THE AMERICAN SOCIETY
OF MECHANICAL ENGINEERS

THE JOURNAL

VOLUME 33

NEW YORK
PUBLISHED BY THE SOCIETY
29 West 39th Street
1911

INDEX TO THE JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

JULY-DECEMBER, 1911

TEST OF AN 85-H.P. OIL ENGINE

By Forrest M. Towl

ABSTRACT OF PAPER

The paper describes a test of a DeLaVergne oil engine, FH type, operating an oil pump, and one of the same engine under the same conditions but with the load applied by a prony brake instead of a pump. The object of the test was to find the friction of the pump and gearing and the efficiency of the plant. Data of test and results of computations are given. The pump and transmission efficiency were 92.1 per cent, the total station efficiency, 25.52 per cent, and the duty per 1,000,000 B.t.u., 198,664,000.

TEST OF AN 85-H.P. OIL ENGINE

By Forrest M. Towl, New York

Member of the Society

A test of a De La Vergne oil engine, FH type, was made at the pumping station of the Standard Oil Company, Fawn Grove, Pa., on April 20 and 21, 1911. The engine was one of the regular 85-h.p. machines, built by the De La Vergne Machine Company, New York, cylinder 17 in. by 27½ in. and running, as installed at Fawn Grove, at about 180 r.p.m.

2 This type of engine operates on the well-known Beau de Rochas cycle. The successive operations take place in much the same manner as in the ordinary 4-cycle gas engine, except that the fuel is injected into the cylinder at the completion of the compression stroke instead of being drawn in gradually as in the gas engine. Figs. 1 and 2, an exterior view and a longitudinal section, show the relationship of the various parts and the internal construction. Fig. 3 shows the engine and pump as installed, with clutch connection.

3 The charge of air is drawn into the cylinder through the inlet valve *A* (Fig. 2), and during the compression stroke which follows is forced into the small combustion chamber at the rear end of the cylinder, where it is compressed to about 300 lb. per sq. in.

4 A valuable feature of this engine is the high thermal efficiency without excessive cylinder pressure. The highest pressure after ignition is approximately 500 lb. per sq. in.

5 Fuel is preferably stored in an underground tank, from which it is raised by a small rotary pump driven by the engine to a miniature standpipe. An oil pump withdraws it from the standpipe and delivers it at high pressure to the spraying device, whence it is propelled into the cylinder at the proper moment in a highly atomized state.

The American Society of Mechanical Engineers 29 West 39th Street, New York. All papers are subject to revision.

6 The spraying nozzle is designed especially with a view to making derangement impossible. The oil and compressed air are admitted on opposite sides of a sleeve which encloses the needle-valve pin. On the surface of the sleeve is cut a series of diagonal grooves and channels through which the oil and air are forced to pass. In this way an extremely minute subdivision of the particles of oil and a most intimate mixture with the air are obtained. The needle valve by which the charge is admitted into the cylinder is about ½ in. in diameter, and with its appurtenances, is so arranged that the whole may be instantly withdrawn for inspection at any time.

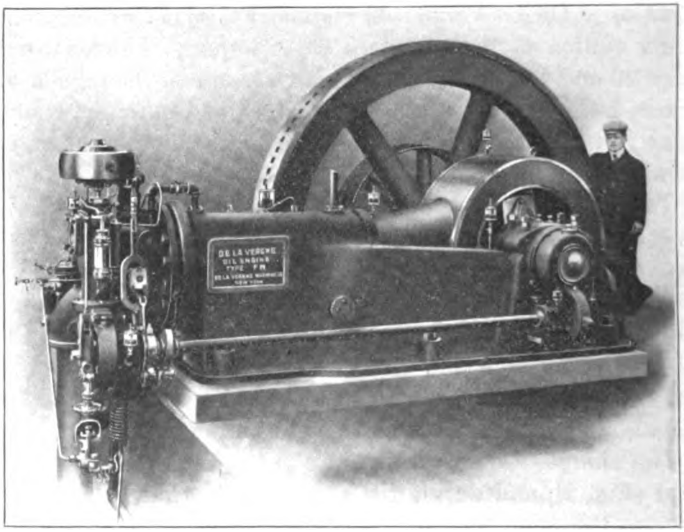

FIG. 1 EXTERIOR VIEW OF 85-H.P. DE LA VERGNE OIL ENGINE, TYPE FH

7 The air for spraying the oil is supplied by a two-stage air compressor, shown at *C*, Fig. 2, driven by an eccentric on the engine shaft. The air compressed by the first stage is stored in a tank at about 150 lb. pressure, and is utilized for starting the engine. The second stage of the compressor is quite small and handles only sufficient air to effect the spraying of the oil from stroke to stroke. The amount of air drawn in by the second stage is controlled by the engine governor to suit the various charges of fuel.

