ENGINEERING RESEARCH INSTITUTE
THE UNIVERSITY OF MICHIGAN
ANN ARBOR

EVALUATION OF LAUSON VA ENGINES

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Project 2481

TECUMSEH PRODUCTS COMPANY
TECUMSEH, MICHIGAN

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ABSTRACT

This report covers the testing and evaluation of four Lauson 2.5-hp engines, Model VA-7. This evaluation included complete performance data (horsepower, torque, specific fuel consumption, air consumption, fuel consumption, air-fuel ratio, inlet manifold pressure, exhaust manifold pressure and temperatures of the cylinder head, oil sump, inlet engine air, exhaust gases and inlet and outlet of the cooling air) on two of the four engines. All four engines were life tested for 500 hours at 80% full load.

The engines met the manufacturer's rating of 2.5 hp at 3600 rpm and completed the 500-hour life tests.

OBJECTIVE

To evaluate the performance characteristics of the Lauson VA series engines.

DESCRIPTION OF ENGINE

The following four engines were received by the Dynamometer Laboratory, Engineering Research Institute, The University of Michigan, for testing (all future references to these engines will be to our distinguishing letter listed below):

Our Designation	Model	Serial
D	VA-7 WS	5612702
E	VA-7W WA	5629107
F	VA-7W WA	5655429
G	VA-7W WA	5655428

The VA-7 series of engine is rated 2.5 hp at 3600 rpm. The engine has one cylinder and is air-cooled, operates on a four-stroke cycle, has an L-head; and the crankshaft is vertical for rotary-mower applications.

The cylinder bore is 2-5/16 inches, the stroke 1-3/4 inches, giving a 7.35-cubic-inch displacement. The engine weight, without gasoline or oil, is 19.5 pounds. The ignition system consists of a Wico magneto mounted at the top of the crankshaft, beneath the flywheel, and a 14-mm Champion J8 spark plug.

Engine D was equipped with a Marvel-Schebler carburetor. Engines E, F, and G were equipped with Walbro carburetors. Both types of carburetors were of the float-feed type and had adjustable idle and power jets.

The engines are equipped with a pressure-type lubrication system. A piston pump operated by an eccentric cam on the cam shaft delivers oil to the upper bearing from the oil sump. An annular groove in the upper bearing then directs oil to the connecting-rod bearing via a rifle-drilled crankshaft.

A streamlined gas tank is located on top of the engine. This tank also forms the shrouding around the air-vane governor.

All bearings are composed of the parent metal, die-cast aluminum alloy.

The cylinder and crankcase are die-cast aluminum alloy and have a cast-iron cylinder liner and hardened-steel valve seat inserts. The piston is aluminum alloy and has two compression rings and one oil-control ring.

An oil-bath air filter is included as standard equipment.

TEST EQUIPMENT

A vertical-shaft dynamometer was not immediately available for performance testing of the engine. Since V-belt and bevel-gear losses often vary, and since the belt or gear arrangement might not stand up under the pulsating load, it was decided not to use a horizontal-shaft dynamometer to load the engine. Since in service (rotary-lawn-mower applications) the engines are loaded for the most part by a fan load, it was decided to test the engines with calibrated fan brakes. A fan brake is also the most convenient and trouble-free method of loading the engine during the life test.

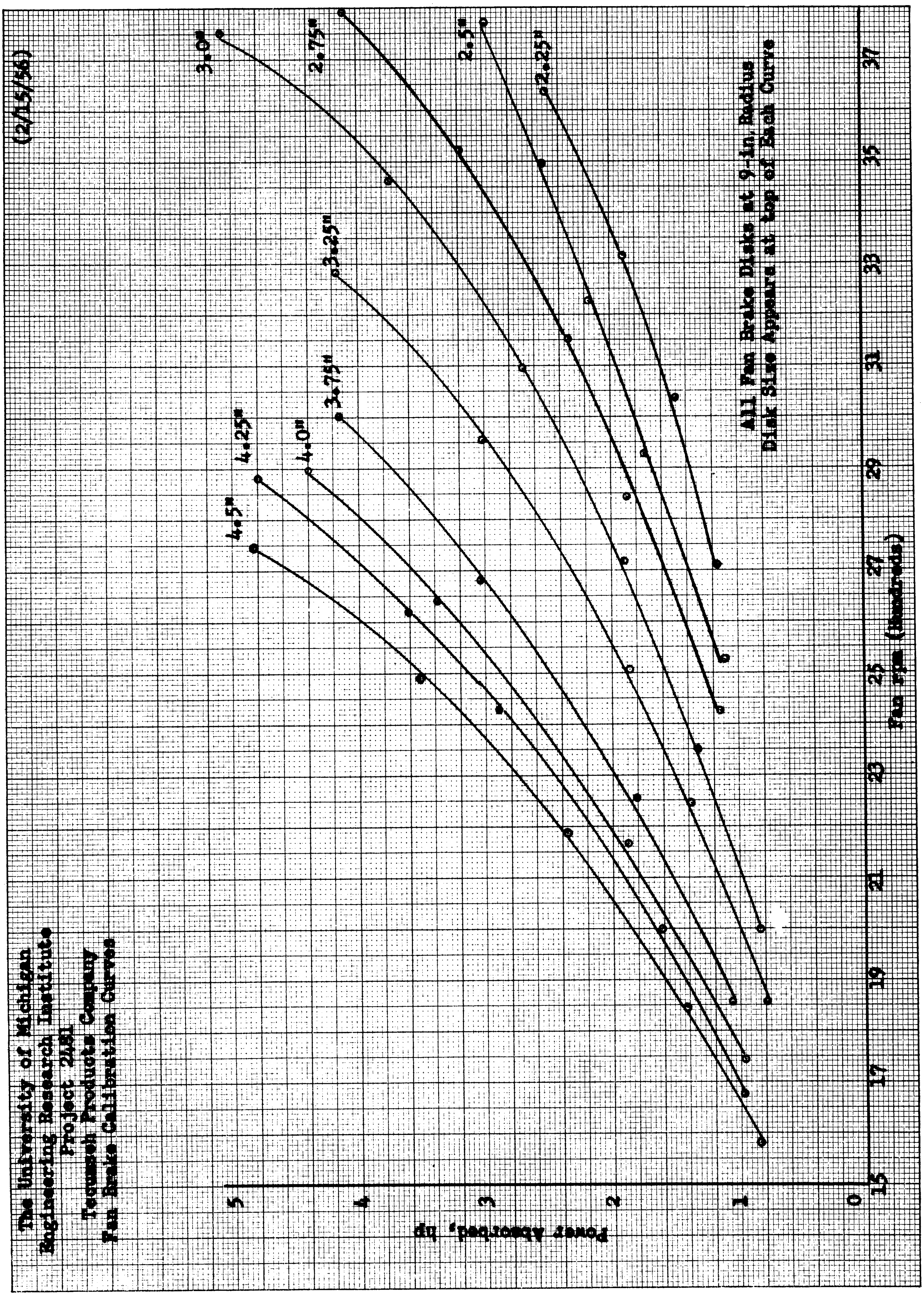
A cage consisting of two 4-foot x 4-foot 1/4-inch-thick steel plates spaced 1 foot apart and surrounded by diamond-mesh expanded metal was fabricated for use as an engine test stand. A suitable opening was cut in the center of the top plate to receive the engine. Load arms were attached to the end of the engine shaft with taper-grip V-belt hubs. A series of semicircular plates having diameters ranging in size from 2-1/4 to 4-1/2 inches in 1/4-inch steps were attached to the load arms at a 9-inch radius to act as the fan brake.

The fan brakes were calibrated with the shaft in a horizontal position and were driven by a 10-hp G.E. motoring dynamometer. The load arm was attached to a dynamometer shaft extension, the same distance from the top plate as it would be if attached to the engine shaft. A sheet-metal cover filled the opening in the top plate during the calibration runs, simulating the engine base and preventing any change of air-flow characteristics.

The fans were calibrated with the same tachometer attached to the shaft as that used during the performance tests; hence, any minute load that may be imposed by the tachometer is indicated in the load curves for the fans.

Thus under carefully controlled calibration conditions, i.e., fan brake position in cage, air-flow characteristics, and tachometer load, horsepower-vs-speed data may be obtained which will give accurate results when used to load the engine. A sample of these calibration curves appears as Fig. 1.

The tachometer used throughout these tests is one of our own design and may be easily constructed from readily available components. A standard magnetic pickup, which generates a voltage pulse each time the magnetic circuit adjacent to its end is disturbed, was connected to a Hewlett-Packard electronic counter. A 60-tooth, 20-pitch, cast-iron gear was attached to the engine shaft with another taper-grip V-belt hub. The magnetic pickup was positioned so that its nose was 1/16 inch from the tips of the gear teeth. With this arrangement, the electronic counter registered one count each time a gear tooth passed in front of it. Since the electronic counter normally counts over a one-second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Tecumseh Products Company
Fan Brake Calibration Curves
(2/15/56)
All Fan Brake Disks at 9-in. Radius
Disk Size Appears at Top of Each Curve
3.0"
2.75"
2.5"
2.25"
3.25"
3.75"
4.0"
4.25"
4.5"
Power Absorbed, hp
0
1
2
3
4
5
Fan rpm (Hundreds)
15
17
19
21
23
25
27
29
31
33
35
37

Fig. 1.

time base and since 60 pulses are registered per revolution, the decades of the counter read directly in rpm's. The tachometer arrangement may be seen in Fig. 2.

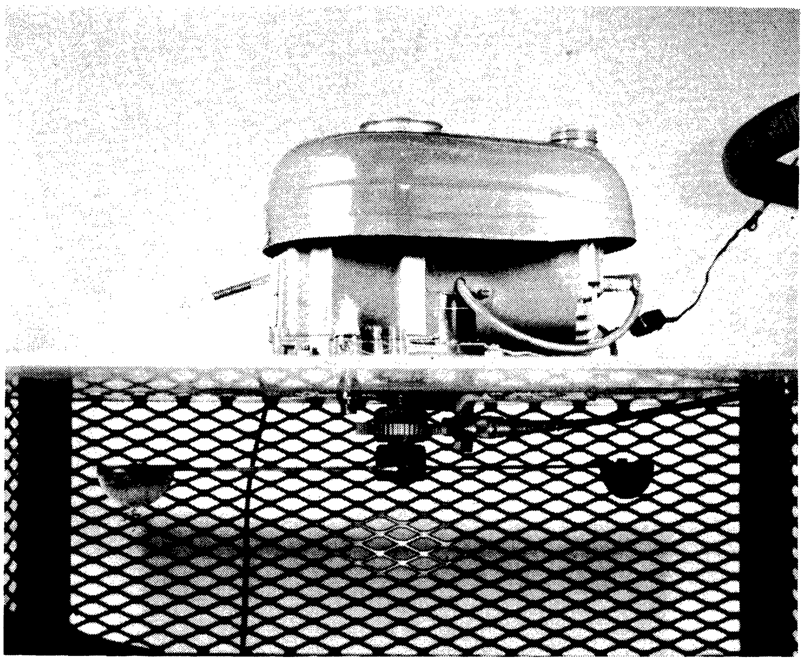


Fig. 2.

