Determination of Installed Horsepower For Lycoming Reciprocating Engines

During the performance testing of an aircraft it is desirable to know the engine power output in flight. The power curves in Avco Lycoming Engine Specifications do not necessarily define the engine power output when the engine is installed in an aircraft. The most common method of determining engine power output in flight is with a calibrated torquemeter. However, since a torquemeter is not always available and/or adaptable to an engine installation for in-flight power checks, an accurate alternate method of determining power output is often required. One such method is detailed herein based on data accumulated at Lycoming for over a 30 year period.

Determination of Installed Horsepower

For Lycoming Reciprocating Engines

The first attached curve shows the relationship of Peak EGT to cylinder head temperature, percent power, and percent of fuel consumption. The second curve shows the effect on percent of best power (indicated horsepower) that percent of best power fuel air ratio or best power indicated specific fuel consumption will have as they are varied. The third curve is a friction horsepower curve for our engines of various cubic inch displacements. The fourth curve gives the best power indicated specific fuel consumption versus indicated mean effective pressure for engines of various compression ratios. It should be noted that for any power setting over 65% of rated power, the value of the portion of the curve with zero slope should be used. If initial calculations show that the power is below 65% of rated, the mean effective pressure can be calculated for the power determined and a new value for specific fuel flow obtained. Though the resulting specific fuel flow value may not be 100% correct, it will be beyond the accuracy of a slide rule. These curves have been established by accumulating empirical data for many years and can be considered to be accurate to within the limits of slide rule calculations. !?

From these curves several facts have been established:

1. At peak EGT the engine is developing 96.8% of its best indicated horsepower for the particular throttle setting.

2. At peak EGT the engine has a fuel air ratio of .0648 which is 84.9% of the best power indicated [redacted] fuel consumption.

3. 100% power occurs at between .0765 and .0840 fuel air ratio. (For calculations .078 has proven an accurate value to use.)

4. The fuel flow varies with the same relationship as the fuel air ratio.

5. A definite value for indicated specific fuel consumption can be established for each engine as long as the compression ratio is known.

Using the aforenumerated facts and referring to the attached curves, the actual installed horsepower of an engine can be determined if the fuel flow is accurately measured and the peak EGT carefully established.

IT SHOULD BE NOTED THAT WHEN USING A FIXED PITCH PROPELLER, THE RPM WILL DROP SLIGHTLY FROM BEST POWER FUEL FLOW TO PEAK EGT FUEL FLOW. SINCE THE CURVES ARE ALL BASED ON A FIXED MANIFOLD PRESSURE, THE RPM AT PEAK EGT IS THE RPM FOR WHICH BEST POWER IS BEING DETERMINED. EXAMPLE:

A. ENGINE O-360-A (FIXED PITCH PROPELLER).

B. RPM SET AT 2500.

C. AT PEAK EGT, FF = 57 LB/HR RPM = 2475.

D. FROM FACTS 2 AND 4, 57 LB/HR IS 84.9% OF BEST POWER (INDICATED) FUEL FLOW.

E. THEREFORE BEST POWER (INDICATED) FUEL FLOW IS 67.1 LB/HR.

F. FROM THE FOURTH CURVE, SINCE THE COMPRESSION RATIO IS 8.5:1, THE BEST POWER INDICATED SPECIFIC FUEL CONSUMPTION IS .407 LB/HP/HR.

G. 67.1 LB/HR OF FUEL DIVIDED BY .407 LB/HP/HR GIVES AN INDICATED HORSEPOWER OF 165 IHP.

H. FROM THE THIRD CURVE, WE DETERMINE THAT AT 2475 RPM THE O-360 ENGINE HAS 25 FHP.

I. SUBTRACTING THE 25 FHP FROM 165 IHP, IT IS SHOWN THAT THE ENGINE IS DEVELOPING 140 BHP AS INSTALLED AT 2475 RPM AT BEST POWER MIXTURE STRENGTH AND AT THE MANIFOLD PRESSURE WHICH WAS USED.

