Preliminary notes on high-speed reciprocating pump investigation

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SUBJECT PRELIMINARY NOTES ON HIGH-SPEED RECIPROCATING PUMP INVESTIGATION

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SUMMARY

A rig was built to study the factors limiting high speed reciprocating pump operation. Various mechanical difficulties including seal leakage and bearing troubles were encountered with the rig. The limiting pumping speed of 19 f.p.s. which was reached could have been due to valve float or cavitation.

A new rig was designed incorporating positive valve gear, improved bearings and a different type of seal. With valve float eliminated as a variable, it should be possible to determine at what speed cavitation limits pumping with various symmetrical and asymmetrical piston head forms. Further tests should be made to investigate the effect of surface roughness, piston material, and air content of the water.

1.0 INTRODUCTION

The output of a free piston engine is now utilized largely in one of two ways: (1) to pump a fluid with direct-acting pistons, (2) to drive a high speed turbine with the exhaust gases.

The first method is at present used mainly for compressing air. The second method is advantageous only in the larger sizes and involves the use of high speed reduction gearing to provide a useable output shaft speed. For some applications this rotary motion must be reconverted to a reciprocating motion.

Alternative methods of using the free piston engine's output deserve consideration. One method is the use of the reciprocating motion of the pistons for direct pumping of liquids, either to move the liquid or to produce a working fluid for a hydraulic power system.

The current state of the art in reciprocating pump design is such that maximum average piston speeds do not exceed 1000 f.p.m. (16.7 f.p.s.). Small free piston engines, however, even at the present stage of development can be expected to run at an average piston speed of 2000 f.p.m. The problem therefore is to produce a pump capable of operation at these relatively high piston velocities.

2.0 TEST RIG

The first experimental step comprised construction of a variable speed reciprocating piston rig to study cavitation and other conditions which might limit high speed operation.

A 2 h.p. variable speed electric motor was used to drive a countershaft by means of two Vee belts. At the end of the countershaft was mounted a flywheel and variable stroke connecting rod and cross head assembly. (Figure 1). The cross head was constructed so that the test piston could be readily replaced. The piston stroke was variable from zero to 6 inches and the speed was variable from 400 r.p.m. to 2500 r.p.m.

Various difficulties were encountered in the operation of the rig, mainly with the use of Oilite in the crankpin bearing and cross head slides. These troubles were overcome by continuous oiling.

3.0 TESTS

Originally it was intended to observe cavitation on the piston operating in a relatively large volume of water with a cross flow to remove the bubbles. Actual tests soon showed that neither visual nor photographic observation could reveal anything. Unlike a conventional cavitation tunnel in which de-aerated water is circulated past the test object at a steady state condition, the reciprocating piston churned up the water so much that it was impossible to establish anything by observation.

Consequently, it was decided to revise the test program. By operating the system as a pump, pump delivery could be plotted against piston speed. A sudden drop in efficiency would indicate either the onset of cavitation or failure of the valves to follow the pumping action.

In order to provide maximum information from a limited series of tests, bodies of revolution in three systematic series were selected. They vary from long through blunt to concave in each series. Figure 2 shows the piston shapes selected. Tests on the three series together with tests on various piston-to-cylinder diameter ratios would indicate the best conditions for high speed reciprocating pump operation.

The pumping tests, were begun with hinged type non-return flap valves as pump valves. Subsequently these valves were modified to poppet and reed valve operation. None of these proved to be mechanically reliable at the test speeds. In addition, air leakage past the piston seals caused the pumping efficiency to be rather inconsistent and nonrepeatable. The highest pumping velocity reached was 19 f.p.s. with an efficiency of 65%, the efficiency usually started to decrease at about 15 f.p.s.

4.0 RECOMMENDATIONS

4.1 Rig Redesign

Redesign of the rig was started because little additional information could be obtained from the original rig.

Positive Valve Gear

A chain driven rotary valve has been designed with coil spring loaded valve plates and fully adjustable valve timing. Suction and delivery valve timing have been made adjustable independently because the amount of valve lead or lag as well as the overlap for optimum pumping will have to be determined experimentally.

Seals

Originally, three single lip type oil seals were used in series. Although the delivery head was only about 3' of water, running experience with reed valves showed that the instantaneous pressure could be very high. (A 0.005" thick stainless steel reed valve with an area of 5/64 sq. in. was sheared through - it is estimated that a pressure of 2600 p.s.i. was required).

