ETHYL ALCOHOL AS FUEL FOR INTERNAL COMBUSTION ENGINES

by

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ABSTRACT

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Performance of a high compression four cylinder automotive engine using Ethyl Alcohol as fuel with different amounts of preheating of the inlet mixture is evaluated. Some discussion of the results and recommendations for further research are included.

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NOMENCLATURE

BHP - Brake Horsepower

IHP - Indicated Horsepower

FHP - Friction Horsepower

BMEP - Brake Mean Effective Pressure

IMEP - Indicated Mean Effective Pressure

FMEP - Friction Mean Effective Pressure

BSFC - Brake Specific Fuel Consumption

ISFC - Indicated Specific Fuel Consumption

Nm - Mechanical Efficiency

Ni - Indicated Thermal Efficiency

Nf/a - Fuel-Air Cycle Efficiency

Nv - Volumetric Efficiency

F/Fc - Ratio of Actual Fuel-Air Ratio to the Stoichemetric Fuel-Air Ratio

F/A - Fuel-Air ratio

Wa' - Actual mass flow of air, lbs./hr

Wa - Computed mass flow of air, lbs./hr

Wf - Fuel flow, lbs./hr

P - Pressure difference across orifice for air flow measurement

P_1 - Pressure at inlet manifold, psia

T_1 - Temperature at inlet manifold, °R

t_i - Temperature at entrance of heat control valve, °F

t_o - Temperature at exit of heat control valve, °F

T - Temperature difference between the entrance and the exit of the heat control valve, °F

Man. Vac. - Manifold vacuum

S-- Piston Speed, ft/min.

RPM - Revolution Per Minute

Ec -Heat Value of Fuel

S. A. - Spark Advance, degrees before top dead center

r - Compression Ratio

N_r - Ratio of actual indicated thermal efficiency to the theoretical fuel-air cycle efficiency

f - Ratio of residual gas content to total cylinder vol.

P_{ex} - Exhaust pressure, psia.

INTRODUCTION

The use of ethyl alcohol as a substitute fuel for gasoline in high compression automotive engines has never been fully studied from the point of view of self-sufficiency except in some special racing engines. Considerable work has been done on gasoline-alcohol blends and on alcohol injection but not on 95% pure ethyl alcohol alone.

It is the purpose of this thesis to give an account of the performance of a typical four-cylinder automotive engine using ethyl alcohol as fuel and operating at a compression ratio which is best suited for the said fuel and to use it in an attempt to gain more knowledge in the topic of performance and fuel economy.

Ethyl alcohol because of its high latent heat of vaporization would naturally require more preheating than gasoline, for optimum performance and economy. This amount of preheating for optimum performance and economy is determined and the results compared with those using gasoline in the same engine but of a lower compression ratio. This particular consideration is important since preheating the inlet mixture tends to reduce air capacity and thus engine power, while poor distribution results in poor fuel economy and at the same time reduce engine power. The effect of the amount of preheating on BMEP, IMEP, BSFC, ISFC, and volumetric efficiency are plotted for both the alcohol and gasoline runs.

Only steady-state running is considered but several speed load combinations are used. The variables which affect the performance in a given engine running in a steady state are:

Speed

Load

Fuel-air ratio

Inlet temperature

Compression ratio.

Since it is not practical to cover all possible combinations, a limited number of these combination are selected for test purposes.

The following are the different speed-load combinations:

Series "A"

rpm = 1800

S = 945 ft/min.

Part Throttle: 8.35 psia manifold pressure.

Series "B"

rpm = 2000

S = 1050 ft/min.

Part Throttle: 8.35 psia manifold pressure.

Series "C"

rpm = 2400

S = 1260 ft/min.

Part Throttle: 8.35 psia manifold pressure.

Series "D"

rpm = 2000

S = 1050 ft/min.

Full Throttle: Atmospheric inlet pressure

(at carburetor intake)

Series "E"

rpm = 2400

S = 1260 ft/min.

Full Throttle: Atmospheric inlet pressure

(at carburetor intake)

Series "F"

rpm = 2800

S = 1470 ft/min.

Full Throttle: Atmospheric inlet pressure

(at carburetor intake)

Series "A-1"

rpm = 1800

S = 945 ft/min.

Part Throttle: 8.35 psia manifold pressure.

Series "E-1"

rpm = 2400

S = 1260 ft/min.

Full Throttle: Atmospheric inlet pressure

(at carburetor intake)

For Series "A" to "F" runs inclusive, compression ratio is at 12:1 and the fuel used is 95% pure Ethyl Alcohol.

For Series "A-1" and "E-1" runs, the compression ratio is at 7.25:1 and the fuel used is 92 octane gasoline.

DESCRIPTION OF APPARATUS

ENGINE:

Make & Model ----------Renault, Type R1090

No. of Cyl. -----------4

Type -----------4-stroke cycle, OHV in-line

Max. BHP -----------32 @ 4200 RPM (manufacturer's rating)

Compression ratio------7.25:1

Bore-------------------58 mm or 2.283 in.

Stroke -----------80 mm or 3.15 in.

Piston Displacement----845 cc or 51.8 cu. in.

INLET SYSTEM:

The air supplied passes through a sharp edged .725 in orifice, (installed with flange taps according to A.S.M.E. specifications), a surge tank, and intake pipe connected to the carburetor air horn by a rubber hose. Temperature of the inlet mixture is varied by the manually controlled heat riser system. (Fig. o).