ALTERNATE METHOD

THE AVCO LYCOMING BOOSTED ENGINES DEVELOP SUFFICIENT POWER TO PRECLUDE PEAK EGT (OR TIT) OPERATION AT THE HIGHER POWER LEVELS. IT IS POSSIBLE TO USE THE ABOVE METHOD TO IDENTIFY THE POWER VERSUS MANIFOLD PRESSURE CURVE AT WHATEVER ENGINE SPEED IS DESIRED. THREE OR MORE POINTS ARE SUFFICIENT AT LOW POWER LEVELS TO DO THIS. DURING THIS DATA ACQUISITION THE COMPRESSOR DISCHARGE OR INJECTOR ENTRANCE AIR TEMPERATURE SHOULD BE ESTABLISHED FOR EACH POINT IN ADDITION TO THE OTHER NECESSARY PARAMETERS.

THE INDICATED HORSEPOWER (BRAKE + FRICTION HP) IS A DIRECT LINEAR FUNCTION OF MANIFOLD PRESSURE AND AN INVERSE FUNCTION OF THE INDUCTION AIR ABSOLUTE TEMPERATURE RAISED TO A GIVEN POWER (*) AS LONG AS MIXTURE STRENGTH REMAINS CONSTANT. THESE FACTS MAY BE USED TO CALCULATE THE POWER AT CONDITIONS WHICH ARE BEYOND THE CAPABILITY OF THE PEAK EGT METHOD ALONE.

(*) WHEN THE ENGINE IS PORT INJECTED THE CORRECTION IS TO THE .8 POWER.

WHEN THE ENGINE IS CARBURETTED OR HAS A "WET" INDUCTION SYSTEM, THE CORRECTION IS TO THE .5 POWER.

TO ILLUSTRATE THIS METHOD WE WILL CONSIDER A TIO-540-J2BD (PORT INJECTED) ENGINE AT 20,000 FEET PRESSURE ALTITUDE. IT IS TURNING AT 2575 RPM AT FULL THROTTLE, RESULTING IN 42.80"HG. MANIFOLD PRESSURE. THE COMPRESSOR DISCHARGE TEMPERATURE IS 326°F AND THE FUEL FLOW IS 225 LB/HR. WE WISH TO DETERMINE THE ACTUAL POWER OUTPUT UNDER THIS CONDITION.

LEANOUT RUNS AT SEVERAL LOW POWER SETTINGS HAVE BEEN MADE THROUGH PEAK EXHAUST TEMPERATURE. THE FUEL FLOW AT PEAK EGT IS PLOTTED AGAINST MANIFOLD PRESSURE TO REMOVE THE DATA SCATTER AND DETERMINE THE FAIRED CURVE. FROM THIS CURVE WE FIND THAT AT 29.50"HG. MANIFOLD PRESSURE AT 2575 RPM PEAK EGT OCCURS AT 109 LB/HR FUEL FLOW. THE INDUCTION AIR TEMPERATURE AT THE INJECTOR ENTRANCE IS 115°F (575°R) AT THIS CONDITION.

AT THE RISK OF BEING REPETITIOUS WE WILL GO THROUGH THE CALCULATION NECESSARY TO DETERMINE THE HORSEPOWER AT THIS CONDITION. THE STEPS TAKEN ON PAGE 2 ARE APPLIED TO THIS SITUATION AS FOLLOWS:

A) 109 LB/HR FUEL FLOW AT PEAK EGT ÷ 84.9% = 128.5 LB/HR FUEL FLOW AT BEST POWER.

B) CURVE NO. 4 SHOWS THAT FOR A COMPRESSION RATIO OF 7.3:1 THE BEST POWER ISFC IS 0.424 LB/IHP/HR.

C) 128.5 LB/HR ÷ 0.424 LB/IHP/HR = 303.1 IHP.

