ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR

FINAL REPORT

RESEARCH AND DEVELOPMENT OF JERED ST-1200-1 TRANSMISSION

Frank L. Schwartz
Supervisor

Robert H. Eaton
Project Engineer

Project 2131

JERED INDUSTRIES
HAZEL PARK, MICHIGAN

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SUMMARY

This report covers the functional and load testing of the Jered ST-1200-1 transmission up to the date of the fire, April 19, 1954. This testing was complete through sixth gear at 1300 ft-lb input torque.

RESEARCH AND DEVELOPMENT OF JERED ST-1200-1 TRANSMISSION

DESCRIPTION

The Jered ST-1200-1 transmission is an eight-speed planetary-gear transmission designed for landing craft or tank use. This transmission is rated at 1300 ft-lb input torque with speeds up to 2800 rpm. It is hydraulically shifted and controlled by an automatic control valve. It has a full-reverse feature which makes possible the same ratios in reverse as in forward. The gear ratios are:

1st - 6.045
2nd - 4.390
3rd - 3.229
4th - 2.345
5th - 1.628
6th - 1.182
7th - .877
8th - .637

The transmission is designed in a "T" shape with the two output shafts at right angles to the input. It is self contained except for the external sump which is necessary because the transmission runs as dry sump unit.

TEST EQUIPMENT

The ST-1200-1 transmission was driven by an Allison V-1710 engine mounted on the same I-beam framework as the transmission. A double-disc friction clutch from a Ford GAF tank engine was adapted to the output end of the Allison engine. This clutch was provided with an air cylinder for quick release in case of transmission trouble. The input to the transmission was measured by a Baldwin SR-4 strain-gage torque meter. The output from the transmission was measured by a strain-gage torque meter made by Jered

Industries. An auxiliary transmission manufactured by Spicer was provided between the torque meter and the dynamometer to adjust the output speed to fall within the operating range of the dynamometer. It was found necessary to provide an oil pump, oil jets, and an oil cooler for the auxiliary transmission to keep the oil temperature within a satisfactory range. The output of the auxiliary transmission was connected to the 2000-hp eddy-current dynamometer through a Falk rubber coupling.

All instruments and controls were mounted remotely in the control room. The two SR-4 meters were mounted next to each other so that a constant check on input and output torque could be maintained. Two standard Electric Time Co. chronotachometers were connected to the same operating switch so that the input and output speeds and revolutions could be compared. This gave an absolute check on gear ratios and clutch slippage. Thermocouples were installed at 22 locations throughout the transmission so the temperatures of the oil coming from operating parts could be checked. The location of these thermocouples is shown in Fig. 1A.

The torque meters were checked and calibrated in a torsion testing machine at the Engineering Mechanics Dept., University of Michigan, Ann Arbor. Both meters were calibrated before the tests were started and again just before the 1300 ft-lb run. Lube oil flow was measured by a Foxboro orifice flow meter. The oil was circulated through a Young heat exchanger to keep the temperature below 175° F. Three Calrod heaters were installed in the oil sump to heat the oil to decrease the warm-up time.

PROCEDURE

Observations of temperature were made at three-minute intervals. Observations of torque, speed, pressures, and oil flow were made at five-minute intervals during the testing period.

Break-In

The transmission was operated at 1200 rpm and no load with the forward and reverse clutches disengaged. The following were observed: oil flow in the center case, shift pressure, lubrication pressure, and temperatures at 22 indicative points throughout the transmission.

With an input torque of 250 ft-lb the transmission was operated for 30 minutes in each of the eight speeds both forward and reverse.

Shifting was always done at no load and low speeds during the break-in period.

Inspection, including disassembly, checking, and reassembly, was conducted after the break-in period was completed.

Load Tests

At a load of 250 ft-lb and speeds of 1500, 1800, 2100, 2400, and 2800 input rpm, the transmission was operated for 10 minutes in the 8 speeds forward and reverse.

After completion of the load test, the transmission was inspected as above.

With a load of 500 ft-lb, the same procedure was followed as with 250 ft-lb.

During the load tests, high temperatures and excessive power losses were encountered. It was therefore decided to next run the friction test as outlined in Part III, Friction Test, of the Jered test request. This test request is included in the Appendix.

Friction Test

The transmission was operated for 20 minutes in each of the eight speeds both in the forward and reverse direction with the output shaft disconnected. Modifications were made to the transmission during the course of the tests in order to decrease the friction horsepower which was found to be much higher than expected.

Load Tests (Con't)

After the completion of the friction tests and subsequent modifications, the load tests were resumed with the same test schedule as described in enclosure A of the Jered test request at an input torque of 1,000 ft-lb.

Following the inspection of the transmission after the 1,000 ft-lb tests, the 1,300 ft-lb tests were begun. The 1st thru 6th speeds in reverse were completed before the fire destroyed the building and equipment on April 19, 1954.

DISCUSSION OF RESULTS

The greater portion of the mechanical difficulties encountered with the ST-1200-1 transmission were caused by the lack of shift pressure at the beginning of the tests. Due to faulty machining of the transmission case, there was a large hole drilled between the high-pressure-shift line and the transmission case. The transmission is designed to operate with a shift pressure of 200 psi, but with the large hole in the system, the pressure probably dropped below that required to prevent slippage in the clutches and brakes.

During the first portion of the break-in period there was some trouble with clutch slippage. Later, during the load tests, there was trouble with the brakes and clutches burning and warping. Near the end of the 500 ft-lb test the hole in the shift pressure system was discovered and plugged.

Difficulty was encountered with the ST-1200-1 pumps. In order to reduce warm-up time, heaters were installed in the oil sump. These heaters were set to bring the temperature up to about 175° F before they shut off. When the transmission was started up and the 175° oil arrived at the shift pressure and lubricating pumps, the pump parts would heat up unevenly and freeze. After consultation with the pump manufacturer, the pumps were modified and functioned satisfactorily.

The greatest portion of the improvements in the transmission were the result of the friction tests. The results of the friction tests are shown in Fig. 2. In an attempt to determine what section was causing the power loss, the transmission was run in neutral in 7th and 8th. The transmission was also run with the port brake released and again with the port brake locked. These curves are shown in Fig. 3. The power loss is plotted against output shaft speed in Fig. 4. In Fig. 5 the split power loss has been deducted from the total power loss. Next the 1st and 2nd speed brakes were removed. This modification caused the friction horsepower in 8th to drop from 216 to 146 hp, as shown in Figs. 6 and 7.

The results of removing the steering brakes and clutches in addition to the 1st and 2nd speed brake and piston is shown in Fig. 8. This dropped the friction horsepower to 64.

The 1st and 2nd speed brake and piston were installed and the transmission operated without the steering brakes and clutches. The results are shown in Fig. 9. This test made the ST-1200-1 transmission similar to the previously tested T-1200. With the addition of the brake and piston the friction losses rose to 97 hp. This would seem to indicate that the 1st and 2nd speed brake and piston accounted for about 33 hp, but the first test showed

that by removing the 1st and 2nd speed brake and piston a saving of 70 hp was realized. Evidently during the original friction test the 1st and 2nd speed brake, or some other part, was dragging considerably.

At this point it was noticed that if the transmission was operated at a high output rpm and then stopped, the oil level would rise several inches in the bottom of the case. It was assumed that this oil came from a torus of oil between each rotating part and the case around it; thus the drag created by this torus of oil would be one of the major causes of high friction horsepower. In an attempt to decrease or eliminate this torus of oil, modifications were made to allow the oil to flow more freely out of the transmission into the sump.

The first modification was to cut away part of the 1st and 2nd speed brake. As shown in Fig. 10, this made no improvement. The second modification was to the starboard reactor. This resulted in slight improvement in 7th speed and a significant drop of 26 hp at 2800 rpm in 8th, as shown in Fig. 11. The third modification was the placing of shim packs in the steering brakes and clutches, thus stopping the oil flow to the brakes and clutches and modifying the cover assembly (3164097). As shown in Fig. 12, this resulted in an increase in friction horsepower. The fourth modification was the enlarging of the oil passage in the starboard brake housing. Figure 13 shows the small resultant improvement. Modification of the port brake reactor resulted in no change in performance as shown in Fig. 14. Figure 15 shows the improvement resulting from the installation of oil jets in the starboard side of the drum assembly. A drop of 46 hp in 8th speed was realized.

Figures 16, 17, and 18 show the cumulative result of the above-mentioned modifications. The friction horsepower showed a decrease of 107 hp at 2800 rpm in 8th speed from an original of 216 hp. The last modification attempted was the use of short brake stops. As shown in Fig. 19, this made little difference. No further modifications were attempted at this time as it was essential that the remainder of the scheduled tests be completed as soon as possible.

Figures 20, 21, and 22 give an indication of the efficiency of the transmission after all the modifications were made. The average efficiency is about 92 percent for an input torque of 1,000 ft-lb.

Figures 23, 24, and 25 show the efficiency with an input load of 1,300 ft-lb for 1st through 6th gears. The average efficiency was about 94 percent in 1st through 6th gears. The efficiency measurements are accurate within 2 percent. Tests were terminated at this point due to the fire.

It should be pointed out that the latest data were taken using a gravity-drain system. In the vehicle it would be necessary to include scavange pumps.

The 1,300 ft-lb tests were run in 1st through 6th gear. The highest losses occur in 7th and 8th gears; therefore, it is necessary to compare performance in the same gear to draw conclusions from the data.

RECOMMENDATIONS

From the completed tests it is apparent that a redesign of the transmission case could result in better oil scavanging and therefore better efficiency.

The results of the efficiency tests in the first six gears were good but probably could be improved by further work. It is recommended that the development of the transmission be continued.

APPENDIX

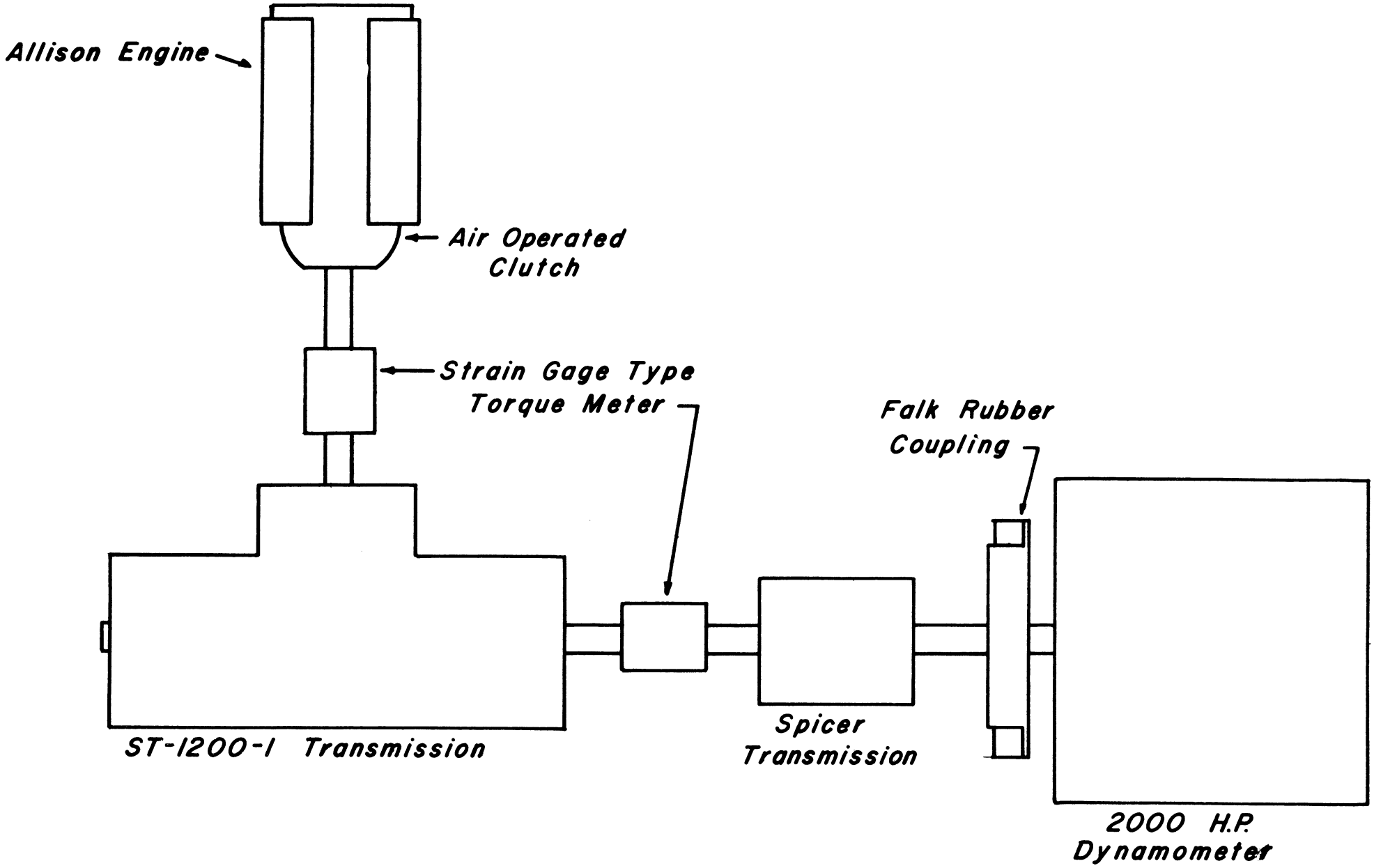
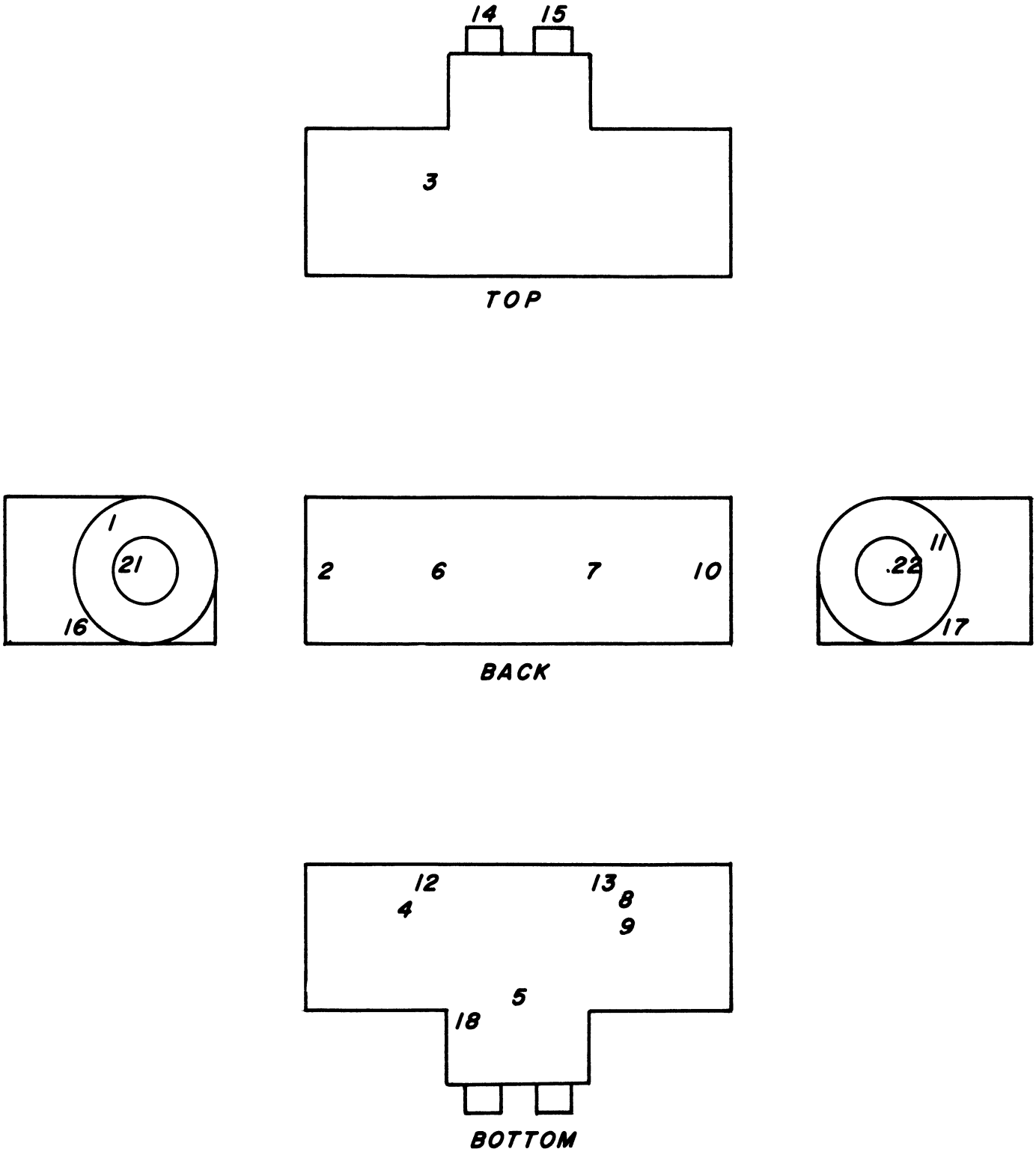

