Free piston gasifier studies: experiments with a pneumatic fuel injection system

Rueter, F.; Swiderski, A. A.

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SECURITY CLASSIFICATION

SUBJECT Free Piston Gasifier Studies: Experiments with a Pneumatic Fuel Injection System

PREPARED BY F. Rueter and A.A. Swiderski

ISSUED TO

Summary

A very brief series of rig tests on a proposed pneumatic fuel injection system to obtain delayed injection in a free piston engine is described.

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1. Introduction

In the usual free piston engine, fuel is injected by means of a jerk type pump actuated by the piston synchronizing mechanism. The latter comes to rest along with the pistons when the inner dead point (IDP) is reached, and thus fuel delivery must be complete well before the largest value of IDP to be encountered. If injection is to continue beyond the end of the pump delivery stroke, an injection delay must be introduced.

In the small free piston gasifier considered here, the required injection delay was provided by adjusting the lengths of the high pressure fuel lines from the pump to the two injection nozzles, thus taking advantage of the elasticity of the fuel to delay the injection process. However, the amount of delay obtainable by this method is limited, and it was thought that more precise control over injection timing might be combined with the possibility of longer delay. Accordingly, a pneumatic injection system was devised in which the fuel injection pump was operated by compressed air controlled by a valve operated by the synchronizing shaft.

2. Description of Pneumatic System

The pneumatically operated actuator for the injection pump, which was devised and developed by Dr. H.U. Wisniowski and Mr. E.J. Prince of this laboratory, is shown in section in Figure 1. Air pressure applied beneath the lower piston causes the piston and rod assembly to rise and actuate the injection pump plunger on its delivery stroke. Lowering the pressure under the piston permits the piston assembly and pump plunger to drop under the influence of the pump return spring. Slamming of the piston against its stops is avoided on either stroke by the upper piston and cylinder, which acts as a pneumatic dashpot, with air leaking past the piston rod.

In the pneumatic injection system under discussion, the required fluctuating pressure under the piston was produced by connecting the lower piston alternately to a source of pressurized air (the shop air supply, at about 100 lb_f/in^2 gauge) and to atmosphere. This was done by means of the cam-operated valve illustrated in Fig. 2, which is shown with its plunger in its lowest position, with the cam follower on the heel of the cam. In this position, the actuator is vented to atmosphere, and the injection pump plunger is at the bottom of its stroke. Lifting of the valve plunger by the cam first closes the atmospheric vent. Further plunger movement lifts the valve from its seat, admitting air pressure from the upper valve chamber to the line connected to the pump actuator. The latter thus moves the pump plunger on its delivery stroke. The valve body was designed for installation in the Bosch fuel pump body in place of all the normal fuel pump parts except the cam follower.

It will be seen that, with the oscillating cam on the engine synchronizing shaft, admission of air to the pump actuator will continue beyond inner dead point until the valve is returned to its seat during the first part of the outward stroke of the engine pistons. A considerable delay in the fuel injection process is thus attainable, as compared with direct actuation of the pump by the cam.

3. Test Rig

The test rig illustrated in Figs. 3, 4, and 5 was assembled for the purpose of testing the injection system described above in comparison with two pumps that were actuated directly in the conventional manner. A cam mounted on the rotating output shaft of a variable speed drive (Master Speedranger) was so designed as to reproduce, as nearly as possible, the motion produced by the oscillating cam on the engine synchronizing shaft. A bracket was arranged so that either a fuel pump body carrying the air valve (Fig. 4) or a complete fuel pump (Fig. 5) could be mounted to be driven by the cam.

Stroboscopic observation of the fuel spray from the injector nozzle was made possible as follows. A steel disc, painted flat black, was mounted on the end of the rotating shaft, and carried an index line diametrically opposite a bright patch of aluminium foil. The latter reflected light to a photo diode so mounted that it could be adjusted circumferentially with respect to the shaft, and the signal from the photo diode was used to trigger a stroboscopic light. A scale partially surrounding the disc, and calibrated in degrees of cam angle, was so oriented with respect to the index line on the disc that a reading of zero corresponded to the beginning of movement of the cam follower.

It was thus possible, by adjusting the position of the photo diode, to view any portion of the spray of fuel from the injector nozzle in an apparently stationary condition, and, by directing the stroboscopic light onto the scale, to read off the corresponding cam angle.

4. Rig Tests and Discussion

Tests were begun with the direct installation, as in Fig. 5, of a Bosch fuel pump with an 8mm, constant beginning plunger connected via an 18-inch steel line to the injection nozzle. Some six test runs with this arrangement provided some useful experience in the operation of the rig, but were scrapped when it was found that the fuel injection nozzle was partially restricted. At this point also, the pump plunger failed, and since a replacement was not immediately available, tests were continued with the 9mm constant ending Bosch pump from the engine. Subsequently, a new plunger and barrel assembly for the 8mm pump was acquired, and the earlier tests were repeated.