D) FROM CURVE NO. 3 WE FIND 44 FRICTION HORSEPOWER AT 2575 RPM FOR THE IO-540 ENGINE SERIES.

E) SUBTRACTING 44 FHP FROM 303.1 IHP RESULTS IN 259.1 BHP OUTPUT AT BEST POWER FUEL FLOW.

HAVING MADE THIS DETERMINATION WE NOW HAVE A BASE WITH WHICH TO COMPARE THE DATA TAKEN AT 20,000 FEET:

A) $\frac{42.80"\text{HG.}}{29.50"\text{HG.}} \times \left(\frac{575°\text{R}}{786°\text{R}}\right)^{.8} \times$ 303.1 IHP ⟶ IHP AT BEST POWER FUEL FLOW

B) 1.450 x 0.778 x 303.1 = 341.9 IHP AT BEST POWER FUEL FLOW.

C) BEST POWER FUEL FLOW IS DETERMINED BY MULTIPLYING 341.9 IHP x 0.424 LB/IHP/HR TO GET 144.9 LB/HR.

Determination of Installed Horsepower For Lycoming Reciprocating Engines (Cont.)

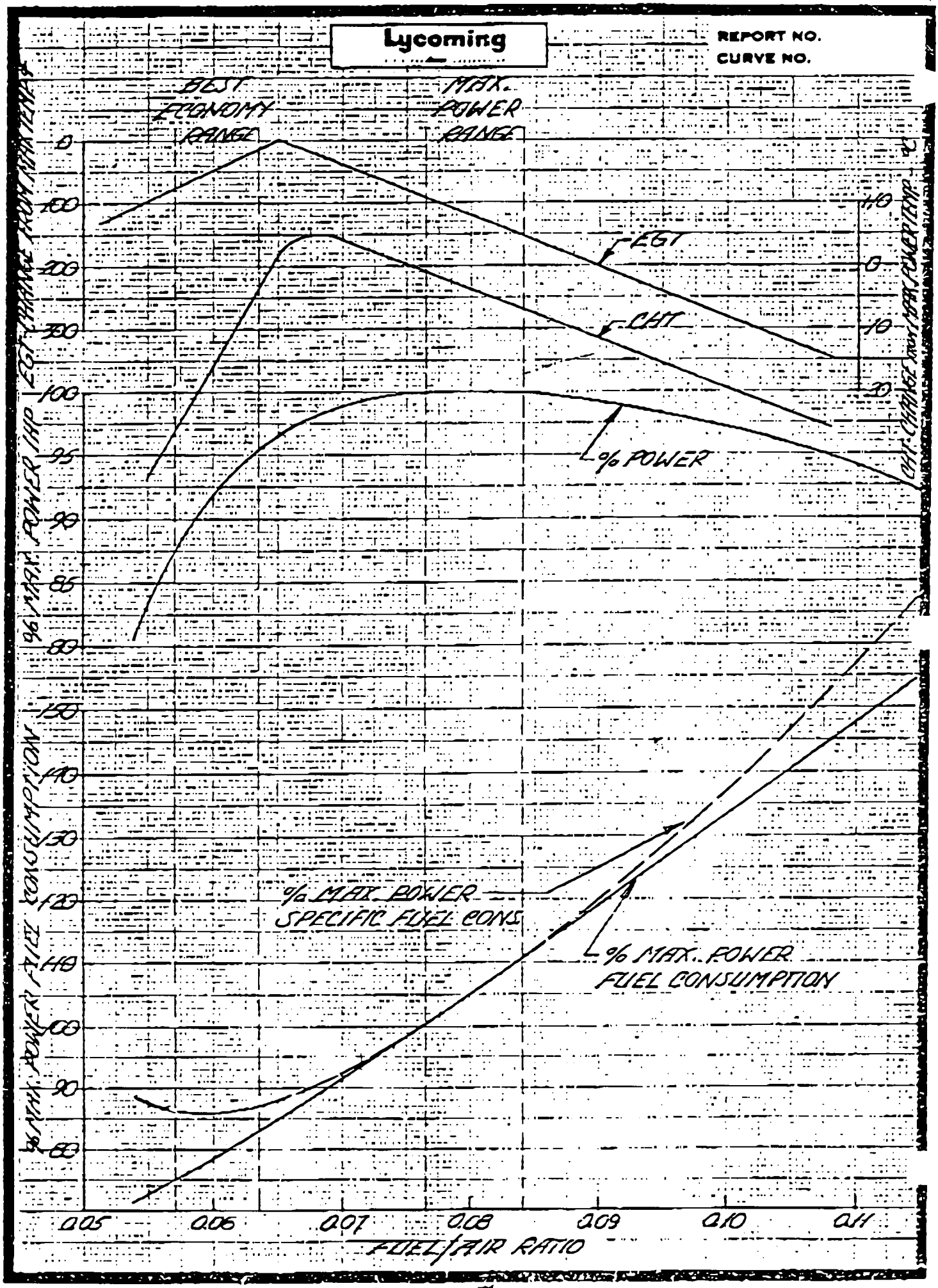
d) But we are richer than best power by $\frac{225}{144.9}$ x 100% or 155.2%.