FUEL AND FUEL SYSTEM:

When the compression ratio is at 7.25:1, 92 octane gasoline is used. For high compression ratio's (12:1) 100 octane gasoline is used for starting and warm-up. 95% pure Ethyl Alcohol is used for steady state running. Gasoline is supplied by the laboratory main fuel pump and is passed through a 3 - way valve before entering the carburetor of the engine. The 3-way valve facilitates switching over from gasoline to alcohol while the engine is running.

Fuel flow is regulated by means of a needle installed at the seat of the main jet. Alcohol is supplied by an overhead supply tank.

COOLING SYSTEM:

The engine is cooled by circulating water around the water jackets by the engine water pump. The temperature is maintained constant by means of a heat exchanger using steam or water.

LUBRICATION SYSTEM:

Lubrication is provided by means of a force-feed wet sump system and the oil temperature is controlled by circulating the oil through a heat exchanger. An electrically driven oil pump is added for circulating the oil through the heat exchanger.

IGNITION SYSTEM:

The ignition is the regular Renault system using an ignition coil, distributor and battery. Spark advance is varied manually.

EXHAUST SYSTEM:

The engine incorporates a two-part exhaust manifold and a heat riser system of conventional design. Thermocouples are installed at the entrance and exit of the heat control valve to measure exhaust temperature at these points.

MEASURING INSTRUMENTS:

An electric cradle-dynamometer is coupled to the output shaft of the engine to measure torque. Engine RPM is measured by a mechanical tachometer connected to the dynamometer, and is further checked by a strobe lamp.

Air flow is measured by a differential manometer with standard sharp edge .725 in. diameter orifice. Fig. 44 is a caliberation of this set-up.

Fuel flow is measured by a conventional rotometer. The same rotometer is used with both alcohol and gasoline but using different floats. Figs. 45 & 46 shows the caliberation of this set-up.

Spark advance is measured by a graduated crankshaft pulley and neon timing light.

Inlet manifold pressure is measured by a mercury manometer which reads the manifold vacuum directly.

Jacket water temperature is measured by a mercury bulb thermometer installed at the discharge pipe at the end of the cylinder head.

Oil temperature is measured by a vapor pressure thermometer.

Temperature of the exhaust gas at entrance and exit of the heat control valve (Fig. o) is measured by thermocouples using Leeds and Northrup millivolt potentiometer indicator.

PROCEDURE

Part I.

The engine is run first using 92 octane gasoline as fuel at a compression ratio of 7.25:1. Fuel - air ratio is varied from F/Fc of .9 at increments of .1 to F/Fc of 1.3.

This is accomplished by turning the needle valve which is installed to control the opening of the carburetor main jet. Stoichemetric fuel -air ratio for gasoline is .06775:1. At each run with a particular fuel-air ratio, the heat control valve opening is varied from fully open to fully closed. The heat control valve position is changed in steps by increments of 1/4 the maximum swing of the valve from the fully open to the fully closed position.

At the fully open position of the heat control valve, no exhaust gas is allowed to recirculate through the underside of the portion of the intake manifold directly under the carburetor, except for some leakage of course. At the fully closed position, all the exhaust gases are channeled so that they circulate through the underside of the portion of the intake manifold directly under the carburetor and serve to heat the incoming mixture of fuel and air.

Two speed load combinations are used namely full throttle at 2400 rpm (1260 ft/min.) and part throttle at 1800 rpm. For the part throttle runs, the manifold pressure is kept constant at 8.35 psia since this corresponds to the condition in which a great majority of automotive or farm tractor engines would operate at part load conditions.

Before any reading is takenthe engine is fully warmed up to operating conditions namely 180°F jacket water temperature and 150°F oil temperature.

Spark advance is set for best power on all runs.

Part II

The compression ratio is raised to 12:1 by the addition of a block of metal screwed on top of the piston. This block of metal is so designed that the space it takes up reduces the clearance volume to an extent that the compression ratio is raised to 12:1.

To reduce warm up time the engine is started by using 100 octane gasoline and the spark retarded around 8° BTC to prevent detonation. Once the jacket water temperature and oil are almost 180°F respectively, the 3-way valve is switched to alcohol, and the spark advanced to best power for alcohol. The water jacket and oil temperature is adjusted to the exact figure of 180°F and 150°F respectively.

As in the gasoline runs, five different fuel-air ratios are used namely F/Fc =.9, F/Fc = 1.0, F/Fc = 1.1, F/Fc = 1.2, and F/Fc = 1.3. The diameter of the main jet is increased by the $\sqrt{1.6}$ or 1.264 to approximately correspond to the lower heating valve of ethyl alcohol.

The amount of preheating is again varied by changing the opening of the heat control valve.

Six speed-load combinations are used namely part throttle at 1800 rpm, part throttle at 2000 rpm, part throttle at 2400 rpm, full throttle at 2000 rpm, full throttle at 2400 rpm, and full throttle at 2800 rpm. These speed-load combinations are chosen so as to be able to determine the effect of piston speed in the several variables.

For part throttle runs, the inlet manifold pressure is kept constant at 8.35 psia and for full throttle runs, the pressure is atmospheric at the carburetor intake.

Spark advance is set for best power at each run. Jacket water temperature and oil temperature are kept constant again at 180°F and 150°F respectively.