The results of these tests and of a static test for each pump are plotted in Figs. 6 and 7, with the fuel control lever position (in arbitrary units) as abcissa. The fuel flow and the shaft angle for the beginning and end of injection are shown with shaft speed as parameter. The injection delay is given by the vertical shift from the static to the dynamic curve for the beginning and end of injection. It will be seen that the delay, in terms of cam angle, increases with increasing shaft speed, so that it tends to be constant in terms of time.

Only one test was carried out with the pneumatic injection system, using an 8mm constant beginning CAV pump driven as shown in Fig. 4. At this point, it was learned from experiments with the engine that performance was improved by advancing, rather than retarding the injection timing from the standard setting, and further testing with the pneumatic system was abandoned.

The results of the single test on the pneumatic system are given in Fig.8. A static test for the system would be meaningless, and the only static line given is for the beginning of movement of the pump plunger. This shows that the first six degrees of cam rotation from the zero position are required to close the atmospheric vent and to begin lifting the pneumatic valve from its seat, admitting air pressure to the pump actuator and initiating plunger movement.

A great deal of scatter will be observed in the plotted points in Fig.8, and it may reasonably be argued that too much license has been exercised in drawing the curves. The system did, in fact, behave quite erratically, with injection occurring in waves or spurts (from 2 at low fuel control lever settings to 8 at high settings), rather than uniformly throughout the injection period.

Comparing the delay from the static condition for the pneumatic system (Fig. 8) with that for the similar constant beginning Bosch pump (Fig. 6), one observes, for a typical fuel control lever setting of 10 and a speed of 1500 rpm, a delay of 8.5 degrees for the directly driven pump as against 24 degrees for the pneumatic system. The end of injection, however, is delayed even more. For the same conditions, the injection period lasts 18.5 degrees of cam angle for the directly driven pump and nearly 43 degrees for the pneumatic system. This would cause an undesirable extension of the injection period well into the expansion stroke of the cycle. Moreover, the pulsating nature of the flow from the injector would certainly have a most unfavourable effect on the combustion process.

5. Conclusions

The very limited tests described in this note suggest that, although a more than adequate amount of injection delay may be obtained by means of the pneumatic injection system, the resulting erratic and pulsating nature of the injection process is hardly likely to prove beneficial to the running of the engine.

It is quite possible that the system could be refined and developed to eliminate its undesirable characteristics. A first move in this direction might be simply to increase the air pressure in the pneumatic pump actuator.