Iron-constantan thermocouples were placed in the following positions:

oil sump
head bolt washer nearest spark plug
cooling-air inlet
cooling-air outlet
engine fuel-air mixture

A Chromel-Alumel thermocouple was placed in the exhaust outlet. Temperatures at the above locations were indicated on a Brown-Honeywell electronic balance potentiometer. Pressures in the intake and exhaust manifolds were taken using vertical and inclined water manometers.

Engine air-flow rates were obtained by replacing the air filter with a surge tank which accepted standard air-flow nozzles. Nozzles were chosen which would closely simulate the pressure drop across the air filter at the particular air-flow rate studied.

Fuel flow was measured by a balance which was modified to control a Standard Electric Timer through a mercury switch and relay. The fuel measuring equipment is shown in Fig. 3.

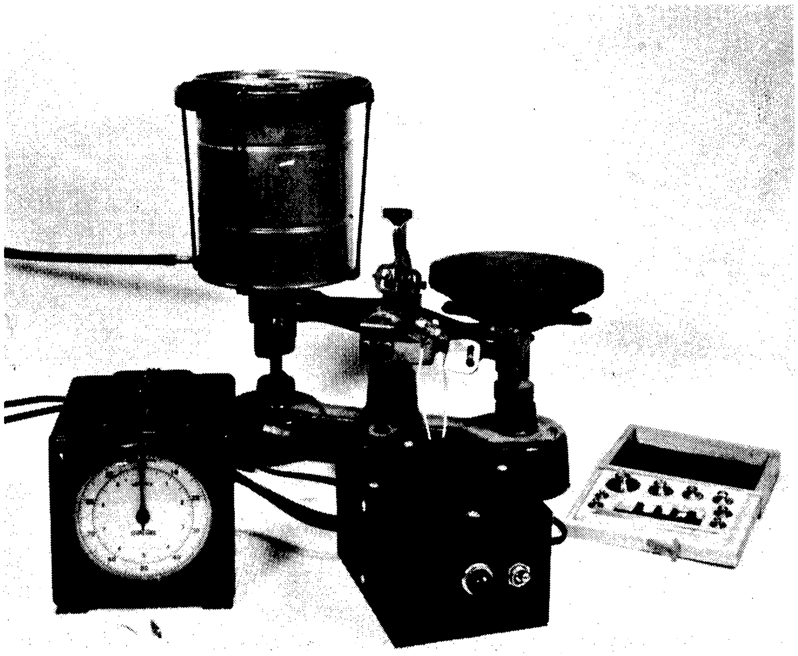


Fig. 3.

The horsepower and torque data obtained at existing atmospheric conditions were corrected to the standard conditions of 29.92 inches of mercury barometric pressure and dry-bulb temperatures of 60°F.

A partial view of the instrumentation is shown in Fig. 4. The Hewlett-Packard electronic counter, the Brown-Honeywell potentiometer, and the vertical manometers appear in that order from left to right.

During the 500-hour life test, the following data were taken on each engine at 30-minute intervals:

1. Speed (hence torque, knowing the fan-disk size)
2. Head temperature
3. Oil temperature
4. Pertinent remarks

The oil used throughout the test was Gulf HD Select 20-20 W. The oil level was checked every five hours and was changed every ten hours. The oil consumed was recorded in the engine log.

An overall view of the test cell is shown in Fig. 5.

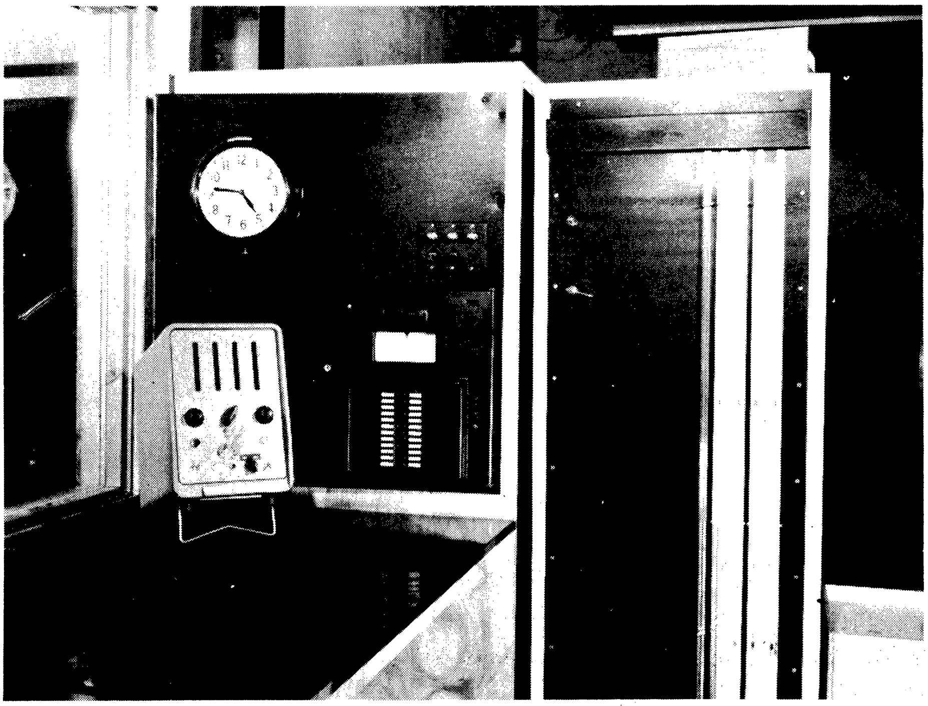


Fig. 4.

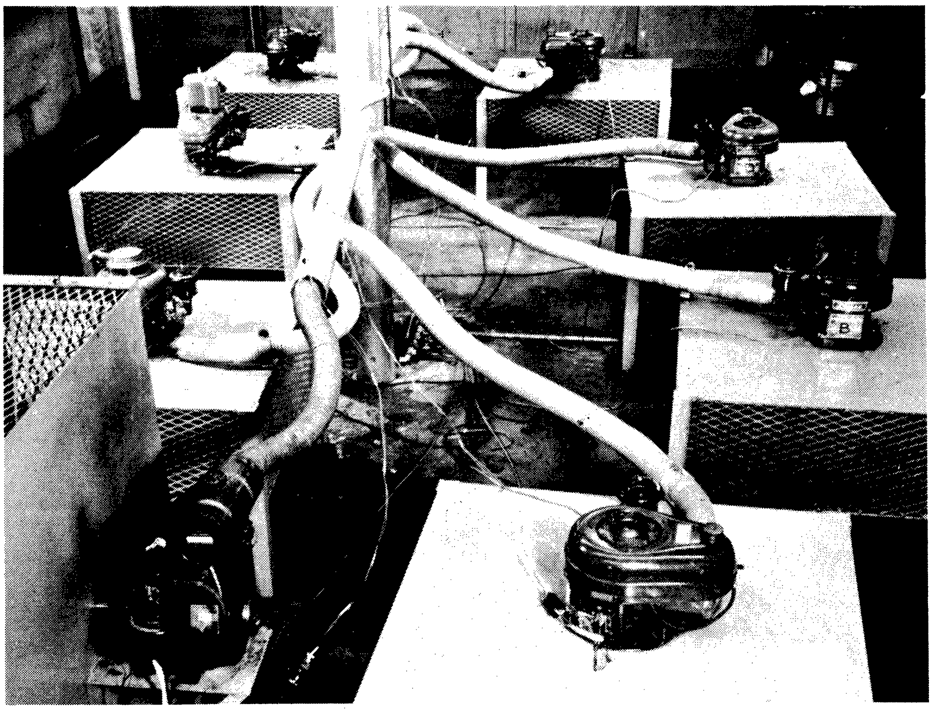


Fig. 5.

TEST PROCEDURE AND RESULTS

TEST PROCEDURE

Each engine was bolted to a test stand and the necessary thermocouples and pressure taps were connected to it. Before the performance runs were made the engine was broken in on the following load schedule:

	Duration (minutes)	Speed (rpm)	Percent Rated Load
	15	Slow idle	0
	60	2200	0
	60	3300	0
	300	3300	25
	300	3300	50
	300	3300	75
	300	3300	100
TOTAL	1335 (22 hr, 15 min)		

After the above break-in, the performance runs were made. The smallest fan-brake disk (2-1/4 inches) was attached to the load arm and the engine started. The carburetor adjustments recommended in the engine instruction manual were then made to give maximum engine performance. These adjustments were not changed at different speed and load conditions. After the engine had completely warmed up and all temperatures stabilized, the following data were taken:

1. Speed (average of at least four successive counts)
2. Intake-manifold pressure
3. Exhaust-manifold pressure
4. Engine air flow
5. Fuel flow
6. Cylinder-head temperature
7. Oil-sump temperature
8. Cooling-air inlet temperature
9. Cooling-air outlet temperature
10. Engine fuel-air mixture temperature
11. Exhaust temperature
12. Test-cell dry-bulb temperature
13. Test-cell wet-bulb temperature
14. Test-cell barometric pressure

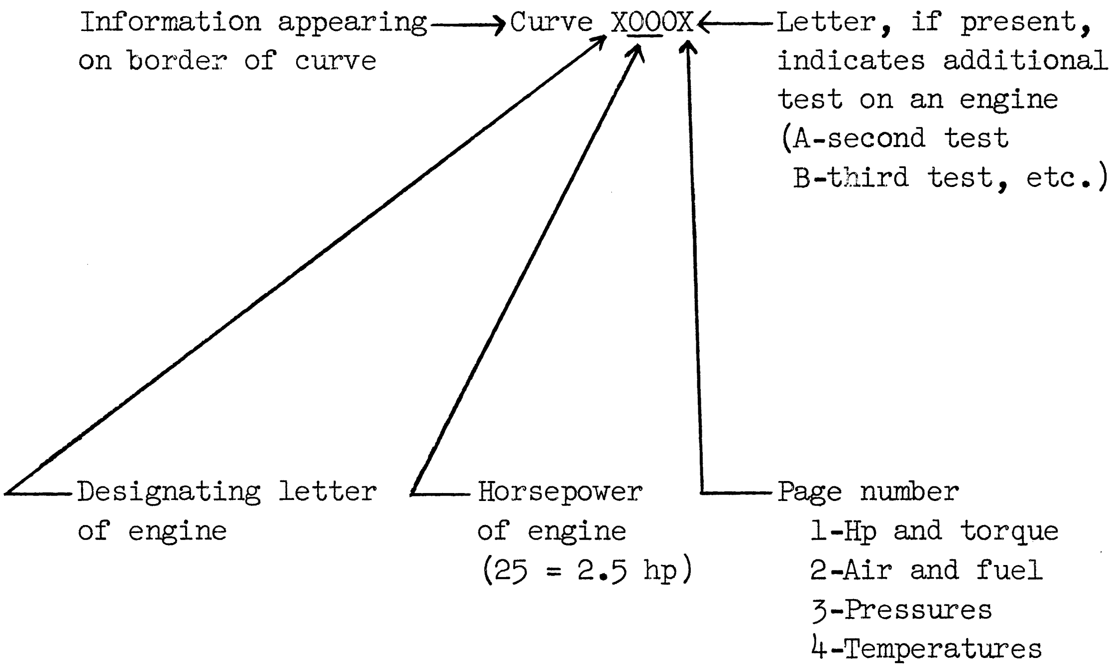
Each of the remaining nine fan-brake disks was attached in turn and the above data taken. The engine was allowed to warm up and stabilize in temperature before each set of readings was taken. All data were obtained at full-throttle settings on the carburetor.

