there were a number of pressure pulses of varying amplitude when nozzles 1 and 3 were tested, the number of pulses was fewer and their amplitude less when the others were tested. This is attributed to the fact that nozzles 1 and 3 have pintles which are exterior to the body so that the line pressures do not receive the damping effect of a fixed jet such as nozzles 2, 4, and 5 possess. The pressure patterns produced by nozzles 1 and 3 are more likely to be affected by disturbances such as sound waves traveling through the fuel.

Visual study of the spray pattern at the nozzle did not definitely reveal any variation in the injection rates for individual strokes. The pattern fluctuated, however, whenever the nozzle line pressure was erratic.

Means are available on the flow bench to physically measure the fuel quantity pumped through each nozzle over a period of time. Good distribution and consistent results have been obtained during calibration tests of the fuel injection system on the flow bench. The fuel measuring means of the flow bench is an integrating device; therefore, stroke-to-stroke fuel quantity variations, such as are suspected, cannot be detected.

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The erratic pressure conditions at the nozzle may affect operation of the check valves located in the American Bosch fuel injection pump. Bench tests indicate that improper seating of the check valves disturbs the output from the pump.

Although absolute evidence could not be obtained, opinions were expressed that the irregularities noted on the oscilloscope and in spray pattern were serious enough to cause erratic engine operation.

Conclusions:

Assuming that the pressure pattern, obtained with a strain gage pickup on the pipe line next to the nozzle, is an indication of the fuel quantity, it was found that the American Bosch nozzle, together with the injection pump, does not provide the same fuel quantity for every injection under certain speed and output conditions.

The Ex-Cell-O nozzle with the same injection pump produced a consistent pressure pattern at all speeds and outputs. However, a quick check on the test bench revealed that fuel distribution between cylinders with this nozzle was not as good as with the American Bosch nozzle. Further work will have to be carried out to establish whether this deficiency is due to this particular nozzle-pump combination or to other factors influencing fuel distribution.

#3

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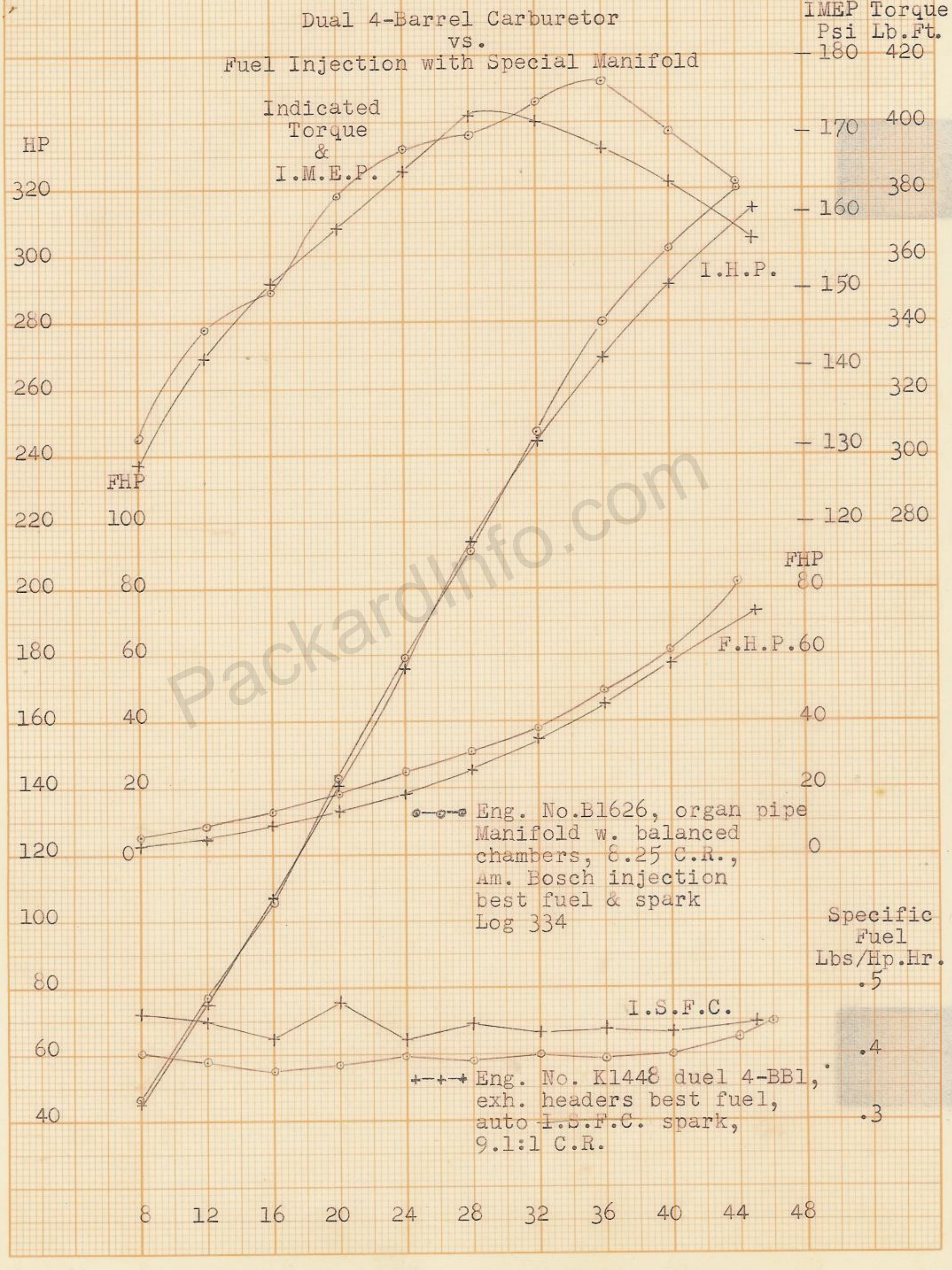