The redesigned rig incorporates Chevron type packing (Figure 3). An increase in pressure tightens the seal and the rings ease off as pressure declines. Chevron seals in two types of material have been obtained: Garlock Style No. 430, a cotton duck and rubber compound and Garlock Style No. 8452, Buna-N rubber. Some carbon-graphite filled teflon is also on hand from which chevron seals can be made if the other two seals do not stand up to the high piston speeds.

Improved Cross Head

A new cross head with pressure feed oiling and greater bearing areas has been incorporated to overcome the overheating troubles of the earlier rig at high speeds.

4.2 Future Tests

Tests on the three series of piston shapes selected should indicate in which direction to proceed. Asymmetric shapes rather than bodies of revolution are a possibility. Changes in piston material and surface roughness should also be investigated.

For experimental purposes, the air content of the water may be controlled, however in actual pumping it may not be practicable.

Operation in supercavitating conditions also does not seem feasible. Supercavitation may be established for steady state flow in one direction but the condition will not obtain for rapidly reversing flow.

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Appendix

Engine Laboratory Drawings Relating to Reciprocating Pump Rig

B23029	Flywheel and Crank Details
B23032	Cross Head Guides
B23033	Cross Head Details
B23036	Flywheel Crank and Cross Head Assembly
B23037	Details
B23038	Tank and Motor Support Stand
B23039	Mounting Plate
B23041	Valve Body
D23042	Valve Plug and Washer

B23044	Water Tank
C23045	Piston Test Pieces
C23054	Synchroniser Wheel
B23056	Synchroniser Details
C23058	Synchroniser Assembly
B23060	General Assembly
D23065	Electronic R.P.M. Pickup Assembly
B23088	Modified Connecting Rod
D23092	Oil Manifold
B23096	Revised Cross Head Guides
C23097	Revised Cross Head and Details
C23102	Revised Cross Head Assembly
B23152	Rotary Valve
C23153	Graphitar Rubbing Discs
C23158	Spring Loaded End Plate
D23159	Spring
B23163	Rotary Valve Mounting Bracket
B23164	Rotary Valve Drive Components
B23166	Revised Cross Head Guides
B23170	Revised Connecting Rod and Cross Head Details
E23174	Gland Housing
E23179	Mounting Brackets
D23180	Connecting Rod Lower End
B23187	General Assembly of Revised Piston Cavitation Rig