The hp output at the speeds at which each of the disks was driven is readily determined from the calibration curves, Fig. 1. From the readings taken and from the hp output obtained from the calibration curves, the following data were computed and plotted vs engine speed:

a. Horsepower output (corrected to standard conditions)
b. Torque (corrected to standard conditions)
c. Engine air, lb/hr
d. Fuel, lb/hr
e. Air-fuel ratio
f. Specific fuel, lb/brake hp hr
g. Exhaust-manifold pressure
h. Intake-manifold pressure
i. Cylinder-head temperature
j. Oil-sump temperature
k. Cooling-air inlet temperature
l. Cooling-air outlet temperature
m. Engine fuel-air mixture temperature
n. Exhaust temperature

All engine-performance curves have been assigned a curve number which appears at the bottom of the curve. Each engine has a different curve series number as explained in the Key below.

Key to Performance-Curve Numbers



RESULTS

Performance Tests.—

1. Power output.

The power output of engine D was 2.5 hp at 3600 rpm. The output of engine E was 2.46 at 3600 rpm. Both of these outputs were obtained immediately after the break-in runs. See curves D251 and E251.

2. Fuel and air consumption.

Engine B, equipped with the Marvel-Schebler carburetor, had a leaner fuel-air mixture than engine E, which was equipped with a Walbro carburetor. The richer mixture provided by the Walbro carburetor did not increase power output, however. See curves D252 and E252.

3. Intake- and exhaust-manifold pressures.

The exhaust-manifold back pressure (measured in the tube before it joins the muffler) was almost identical in both engines and varied from 16.5 inches of water at 3600 rpm to approximately 4 inches of water at 1700 rpm.

Intake-manifold vacuums varied from 6 inches of water at 3600 rpm to 1.5 inches at 1700 rpm. Manifold pressures are shown on curves D253 and E253.

4. Temperature.

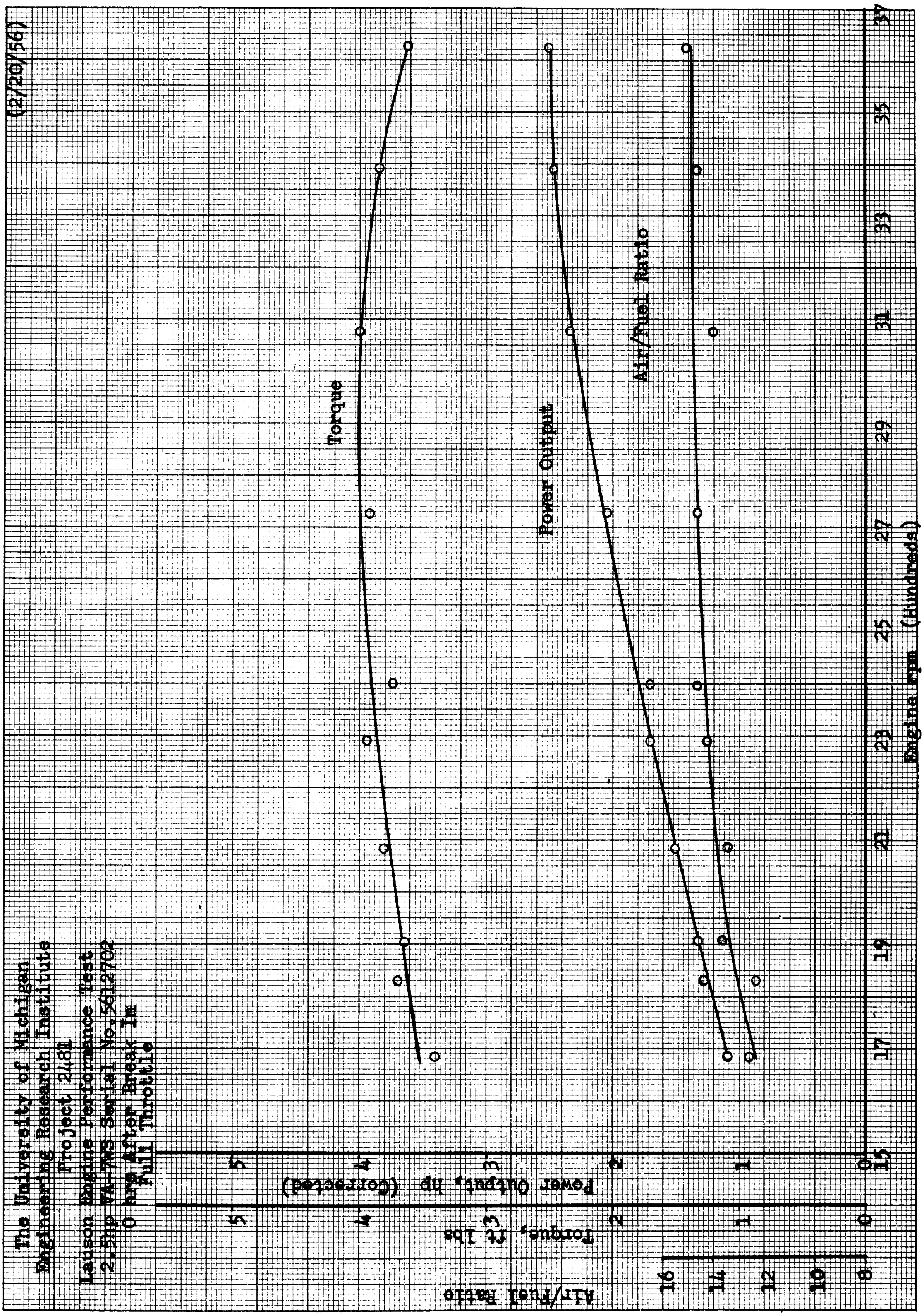
The engine-air, oil-sump, and cooling-air outlet temperatures were nearly the same for both engines. Exhaust temperature on engine E was approximately 100 degrees less than the exhaust temperature of engine D at all speeds. Cylinder-head temperatures were also lower on engine E. The lower temperatures can be attributed to the richer fuel mixture of engine E. The excess fuel absorbs some of the heat of combustion and allows cooler operating temperatures.

Temperatures of the cylinder head, oil sump, cooling-air inlet, cooling-air outlet, fuel mixture, and exhaust gas are plotted vs speeds in curves D254 and E254.

Life Tests.—Engine D and E started the 500-hour life test after the performance runs. Engines F and G started the life test immediately after break-in. The life-test load on the engine was imposed by the 2.5-inch disk being driven at 3200 rpm. At this speed the 2.5-inch disk absorbs 2.07 hp. This load of 2.07 hp at 3200 rpm is 82.8% of the rated load of 2.5 hp at 3600 rpm.

1. Maintenance required.

The following maintenence was required during the 500-hour life test: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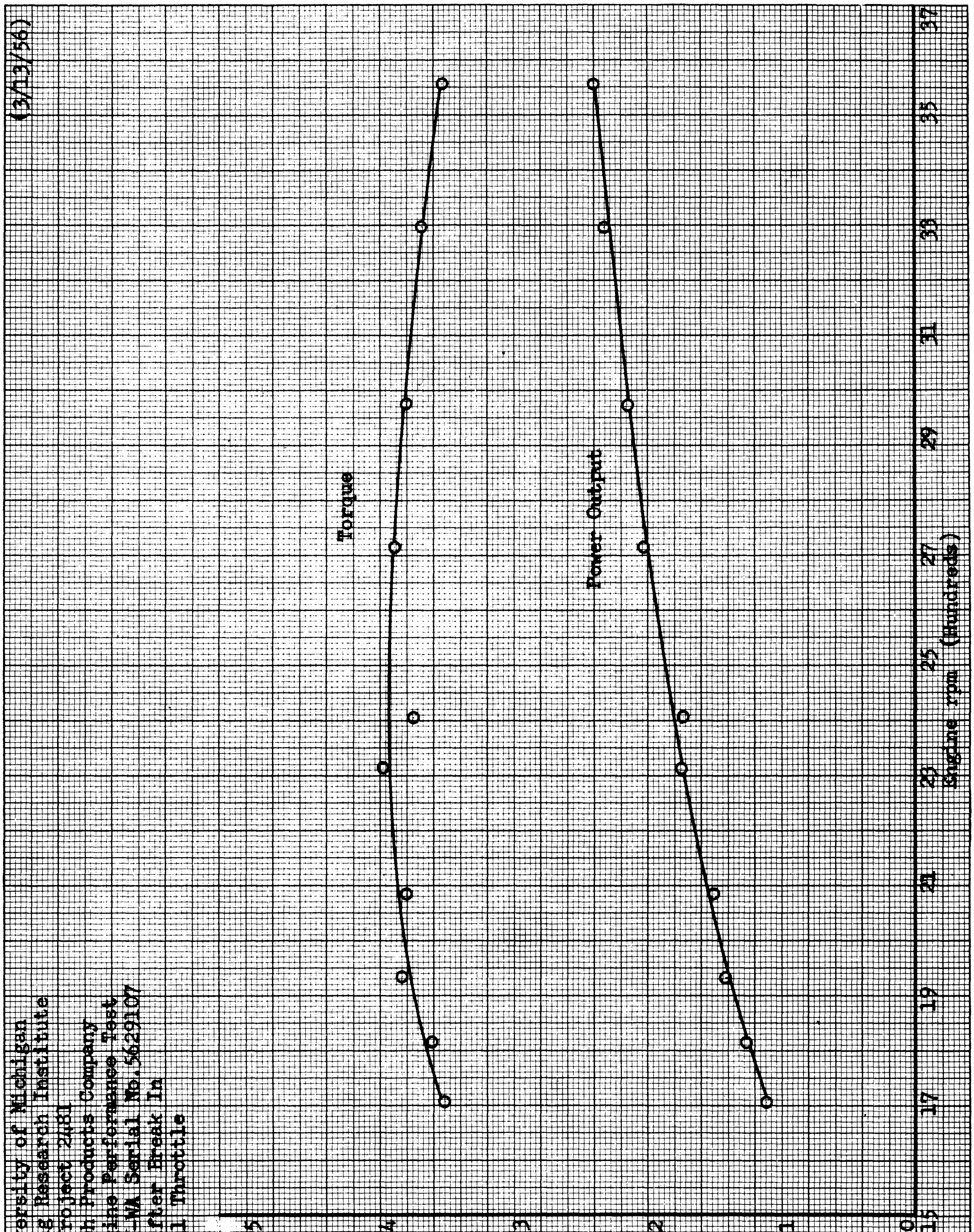
Lauson Engine Performance Test
2.5hp VA-7MS Serial No. 5612702
0 hrs After Break In
Full Throttle
(2/20/56)
Torque
Power Output
Air/Fuel Ratio
Engine rpm (Hundreds)
Power Output, hp (Corrected)
Torque, ft lbs
Air/Fuel Ratio