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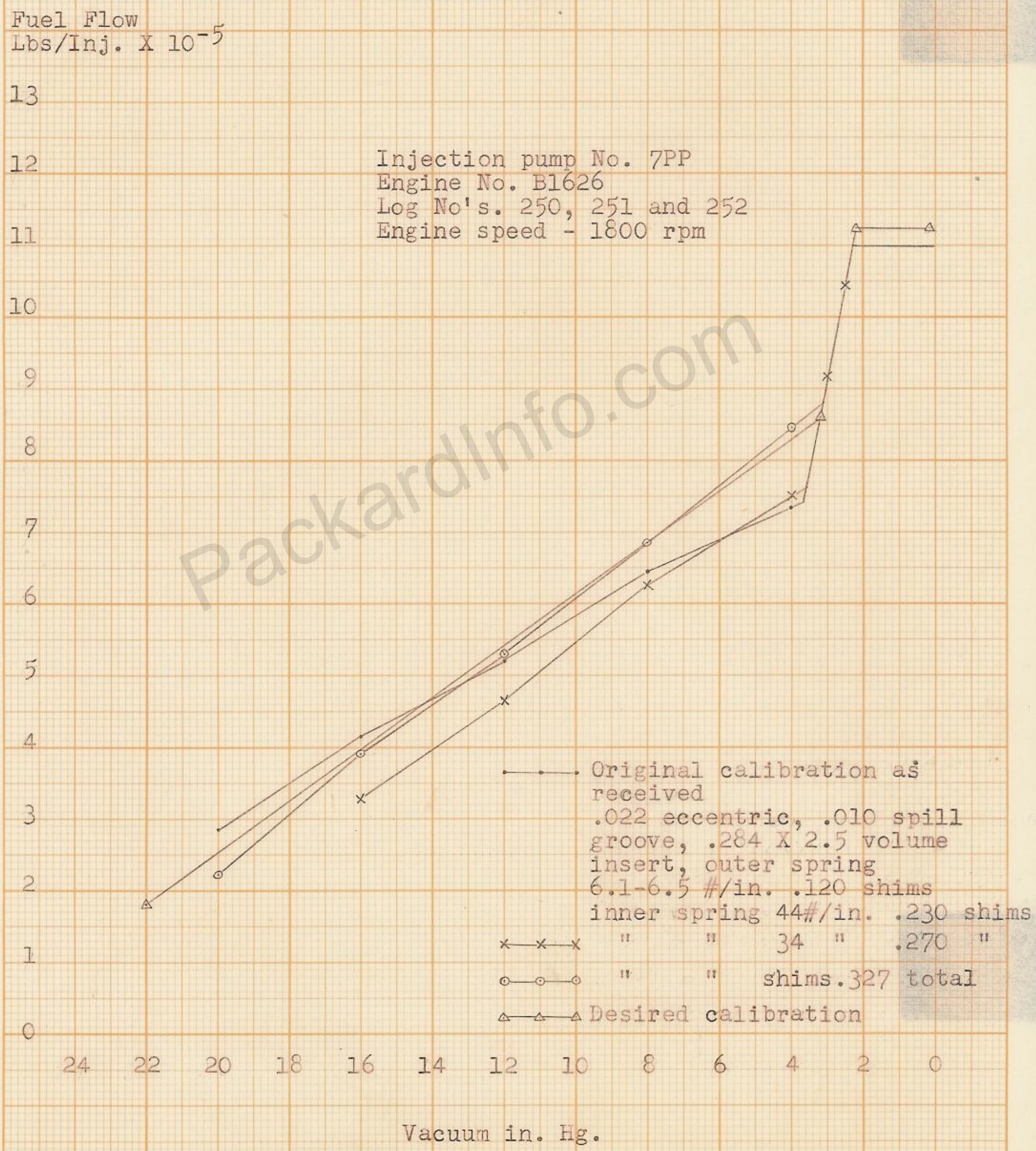