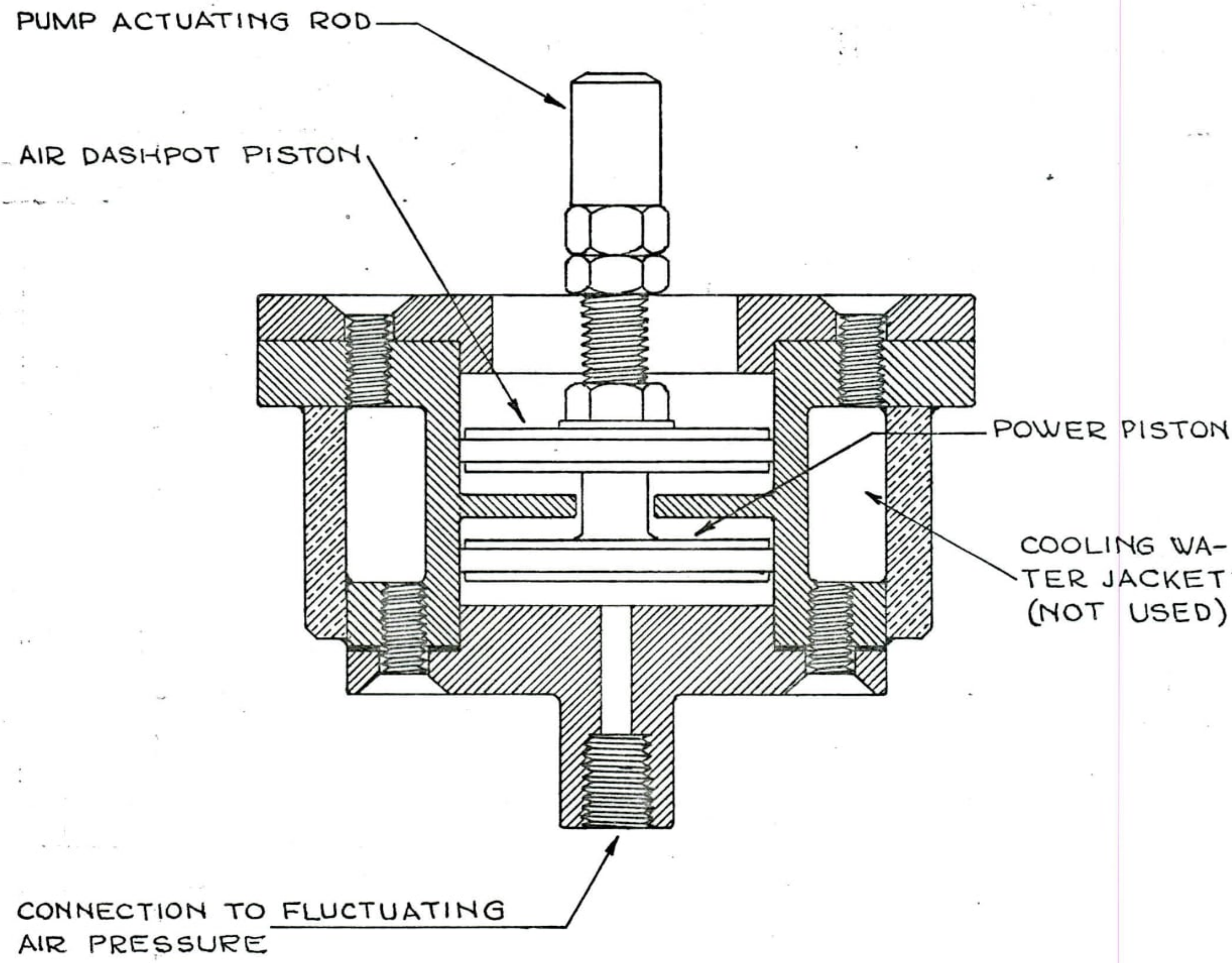

FIGURE 1 PNEUMATIC PUMP ACTUATOR

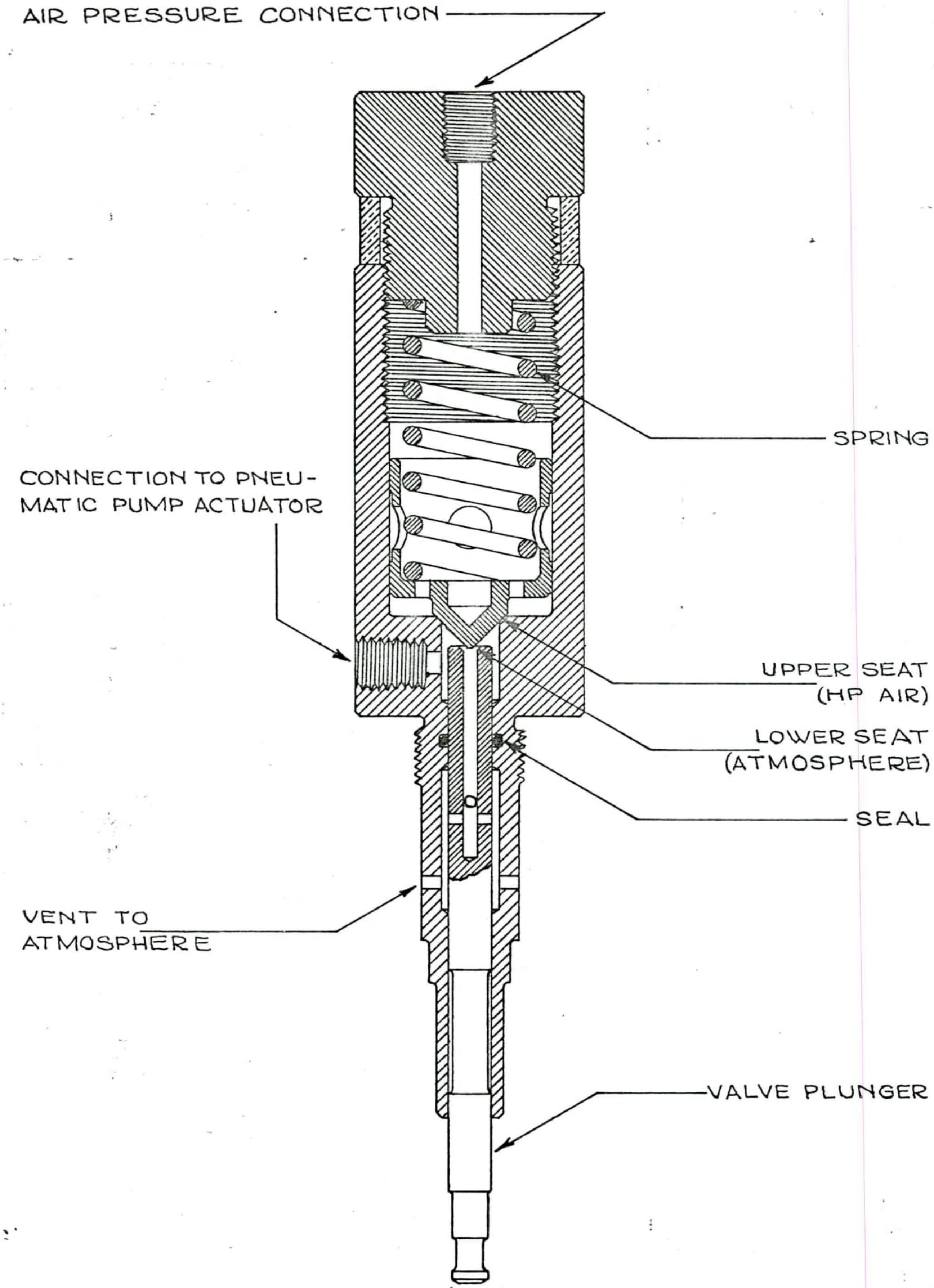

FIGURE 2 AIR VALVE