Curve D251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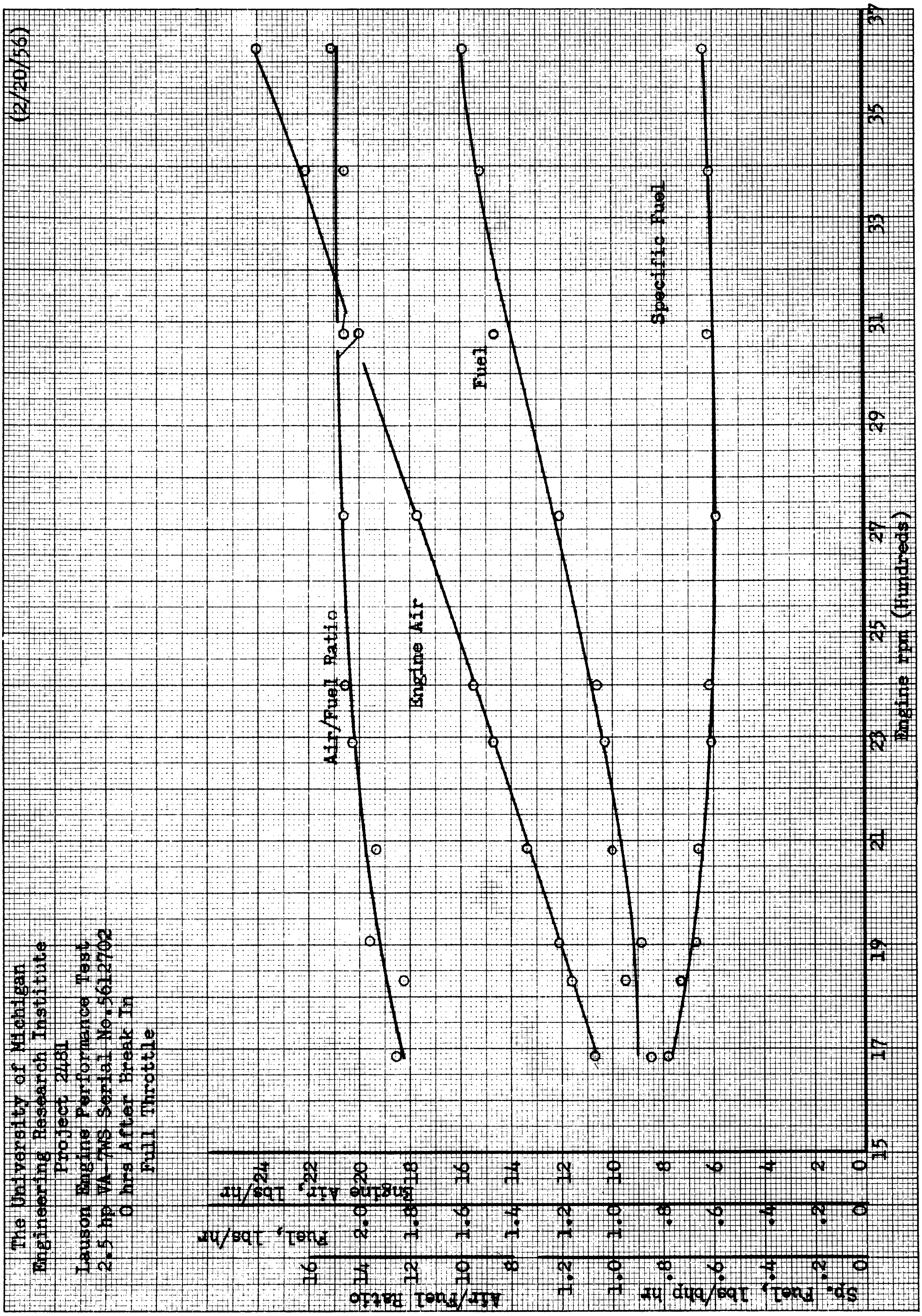
Lauson Engine Performance Test
2.5hp VA-7M-NA Serial No.5629107
0 hrs After Break In
Full Throttle
(3/13/56)
Torque
Power Output
Engine rpm (Hundreds)
Power Output, hp (Corrected)
Torque, ft lbs

Curve E251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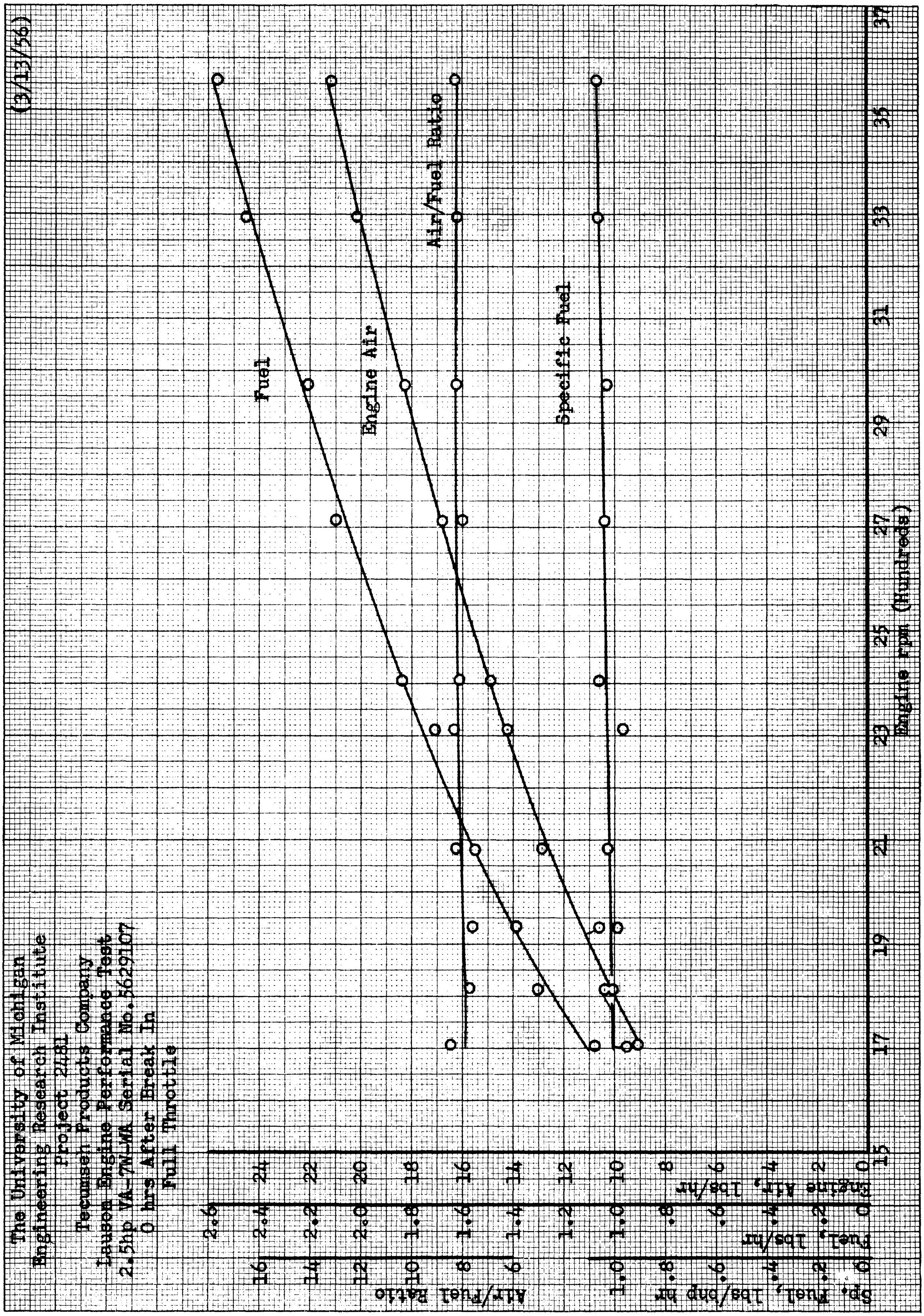
Lauson Engine Performance Test
2.5 hp VA-7WS Serial No. 5612702
0 hrs After Break In
Full Throttle
(2/20/56)
Air/Fuel Ratio
Engine Air
Fuel
Specific Fuel
Engine rpm (Hundreds)
Engine Air, lbs/hr
Fuel, lbs/hr
Air/Fuel Ratio
Sp. Fuel, lbs/bhp hr

Curve D252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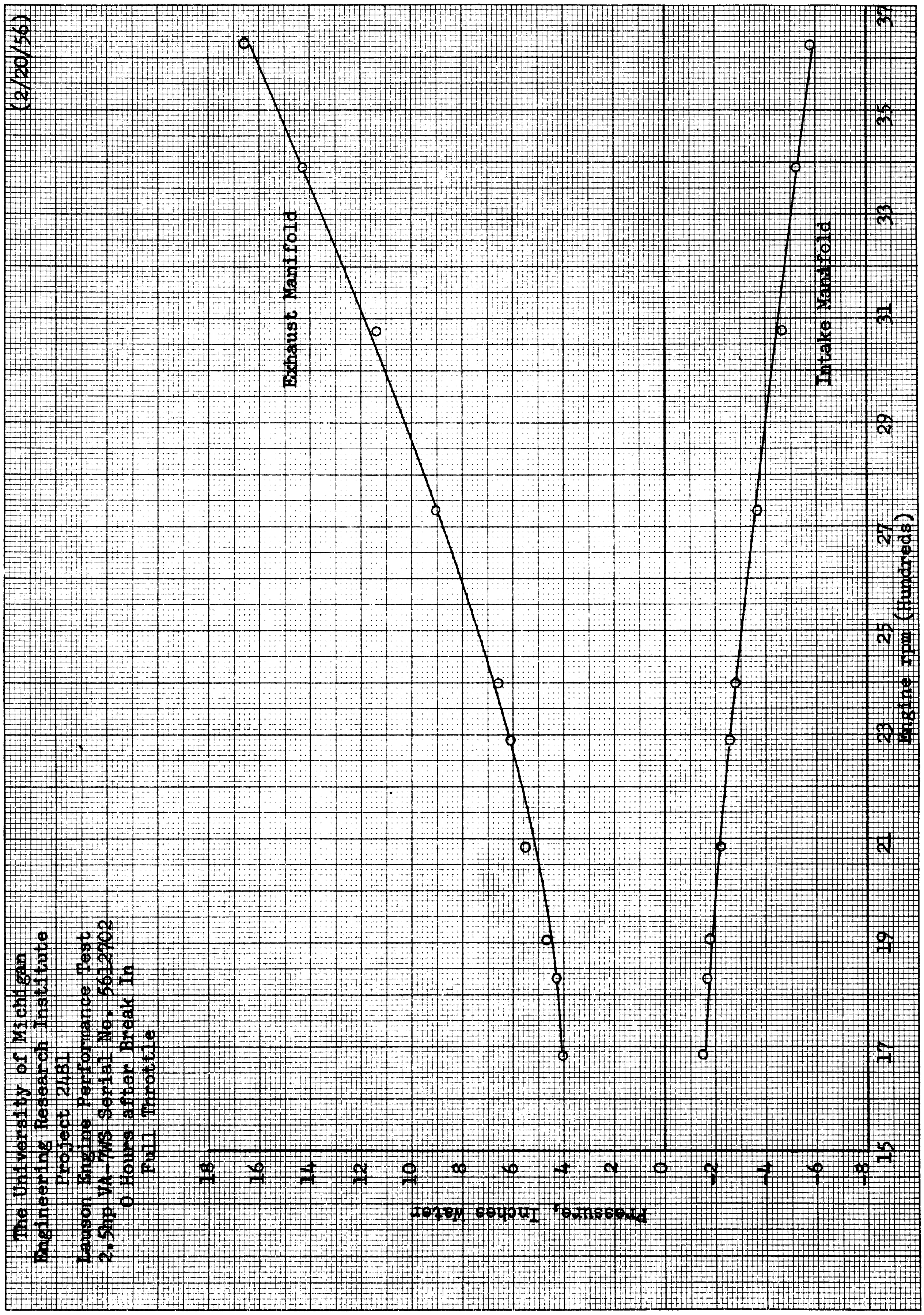
Tecumseh Products Company
Lauson Engine Performance Test
2.5hp VA-7N-MA Serial No. 5629107
0 hrs After Break In
Full Throttle
(3/13/56)
Fuel
Engine Air
Air/Fuel Ratio
Specific Fuel
Sp. Fuel, lbs/bhp hr
Air/Fuel Ratio
Fuel, lbs/hr
Engine Air, lbs/hr
Engine rpm (Hundreds)
15
17
19
21
23
25
27
29
31
33
35
37