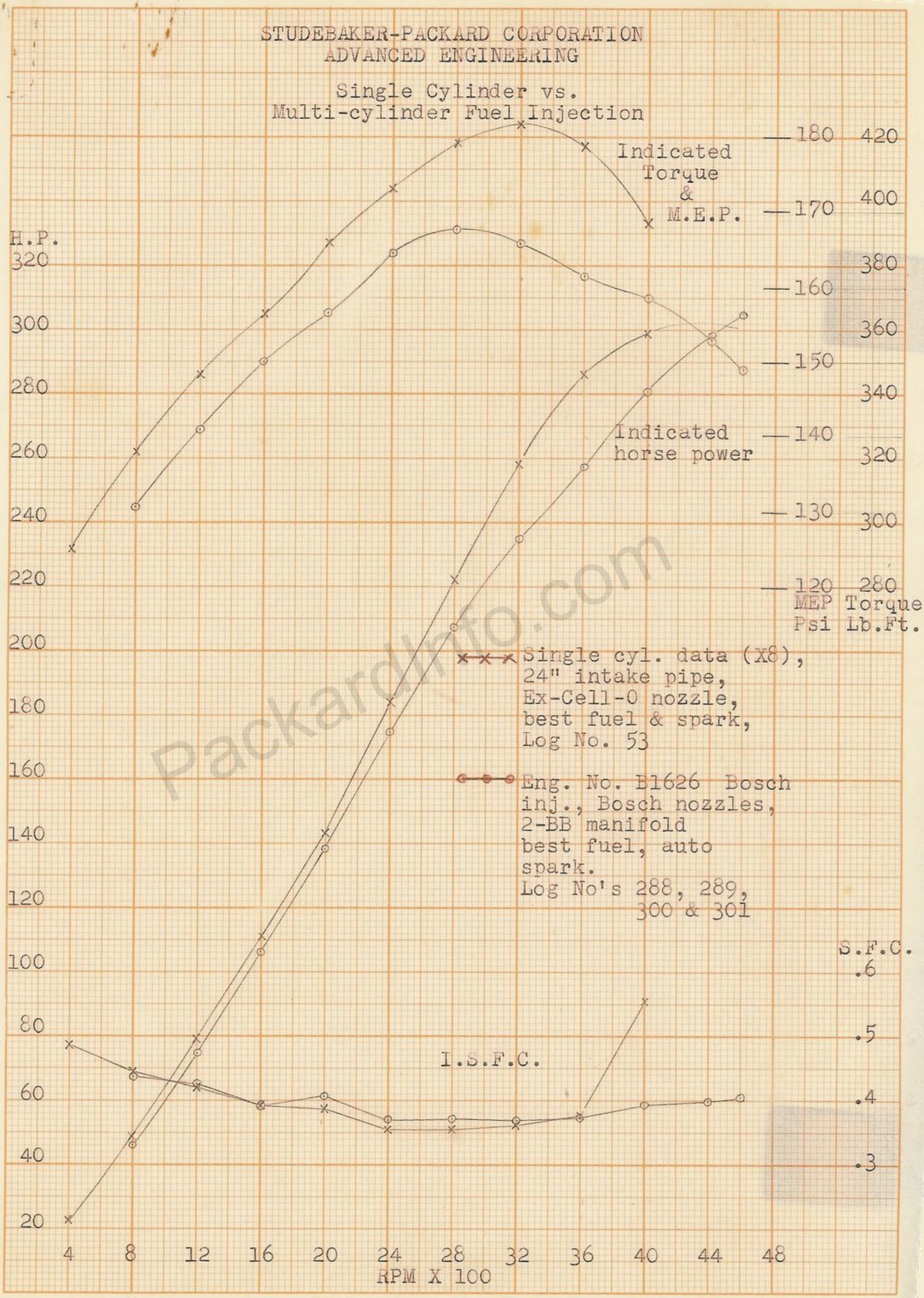
American Bosch Injection Pump
Engine Calibration