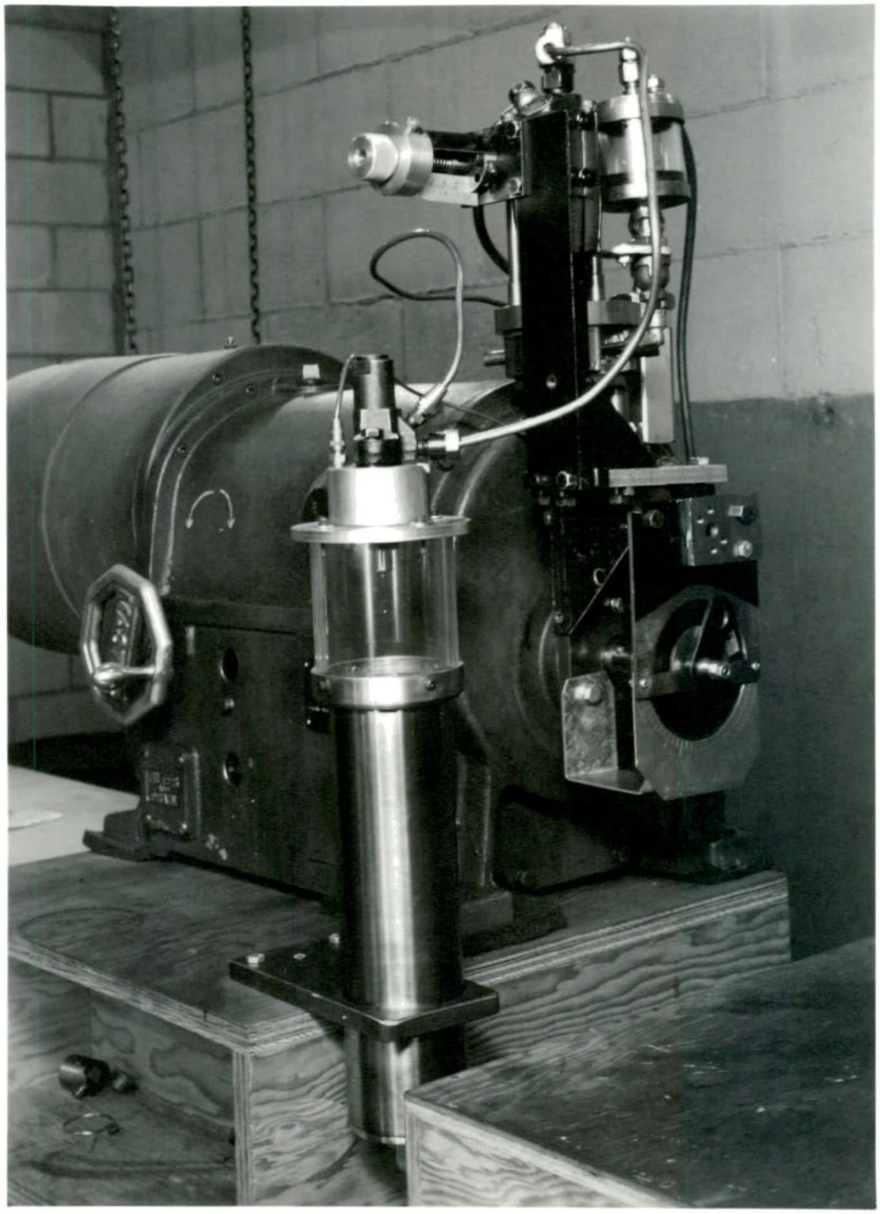

FIGURE 3 PHOTOGRAPH OF TEST RIG

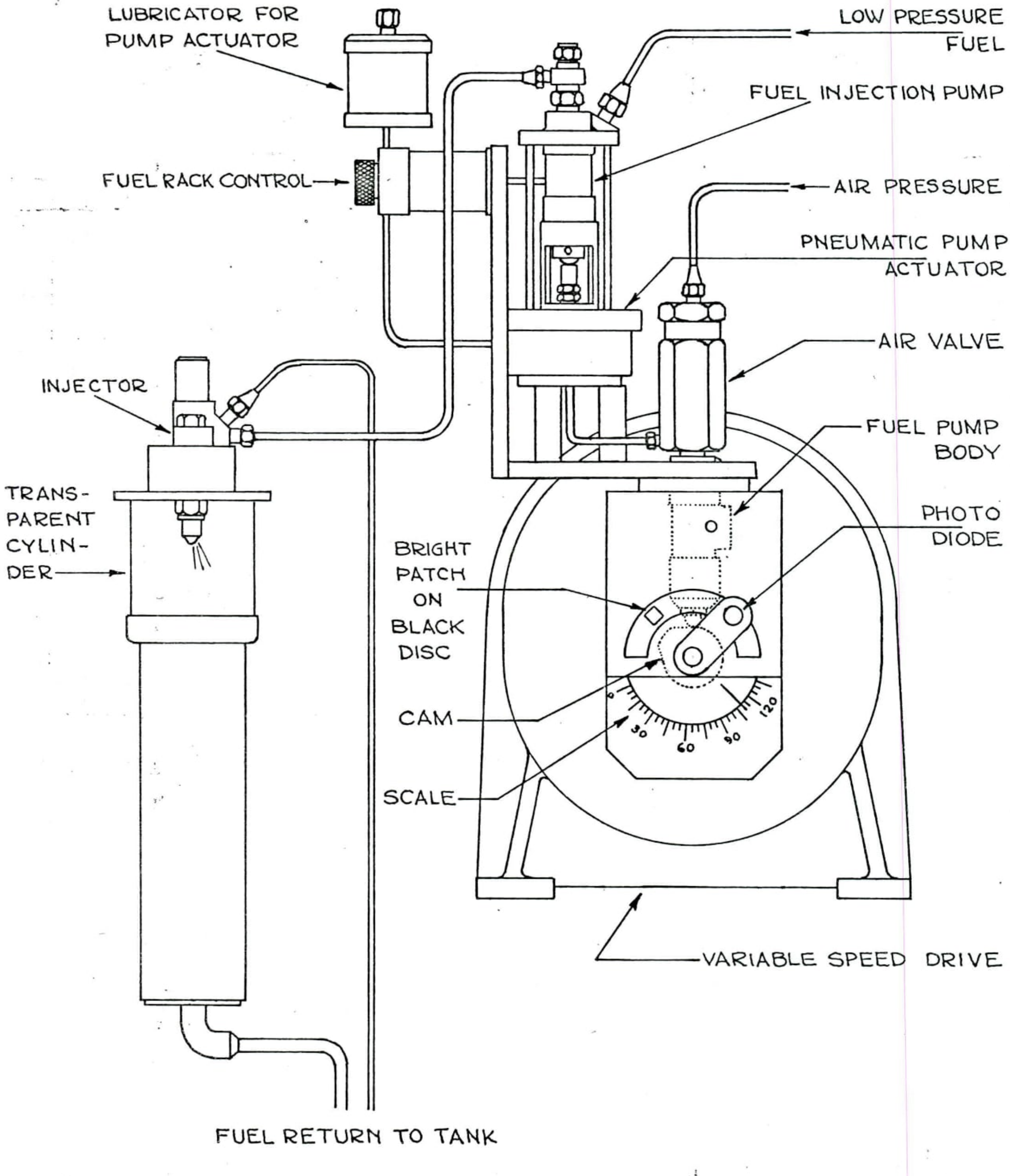