Discussion of Results

Part I

(A) The effect of inlet mixture preheating on Brake and Indicated Specific Fuel Consumption - using gasoline as fuel:

Figures 1 & 2 shows the efffect of preheating the inlet mixture on the BSFC of the engine when 92 octane gasoline is used as fuel. At low speeds (S=945 ft/min) and at part throttle, BSFC decreases with the increase in of the ΔT between the inlet and outlet portions of the heat control valve. The minimum BSFC would be at a higher ΔT for a richer mixture. For leaner mixtures the minimum BSFC are at lower ΔTs except for the leanest mixture (F/Fc= .9) in which the minimum BSFC is again at a high ΔT.

When a rich mixture is used there is an excess of fuel that all the cylinders have a rich mixture, which means that no cylinders tend to run lean, but the air capacity decreases at a faster rate than the improvement in fuel-air mixture distribution. But when the mixture is very lean, there is not enough excess fuel in the manifold to take care of the difference in fuel-air ratios amoung the cylinders, that distribution plays an important role. Increasing the ΔT in the heat control valve will heat and speed up the vaporization of the fuel particles, consequently improving distribution and the BMEP.

When the engine is speeded up and the throttle fully opened, (Fig. 2), velocities in the manifold increase and distribution improves that less heat in proportion to the fuel that comes in is necessary, that increasing the ΔT increases the BSFC. This is true in Stoichemetric fuel-air ratios and higher. In this case the improvement in distribution is slower than the rate of decrease of the air capacity. This is more clearly shown by comparing Figs. 1 & 3 or 2 & 4. The increase of BSFC in proportion to ΔT is faster than that of the ISFC because of the drop in air capacity and consequently the mechanical efficiency.

But again, for fuel-air ratios less than stoichemetric, distribution is a more important factor because of the absence of excess fuel. Here the BSFC and ISFC continues to improve as the ΔT is increased.

(B) The effect of inlet mixture preheating on Brake and Indicated Mean Effective Pressure using gasoline as fuel:

Figs. 6,7,8, & 9 show the effect of increasing ΔT on brake and indicated mean effective pressure. Except for fuel-air ratios less than stoichemetric, mean effective pressure decreases as the ΔT is increased due to the reduced air capacity. With very lean fuel-air ratios, some cylinders tend to misfire thereby reducing engine power, that inspite of the reduced air capacity due to the preheating inlet mixture, the mean effective pressure remains somewhat constant. In this case the improvement in distribution is somewhat proportional to the decrease in air capacity.

(C) The effect of fuel-air ratio on specific Fuel Consumption using gasoline as fuel.

On Figs. 11 & 12 two lines are plotted for BSFC and ISFC. One line is for either BSFC or ISFC with the heat control valve closed and the other with the heat control valve open.

As can be expected, the point of minimum BSFC with the heat control closed occurs at a lower fuel-air ratio than when the heat control is open. This is explained by the fact that there is better distribution of fuel with high inlet manifold temperatures, that a leaner mixture can be used. The value of the BSFC or ISFC with the heat control valve closed, at their minimum point is not the minimum BSFC or ISFC of the runs because of the reduced air capacity which reduces power.

Part II

(A) The effect of preheating the inlet mixture on Brake and Indicated Specific Fuel Consumption using 95% pure Ethyl Alcohol as fuel:

Figs. 13 to 16 inclusive, show the effect of preheating the inlet mixture on the BSFC and ISFC when alcohol is used as fuel. Because of the high latent heat of vaporization of alcohol, increasing the ΔT across the heat control valve, decreases both the brake and indicated specific fuel consumption. Increasing the ΔT improves the distribution to such an extent that even though the air capacity is reduced slightly, the power increases. Figs. 13 & 15 show that at low fuel-air ratios and at low manifold pressures (part throttle), the BSFC & ISFC will reach a minimum point at a ΔT of approximately 120^{o}F and will increase slightly as the ΔT is increased futher. This is due to the fact that at low fuel-air ratios, the amount of heat transferred from the exhaust gases to the inlet mixture is just about right for good distribution but not too excessive as to reduce the air capacity.

When speed is kept constant but manifold pressure is increased, i.e. throttle fully opened, the minimum BSFC and ISFC occurs at the same value of ΔT, but in this case this value of ΔT is the maximum and when the ΔT is decreased there is a faster rate of rise of BSFC and ISFC in proportion to the rate of decrease of the ΔT, than w when manifold pressure was low. This is probably due to the fact that more fuel has to be heated and the time element involved is not sufficient to heat up the mixture as much as it did when the manifold pressure was low.

(B) The effect of preheating the inlet mixture on Brake and Indicated Mean Effective pressure, using 95% pure Ethyl Alcohol as fuel:

Again, for part throttle runs, the rate of increase of both BMEP and IMEP as the ΔT is increased is slower than the rate of increase of the BMEP and IMEP of the full throttle runs. Figs 17 to 28 inclusive, show these relationships. From these graphs it can be noted that when manifold pressure is kept constant, points of maximum BMEP or IMEP occur at a lower ΔT when the speed is increased. As engine speed increases, the velocity of the gases in the manifold also increase and improves distribution that less preheating is necessary for satisfactory distribution of fuel among the cylinders. The lower ΔTs obtained in high speed runs are due to the fact that there is less time for heat transfer from the exhaust gases to the inlet mixture at high speeds than for low speeds.

(C) The effect of preheating the inlet mixture on volumetric efficiency:

Figs. 29 to 34 inclusive show the effects of increasing the ΔT on the volumetric efficiency. As can be expected, the volumetric efficiency or air capacity drops as the ΔT increases, but the drop is less when alcohol is used as fuel instead of gasoline. The high latent heat of vaporization of alcohol accounts for this because it prevents a great rise in the temperature of the inlet mixture. In other words, the charge density may even increase due to the cooling down of the mixture as it vaporizes with the addition of heat.