Allison Engine
Air Operated Clutch
Strain Gage Type Torque Meter
Falk Rubber Coupling
ST-1200-1 Transmission
Spicer Transmission
2000 H.P. Dynamometer

Fig. 1



19-COLD OIL RESERVOIR
20-HOT OIL RESERVOIR
23-SPICER TRANSMISSION
24-AIR

FIG. 1A - LOCATION OF THERMOCOUPLES

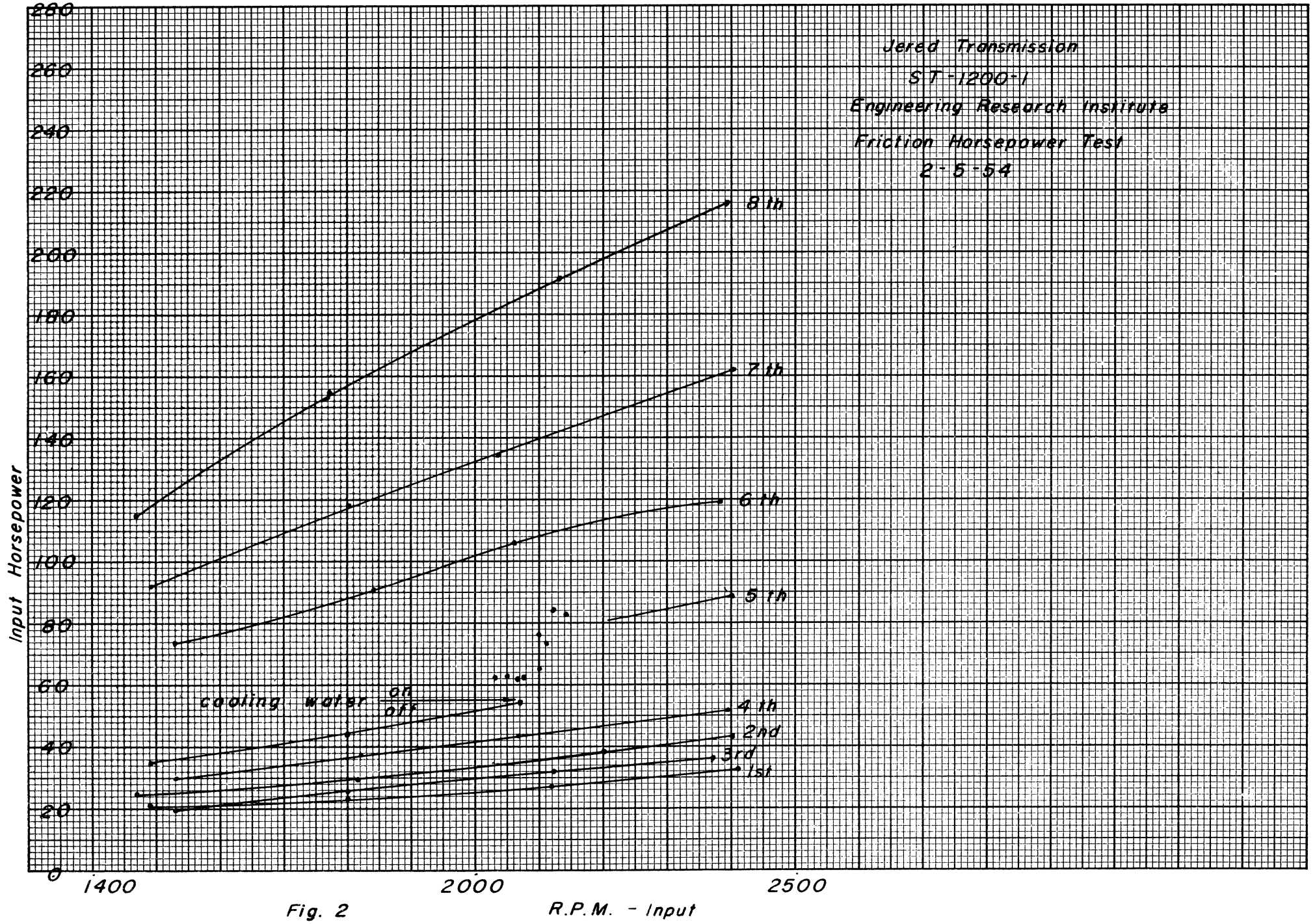

Jered Transmission
ST-1200-1
Engineering Research Institute
Friction Horsepower Test
2-5-54
Input Horsepower
R.P.M. - Input
8th
7th
6th
5th
4th
2nd
3rd
1st
cooling water on / off
260
240
220
200
180
160
140
120
100
80
60
40
20
0
1400
2000
2500

Fig. 2

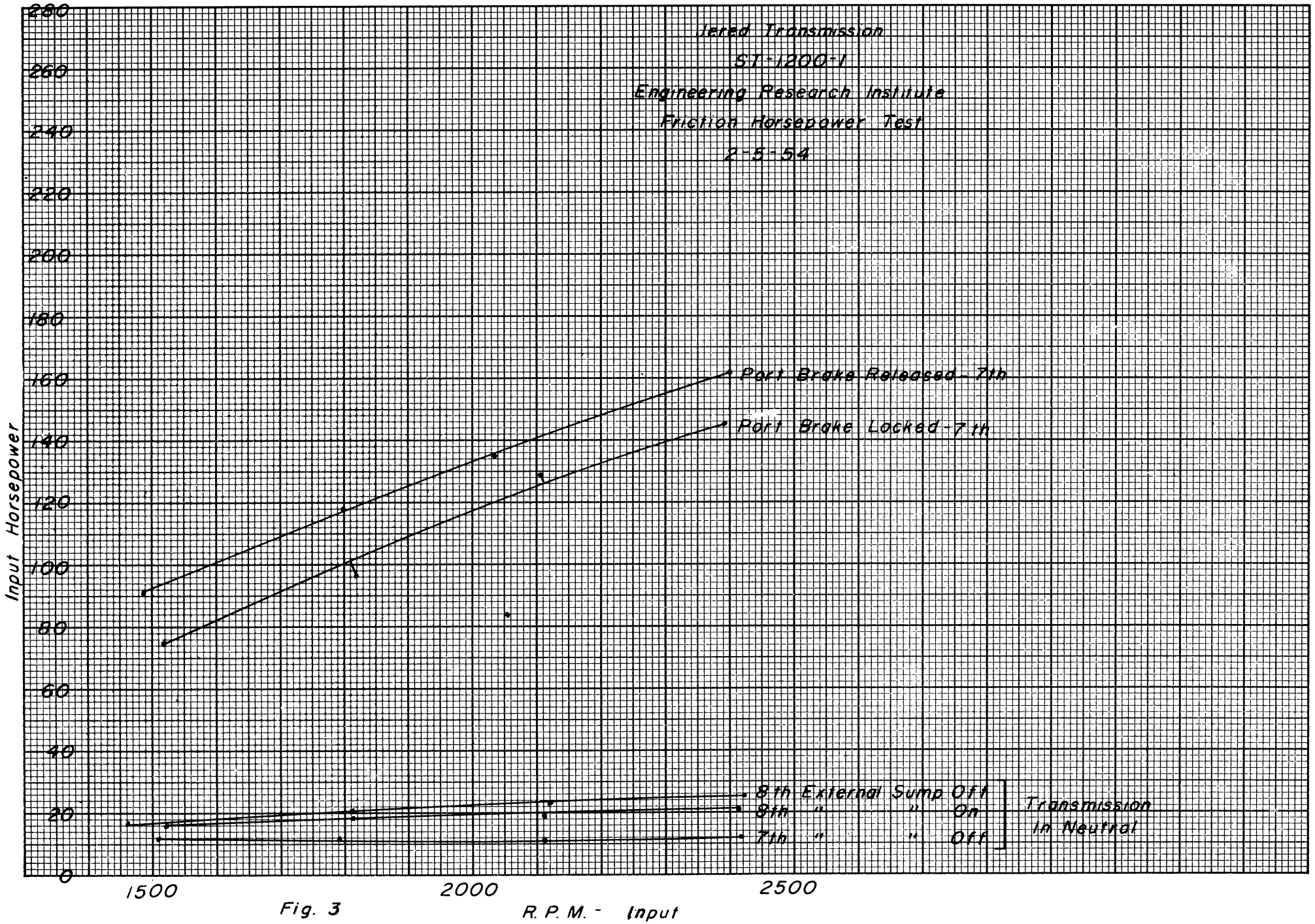

Jered Transmission
ST-1200-1
Engineering Research Institute
Friction Horsepower Test
2-5-54
Input Horsepower
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
Port Brake Released - 7th
Port Brake Locked - 7th
8th External Sump Off
8th " " On
7th " " Off
Transmission In Neutral
1500
2000
2500
R. P. M. - Input