FIGURE 4 DIAGRAM OF TEST RIG WITH PNEUMATICALLY OPERATED PUMP

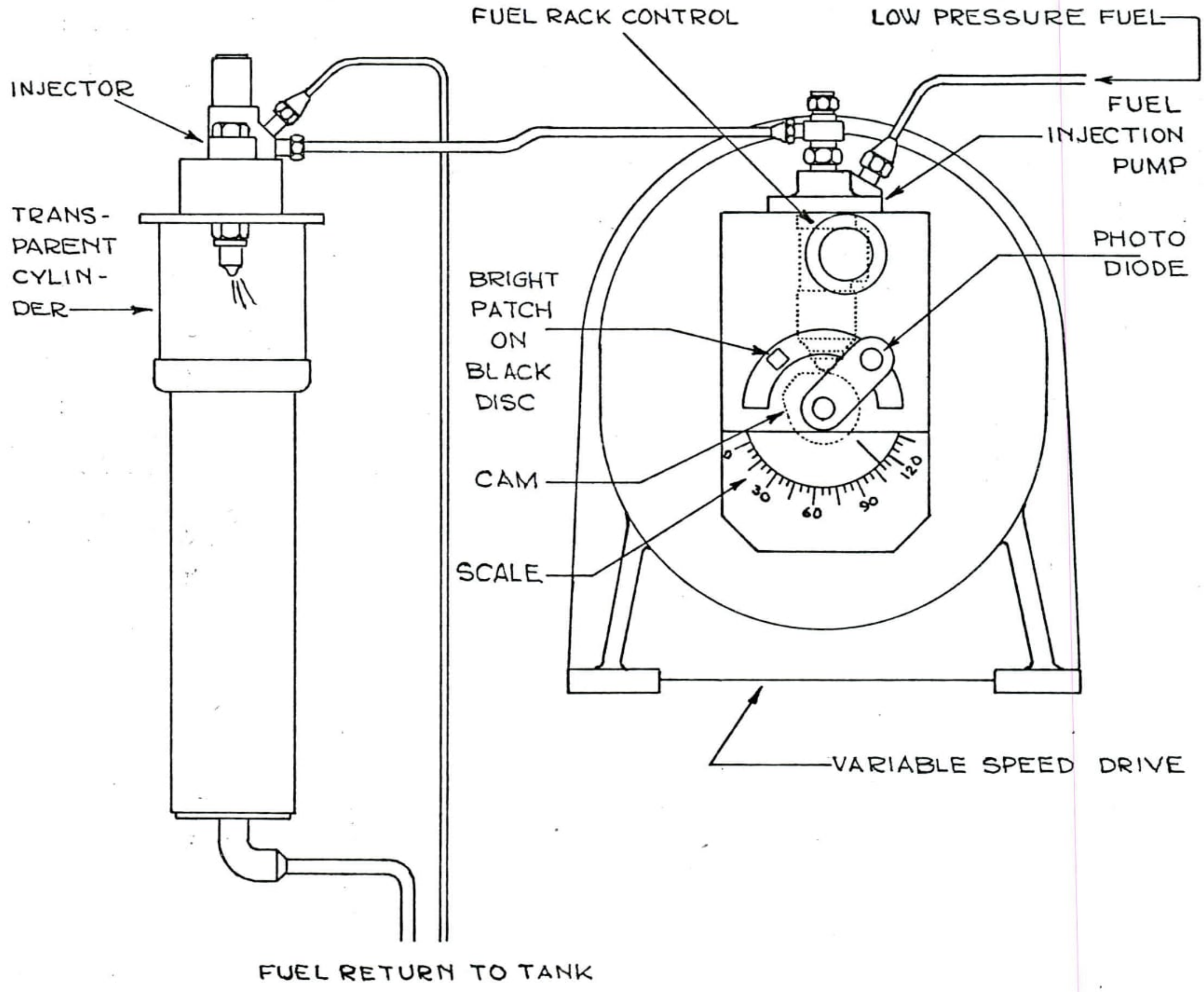

FIGURE 5 DIAGRAM OF TEST RIG