(D) The effect of piston speed on Mean Effective Pressure using 95% pure Ethyl Alcohol as fuel:

Fig. 35 shows the variation of BMEP and IMEP with piston speed keeping the fuel-air ration and manifold pressure constant at 8.35 psia. Both BMEP and IMEP have their peak at approximately the same speeds and they are always higher with the heat control valve fully open (no exhaust gas recirculated).

For full throttle runs (Fig. 36) the peak of the BMEP an IMEP occurs at a lower piston speed because of the decrease of volumetric efficiency as the speed goes up (Fig. 39). With the heat control open the drop in both BMEP and IMEP is less as the speed goes up because of the higher charge density and volumetric efficiency, although their values are lower to start with.

(E) The effect of speed on Specific Fuel Consumption:

Minimum BSFC and ISFC occurs at about the same speed for low manifold pressure and at F/Fc of 1.1. Running at this particular fuel-air ratio it can be noticed on Fig. 37 that the curves for BSFC and ISFC with the heat control valve fully open and fullly closed overlap at very low speeds. This is due to the fact that at low speeds and at low manifold pressures there is sufficient time for the fuel-air mixture to vaporize even though the heat control valve is open.

valve is open. Run No. 90, Table III shows that even though the heat control valve is open, there is a Δ T of 59°F which means that some of the exhaust gas leak through the heat control valve and preheat the incoming fuel-air mixture. This amount of heat leakage is sufficient at this speed and fuel-air ratio to vaporize enough of the fuel to insure good distribution.

As the speed is increased to 1260 ft/min., there is less time for heat transfer from the exhaust gases to the incoming mixture that even though the heat control valve is fully closed, not enough heat is available that the difference between BSFC or ISFC with the heat control valve fully open and fully closed is again slight.

For full throttle runs (Fig. 38) the picture is similar except that the low speed in which the BSFC or ISFC curves with heat the control valve fully open moves towards the BSFC or ISFC curves with the heat control valve fully closed, is not reached. But at high speeds it is clearly shown in Fig. 38 that the curves start to move towards each other, again because of the limited time available for heat transfer between the exhaust gases and the inlet mixture.

(F) The effect of fuel-air ratio on Mean Effective Pressure:

For part throttle runs, (Fig. 40) the mean effective pressure increases only very slightly with increasing fuel-air ratio once stoichemetric fuel-air ratio is reached unlike the mean effective pressure using gasoline. This is explained by the fact that alcohol being a single compound vaporizes at a single temperature, and any increase of alcohol in proportion to air does improve the distribution of the fuel among the cylinders.

The picture is similar for full throttle runs, (Fig. 41), although the peak is at a higher fuel-air ratio. By comparing Fig. 41 and Fig. 10, it can be seen that the peak of the mean effective pressure occurs at about 1.175 F/Fc for alcohol while for gasoline it occurs at 1.3 F/Fc, also because of alcohol being a single compound, consequently a single vaporization temperature.

(G) The Effect of fuel-air ration on Specific Fuel Consumption using 95% pure Ethyl Alcohol as fuel:

Regardless of engine speed, minimum BSFC occurs in the vicinity of .975 F/Fc, and minimum ISFC at .95F/Fc. By comparing Figs. 42, 43, 11, and 12, one will notice that the minimum specific fuel consumption for alcohol occurs at a lower F/Fc than for gasoline because the mean effective pressure, when alcohol is used as fuel, does not rise appreciably when the fuel-air mixture is enriched.

For both part throttle and full throttle runs using alcohol (Figs. 42 & 43) the minimum BSFC and ISFC with the heat control closed (max. heat) is at a slightly lower F/Fc than when the heat control valve is fully open (min. heat) because of improved distribution of fuel when a greater part of it is vaporized.

The reason for the minimum ISFC occuring at a slightly lower F/Fc than that of the minimum BSFC is that at F/Fc lower than stoichemetric the brake mean effective pressure drops sharply that the mechanical efficiency decreases faster than the decrease in fuel consumption.

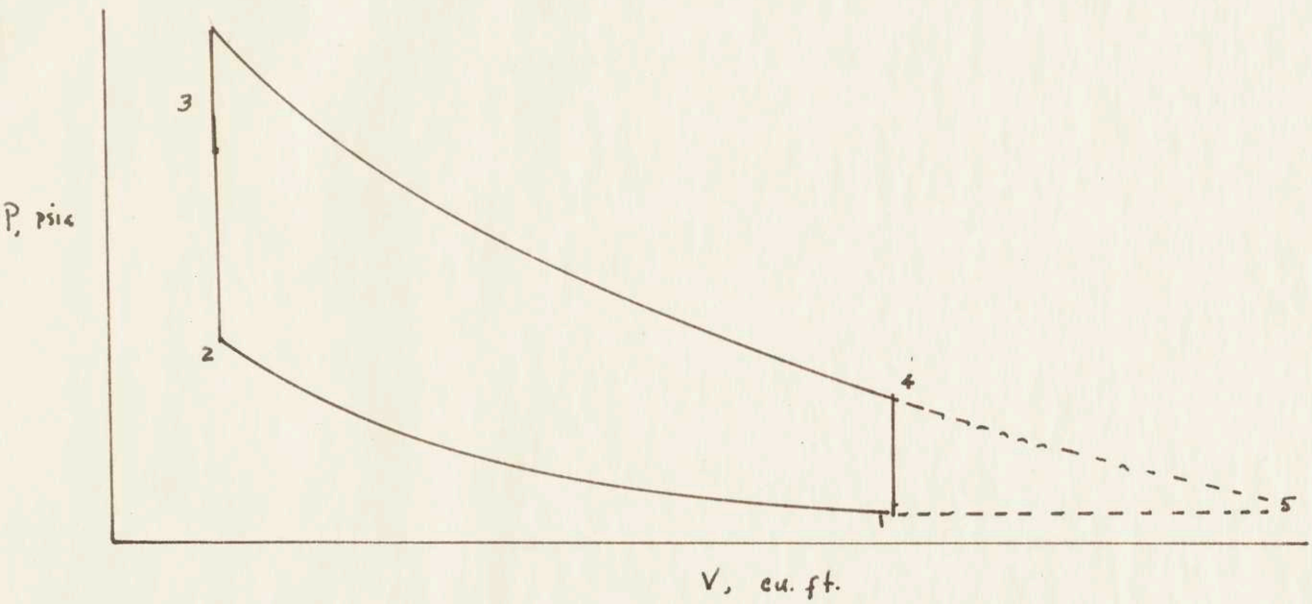
Throughout the range of fuel-air ratios, the specific fuel consumption for alcohol with the heat control closed is always lower than the ones with the heat control open. This is opposite to the results that are obtained when gasoline is used.