Fig. 3

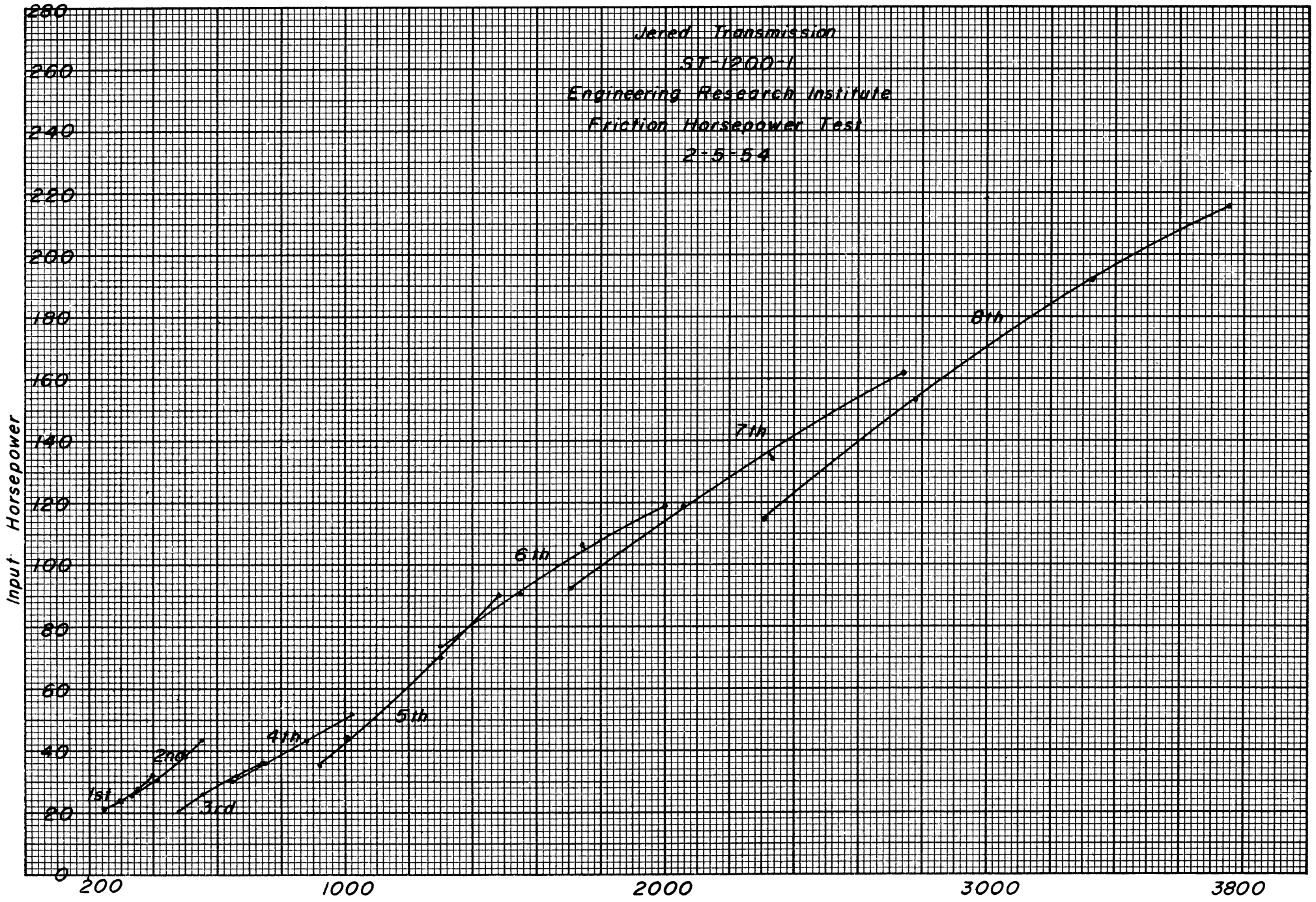


Fig. 4 R.P.M. - Output

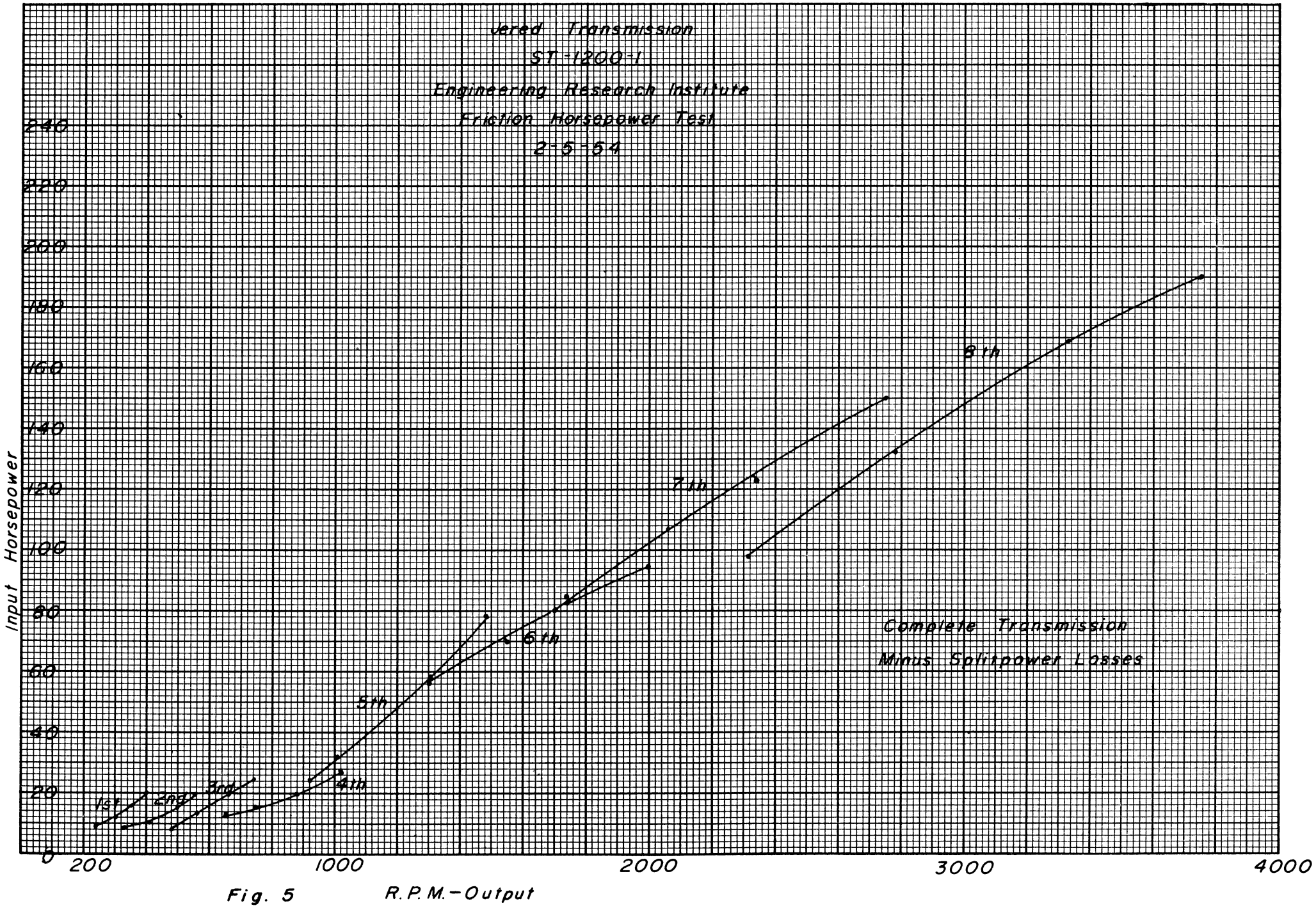


Fig. 5 R.P.M. – Output

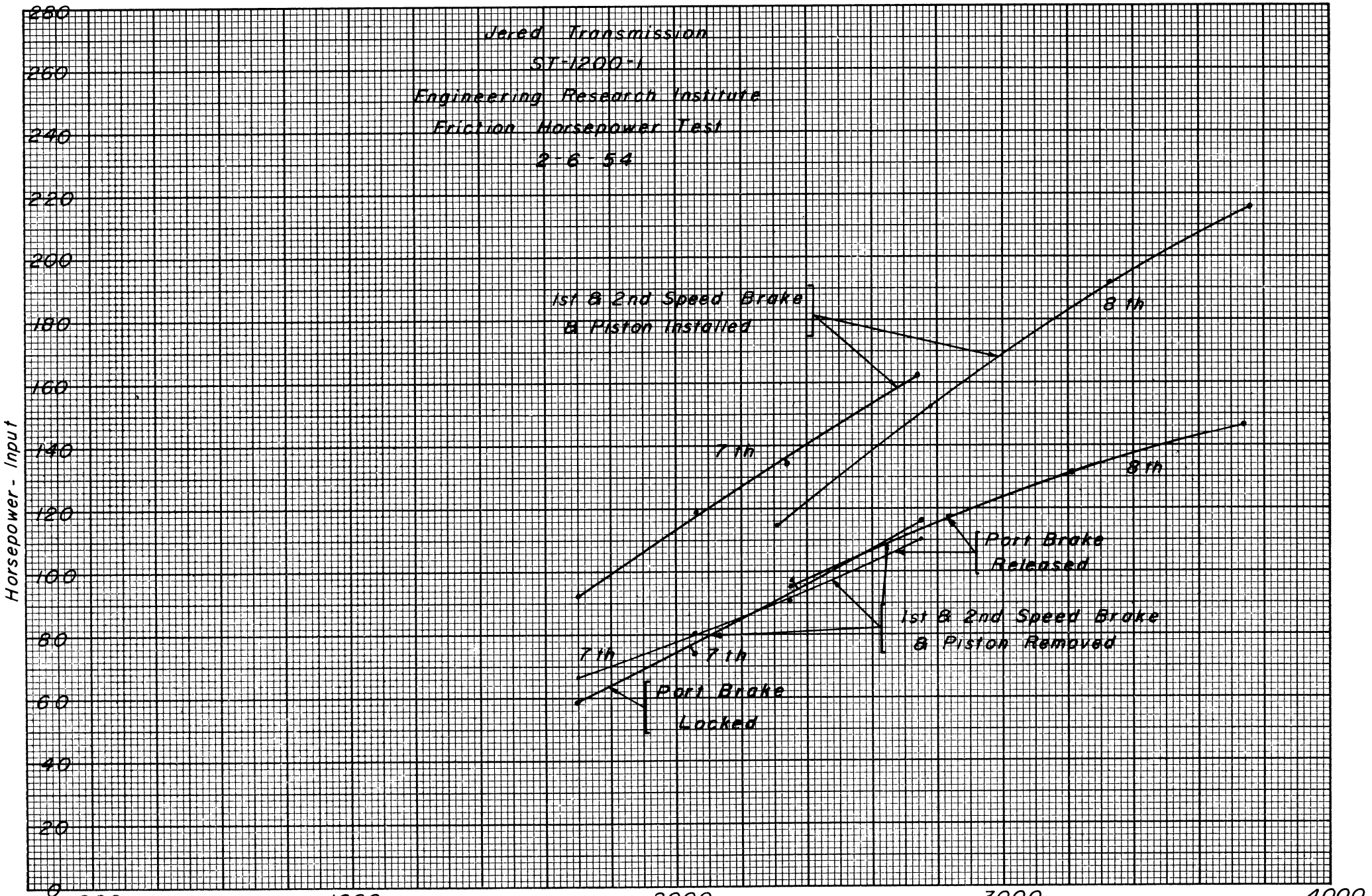

Jered Transmission
ST-1200-1
Engineering Research Institute
Friction Horsepower Test
2-6-54
Horsepower - Input
R.P.M. - Output
260
240
220
200
180
160
140
120
100
80
60
40
20
0
200
1000
2000
3000
4000
1st & 2nd Speed Brake
& Piston Installed
8 th
7 th
8 th
Port Brake
Released
1st & 2nd Speed Brake
& Piston Removed
7 th
7 th
Port Brake
Locked

Fig. 6

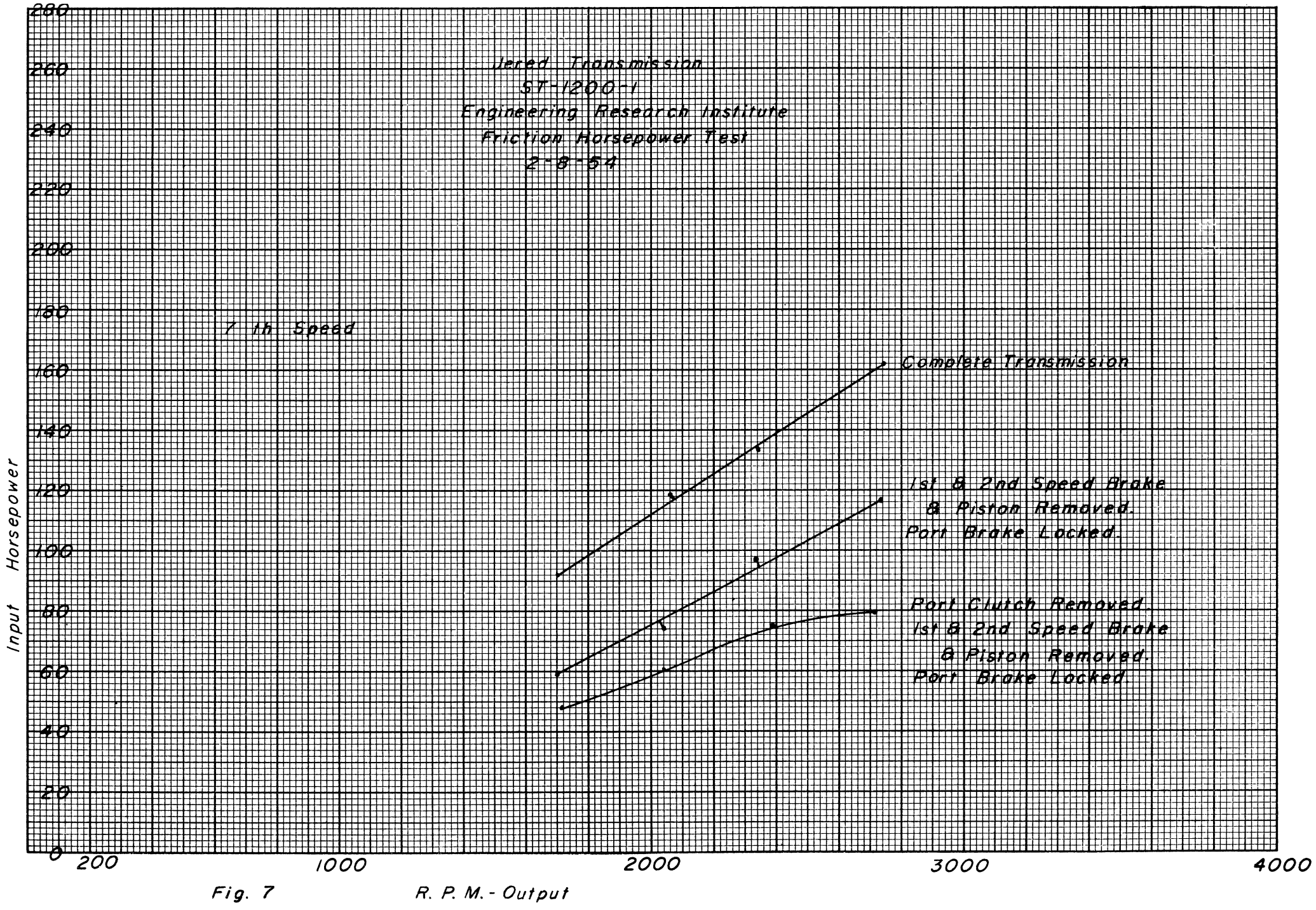

Jered Transmission
ST-1200-1
Engineering Research Institute
Friction Horsepower Test
2-8-54
1 th Speed
Comelete Transmission
1st & 2nd Speed Brake
& Piston Removed.
Port Brake Locked.
Port Clutch Removed.
1st & 2nd Speed Brake
& Piston Removed.
Port Brake Locked.
Input Horsepower
R. P. M. - Output
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
200
1000
2000
3000
4000

Fig. 7

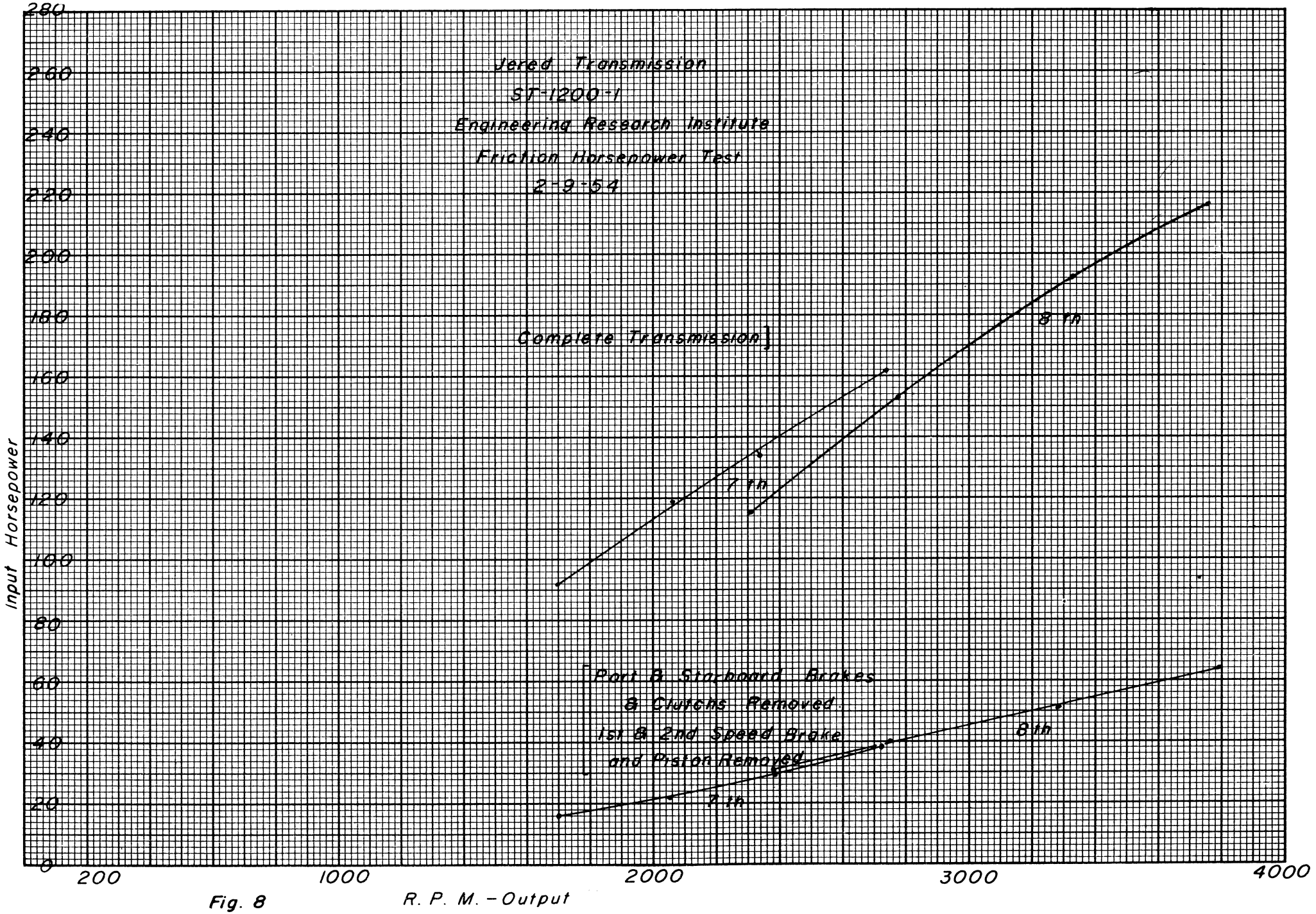

Jered Transmission
ST-1200-1
Engineering Research Institute
Friction Horsepower Test
2-9-54
Complete Transmission
8 th
7 th
Port & Starboard Brakes
& Clutchs Removed
1st & 2nd Speed Brake
and Piston Removed
8th
7 th
Input Horsepower
R. P. M. – Output
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
200
1000
2000
3000
4000