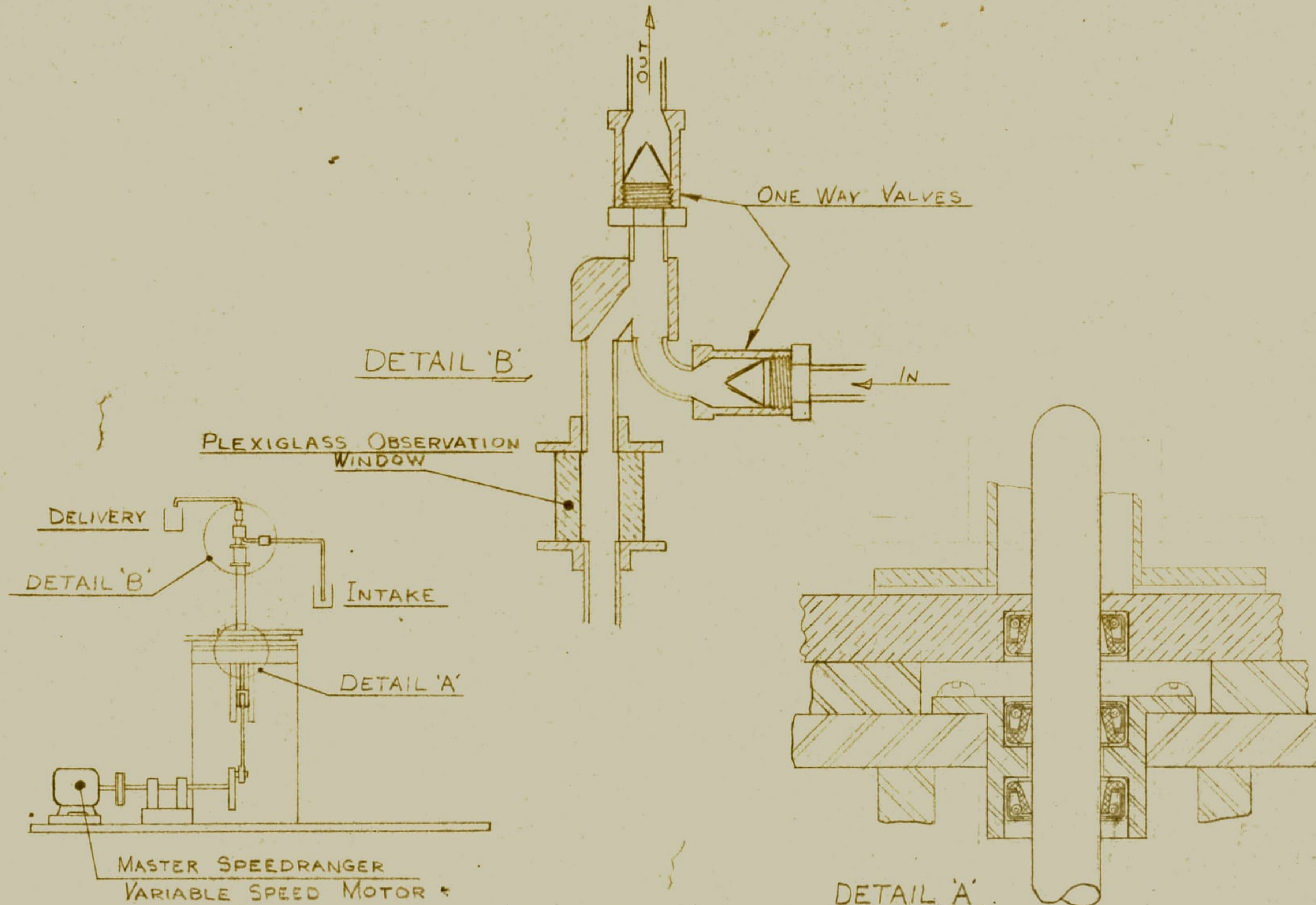

OUT
ONE WAY VALVES
DETAIL 'B'
IN
PLEXIGLASS OBSERVATION WINDOW
DELIVERY
DETAIL 'B'
INTAKE
DETAIL 'A'
MASTER SPEEDRANGER
VARIABLE SPEED MOTOR
DETAIL 'A'