e) Plug 155.2% best power fuel flow into Curve No. 2 and find that 91.2% of available indicated horsepower is being produced.

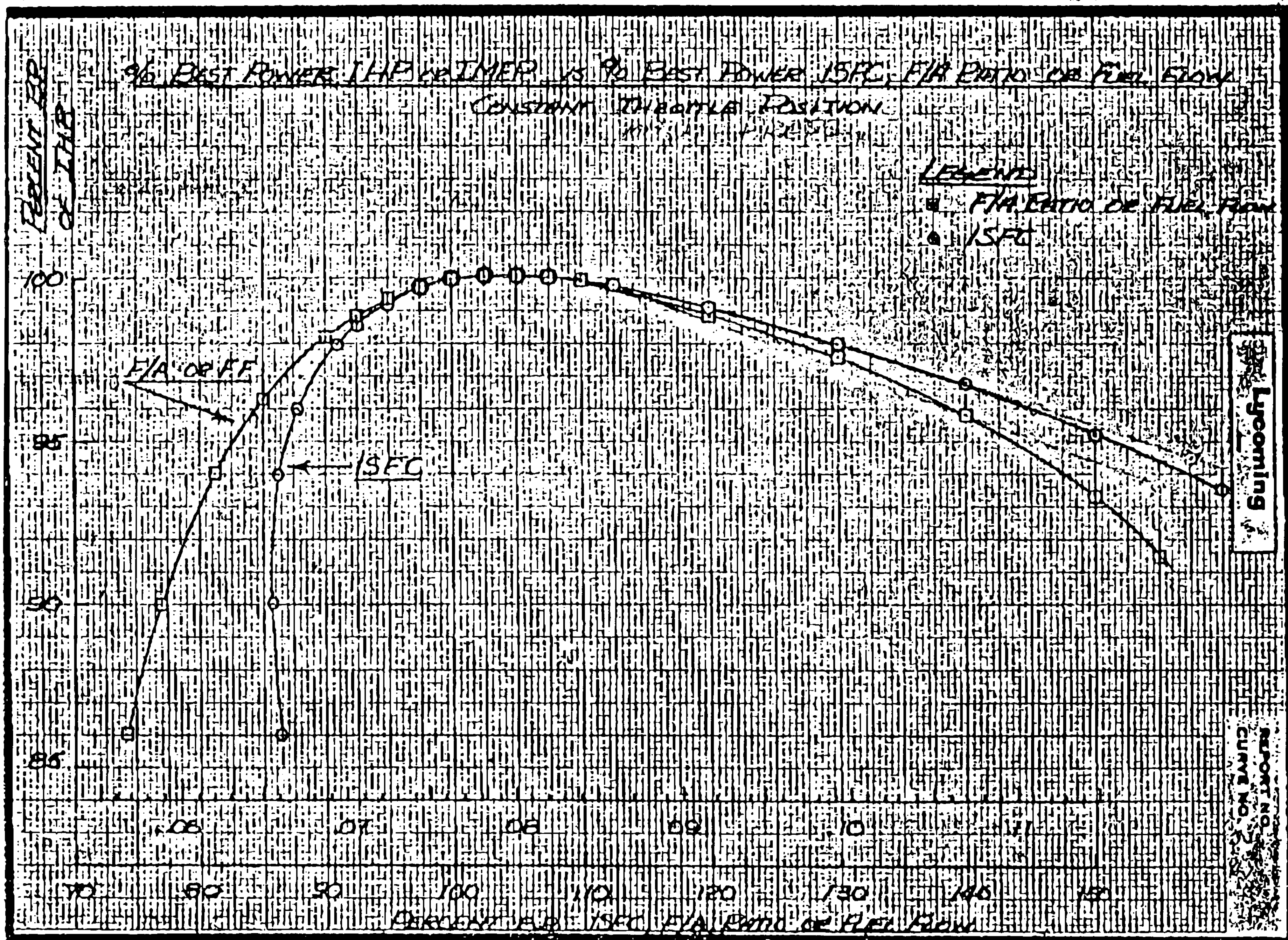
f) 91.2% x 341.9 IHP = 311.8 IHP at 225 lb/hr fuel flow.