8 Ignition of the charge is effected by means of the vaporizer or hot cap shown at *D*, a device consisting of a massive gun-iron thimble,

heavily ribbed on the inside to increase its radiating surface. It is located on the side of the cylinder head and opens directly into the combustion chamber, across which and into the vaporizer the charge of fuel is injected. By this device the fuel is ignited as soon as the spraying valve is opened, and it is therefore possible exactly to time the point of ignition. As the fuel is not introduced into the cylinder until the moment of ignition, a relatively high compression may be had without the possibility of back-firing. The vaporizer must be heated by a blast lamp for a few minutes before the engine is started; but this may be removed as soon as the engine is in operation.

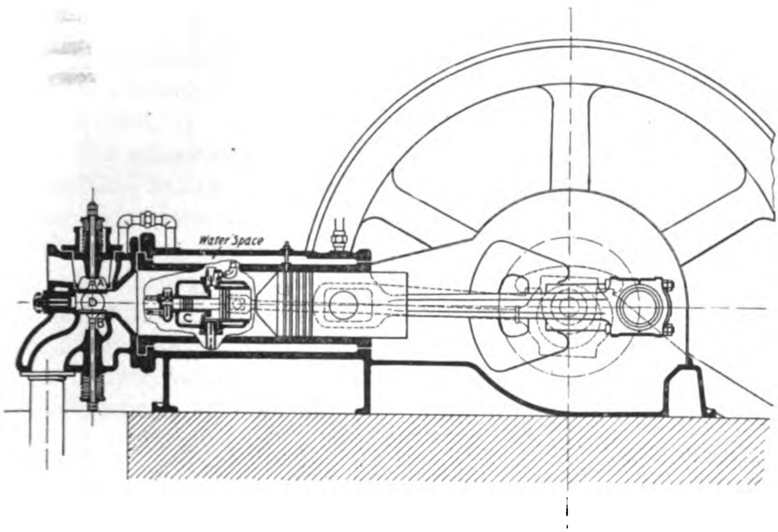

Fig. 2 Longitudinal Section of Oil Engine

9 Before shipment the engine was tested and developed a brake horsepower with 0.474 lb. of Solar fuel oil per hour when running at 65.11 b.h.p., and 0.462 lb. when running at 85.74 b.h.p.

10 In order to obtain as accurate data as possible, not only of the engine but of the combined pumping plant, it was decided to make a second brake test at Fawn Grove with the engine doing practically the same work as when pumping, and to ascertain as accurately as possible the ratio between the b.h.p. and the pump h.p.

11 In preparation for the test, a Government sealed platform scale, weighing to single ounces, was procured for weighing the oil. The water for cooling purposes was taken by gravity from a tank and