Curve E252



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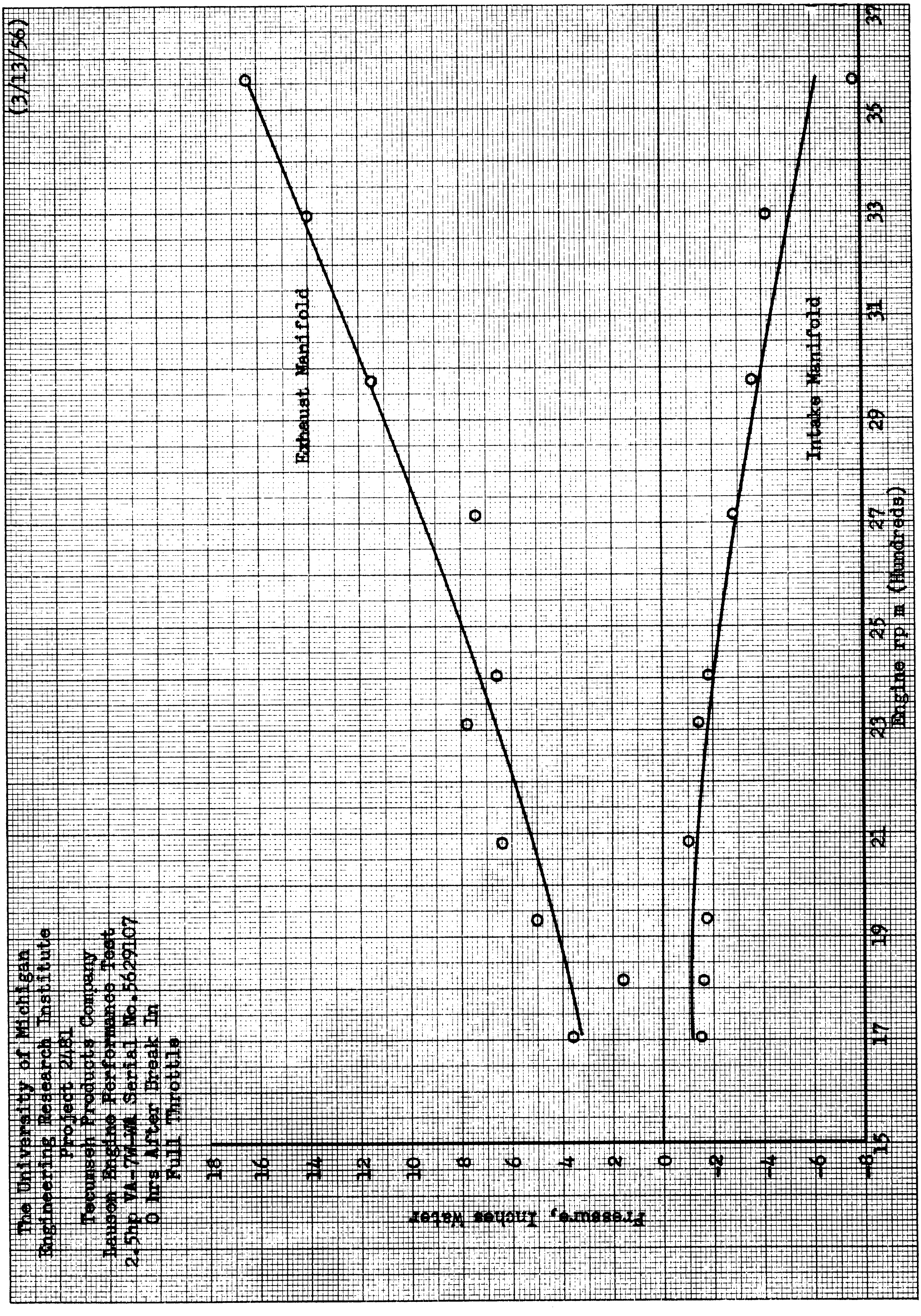
Lauson Engine Performance Test
2.5hp VA-7MS Serial No. 5612702
0 Hours after Break In
Full Throttle
(2/20/56)
Exhaust Manifold
Intake Manifold
Pressure, Inches Water
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
15
17
19
21
23
25
27
29
31
33
35
37
Engine rpm (Hundreds)

Curve D253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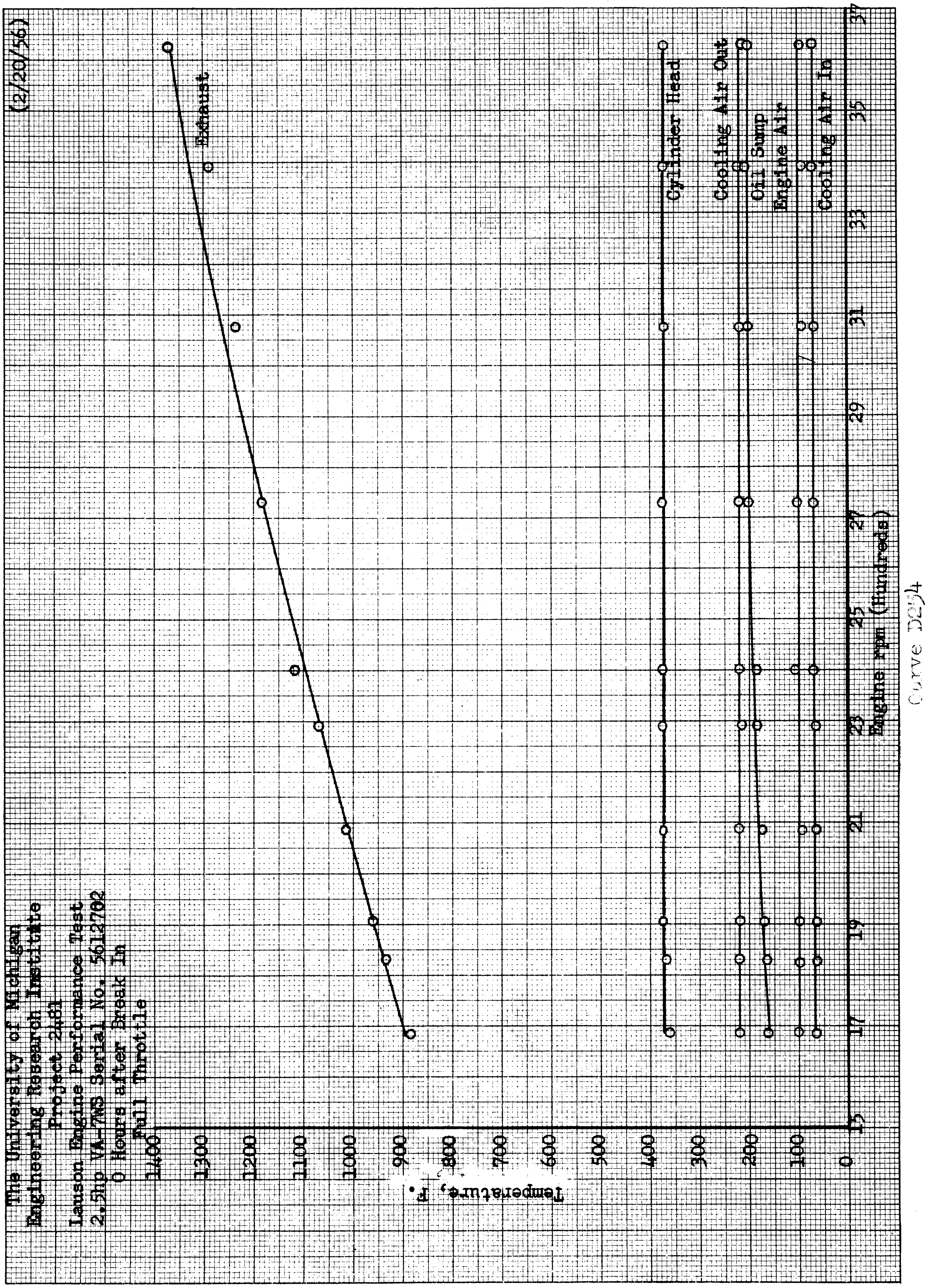
Tecumseh Products Company
Lauson Engine Performance Test
2.5hp VA-74-M Serial No. 5629107
0 hrs After Break In
Full Throttle
(3/13/56)
Exhaust Manifold
Intake Manifold
Pressure, Inches Water
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
15
17
19
21
23
25
27
29
31
33
35
37
Engine rp m (Hundreds)