Fig. 8

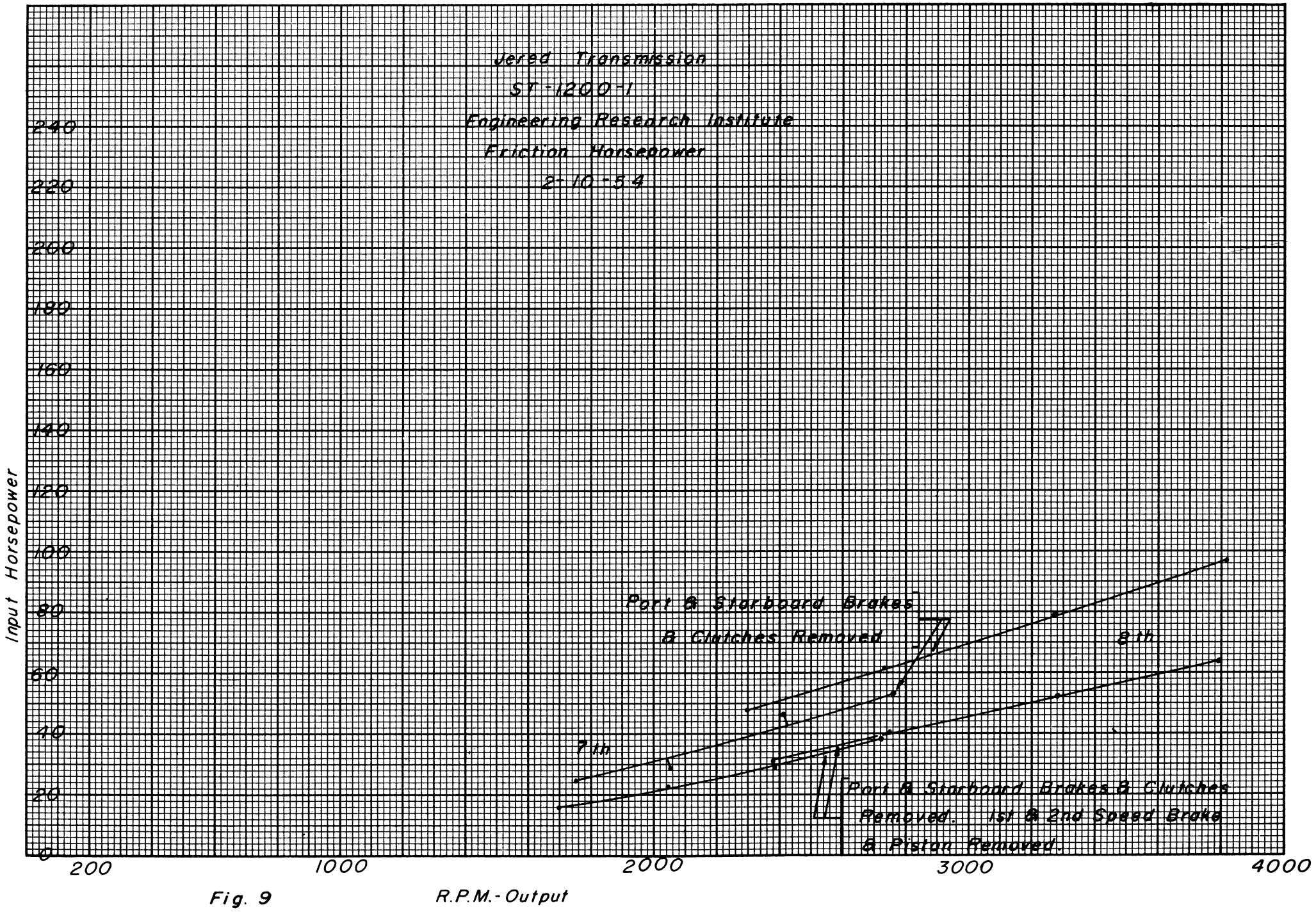

Jered Transmission
ST-1200-1
Engineering Research Institute
Friction Horsepower
2-10-54
240
220
200
180
160
140
120
100
80
60
40
20
0
Input Horsepower
200
1000
2000
3000
4000
R.P.M.-Output
Port & Starboard Brakes & Clutches Removed
8th
7th
Port & Starboard Brakes & Clutches Removed. 1st & 2nd Speed Brake & Piston Removed.

Fig. 9

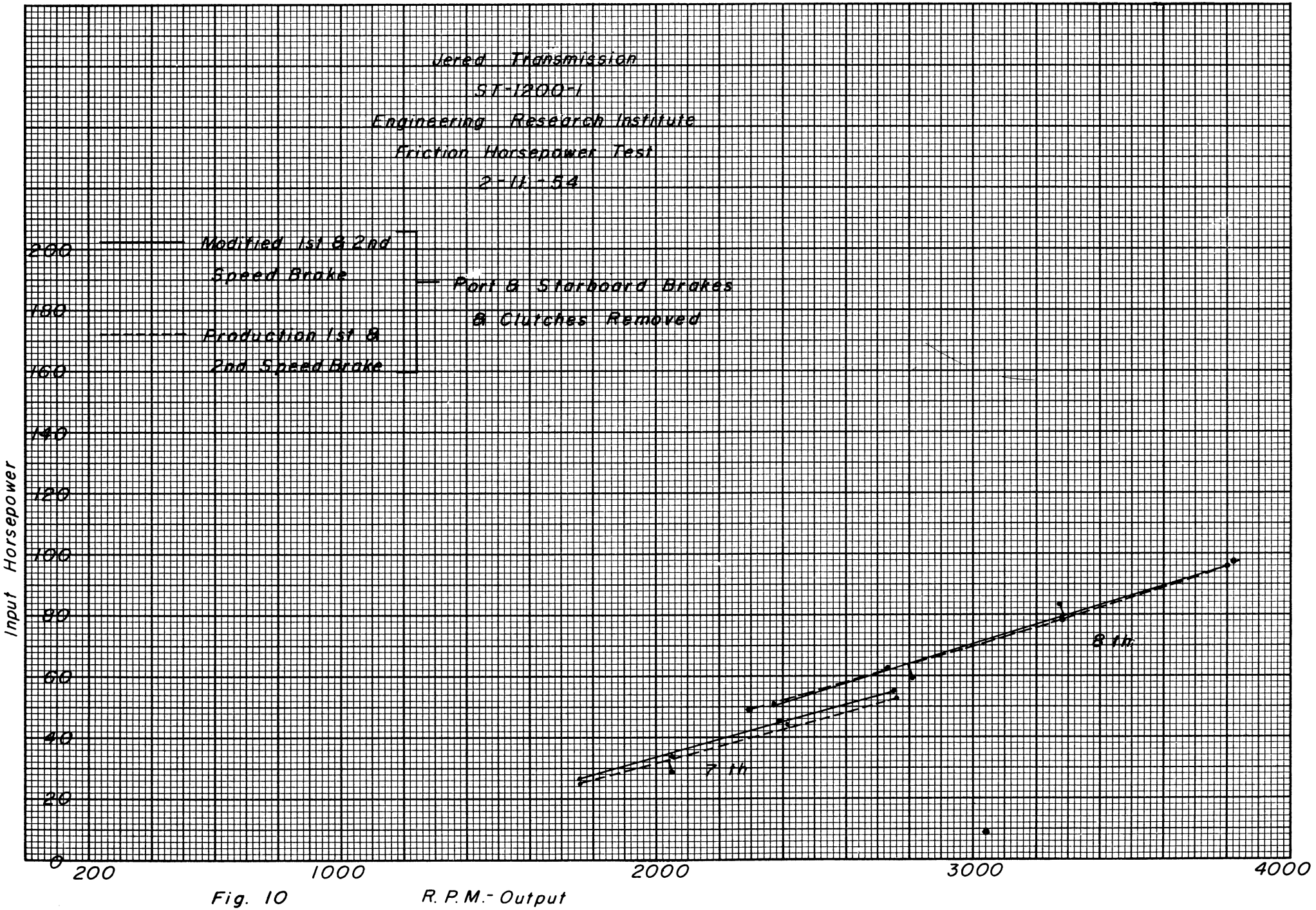

Jered Transmission
ST-1200-1
Engineering Research Institute
Friction Horsepower Test
2-11-54
Modified 1st & 2nd Speed Brake
Port & Starboard Brakes & Clutches Removed
Production 1st & 2nd Speed Brake
Input Horsepower
0
20
40
60
80
100
120
140
160
180
200
200
1000
2000
3000
4000
R. P. M. - Output
8 th.
7 th

Fig. 10

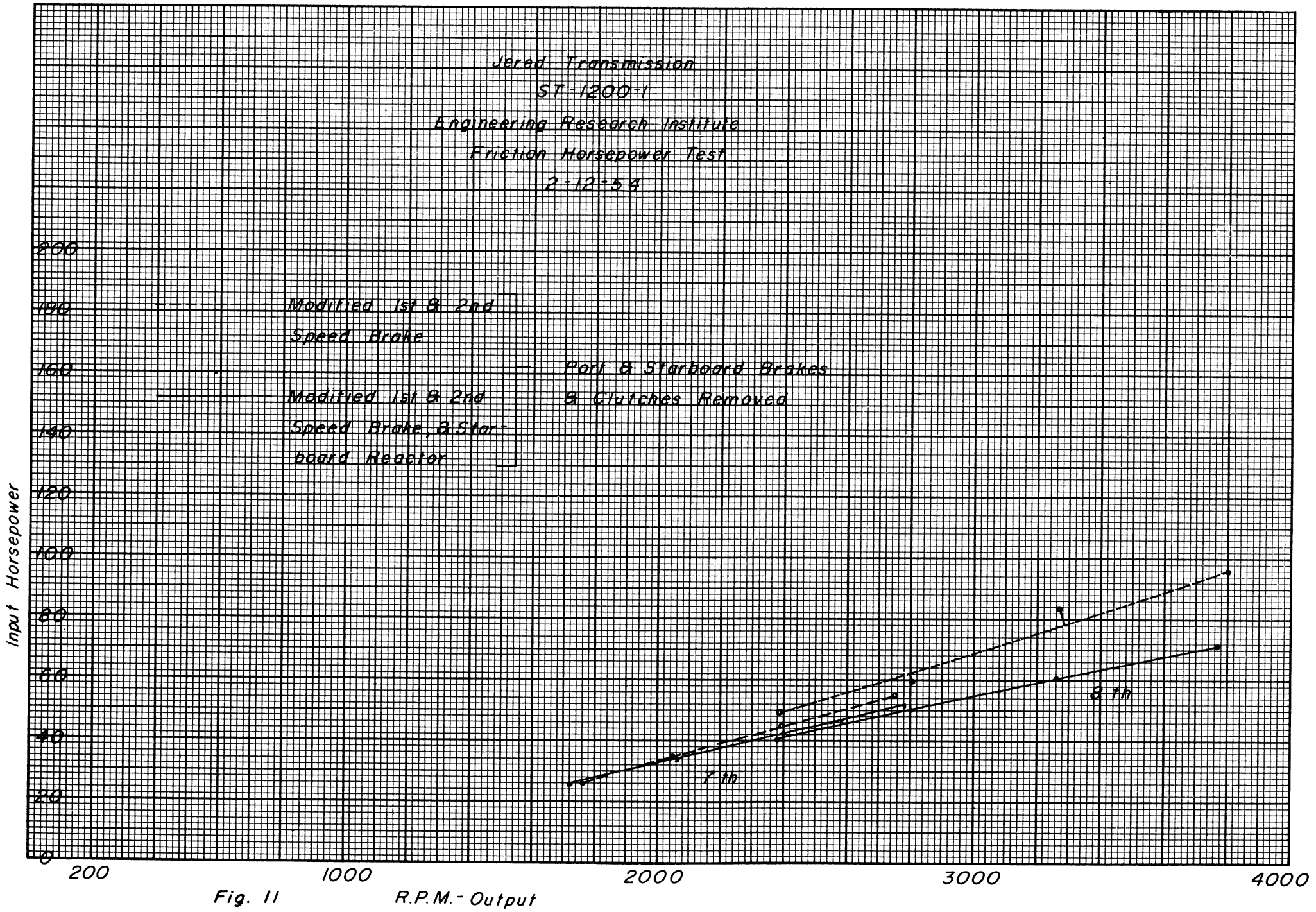

Jered Transmission
ST-1200-1
Engineering Research Institute
Friction Horsepower Test
2-12-54
Modified 1st & 2nd Speed Brake
Modified 1st & 2nd Speed Brake, & Starboard Reactor
Port & Starboard Brakes & Clutches Removed
8 th
7 th
Input Horsepower
0
20
40
60
80
100
120
140
160
180
200
200
1000
2000
3000
4000
R.P.M. - Output