ANALYSIS OF RESULTS

Theoretical Fuel-Air Constant Volume Cycle using Gasoline:

$r = 7.25$, $P_1 = (14.7) - (1.5 \times .491)$
$= 14.7 - .73 = 13.97$

$f = .03$ (assumed)
$T_1 = 600^{o}R$ (assumed)
$P_{ex} = 14.7$ psia
$F/A = .06775$
$F/F_c = 1.0$



Pt. (1) $P_1 = 13.97$, $T_1 = 600^{o}R$

$V_1 = 16$ cu. ft. $E_1 = 16$

Process (1) ---------(2) (Compression)

$$\frac{V_1}{V_2} = 7.25, \quad V_2 = \frac{16}{7.25} = 2.2 \text{ cu. ft.}$$

At $V_2 = 2.2$ cu. ft.,

$P_2 = 205$ $T_2 = 1175$, $E_2 = 142$

Process (2)--------------(3) (Combustion)

$$E_3 = E_2 + E \text{ comb.}$$
$$= 142 + 1280 (1 - .03)$$
$$= 142 + 1280 (.97)$$
$$= 1382 \text{ B. t. u.}$$

At $E_3 = 1382$, & $V_3 = 2.2$, cu. ft.
$T_3 = 5060^{o}R$ $P_3 = 950$ psia

Process (3)--------------(4) (Expansion)

$V_4 = V_1 = 16$ cu. ft.
$T_4 = 3450^{o}R$ $P_4 = 89$ psia $E_4 = 747$

Pt. (5)

$T_5 = 2400^{o}R$ $V_5 = 66$ cu. ft. $E_5 = 442$

$$\frac{W}{J} = (E_3 - E_4) - (E_2 - E_1)$$
$$= (1382 - 747) - (142 - 16)$$
$$= 635 - 126$$
$$= 509 \text{ B.t.u.}$$

$$IMEP = \frac{W}{V_1 - V_2} = \frac{509 \times 778}{144 (16-2.2)}$$
$$= 5.4 \frac{509}{13.8}$$
$$= 199 \text{ psia}$$

$$N f/a = \frac{W}{(1-f)(E \text{ Comb})} = \frac{509}{.97 \times 1280}$$
$$= \frac{509}{1240} = .41 \text{ or } 41\%$$

Actual Indicated Thermal Efficiency, Ni:

$r = 7.25$, $F/Fc = 1.0$, RPM $= 2400$
$P_1 = 13.97$ psia, $T = 600^{o}R$ (estimated, with $\Delta T = 0$)

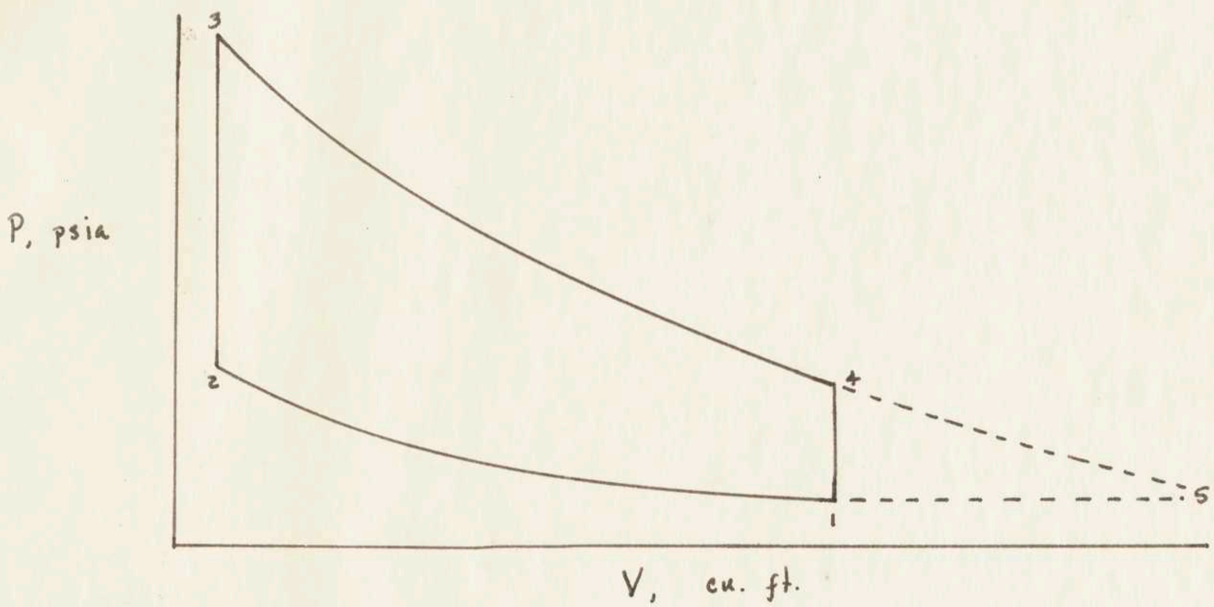
$$Ni = \frac{2545}{ISFC \times E_c} = \frac{2545}{.427 \times 19{,}000}$$
$$= \frac{2545}{8{,}100} = .314 \text{ or } 31.4\%$$