Curve E253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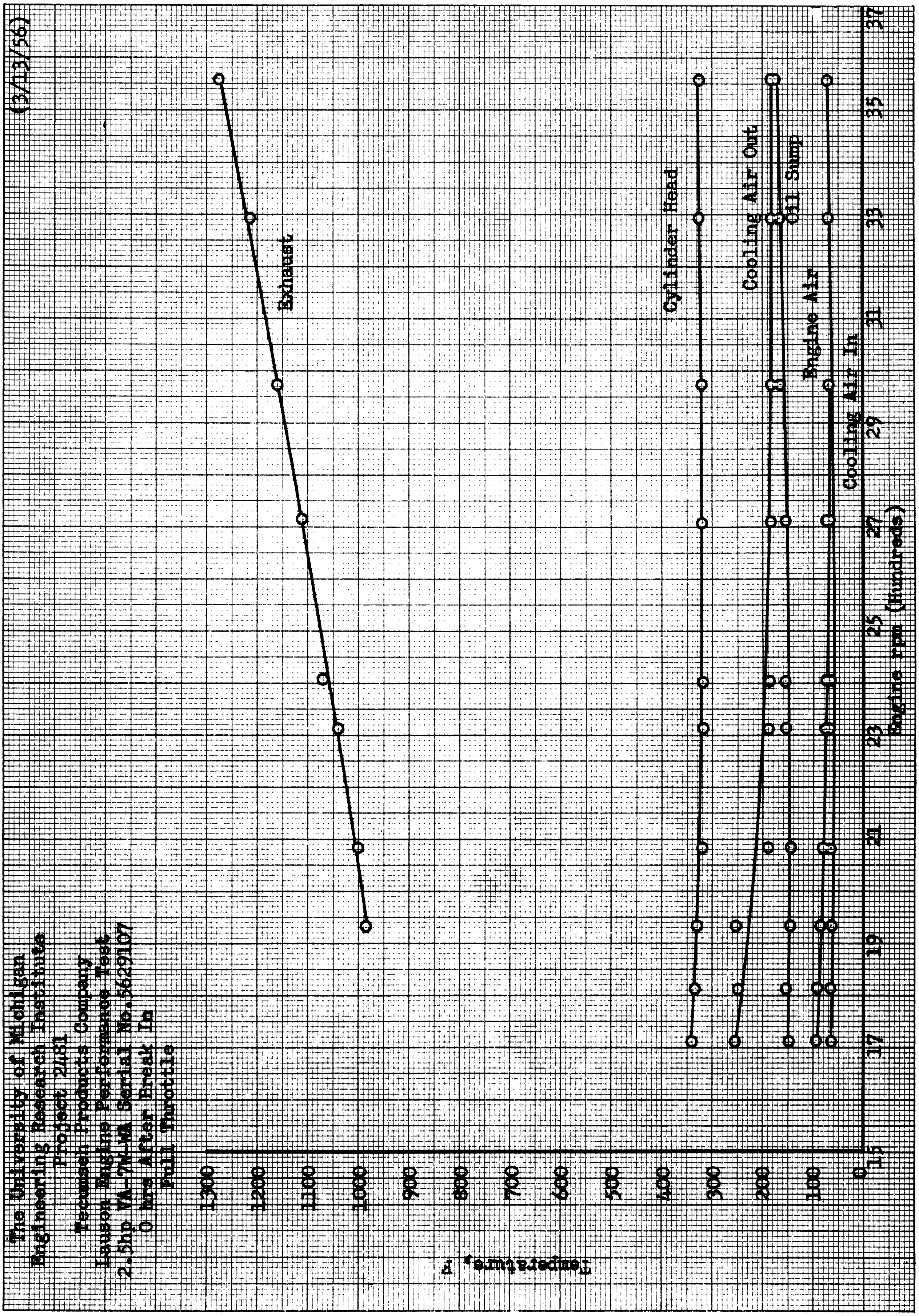
Lauson Engine Performance Test
2.5hp VA-7NS Serial No. 5612702
0 Hours after Break In
Full Throttle
(2/20/56)
Exhaust
Cylinder Head
Cooling Air Out
Oil Sump
Engine Air
Cooling Air In
Temperature, F.
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
15
17
19
21
23
25
27
29
31
33
35
37
Engine rpm (Hundreds)
Curve D254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Tecumseh Products Company
Lauson Engine Performance Test
2.5hp VA-7M-M Serial No.5629107
0 hrs After Break In
Full Throttle
(3/13/56)
Temperature, F
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
15
17
19
21
23
25
27
29
31
33
35
37
Engine rpm (Hundreds)
Exhaust
Cylinder Head
Cooling Air Out
Oil Sump
Engine Air
Cooling Air In

Curve E254

Engine D

70 hr Exhaust valve burned; replaced on existing seat. Carbon cleaned. Points and plug cleaned and gapped.

129 hr Hole in governor air vane elongated, permitting control wire to drop free. Replaced.

152 hr Exhaust valve burned; replaced in existing seat.

153 hr Carburetor float valve worn and leaking. Replaced.

202 hr Exhaust valve burned. Valve seats reground to give an even seat which was concentric with and perpendicular to the valve guide. Width of seat approximately 3/32 inch. Points and plug cleaned and gapped.

260 hr Cleaned and gapped plug.

376 hr Cleaned and gapped plug.

426 hr Cleaned and gapped plug.

495 hr Hole in governor air vane elongated, permitting control wire to drop free. Replaced.

498 hr Carburetor float valve worn and leaking. Replaced.

Engine E

129 hr Intake valve damaged from beating on seat. Valve replaced. Carbon cleaned. Cleaned and gapped plug.

204 hr Engine failed to start. No compression. Carbon under valves. Carbon cleaned.

253 hr Cleaned and gapped plug.

347 hr Engine failed to start. Much carbon build-up. Exhaust valve slightly burned. Both valves slightly damaged from beating against seat. Carbon cleaned. Same valves installed. Points and plug cleaned and gapped.

488 hr Carbon particle lodged under exhaust valve. Intake valve damaged by beating against seat. Intake valve replaced. Carbon cleaned.

492 hr Engine backfired through carburetor. Magneto condenser loose in its mount, causing erratic spring tension on points. Condenser spring clip tightened.

502 hr (After life test and performance spot check.) Both valve seats reground to give an even seat concentric with and perpendicular to the valve guide.

Engine F

40 hr Exhaust valve burned. Replaced with new valve, lapped in. Carbon cleaned.

132 hr Exhaust valve burned. Both valve seats reground to give an even seat which was concentric with and perpendicular to the valve guide. Width of seat approximately 3/32 inch. New exhaust valve and reground intake valve installed.

424 hr Burned exhaust valve. Burned area covered only a very small angular section and extended across entire width of seat. Failure may be due to imperfection of valve material. New exhaust valve installed.

Engine G

71 hr Burned exhaust valve. Exhaust valve replaced and lapped in. Carbon cleaned.

180 hr Burned exhaust valve. Damaged intake valve due to beating against seat. Both seats reground to give even seating, concentric with and perpendicular to valve guides. Width of seat approximately 1/32 inch.

420 hr Carbon particle lodged under exhaust valve. Carbon cleaned. Plug cleaned and gapped.

2. Oil consumption.

Engine D

In the 500-hr period, 237.4 liquid oz used, distributed as follows:

Period (hr)	Rate of Use (oz/hr)
0-25	.53
25-50	.63
50-100	.62
100-200	.44
200-300	.48
300-400	.44
400-500	.40
Average	.47

Engine E

In 500-hr period, 77.9 liquid oz used, distributed as follows:

Period (hr)	Rate of Use (oz/hr)
0-25	.19
25-50	.16
50-100	.10
100-200	.14
200-300	.20
300-400	.19
400-500	.10
Average	.15

Engine F

In 500-hr period, 544.3 liquid oz used, distributed as follows:

Period (hr)	Rate of Use (oz/hr)
0-25	.50
25-50	.98
50-100	1.00
100-200	.92
200-300	1.26
300-400	.88
400-500	1.51
Average	1.09

Engine G

In 500-hr period, 577.0 liquid oz used, distributed as follows:

Period (hr)	Rate of Use (oz/hr)
0-25	.16
25-50	.34
50-100	.59
100-200	.42
200-300	1.22
300-400	1.79
400-500	1.91
Average	1.15

Performance Spot Check.—A performance spot check (hp and torque vs speed at full throttle) was made on all four engines after the 500-hr life test.

The hp output of engines D and E was higher after the life test than it was immediately after the break-in. This increase may be attributed to further "loosening up" of the engine and also to the valve maintenance during the life test. The output of engines F and G was considerably above the rated 2.5 hp and 3600 rpm. Results of the performance spot checks are shown in curves D251A, E251A, F251, and G251.

Engine Conditions.—After the performance spot checks, the engines were entirely disassembled, cleaned, and the following items noted:

Engine D

Intake valve in excellent condition (see valve modification at 202 hr).

Exhaust valve slightly pitted but still sealing effectively (see valve modification at 202 hr).

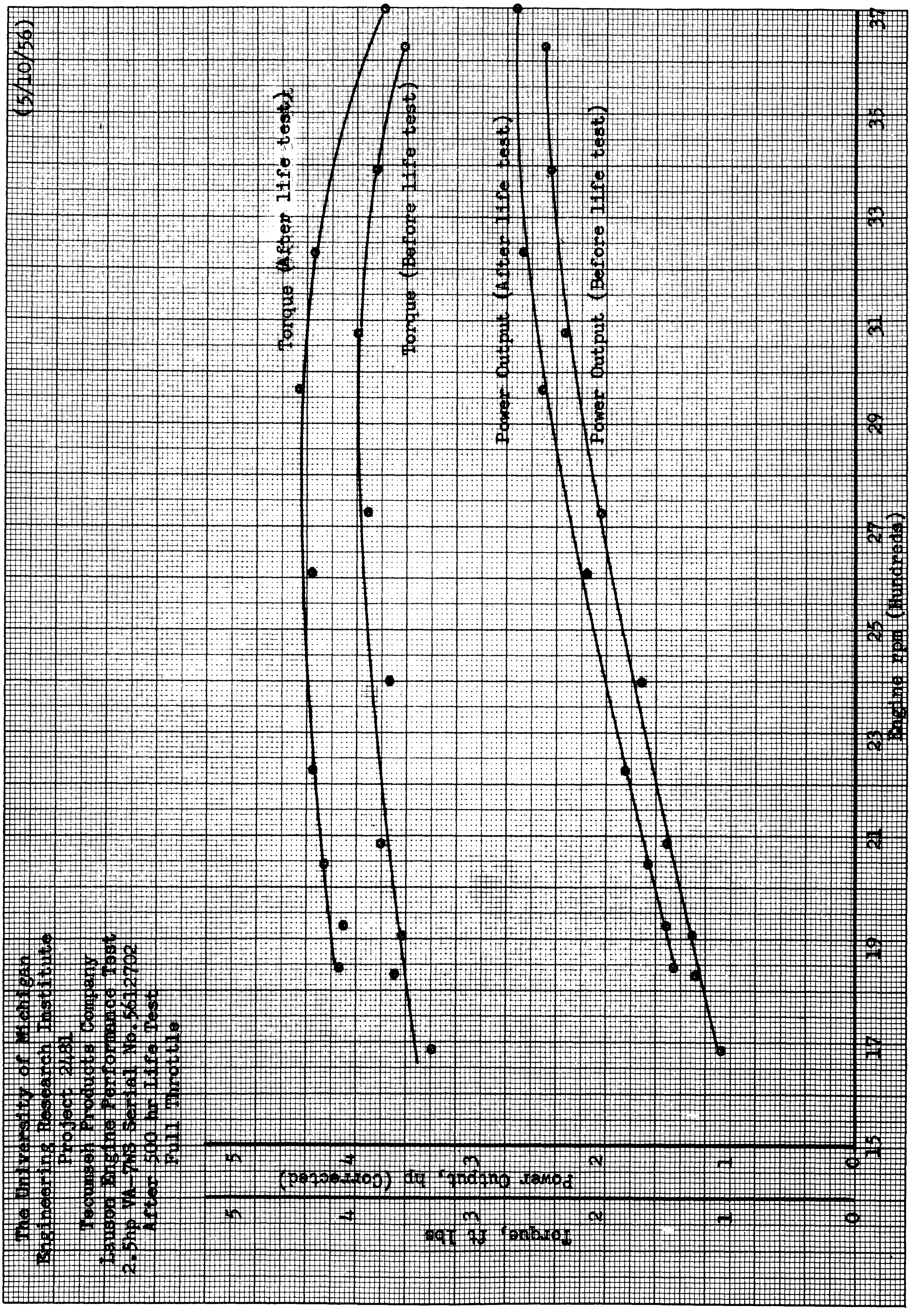
All journals slightly scored but in very good condition.