Fig. 11

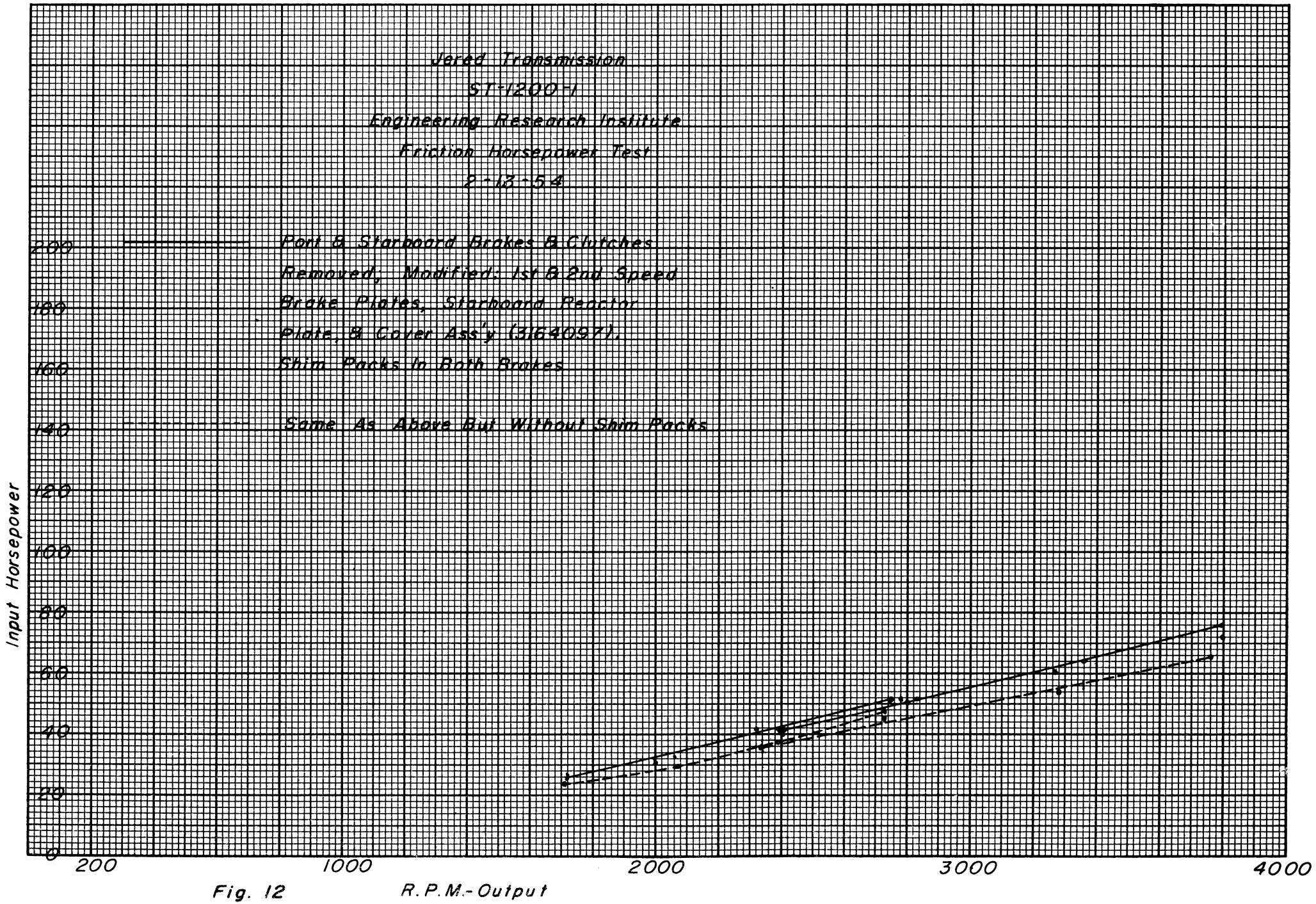

Jered Transmission
ST-1200-1
Engineering Research Institute
Friction Horsepower Test
2-13-54
Port & Starboard Brakes & Clutches
Removed, Modified: 1st & 2nd Speed
Brake Plates, Starboard Reactor
Plate, & Cover Ass'y (3164097),
Shim Packs In Both Brakes
Same As Above But Without Shim Packs
Input Horsepower
0
20
40
60
80
100
120
140
160
180
200
200
1000
2000
3000
4000
R.P.M.- Output

Fig. 12

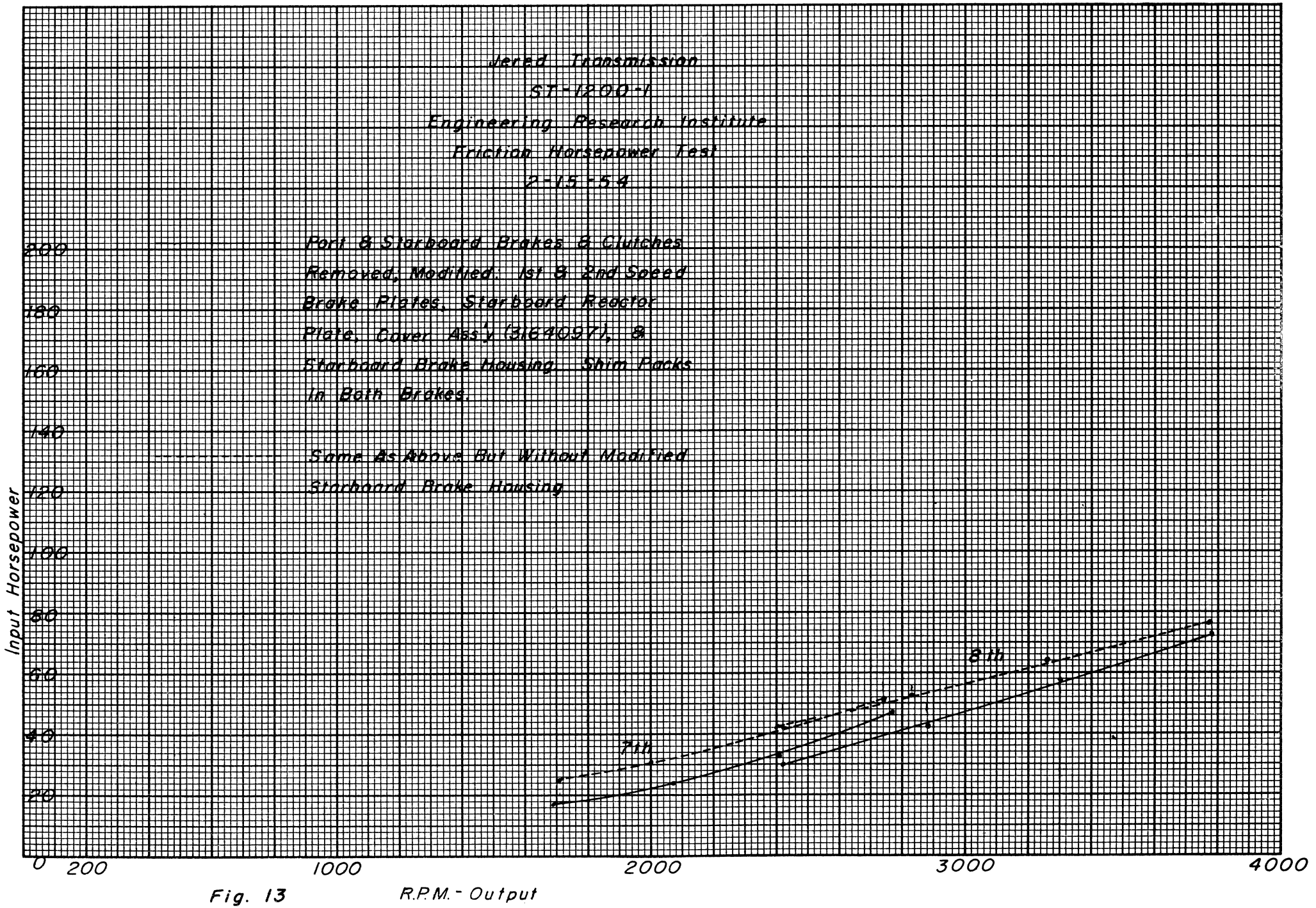

Jered Transmission
ST-1200-1
Engineering Research Institute
Friction Horsepower Test
2-15-54
Port & Starboard Brakes & Clutches
Removed, Modified. 1st & 2nd Speed
Brake Plates, Starboard Reactor
Plate, Cover Ass'y. (3164097), &
Starboard Brake Housing. Shim Packs
In Both Brakes.
Same As Above But Without Modified
Starboard Brake Housing
Input Horsepower
200
180
160
140
120
100
80
60
40
20
0
200
1000
2000
3000
4000
8th
7th
R.P.M. - Output