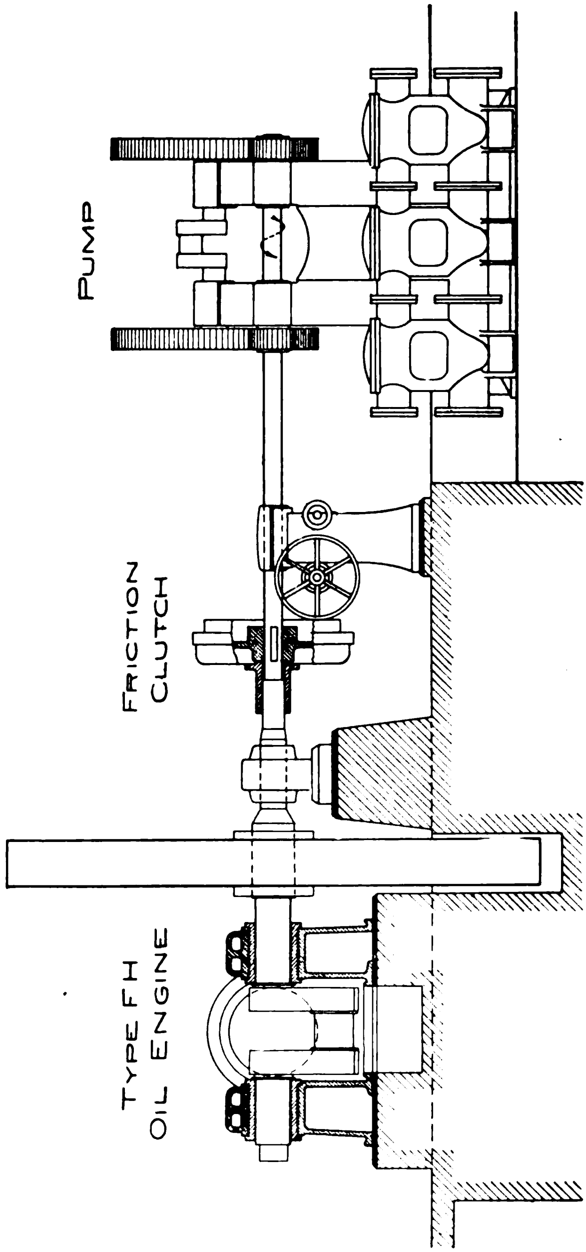

FIG. 3 ENGINE AND PUMP INSTALLED WITH CLUTCH CONNECTION

allowed to waste, the amount used being computed from measurements taken. The inlet temperature was taken at the tank, and the temperature of the water after passing the jackets by placing a thermometer in the line near the engine.

12 The amount pumped was ascertained by gaging the tank at Fawn Grove, and checked by gaging the tank into which the oil was pumped. The pressure was recorded by a Bristol recording gage and also read on a special Ashcroft gage, the latter, on the completion of the test, being taken to New York and compared with the standard gage of the company, which is graduated from a mercury column, situated in the Standard Oil Building, high enough to give direct readings up to 875 lb. per sq. in. The temperatures were taken with standardized thermometers, and the cards with a Crosby indicator, which was returned to the makers at the close of the test and found to be correct.

13 The exhaust gases were tested on the ground by using an Orsat apparatus. Samples of the oil were tested for calorific power. The average as obtained by one observer was 19,059 and this figure was used in working up the tests. Two tests were made by another observer and recorded 18,920 and 19,300 B.t.u. Prof. H. C. Sherman's formula, B.t.u. = 18,650 + 40 (Baumé deg. −10)[1] makes this 19,570. This formula is roughly applicable to all the American crude oils.

14 No analysis of the oil was made, but for the purposes of chemical calculations, it was assumed to be as follows:

	Per cent by weight
Carbon	86
Hydrogen	12
Other material	2
	100

The accuracy of the method used in analysing the gases is not such as to warrant going to the trouble of making an analysis of the oil. By comparison with available analyses the above is believed to be substantially correct.

15 In order to attach the Prony brake to the engine, it was necessary to remove the drag-link coupling between the engine and the friction clutch, thus running an extra shaft-bearing during the brake test. The brake had an arm 5 ft. 4 in. long and an unbalanced weight of 48 lb.

[1]Am.Chem.Soc., vol. 30, October 1908.

16 Three tests were made, the first, *A*, a full-load brake test; the second, *B*, a pumping test using the engine under the actual operating conditions; and the third, *C*, without disturbing any of the engine adjustments, but simply substituting the brake load for the pump load, so that the oil consumption and speed were, as nearly as possible, the same. By comparing *B* and *C* it was thought that the friction of the pump could be more accurately ascertained than in any other way.

17 The duration of each test was 3 hours, and each hour checked so closely that it was considered unnecessary to continue the runs for a longer period.

18 The air for spraying the oil was pumped by an attached compressor. There was no auxiliary machinery used, the cooling water being delivered by gravity.

19 The number of revolutions per hour was obtained by using an Ashcroft counter. During test *B* the counter was on the pump and the revolutions were computed in the ratio of the gearing; during tests *A* and *C* the counter was connected direct to the engine. The resistance of the pump load, test *B*, was so constant and the regulation of the engine so good, that the number of counts recorded for each hour was the same. The fuel consumed for the first hour was 31 lb. 2 oz., the second, 31 lb. 3 oz., and the third, 31 lb. During the brake test *C* the number of revolutions recorded was respectively 10918, 10916 and 10919. The fuel consumption for the above hours was 31 lb. 6 oz., 31 lb. 8 oz., and 31 lb. 4 oz.