All parent metal bearings in good condition.

Cylinder wall in excellent condition.

Top oil seal damaged.

Points in rather poor shape.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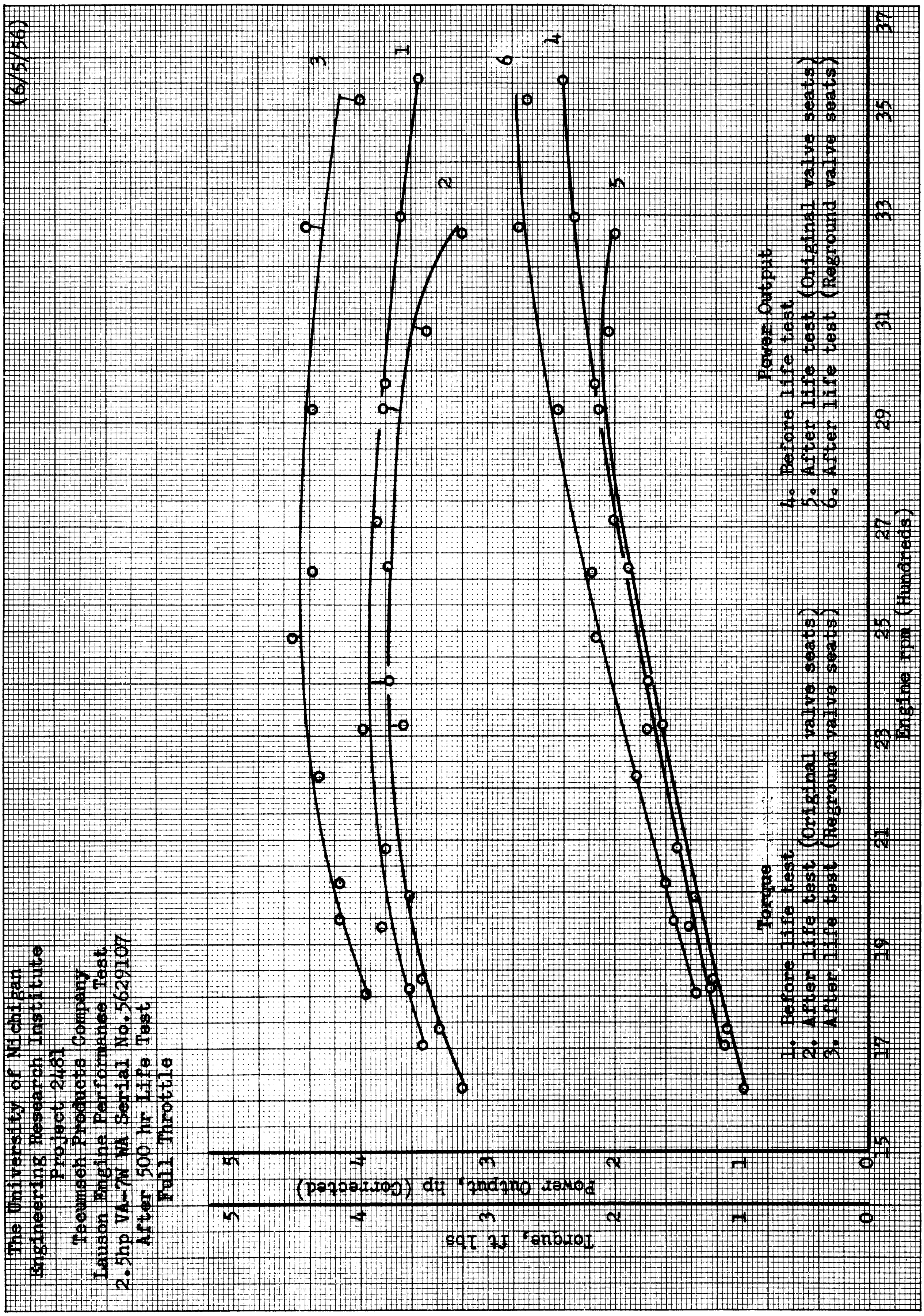
Tecumseh Products Company
Lauson Engine Performance Test
2.5hp VA-7MS Serial No. 5612702
After 500 hr Life Test
Full Throttle
(5/10/56)
Torque (After life test)
Torque (Before life test)
Power Output (After life test)
Power Output (Before life test)
Torque, ft lbs
Power Output, hp (Corrected)
Engine rpm (Hundreds)
15
17
19
21
23
25
27
29
31
33
35
37
0
1
2
3
4
5

Curve D251A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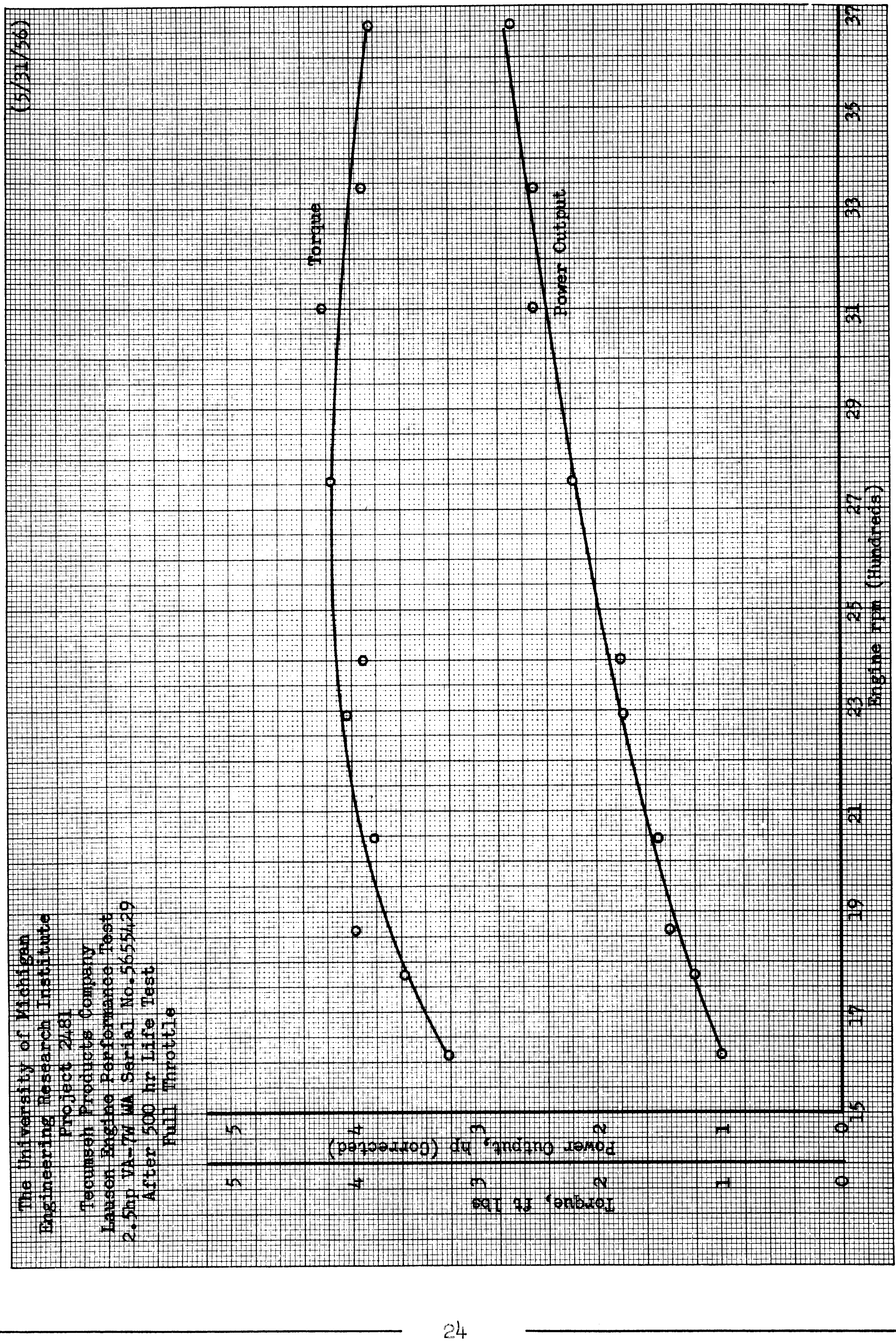
Tecumseh Products Company
Lauson Engine Performance Test
2.5hp VA-7N NA Serial No.5629107
After 500 hr Life Test
Full Throttle
(6/5/56)
Torque
1. Before life test
2. After life test (Original valve seats)
3. After life test (Reground valve seats)
Power Output
4. Before life test
5. After life test (Original valve seats)
6. After life test (Reground valve seats)
Torque, ft lbs
Power Output, hp (Corrected)
Engine rpm (Hundreds)
15
17
19
21
23
25
27
29
31
33
35
37
0
1
2
3
4
5