Ratio of Actual Indicated Thermal Efficiency t Theoretical Fuel-Air Cycle Efficiency, Nr:

$$Nr = \frac{.314}{.41} = .765 \text{ or } 76.5\%$$

Theoretical Fuel-Air Constant Volume Cycle using 95% Pure Ethyl Alcohol as fuel:

$r = 12$, $P_1 = 13.97$
$f = .02$ (assumed)
$T_1 = 600^oR$ (assumed
$P_{ex} = 14.7$ psia
$F/A = .1114$
$F/F_c = 1.0$



Pt. (1) $P_1 = 13.97$, $T_1 = 600^oR$
$V_1 = 17$ cu. ft. $E_1 = 52$

Process (1)------(2) (Compression)

$$\frac{V_1}{V_2} = 12, \quad V_2 = \frac{17}{12} = 1.415 \text{ cu. ft.}$$

At $V_2 = 1.415$ cu. ft.
$P_2 = 365$ psia $T_2 = 1280^oR$ $E_2 = 212$

Process (2)-----------(3) (Combustion)

$$E_3 = E_2 + E_{comb}$$
$$= 212 + 1288\ (1 - f)$$
$$= 212 + 1288\ (.98)$$
$$= 212 + 1260$$
$$= 1472$$

At $E_3 = 1472$ & $V_3 = 1.415$ cu. ft.
$T_3 = 5060^oR$ $P_3 = 1550$ psia

Process (3)----------(4)
$V_4 = V_1 = 17$ cu. ft.
$T_4 = 2810$ $P_4 = 70$ $E_4 = 630$

Pt. (5)
$T_5 = 2000^oR$, $V_5 = 57$ cu. ft. $E_5 = 370$

$$\frac{W}{J} = (E_3 - E_4) - (E_2 - E_1)$$
$$= (1472 - 630) - (212 - 52)$$
$$= 842 - 160$$
$$= 682 \text{ B.t.u.}$$

$$IMEP = \frac{W}{V_1 - V_2} = \frac{682 \times 778}{144\ (17-1.415)}$$

$$= 5.4\ \frac{682}{15.585}$$

$$= 236 \text{ psi}$$

$$Nf/a = \frac{W}{(1-f)\ (E\ comb)} = \frac{682}{.98\ (1288)}$$

$$= \frac{682}{1260} = .54 \text{ or } 54\%$$

Actual Indicated Thermal Efficiency, Ni:
r = 12, F/Fc = 1.0, RPM = 2400
$P_1 = 13.97$ psia, $T_1 = 600^o$ (estimated, with max ΔT)

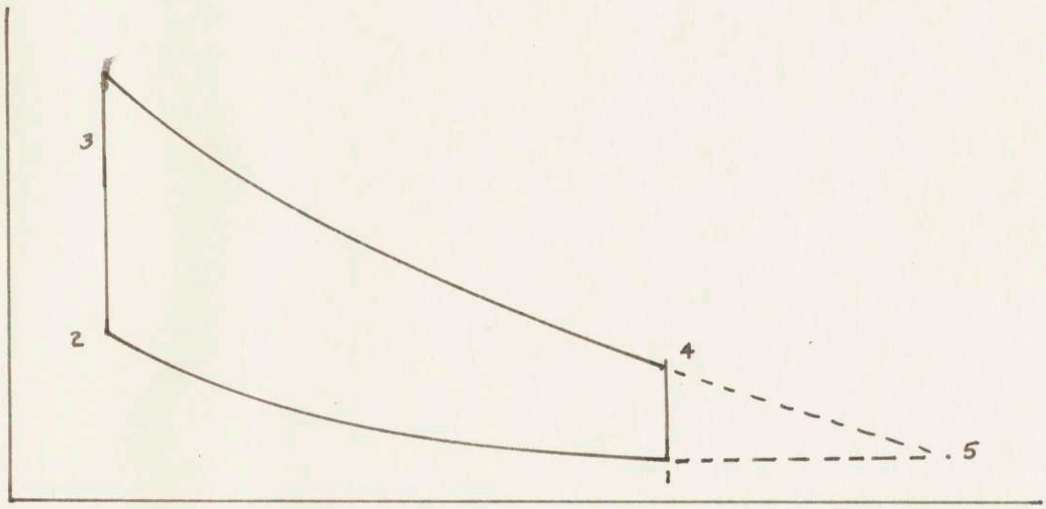
$$Ni = \frac{2545}{ISFC \times Ec} = \frac{2545}{.637 \times 11{,}600}$$

$$= \frac{2545}{7380} = .345 \text{ or } 34.5\%$$

$$Nr = \frac{.345}{.54} = .64 \text{ or } 64\%$$

Theorectical Fuel-Air Constant Volume Cycle using Gasoline

$r = 7.25$, $P_1 = 8.35$ psia
$f = .06$ (ass) $T_1 = 600^oR$ (assumed)
Pex = 14.7 psia
F/A = .06775
F/Fc = 1.0