Fig. 13

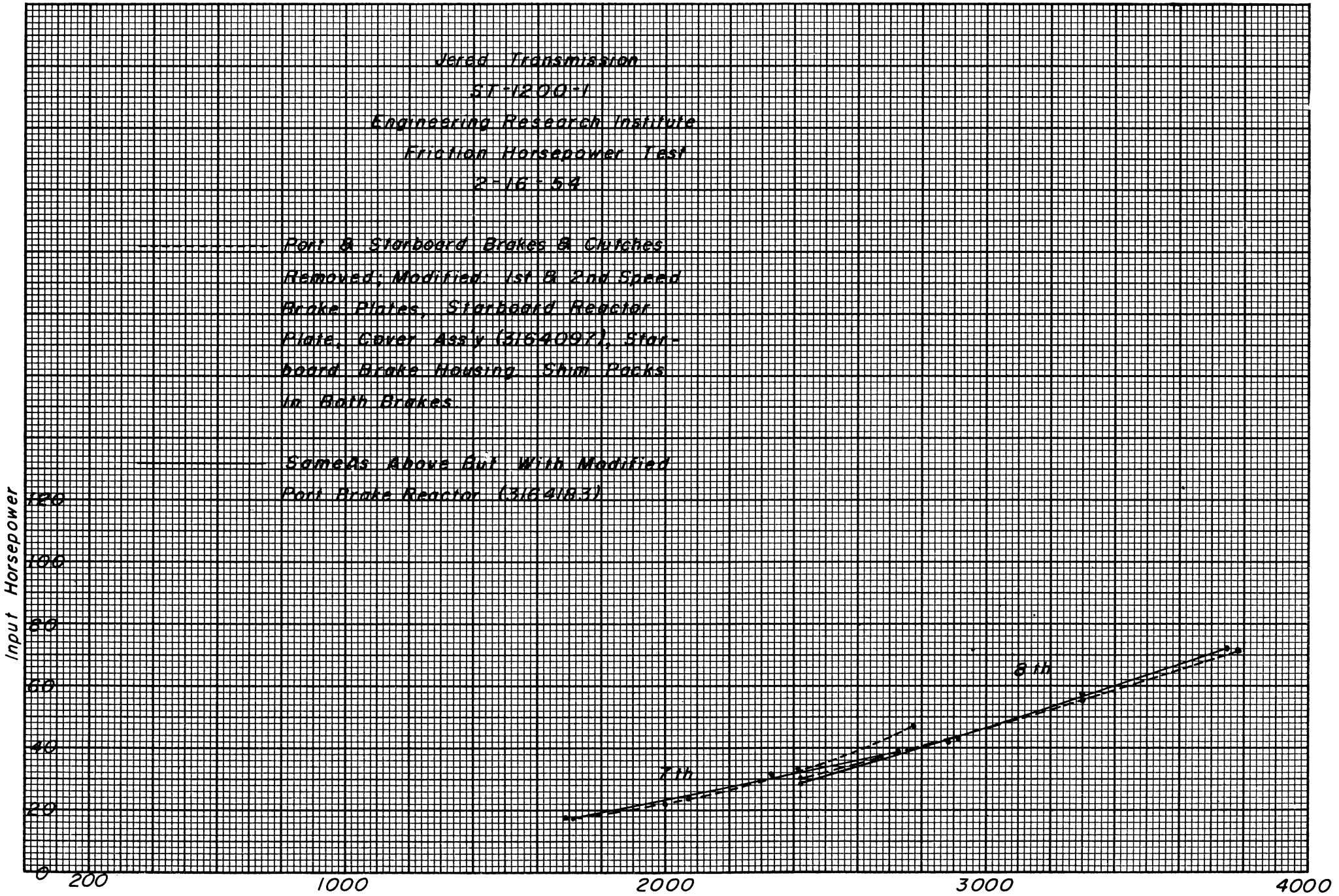


Fig. 14, R.P.M.- Output

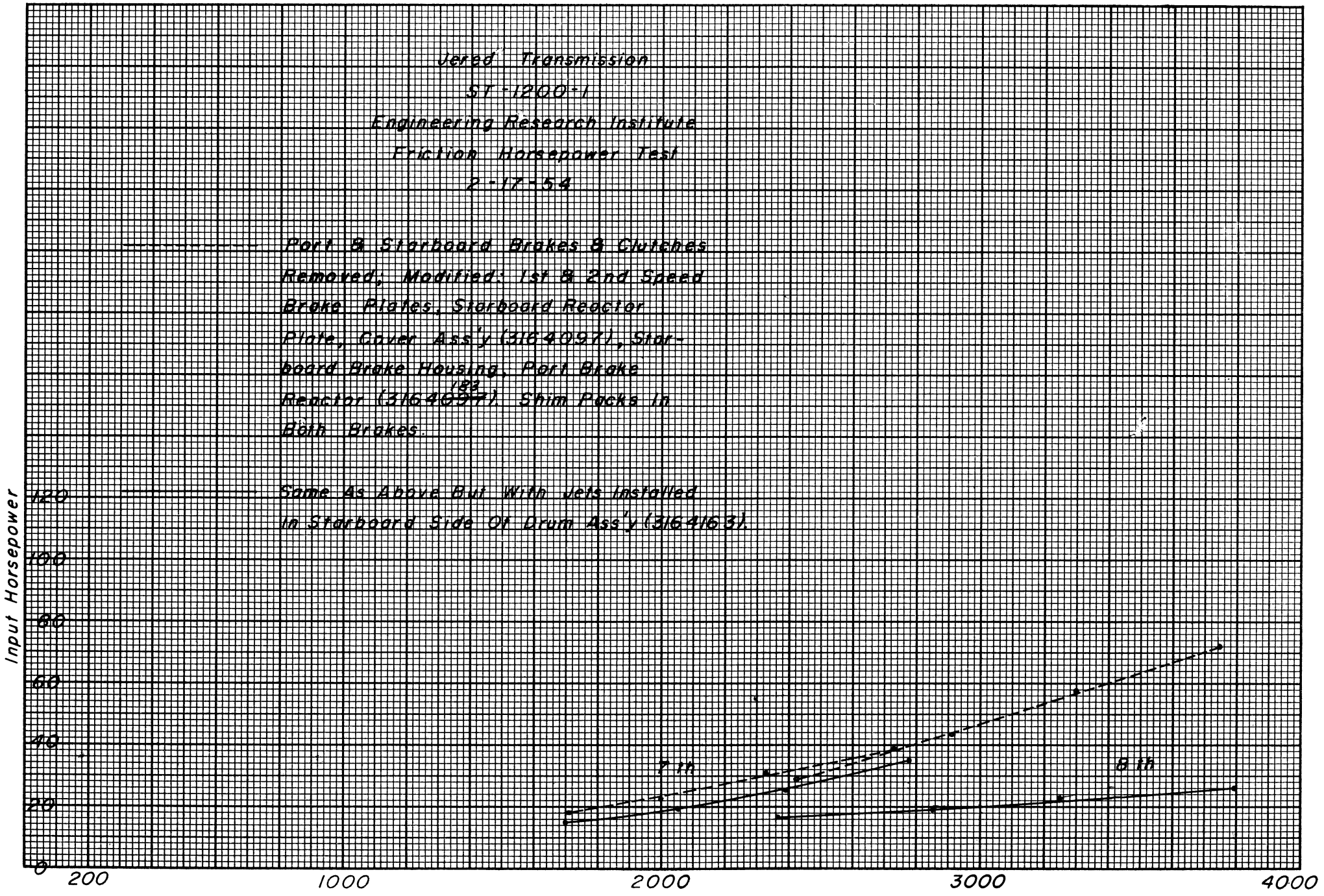


Fig. 15. R.P.M.- Output

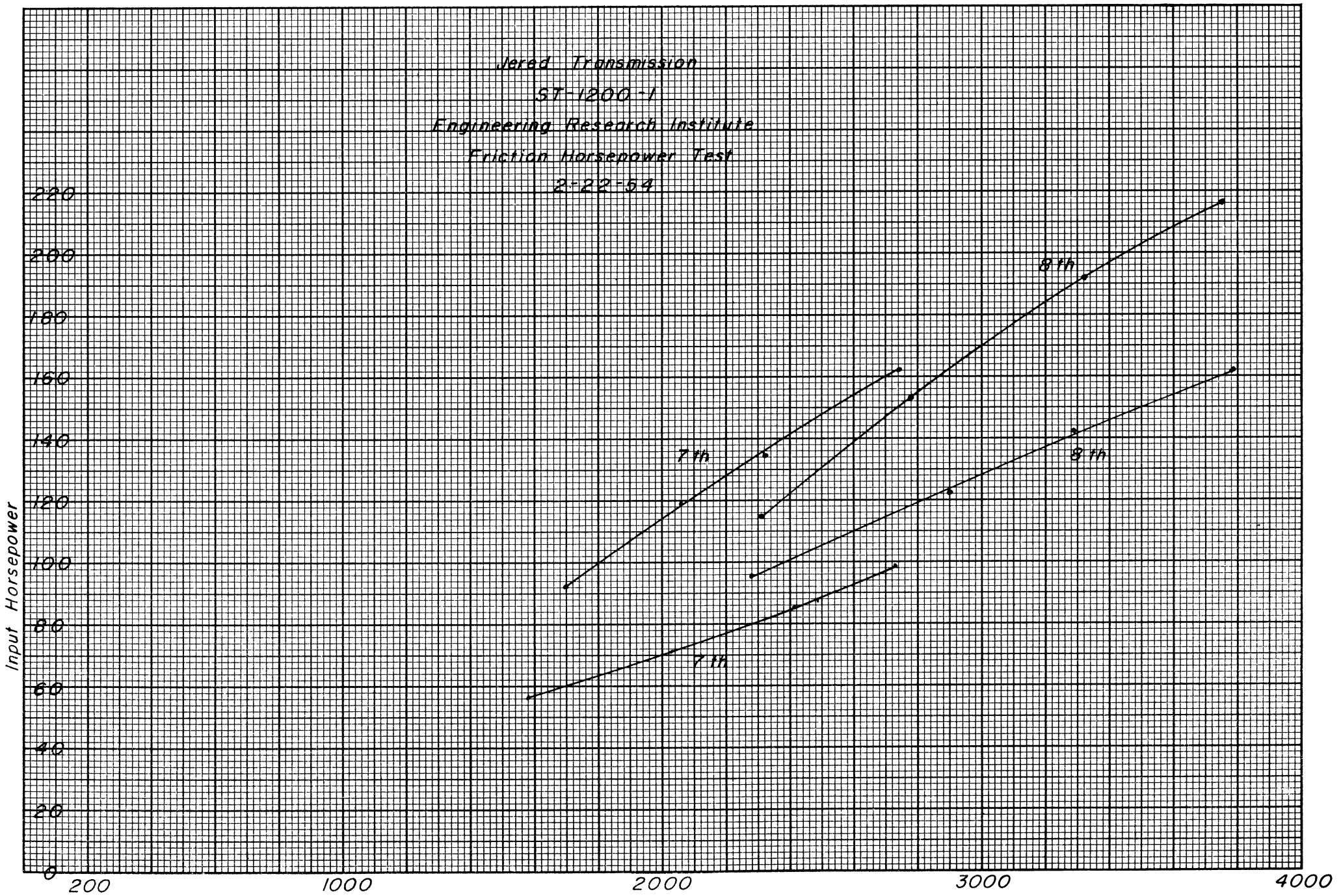


Fig. 16. R.P.M. - Output

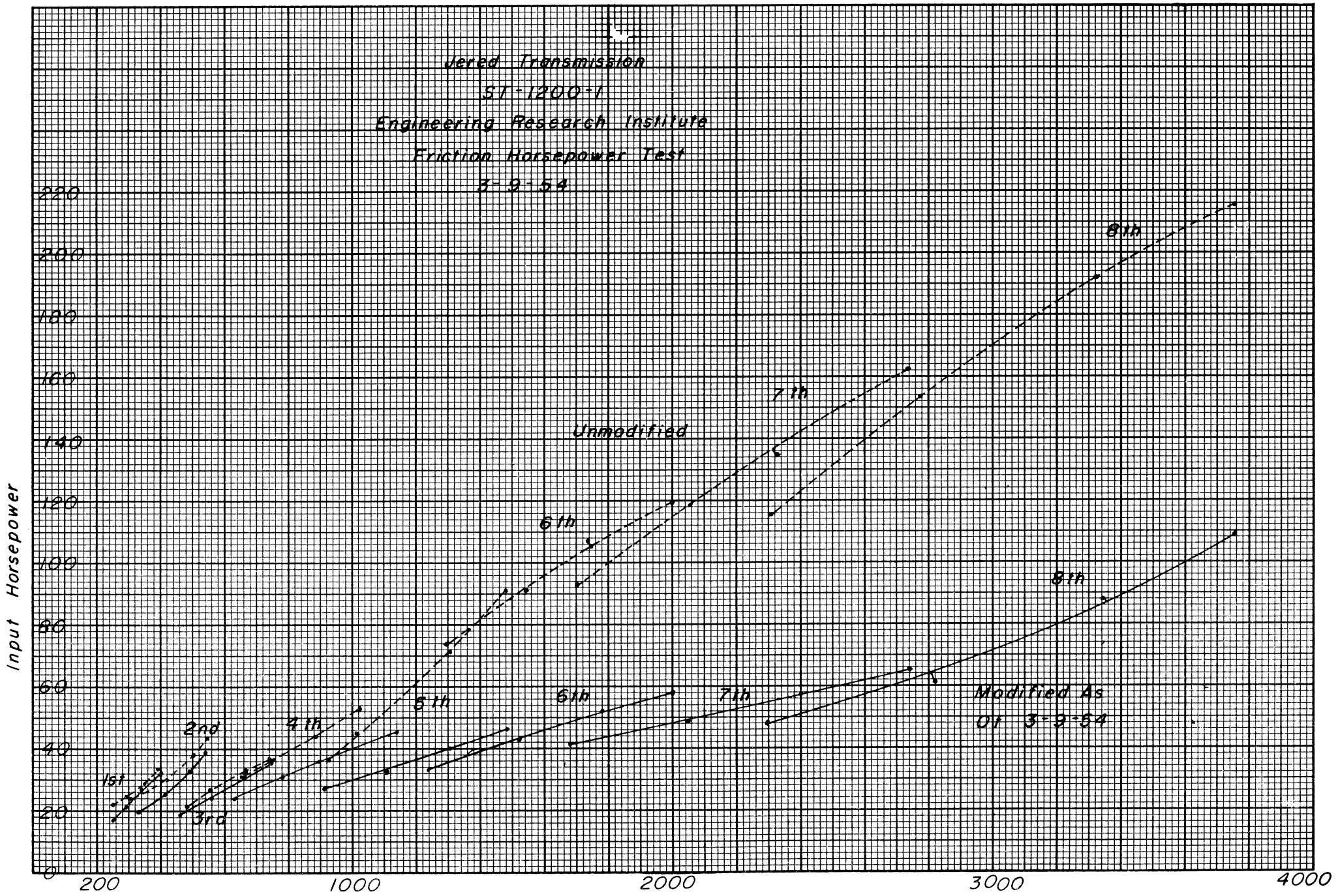


Fig. 17. RPM- Output

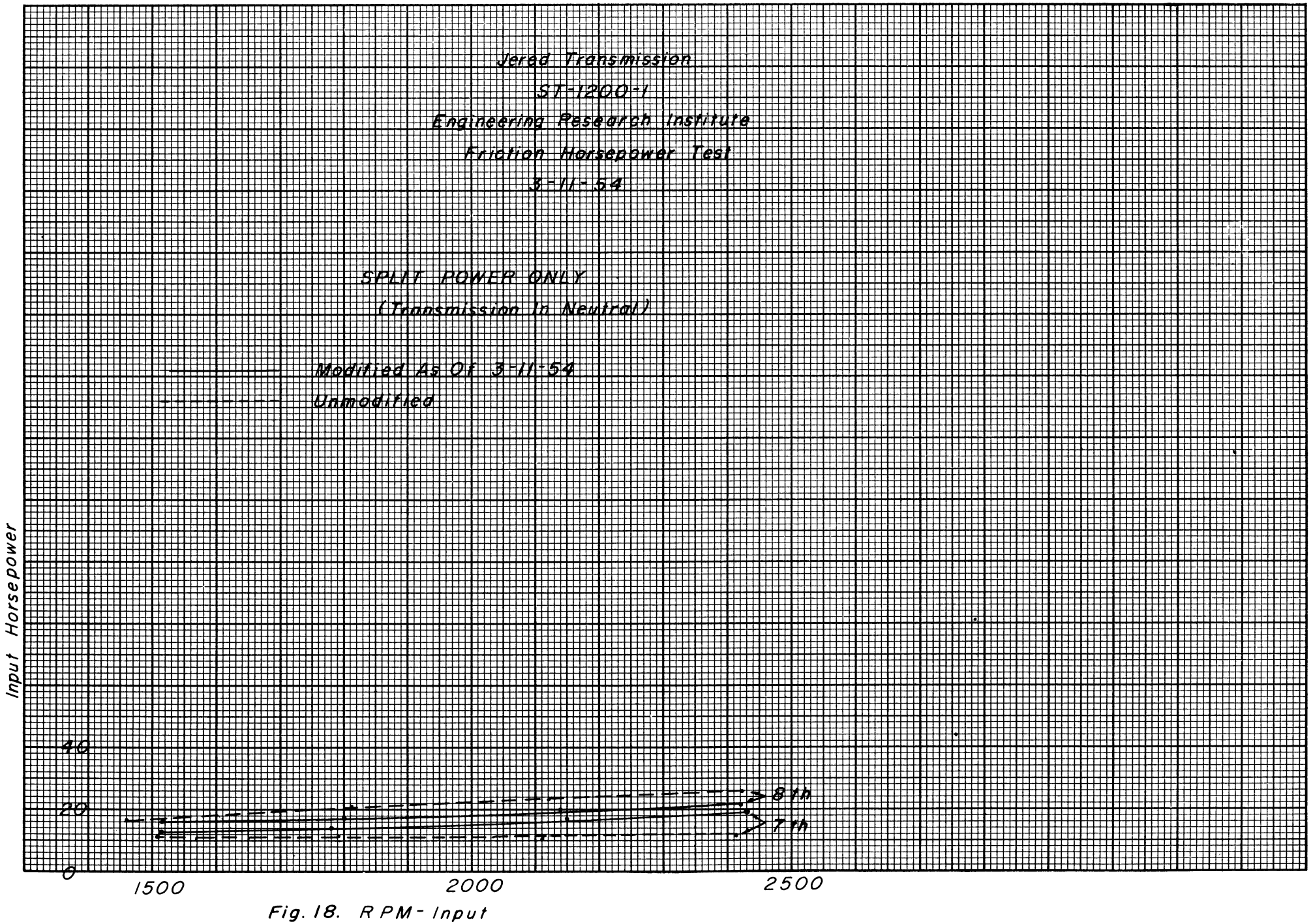


Fig. 18. RPM - Input

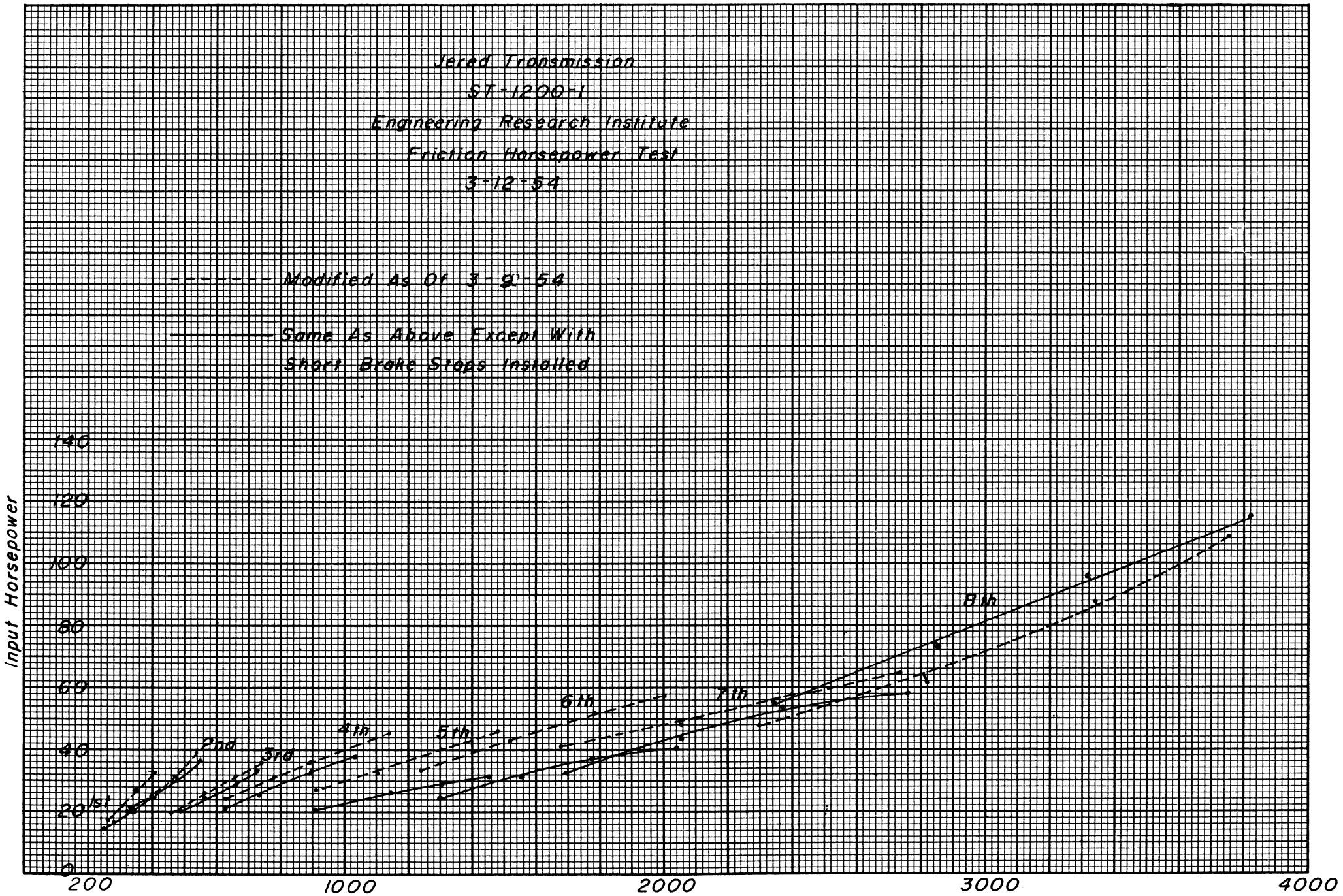


Fig. 19. RPM-Output

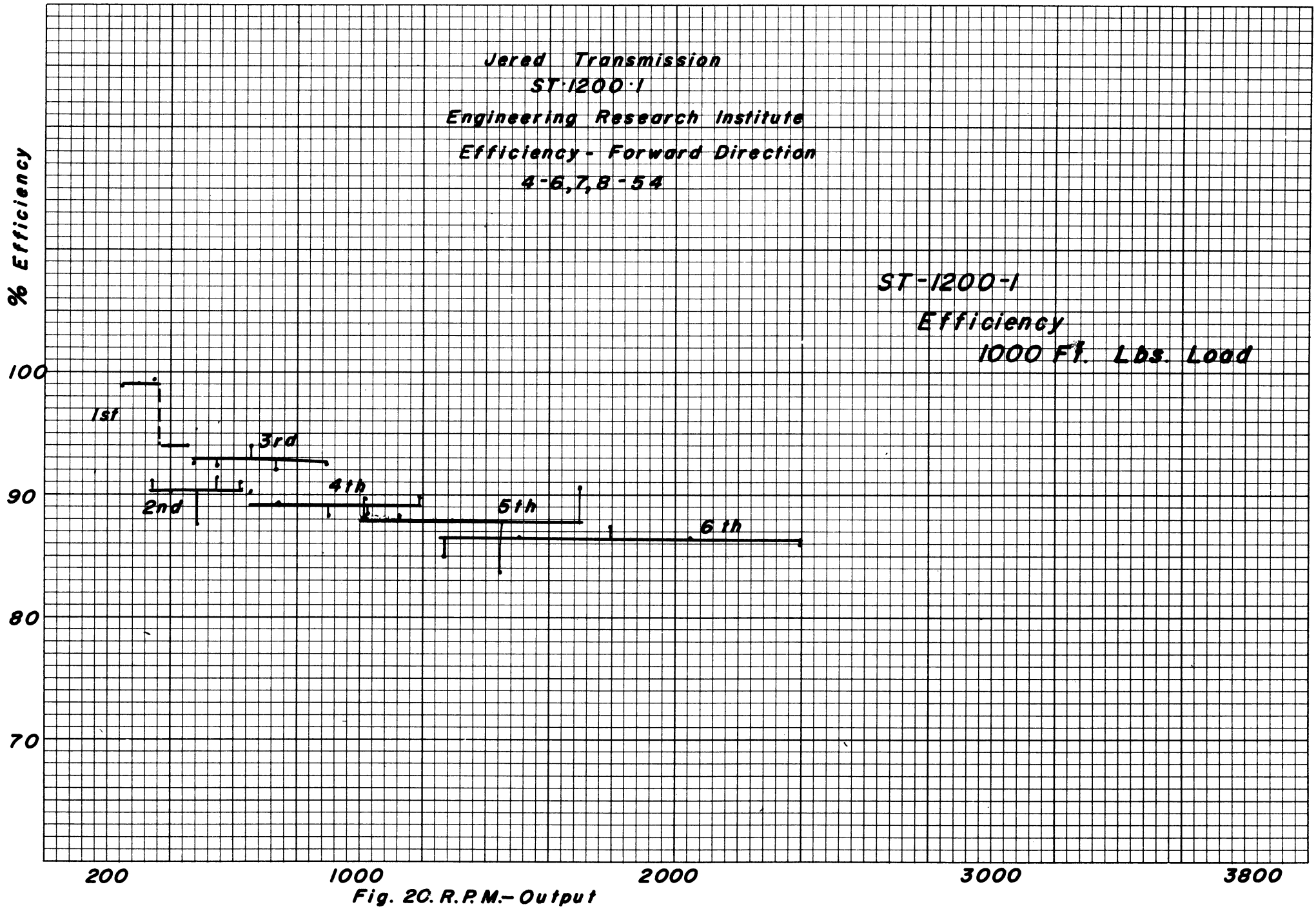


Fig. 20. R.P.M.– Output

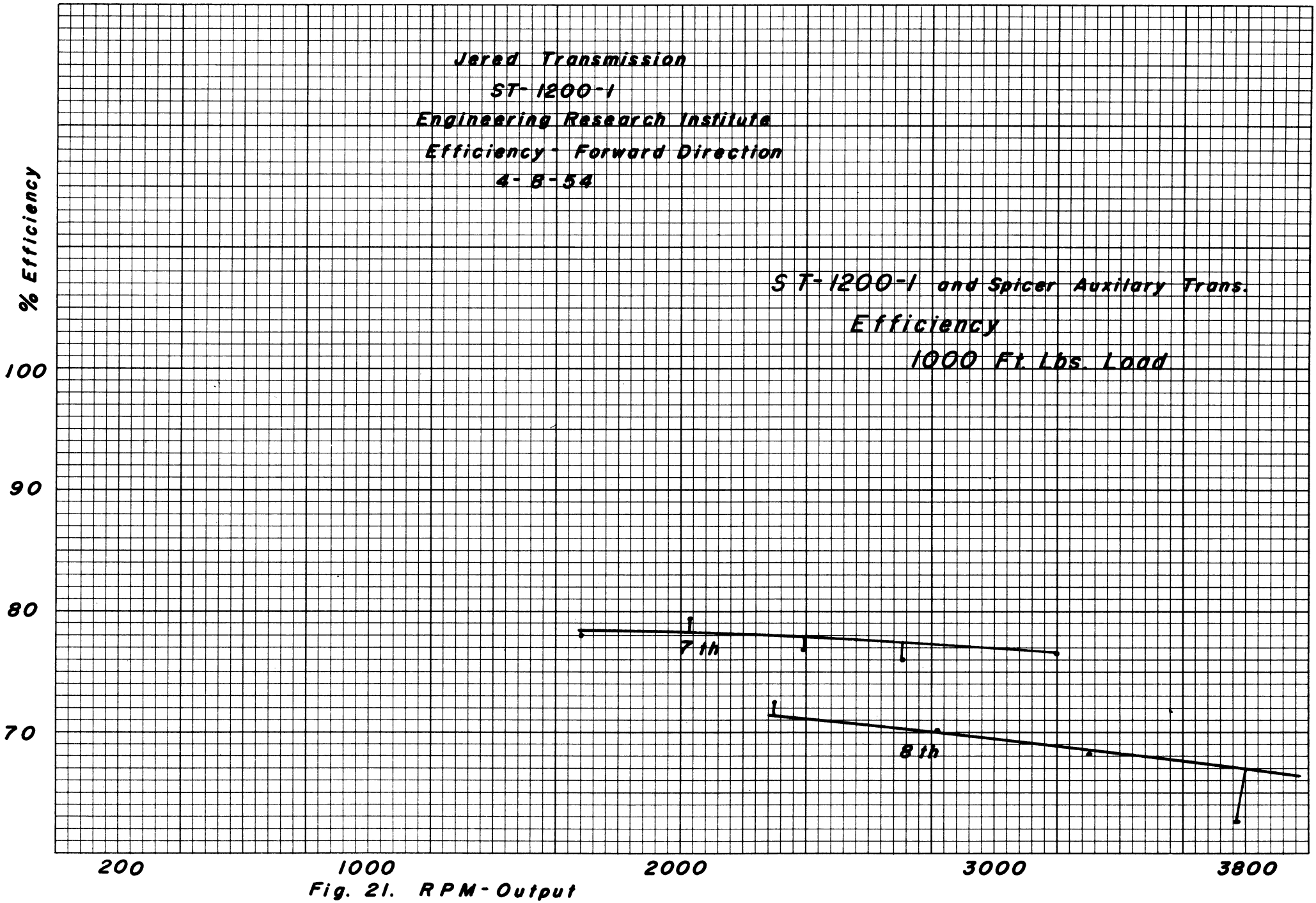


Fig. 21. RPM-Output

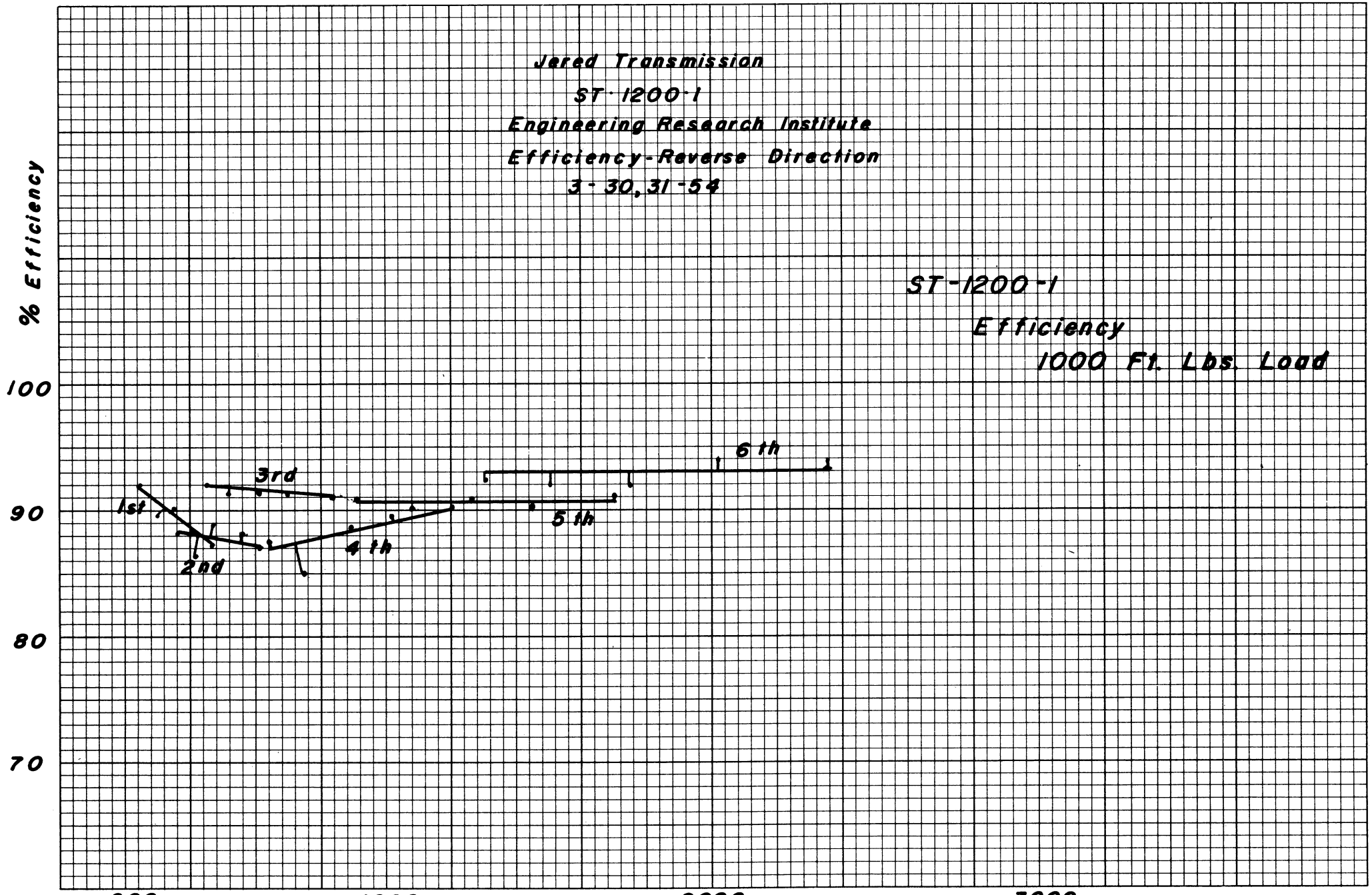


Fig. 22. RPM-Output

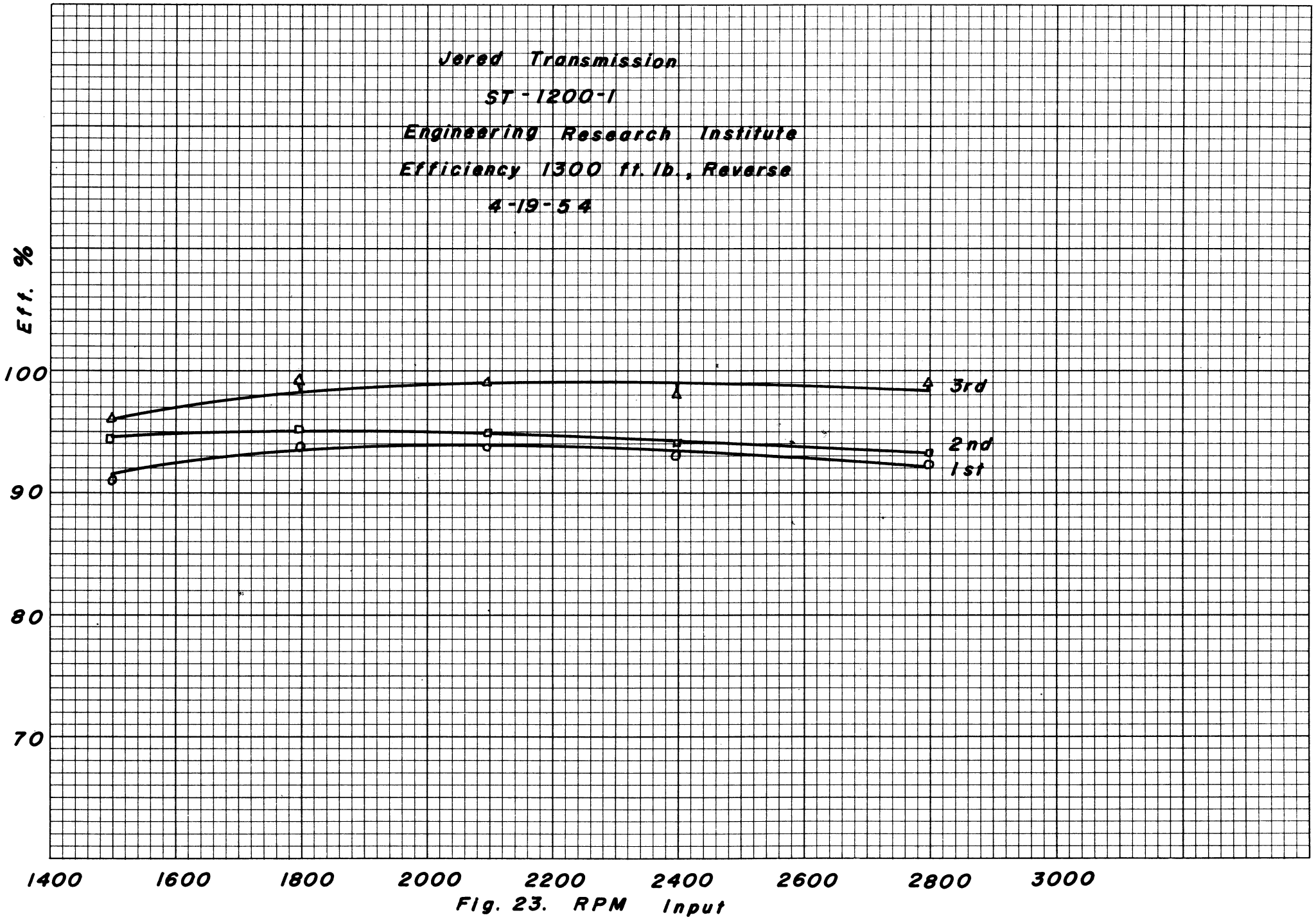

Jered Transmission
ST - 1200-1
Engineering Research Institute
Efficiency 1300 ft. lb., Reverse
4-19-54
Eff. %
100
90
80
70
3rd
2nd
1st
1400
1600
1800
2000
2200
2400
2600
2800
3000
RPM Input

Fig. 23.

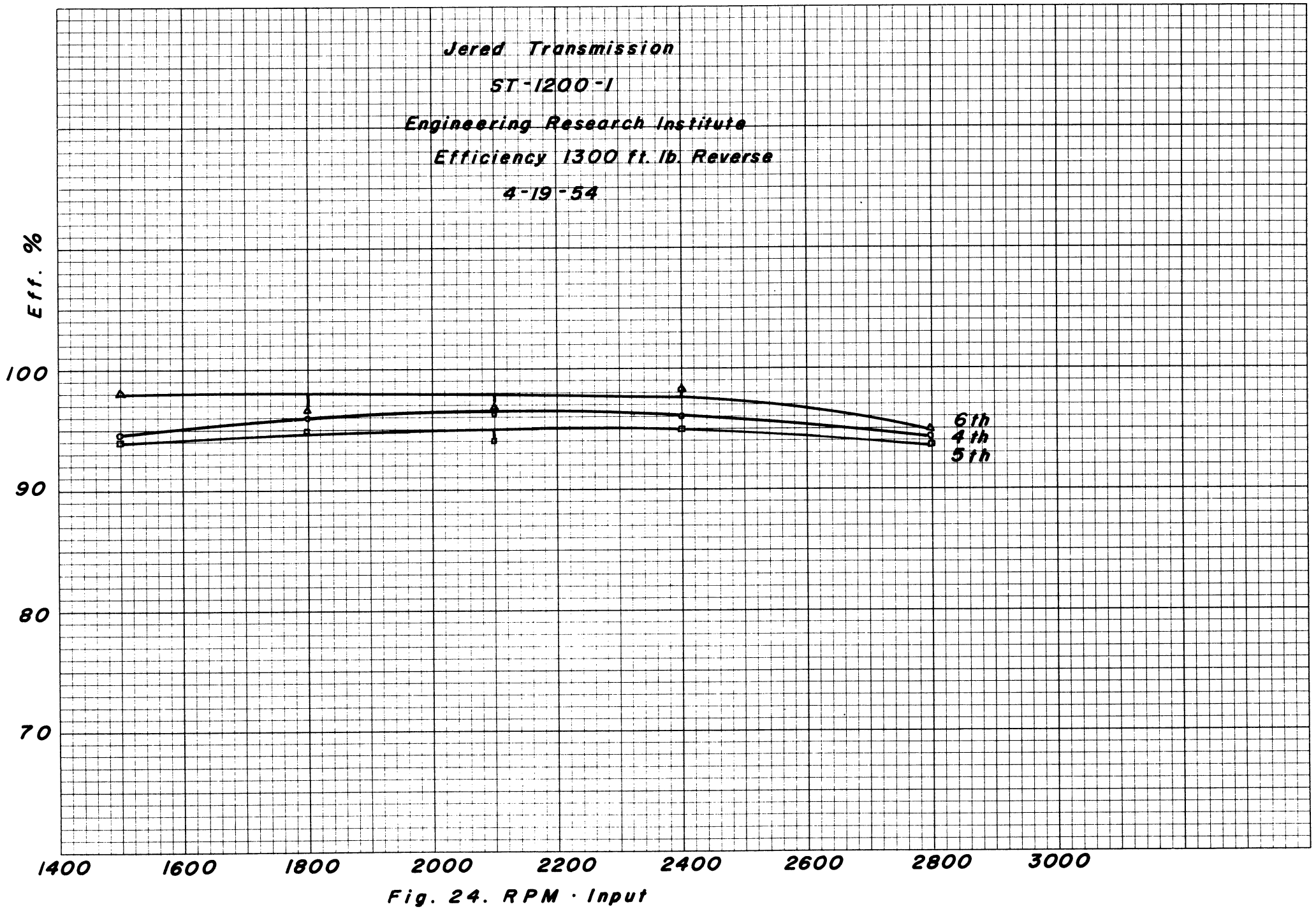


Fig. 24. RPM · Input

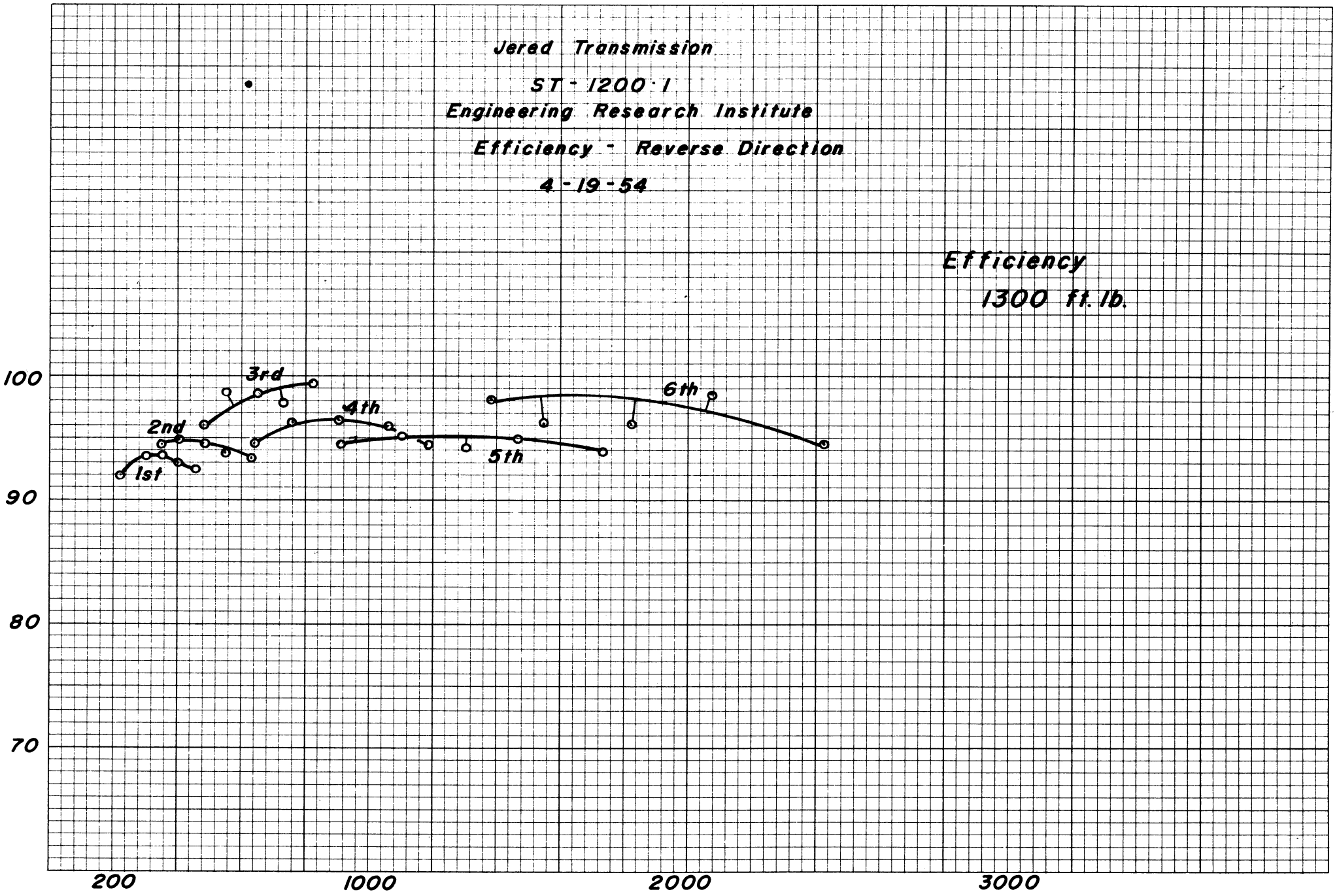


Fig. 25. RPM - Output

Preliminary Test Procedure
for Jered Transmission ST-1200

I. Break-in

A. Complete set-up as shown in Figure I.

B. At an input of 1200 rpm and no load, run the transmission in 1st gear with the forward and reverse clutches disengaged, observing lube flow, pressures, temperatures, etc.

C. Record the following:

(1) Input torque
(2) Input speed
(3) All temperatures
(4) All pressures
(5) Lube and Control Flow
(6) Output torque and speed

D. With the ST-1200 in 1st and the forward clutch engaged, operate transmission at 1200 rpm until the inlet oil temperature reaches 120°F.

E. Repeat part "C" every three (3) minutes.

F. With an input torque of 250 ft# and 1500 rpm operate transmission for thirty (30) minutes in all eight (8) speeds. Record data every three (3) minutes.

Note: ST-1200 is to be shifted at no loads and at 1000 rpm or less.

G. Disassemble and inspect all parts. Report and photograph all parts showing wear.

II. Load Test

A. Upon approval from Jered re-assemble the transmission and install on original test set-up.