WITH DIRECTLY OPERATED PUMP

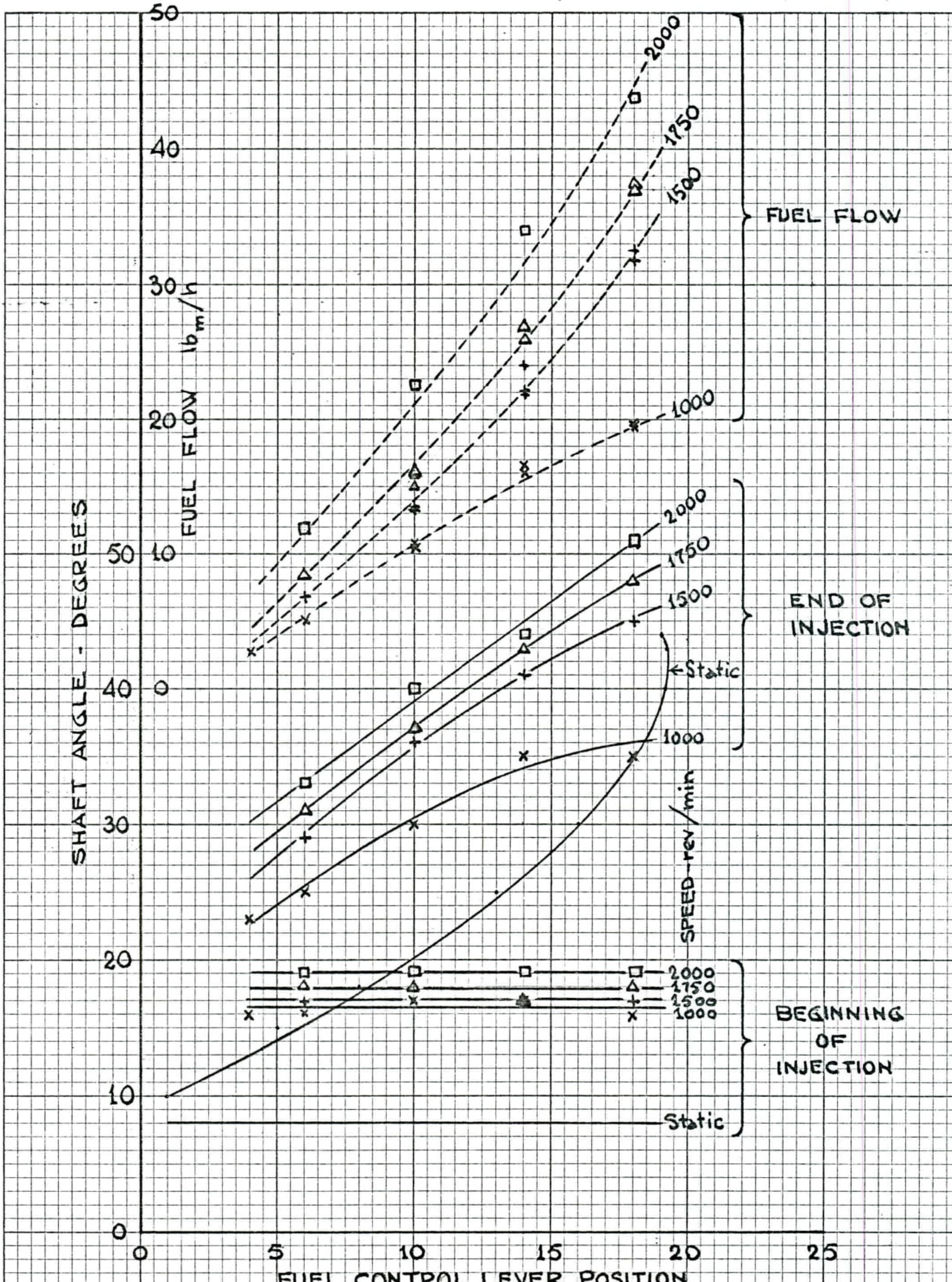

FIGURE 6 CHARACTERISTICS OF 8mm BOSCH FUEL PUMP, CONSTANT BEGINNING