P Pt. (1) $P_1 = 8.35$ psia $T_1 = 600^oR$
$V_1 = 26$ cu. ft. $E_1 = 16$

Process (1)----------(2) (Compression)

$$\frac{V_1}{V_2} = 7.25, \quad V_2 = \frac{26}{7.25} = 3.58 \text{ cu.ft.}$$

At $V_2 = 3.58$ cu. ft.
$P_2 = 138$ psia $T_2 = 7190$ $E_2 = 142$
Process (2)---------(3) (Combustion)
$E_3 = E_2$ E comb
$= 142 + 1280 (1 - .06)$
$= 142 + 1280 (.94)$
$= 142 + 1200$
$= 1342$ B.t.u.

At $E_3 = 1342$, & $V_3 = 3.58$ cu. ft.
$T_3 = 4950^oR$ $P_3 = 570$

Process (3)------------(4)
$V_2 = V_1 = 26$ cu. ft.

T_4 = 3290°R P_4 = 45 psia E_4 = 695

Pt. (5)

T_5 = 2730°R V_5 = 68 cu. ft. E_5 = 510

$$\frac{W}{J} = (E_3 - E_4) - (E_2 - E_1)$$
$$= (1342 - 695) - (142 - 16)$$
$$= 647 - 126$$
$$= 521$$

$$IMEP = \frac{W}{V_1 - V_2} = \frac{521 \times 778}{144\,(26 - 3.58)}$$
$$= 5.4\ \frac{521}{22.42} = 125.5 \text{ psi}$$

$$Nf/a = \frac{W}{(1-f)(E\ comb)} = \frac{521}{(.94)(1280)}$$
$$= \frac{521}{1200} = .434 \text{ or } 43.4\%$$

Actual Indicated Thermal Efficiency, Ni:

r = 7.25, F/Fc = 1.0 RPM = 1800

P_1 = 8.35 psia T_1 = 600°R (estimated, with optimum Δ T)

$$Ni = \frac{2545}{ISFC \times E_c} = \frac{2545}{.492 \times 19{,}000} = \frac{2545}{9325}$$
$$= .2725 \text{ or } 27.25\%$$

$$Nr = \frac{.2725}{.434} = .629 \text{ or } 62.9\%$$

Theoretical Fuel-Air Constant Volume Cycle using 95% Pure Ethyl Alcohol as Fuel

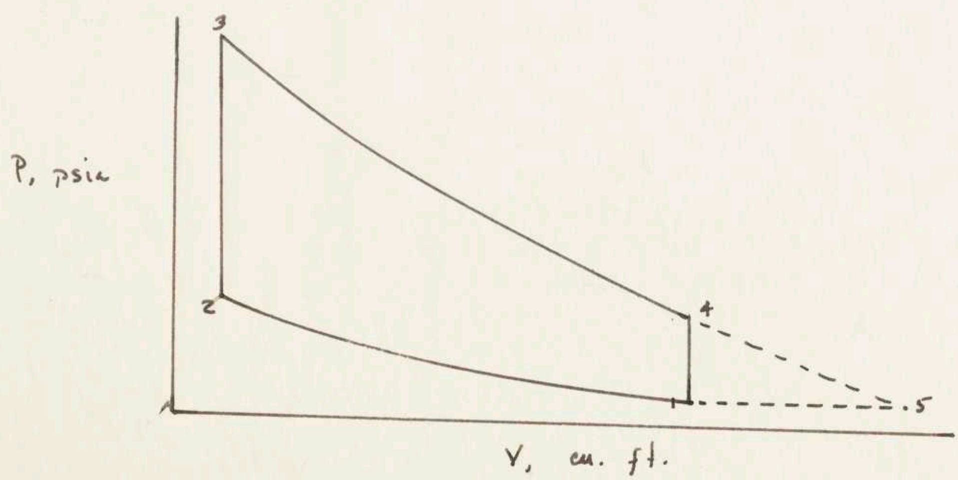
r = 12, P_1 = 8.35 psia

f = .04 (assumed) T_1 = 600°R (assumed)

Pex = 14.7 psia

F/A = .1114

F/Fc = 1.0



Pt. (1)
$P_1 = 8.35$ psia $T_1 = 600^{o}R$
$V_1 = 26$ cu. ft. $E_1 = 52$

Process (1)----------(2) (Compression)

$$\frac{V_1}{V_2} = 12, \qquad V_2 = \frac{36}{12} = 2.16 \text{ cu. ft.}$$

At $V_2 = 216$ cu. ft.
$P_2 = 250$ $T_2 = 1350^{o}R$ $E_2 = 235$

Process (2)----------(3) (Combustion)

$$\begin{aligned} E_3 &= E_2 + E \text{ comb} \\ &= 225 + 1288\ (1 - f) \\ &= 225 + 1288\ (.96) \\ &= 225 + 1235 \\ &= 1460 \text{ B.t.u.} \end{aligned}$$