20 The following chemical computation was made in connection with test *C*, and is based on the analysis previously given, assuming that all of the oil was burned.

	Lb. per Hr.	
Oxygen for hydrogen combustion	30.12	
Oxygen for carbon	71.95	
Total oxygen	102.07	
Air used for combustion		443.8
Excess air (165.2 per cent)		733.2
Hydrogen burned		3.765
Carbon burned		26.983
		1207.748

21 For comparison with other pump tests the duty per 1,000,000 B.t.u. is given. This duty is, however, based on the heat units in the oil and not on the heat units delivered to the engine in the steam, as is the customary duty of a steam pumping engine.

22 It may be interesting to compare this duty with that obtained by Professor Denton in his test of the Laketon pumping engine,[1] as oil fuel was used during that test. The fuel used at Laketon contained, by Professor Sherman's formula, 19,770 B.t.u. The evaporation, test 5, was 16.64 lb. from and at 212 deg. This makes the boiler efficiency 81.3 per cent. The engine performance was 124,-375, 834 ft-lb. per 1,000,000 B.t.u., or 15.985 per cent, and the total

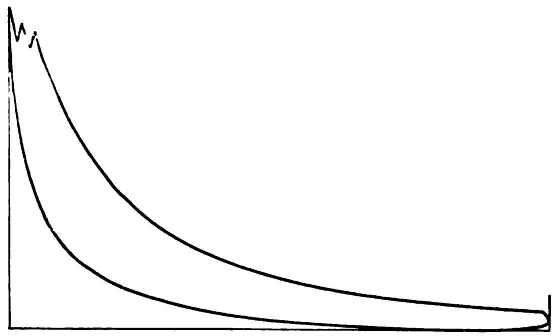

Fig. 4 Typical Indicator Diagram, Test *A*
180 r.p.m.; 89 m.e.p.; 126 i.h.p.

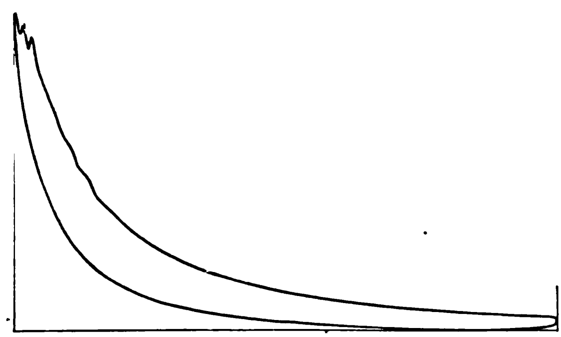

Fig. 5 Typical Indicator Diagram, Tests *B* and *C*
182 r.p.m.; 68 m.e.p.; 98 i.h.p.

efficiency of the plant was 13 per cent, as against 27.75 per cent for the engine and 25.52 per cent for the plant obtained from the present tests. Professor Carpenter's test of the North Point, E. P. Allis & Company pumping engine, if figured at the same boiler efficiency, would give a plant efficiency of 14.38 per cent. The Standard Oil

[1] Trans.Am.Soc.M.E., vol. 14, pp. 1349 and 1373.

Company of Louisiana have 12 of this same type of engine. Tests of two, made at Flora, La., by James Anderson, Jr., show that the engines developed a pump horsepower with 0.545 and 0.5205 lb. of crude oil per hour respectively.

23 After the engine at Fawn Grove was tested, several adjustments were made and resulted in the development of a pump horsepower with 0.48 lb. of oil per hour.