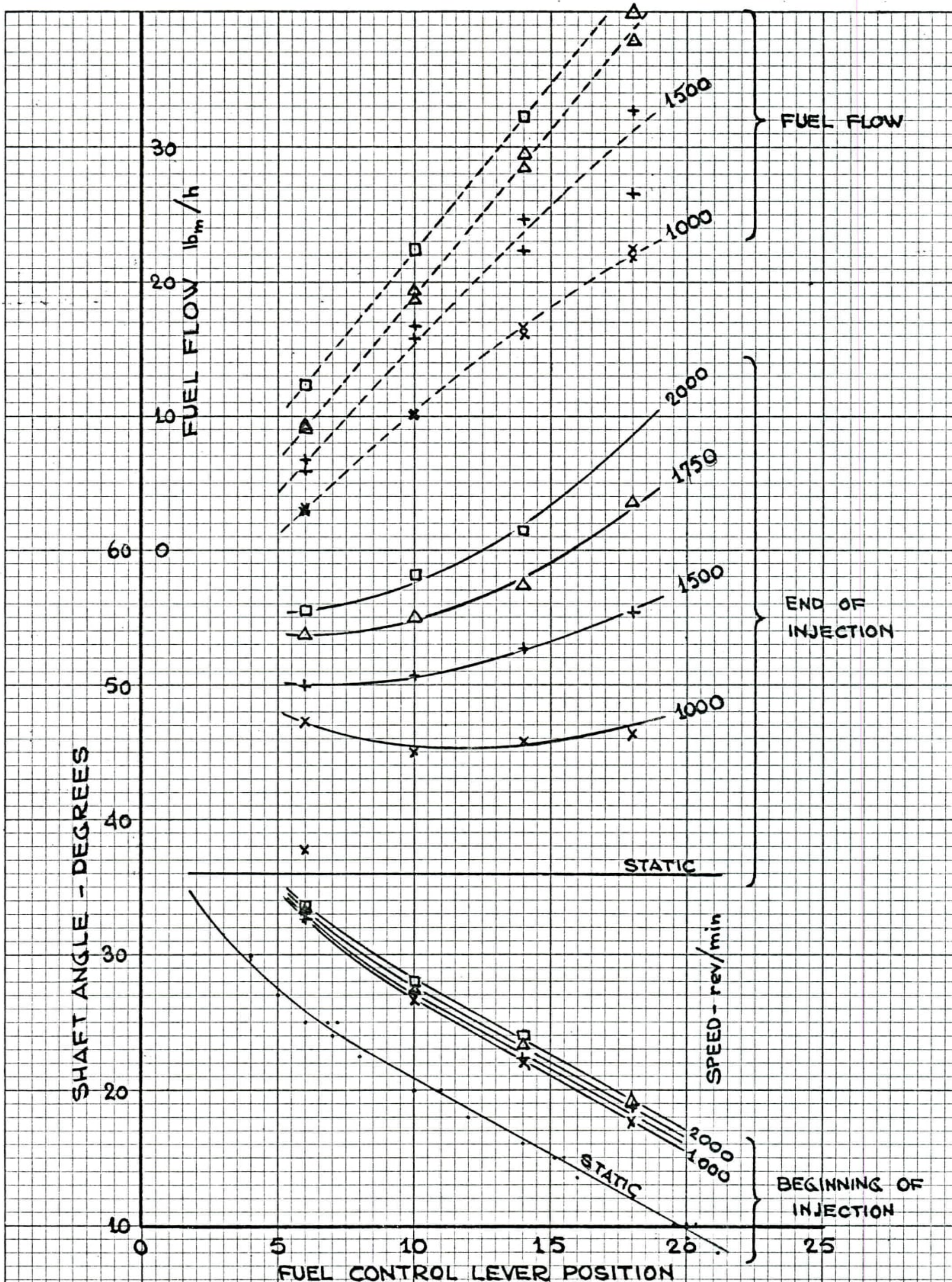

FIGURE 7 CHARACTERISTICS OF 9 mm BOSCH FUEL PUMP, CONSTANT ENDING