Curve E251A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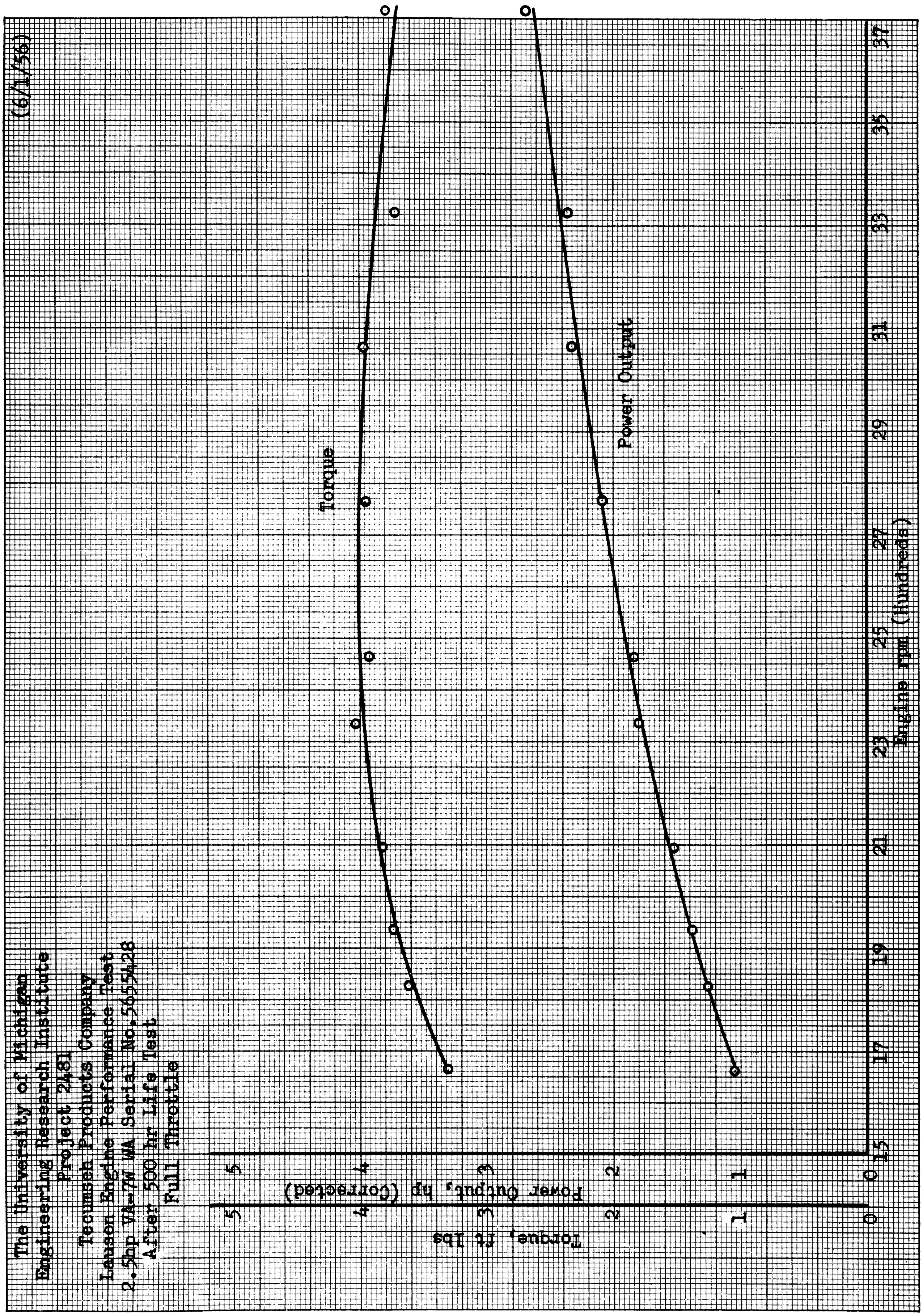
Lauson Engine Performance Test
2.5hp VA-7W MA Serial No. 5655429
After 500 hr Life Test
Full Throttle
(5/31/56)
Torque
Power Output
Torque, ft lbs
Power Output, hp (Corrected)
Engine rpm (Hundreds)
0
1
2
3
4
5
15
17
19
21
23
25
27
29
31
33
35
37

Curve F251


(6/1/56)
The University of Michigan
Engineering Research Institute
Project 2481
Tecumseh Products Company
Lauson Engine Performance Test
2.5hp VA-7W WA Serial No.5655428
After 500 hr Life Test
Full Throttle
Torque
Power Output
Torque, ft lbs
Power Output, hp (Corrected)
Engine rpm (Hundreds)
15
17
19
21
23
25
27
29
31
33
35
37
0
1
2
3
4
5

Curve C251

Engine E

Intake valve (before regrind) mechanically beaten against seat until groove was formed in valve face. Intake seat narrow and uneven.

Exhaust valve (before regrind) slightly burned and leaking, seat narrow and uneven.

Cylinder wall scored deeply in two places by wrist pin. Wrist-pin-retaining spring clip was not installed on one side of the piston. These scores apparently did not cause the engine to burn oil (see oil-consumption data above); the oil-control ring was free from carbon and sludge.

All journals in excellent condition.

All parent metal bearings in excellent condition.

Governor air-vane hole elongated but still holding control wire.

Governor control wire cut halfway through from rubbing on cylinder fin.

Timing gear-tooth surface in poor condition.

Points in good condition.

Engine F

Intake valve and seat in excellent condition (see valve modification at 132 hr).

Exhaust valve and seat in excellent condition (see valve modification at 132 hr and at 424 hr).

All journals in good condition.

All parent metal bearings in good condition.

Cylinder wall very slightly scored but in good condition.

Oil-control ring clogged with sludge and carbon. Higher rate of oil consumption indicates the ring was not functioning properly.

Governor air-vane hole elongated but still holding control wire.

Gear-tooth surface on timing gears in rather poor shape.

Points in good condition.

Engine G

Intake valve and seat in excellent condition (see valve modification at 180 hr).

Exhaust valve and seat in excellent condition (see valve modification at 180 hr).

All journals in excellent condition.

All parent metal bearings in excellent condition.

Cylinder wall scored in one place but otherwise in good condition.

Oil-control ring clogged with sludge and carbon. Higher rate of oil consumption indicated the ring was not functioning properly.

Governor air-vane hole elongated but still holding control wire.

Governor control wire cut halfway through due to rubbing on cylinder fin.

One gear tooth broken from camshaft timing gear. Surface of gear teeth in poor condition. Crankshaft gear still able to drive camshaft, however.

Guide hole in brass intake-valve spring keeper elongated.

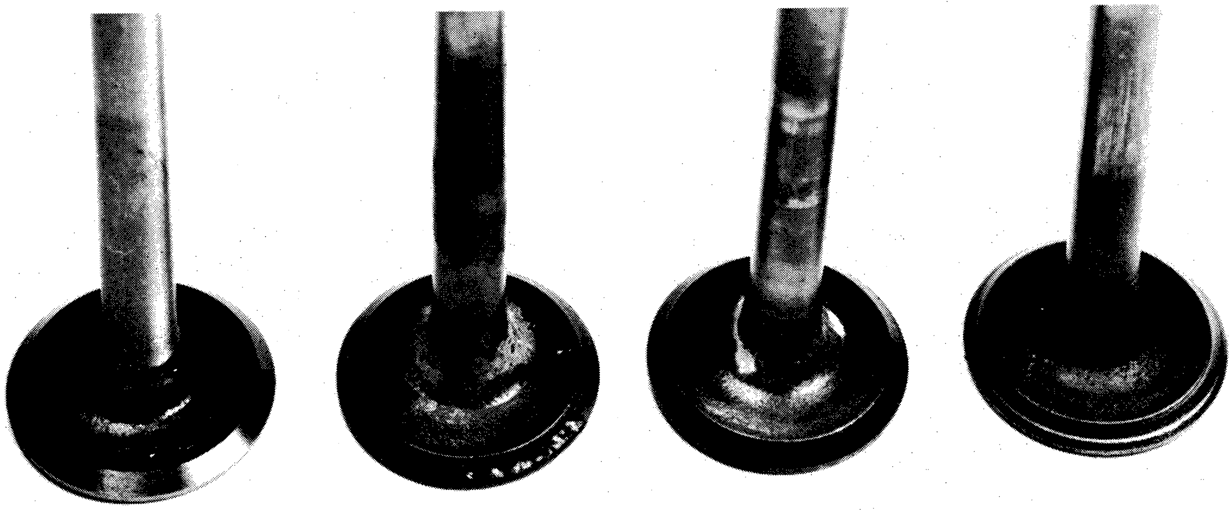
Points in good condition.

CONCLUSIONS

The engine output meets the manufacturer's rating of 2.5 hp at 3600 rpm after a break-in period as specified in the test procedure.

The average oil consumption varies from 0.15 liquid oz per hour to 1.15 liquid oz per hour. The oil-control rings of engines F and G (average oil consumption of 1.09 and 1.15 oz per hour, respectively) were clogged with sludge and carbon.

The valve seats in the engines, as received, were not conducive to long valve life or to effective sealing. The valve-seat inserts were not concentric with or perpendicular to the valve guides. This irregular position resulted in an uneven seat width around the circumference of the valve. The nonuniformity of the seating surface allowed different rates of heat transfer from the valve to the seat and resulted in burned exhaust valves. After the valve seats were reworked to obtain even seating surfaces that were concentric with and perpendicular to the valve guides, valve failures due to burning were eliminated. See Fig. 6.



(1) (2) (3) (4)

(1) New exhaust valve.

(2) Burned exhaust valve after 70-hr service on narrow, uneven seat.

(3) Exhaust valve after 300-hr service on wide, even seat.

(4) Intake valve damaged after 129-hr service on narrow seat.

Fig. 6.

Valve seats with narrow seating surfaces tend to damage the valves. The higher unit pressures resulting from narrow valve seats form a groove around the circumference of the valve which prevents effective sealing. See Fig. 6. Carbon particles dislodged from the combustion chamber are able to hold narrow seat valves open just as readily as wide seat valves, under the load conditions of this test.

All parent metal bearings and all journals were in good condition following the 500-hr life test, indicating an adequate lubricant supply and low bearing stresses.

The timing gear teeth approach the end of their useful life at 500 hr. On one engine one tooth had broken completely off a camshaft gear and on all engines the gear teeth were in rather poor condition.

The governor air-vane holes are greatly elongated during normal operation of the governor. On two occasions the control wire on engine D dropped free from the air vane.

The governor control wire, if not adjusted properly, will rub on the cylinder fin and will eventually be cut in two.

The cylinder walls in general were in good condition following the life test.

Production workmanship in general was excellent. Only one engine was found to be deficient in any way. A wrist-pin-retaining spring clip was not installed on one side of the piston in engine E. The unretained wrist pin scored the cylinder wall but did not lead to high oil consumption.

The average production engine, if equipped with good valve seats, will match or exceed the manufacturer's rating and is capable of at least 500 hr of life at 80% full load with little maintenance other than carbon removal and spark-plug cleaning.

RECOMMENDATIONS

Steps should be taken in production to insure that the inner diameter of the valve-seat insert is concentric with the valve guide and that the top surface of the insert is perpendicular to the valve guide.

Under the load conditions of this test, wide valve seats (approximately 3/32 inch) are preferred over narrow seats (approximately 1/32 inch) to insure longer valve life.

Methods of reinforcing the governor air-vane holes should be investigated. Two solutions to this problem are:

1. Piercing the holes, rather than punching them, so that the displaced metal forms a collar around the hole.

2. Installing hollow rivets in the holes.

Care should be taken in production to insure that the governor control wire does not rub on the cylinder fin.

An investigation should be made of the stresses on the timing gear teeth and these stresses should be reduced to insure 500-hr gear life. A tooth-width increase may eliminate this problem with little additional cost or redesign.