B. At a load of 250 ft#, operate the transmission for ten (10) minutes at each of the following speeds: 1500, 1800, 2100, 2400, and 2800 rpm. These speeds are to be run in each of the eight (8) speeds of the

transmission. Make all recordings as outlined in Section I, Part C every three (3) minutes.

C. Disassemble and inspect all parts. Report and photograph all parts showing wear.

D. Repeat parts A, B, and C at 500, 1000, and 1300 ft# input torque.

III. Friction Test

A. Upon approval from Jered, reassemble transmission and install on original test set-up with exception of connecting the ST-1200 to the dynamometer.

B. With the transmission at operating temperature, drive ST-1200, 1500, 1800, 2100, 2400, and 2800 rpm in all eight (8) speeds of ST-1200. Record all readings as outlined in Section I, Part C for each run.

IV. Full Load Manual Shift Test

A. At an input speed of 2400 rpm and an input torque of 1200 ft#, run the transmission in 1st speed for a period of five (5) minutes.

B. Shift ST-1200 from 1st to 2nd while running at 1200 ft# input torque and 2400 rpm. Adjust dynamometer setting and run for a period of five (5) minutes.

C. Record all readings as outlined in Section I, Part C, every three (3) minutes. Make visual observations of transmission during each shifting operation.

D. Repeat steps B and C through all speeds of transmission. This includes both up and down shifting.

Note: Input speed not to exceed 2300 rpm in 8th speed.

E. Shift transmission through all speeds while running at an input speed of 2400 rpm and 1200 ft# torque. Time intervals between shift should be as short as that time which is required to balance the system at 1200 ft# and 2400 rpm after each shift.

F. Record all readings as outlined in Section I, Part C, every three (3) minutes.

G. Repeat steps E and F five (5) times.

H. Disassemble and inspect all parts. Report and photograph all parts showing wear.

V. Control Test

A. Upon approval of Jered, reassemble transmission and install control valve.