g) Power output at the crankshaft (brake horsepower) is 311.8 IHP - 44 FHP = 267.8 BHP at the conoition presented.

The reliability of this method has been established through comparison of dynamometer data. When the baseline is accurately established the subsequent calculated power is well within slide rule accuracy.


Lycoming
REPORT NO.
CURVE NO.
BEST ECONOMY RANGE
MAX. POWER RANGE
EGT
CHT
% POWER
% MAX. POWER SPECIFIC FUEL CONS
% MAX. POWER FUEL CONSUMPTION
FUEL/AIR RATIO
0.05
0.06
0.07
0.08
0.09
0.10
0.11

CURVE #1


Lycoming
REPORT NO.
CURVE NO.
% BEST POWER IHP or IMEP vs % BEST POWER ISFC, F/A RATIO OR FUEL FLOW
CONSTANT THROTTLE POSITION
LEGEND
F/A RATIO OR FUEL FLOW
ISFC
F/A OR FF
ISFC
PERCENT BP OF IHP
100
95
90
85
.06
.07
.08
.09
.10
.11
70
80
90
100
110
120
130
140
150
PERCENT BP ISFC F/A RATIO OF FUEL FLOW

Lycoming

REPORT NO.
CURVE NO.

FRICTION HORSEPOWER FOR AIRCRAFT ENGINES

AVERAGE FRICTION HORSEPOWER FOR LYCOMING AIRCRAFT ENGINES

FRICTION HORSEPOWER

0 10 20 30 40 50 60 70 80 90 100

RPM

0 21 22 23 24 25 26 27 28 29 30 31 32 33 34

HUNDREDS OF REVOLUTIONS PER MINUTE

540 & 720

480

540 SERIES

400

360

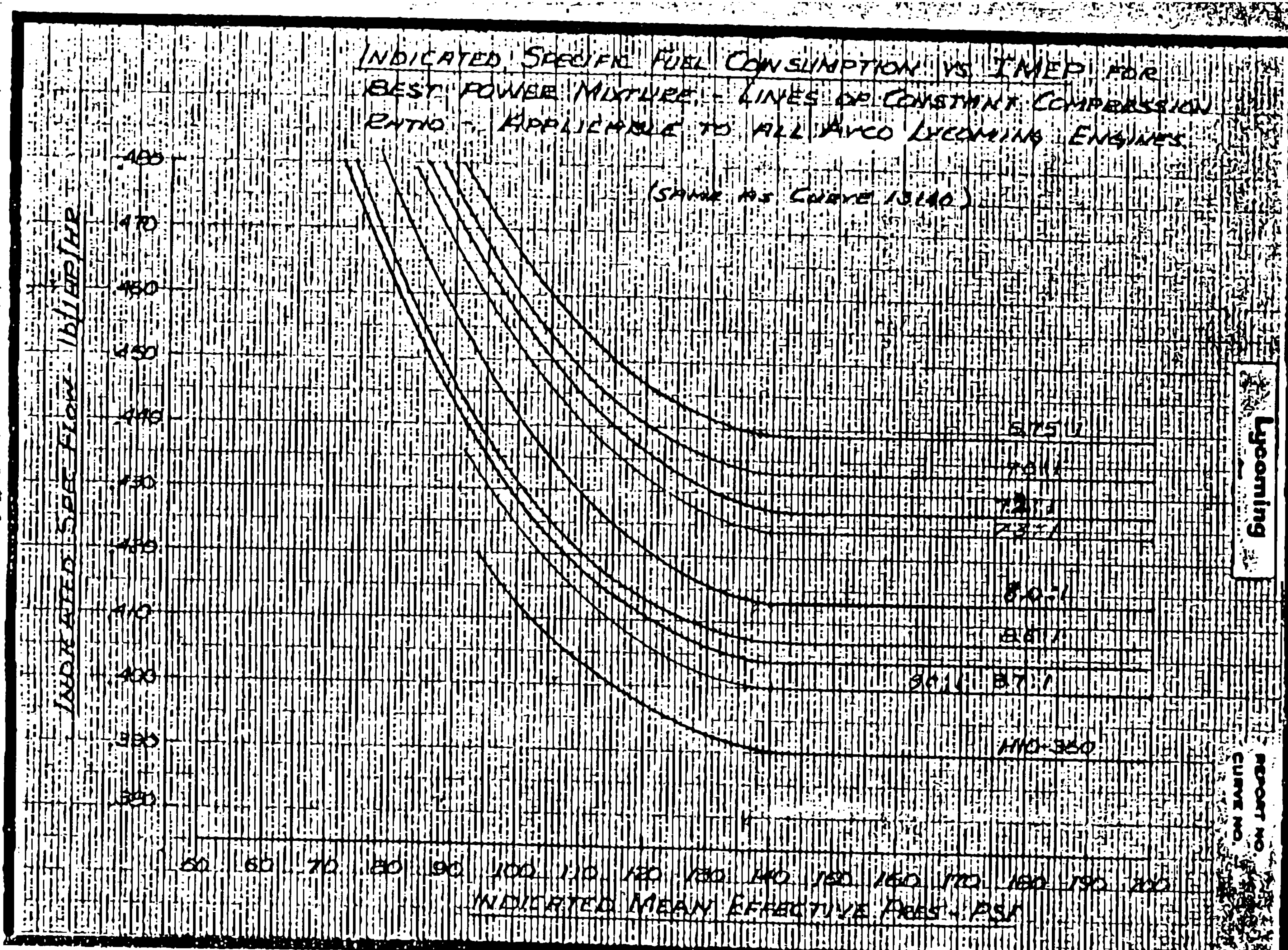
320

235

NOTES

1) SUFFIX "S" DENOTES 60 & 120 ENGINES

2) ALL OTHER DISPLACEMENT DESIGNATIONS ARE FOR 0 TO 10, 10 TO 20 & 20 TO 40 HP GEARED ENGINES


Lycoming
REPORT NO.
CURVE NO.
INDICATED SPECIFIC FUEL CONSUMPTION VS IMEP FOR
BEST POWER MIXTURE - LINES OF CONSTANT COMPRESSION
RATIO - APPLICABLE TO ALL AVCO LYCOMING ENGINES
(SAME AS CURVE 13140)
INDICATED SPEC FLOW lb/IHP/HR
INDICATED MEAN EFFECTIVE PRES - PSI
50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
HIO-360