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Single Cylinder vs.
Multi-cylinder Fuel Injection
Indicated
Torque
&
M.E.P.
Indicated
horse power
H.P.
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
180
170
160
150
140
130
120
MEP
Psi
420
400
380
360
340
320
300
280
Torque
Lb.Ft.
Single cyl. data (X8),
24" intake pipe,
Ex-Cell-O nozzle,
best fuel & spark,
Log No. 53
Eng. No. B1626 Bosch
inj., Bosch nozzles,
2-BB manifold
best fuel, auto
spark.
Log No's 288, 289,
300 & 301
S.F.C.
.6
.5
.4
.3
I.S.F.C.
4
8
12
16
20
24
28
32
36
40
44
48
RPM X 100

#2

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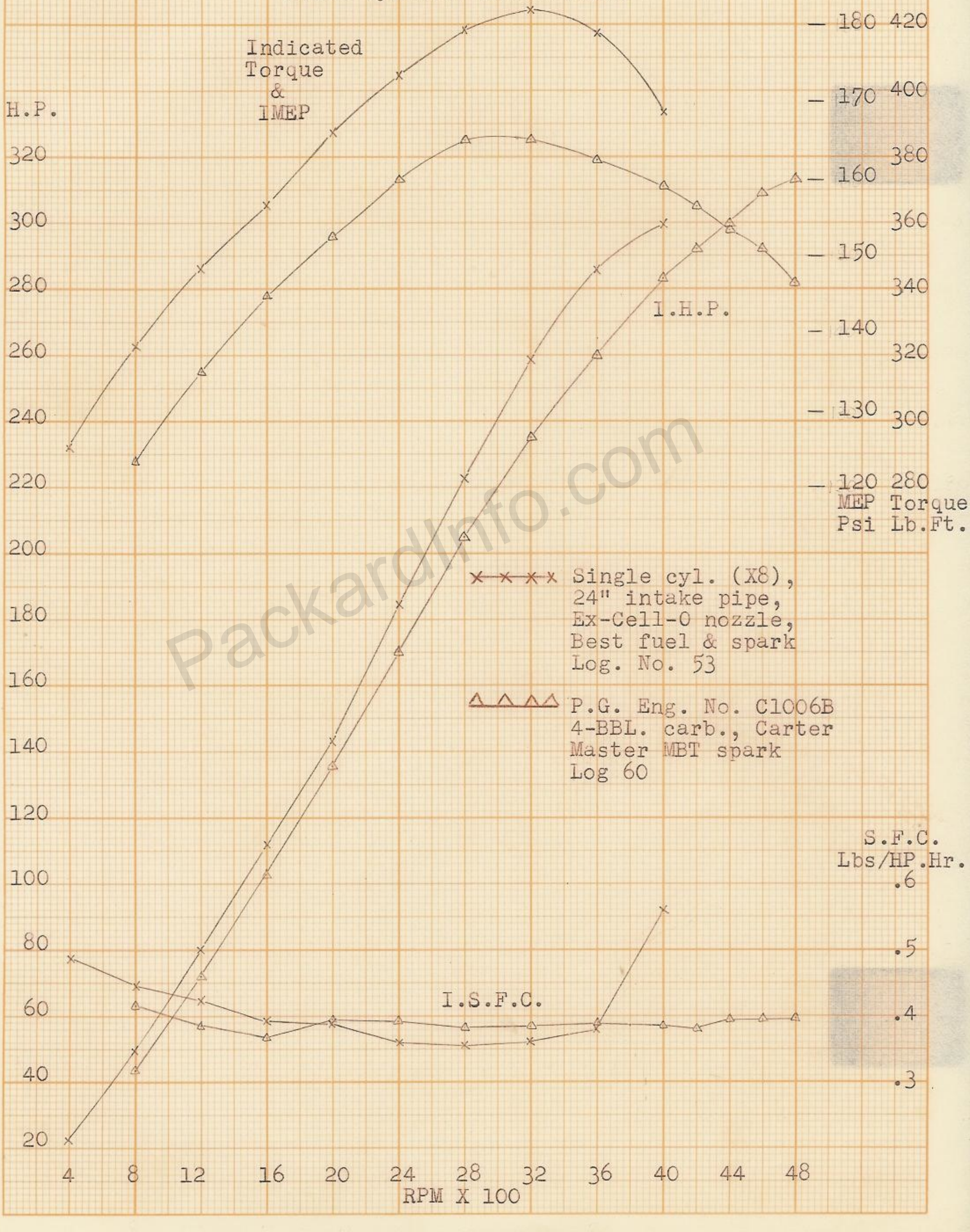
Single Cylinder Injection vs. Multi-Cylinder Carburetion



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Desired Metering Calibration at 1800 r.p.m.

American Bosch Injection -
2" nozzles
Inj. Timing 40°A.T.C.
Based on Fish-hook Data.

RWD 1-27-56