Note: Throttle linkage of valve not to be connected to throttle linkage of engine.

B. Complete set up as shown in Figure 2.

C. With the throttle linkage on the control valve at the closed throttle position and no load on the dynamometer, increase engine speed until transmission shifts through all eight (8) speeds. Lock engine throttle in this position.

D. Slowly apply load on dynamometer until transmission shifts down through all eight (8) speeds.

E. Record input speeds and torque at which each shift occurs. Record pressures and temperatures every three (3) minutes during entire test.

F. Decrease load on dynamometer to allow transmission to up-shift through all eight (8) speeds. Record as in Item "E".

Note: At no time should the input torque exceed 1000 ft#.

G. Repeat Items C through F with the valve throttle linkage set at 1/4, 1/2, 3/4, and full throttle quadrant movement.

VI. Full Load Automatic Shift Test

A. Set the valve throttle linkage at full throttle quadrant.

B. Increase the engine throttle and dynamometer load, holding the transmission in 1st until the input speed is 2400 rpm and the input torque is 1200 ft#. Lock engine throttle in this position. Run for five (5) minutes.

C. Decrease dynamometer load until the engine speed has increased sufficiently to shift transmission from 1st to 2nd.

D. Adjust dynamometer load until the input torque of 1200 ft# and an input speed of 2400 rpm is reached. Operate in 2nd speed for five (5) minutes.

E. Repeat Items C and D through all eight (8) speeds of transmission.

VII. Cyclic Life Test

A. Cyclic tests are to be run at full engine throttle during entire test.

B. ST-1200 to be shifted by increasing or decreasing load only.

C. Start in 1st gear and upshift to 8th in the following time intervals:

1st gear..... 5 minutes
2nd gear.....10 minutes
3rd gear.....20 minutes
4th gear.....25 minutes
5th gear.....20 minutes
6th gear.....10 minutes
7th gear..... 5 minutes
8th gear..... 5 minutes

D. Down shift transmission using the same time intergrals in each gear.