FIG. 1

PISTON HEAD SHAPES

FIG. 2

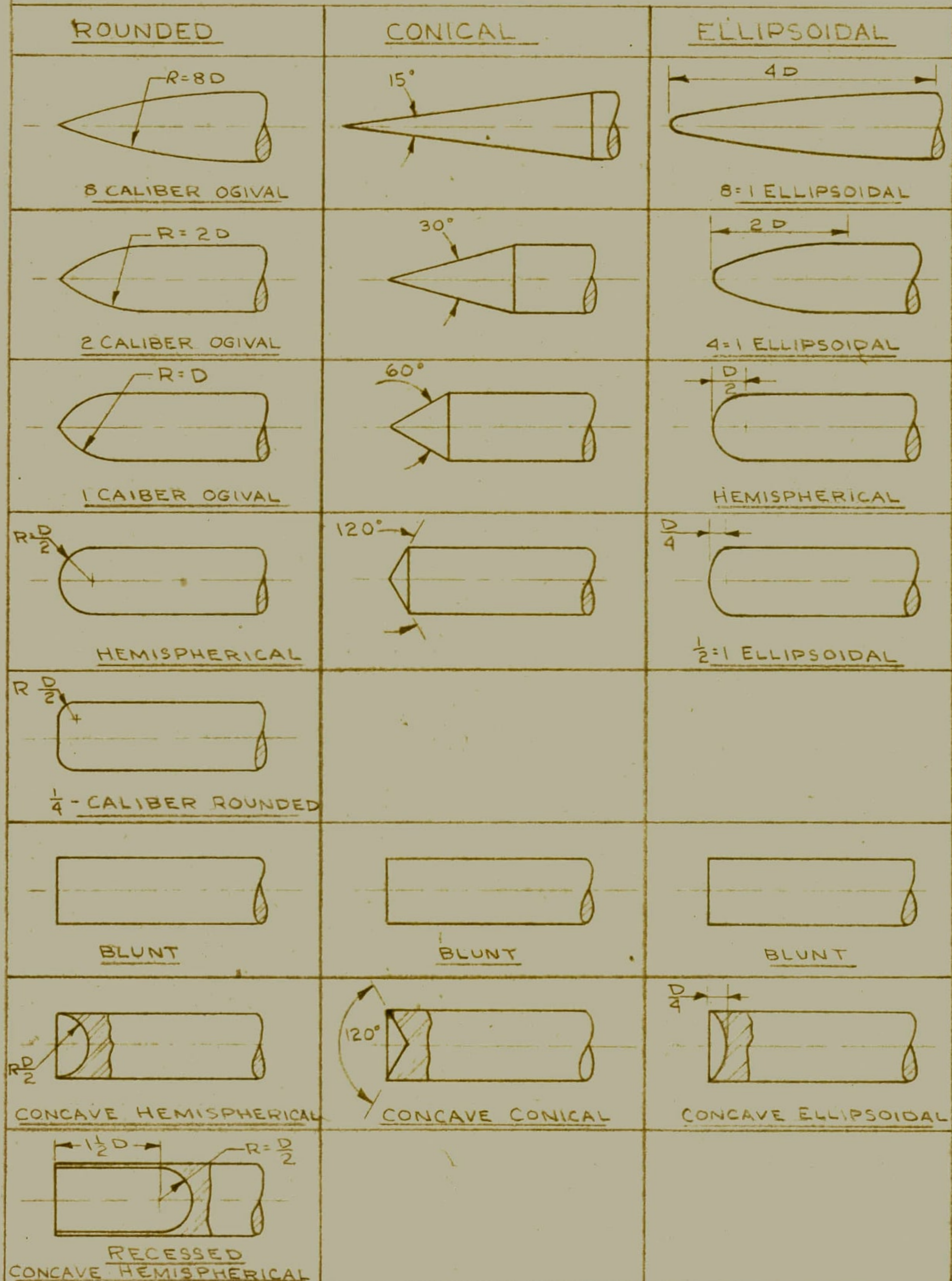
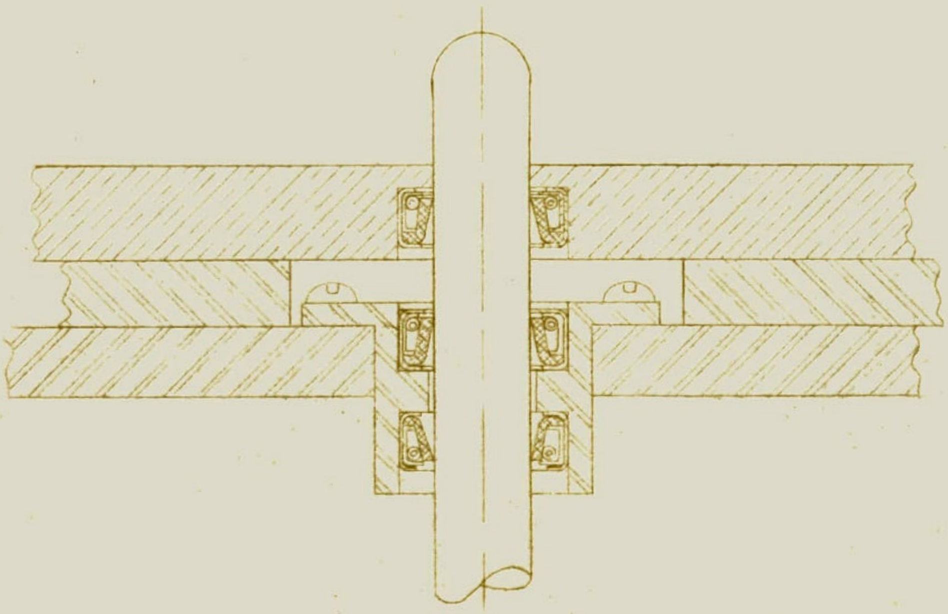


FIG. 3

ORIGINAL SEAL

HUMPHREY OIL SEAL PART NO. 08716



REDESIGNED SEAL

GARLOCK CHEVRON PACKING STYLE NO. 430
OR MADE OF CARBON-GRAPHITE FILLED TEFLON