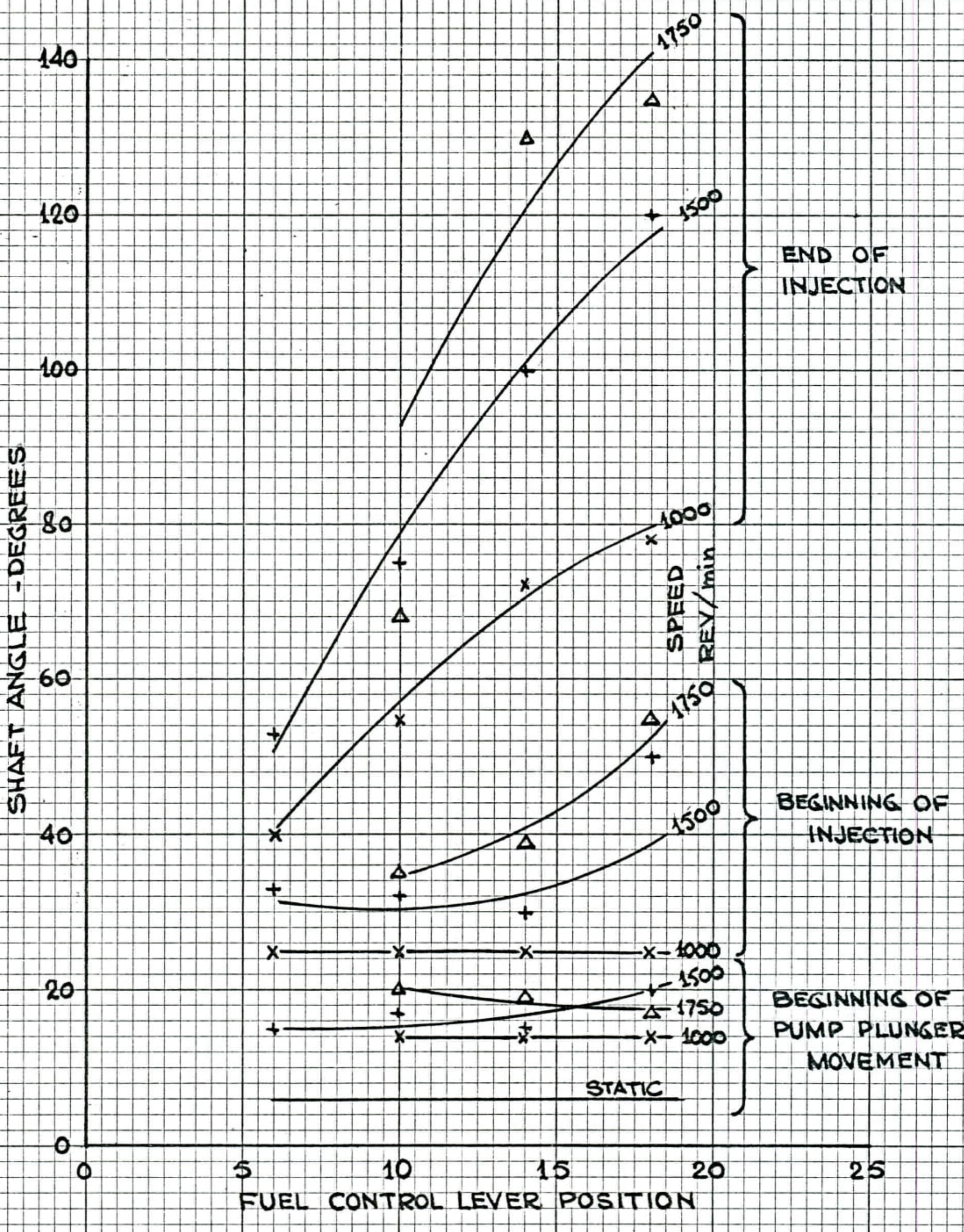

FIGURE 8 CHARACTERISTICS OF PNEUMATIC INJECTION SYSTEM, USING 8mm CAV FUEL PUMP, CONSTANT BEGINNING