24 Fig. 4 shows a typical indicator diagram for test *A*; Fig. 5, a diagram for tests *B* and *C*. The details of the test are as follows:

HORSEPOWERS

Test number	*A*	*B*	*C*
Date	4/20/11	4/20/11	4/21/11
Start	9.00 a.m.	2.00 p.m.	9.00 a.m.
End	12.00 m.	5.00 p.m.	12.00 m.
Duration, hr	3	3	3
Average r.p.m	181.528	182.5	181.96
Average m.e.p. of cards, lb. per sq.in.	86.14	65.6	65.85
Average i.h.p.*	123.14	94.2	93.36
Prony brake load, lb	465.00		350.00
Scale load, lb	560.00		445.00
Average b.h.p	85.86	64.57 (computed)	64.68

Pressure pumped against lb. per sq. in.	570.00
Gage bbl. pumped 42 gal. per bbl	769.14
Average gage bbl. per hr	256.38
Pump h.p. by piston displacement	60.143
Pump h.p. by actual gage bbl. pumped	59.48

EXHAUST

Test number	*A*	*B*	*C*
Temperature of gases, deg. fahr	678	483	485
Average Analyses			
CO_2, per cent	7.77	5.37	5.44
CO, per cent	0	0	0
O, per cent	10.17	13.5	13.24
N, per cent	82.06	81.13	81.32
Specific heat	0.2393	0.2388	0.2387
Amount of gases			
By calculation of displacement, 70 deg. fahr. lb. per hr	1455.00	1500.00	1491.00
If temperature were same as jacket water	1181.00		1220.00
From chemical test (Par. 20)			1208.00

* I.h.p. probably high due to the momentum of indicator parts. This accounts for comparatively low mechanical efficiency shown in a table which follows.

JACKET WATER

(Capacity of tank 39.429 gal. per in. depth)

Test number	A	C
Inches used from tank	18	$12\frac{7}{16}$
Total gal. used	709.7	490.4
Average lb. per hr	1971.0	1362.0
Average lb. per. b.h.p-hr	22.97	21.05
Average inlet temperature, deg. fahr	68.7	71.3
Average outlet temperature, deg. fahr	193.3	187.8

HEAT BALANCES

Test number	A	B	C
Input, B.t.u-hr	815,153	592,813	597,976
Engine useful work			
B.t.u-hr	218,514	164,331	164,610
Per cent	26.8	27.75	27.52
Loss in cooling water			
B.t.u-hr	246,375		158,673
Per cent	30.2		26.5
Loss in exhaust			
B.t.u-hr			119,520
Per cent			20.03
Loss in friction and radiation by difference			
B.t.u-hr			155,173
Per cent			25.95
B.t.u. per hr. in cylinder work	313,391	239,739	240,046
B.t.u. per hr. in useful pump-work output of station		151,376	
B.t.u. per hr., input per b.h.p	9,491	9,186 (calculated)	9,244
B.t.u. per hr. input per pump h.p		9,987	
Duty, ft-lb. per 1,000,000 B.t.u (based on oil pumped per actual gage)		198,664,000	

EFFICIENCIES

Test number	A	B	C
Engine efficiency			
Thermal, per cent	38.4	40.45	40.2
Mechanical, per cent*	69.71	68.55 (assumed same as test C)	68.55
Total, per cent	26.8	27.75	27.52
Pump			
Volumetric, per cent		98.9	
Pump and transmission, per cent		92.1	

FUEL CONSUMPTION

Test number	A	B	C
Lb. of fuel per hr	42.77	31.1041	31.375
Lb. of fuel i.h.p. per hr	0.347	0.331	0.333
Lb. of fuel b.h.p. per hr	0.498	0.482	0.485
Lb. of fuel pump h.p. by displacement		0.5171	
Lb. of fuel pump h.p. per hr. by gage bbl		0.524	

ENGINE DATA

Governor lift, in	$\frac{3}{64}$	$\frac{5}{32}$	$\frac{5}{32}$
Air pressure in tanks, lb., per sq. in	94	96	97
Regulation full load to no load, r.p.m		182–186	
Compression, lb. per sq.in		347	

LUBRICATION

Test number	A	B	C
Cylinder oil			
Lb. per hr		0.6875	0.9375
Lb. per 100 b.h.p. per hr		1.0625	1.445
Engine oil			
Lb. per hr		1.78	1.16
Lb. per hr. 100 b.h.p. per hr		2.76	1.795

FUEL OIL CHARACTERISTICS

Illinois Crude Oil

Baumé	33 deg.fahr.	specific gravity	0.863
Flash point	35 deg.fahr.	burning point	65 deg. fahr.
Heating value	19,059 B.t.u. per lb. per test		
	19,570 per Professor Sherman's formula		