At $E_3 = 1460$ & $V_3 = 2.16$ cu. ft.
$T_3 = 4980^{o}R$ $P_3 = 970$ psia

Process (3)------------(4) (Expansion)
$V_4 = V_1 = 26$ cu. ft.
$T_4 = 2880^{o}R$ $P_4 = 45$ $E_4 = 650$

Pt. (5)
$T_5 = 2220^{o}R$ $V_5 = 70$ cu. ft. $E_5 = 430$

$$\begin{aligned} \frac{W}{J} &= (E_3 - E_4) - (E_2 - E_1) \\ &= (1460 - 650) - (225 - 52) \\ &= 810 - 173 \\ &= 637 \text{ B.t.u.} \end{aligned}$$

$$\begin{aligned} IMEP &= \frac{W}{V_1 - V_2} = \frac{637 \times 778}{144\ (26 - 2.16)} \\ &= 5.4\ \frac{637}{144(26-2.16)} \\ &= 144.3 \text{ psi} \end{aligned}$$

$$\begin{aligned} Nf/a &= \frac{W}{(1-f)(E \text{ comb})} = \frac{637}{(.96)(1288)} \\ &= \frac{637}{1235} \\ &= .515 \text{ or } 51.5\% \end{aligned}$$

Actual Indicated Thermal Efficiency, Ni:
$r = 12$, $F/Fc = 1.0$, RPM = 1800
$P_1 = 8.35$ psia $T_1 = 600^{o}R$ (estimated, with optimum ΔT)

$$Ni = \frac{2545}{ISFC + E_2} = \frac{2545}{.735 \times 11{,}600}$$
$$= .2984 \text{ or } 29.84\%$$

$$Nr = \frac{.2984}{.515} = .58 \text{ or } 58\%$$

Decrease of Nr from full throttle @ 2400 RPM to part throttle at 1800 RPM

Using Gasoline:

$$\text{Decrease} = \frac{76.5 - 62.9}{76.5} = \frac{13.6}{76.5}$$
$$= .1775 \text{ or } 17.75\%$$

Using Alcohol:

$$\text{Decrease} = \frac{64-58}{64} = .0937 \text{ or } 9.37\%$$

Decrease in Max. BMEP from full throttle @ 2400RPM to part throttle @ 1800 RPM:

Using Gasoline: (using max. values, Tables I & II)

$$\text{Decrease} = \frac{112.2 - 44.75}{112.2} = \frac{67.45}{112.2} = .60 \text{ or } 60\%$$

Using Alcohol: (using max. values, Tables III & VII)

$$\text{Decrease} = \frac{123 - 59.25}{123} = \frac{63.75}{123} = .518 \text{ or } 51.8\%$$

Increase in Min. BSFC from full throttle @ 2400 RPM to part throttle @ 1800RPM:

Using Gasoline (using min. values, Tables I & II)

$$\text{Decrease} = \frac{.710 - .492}{.492} = \frac{.218}{.492} = .443 \text{ or } 44.3\%$$

Using Alcohol: (using min. values, Tables III & VII

$$\text{Increase} = \frac{.939 - .760}{.760} = \frac{.179}{.760} = .2355 \text{ or } 23.55\%$$

Theoretical increase in IMEP from r = 7.25 using gasoline to r = 12 using alcohol based on fuel-air cycle. (full throttle)

$$\text{Increase} = \frac{236 - 199}{199} = \frac{37}{199} = .186 \text{ or } 18.6\ \%$$

Actual increase (using max. values, Tables II & VII)

Actual Increase (using max. values, Tables II &VII)

$$= \frac{145.85 - 130}{130} = \frac{15.85}{130} = .122 \text{ or } 12.2\ \%$$

Theoretical Increase in thermal efficiency fro r = 7.25 using gasoline to r = 12 using alcohol based on fuel-air cycle. (Part Throttle)

$$\text{Increase} = \frac{.515 - .434}{.434} = \frac{.081}{.434} = .186 \text{ or } 18.6\%$$

$$\text{Actual Increase} = \frac{.2984 - .2725}{.2725} = \frac{.0259}{.2725} = .0952 \text{ or } 9.52\%$$

(a) Charles Kettering Study: (Ref. 1, Fig. 13)

Max. BMEP @ 2400 (High Compression Engine) = 127.5 psia or 12.5:1.
Max. BMEP @ 2400 (Stock Engine) = 102 psi (r = 6.4)

$$\text{Compression ratio factor} = \frac{12.5}{6.4} = 1.95$$

$$\text{Ratio of BMEP's} = \frac{127.5}{102} = 1.25$$

For compression ratio factor of 1.655,
ratio of BSMEP's = 1.655 $\frac{1.25}{1.95}$

= 1.06

(b) Max. BMEP @ 2400 (High Compression Engine using alcohol) = 123 psi (r = 12:1)
Max. BMEP @ 2400 (Stock Engine using gasoline) = 109.3 (r = 7.25:1)

$$\text{Compression ratio factor} = \frac{12}{7.25} = 1.655$$

$$\text{Ratio of BMEP's} = \frac{123}{109.3} = 1.126$$

CONCLUSIONS AND RECOMMENDATIONS

(1)

For a typical 4-cylinder four-stroke engine to run efficiently on ethyl alcohol, more inlet mixture preheating is necessary because of ethyl alcohol's high latent heat of vaporization.

At light throttle and piston speeds of 1000 ft/min or less, the exhaust gases provide enough heat for satisfactory vaporization of alcohol in the inlet manifold. But at full throttle or high manifold pressure and at piston speeds in excess of 1000 ft/min., the amount of heat transfer from the exhaust gases to the inlet mixture is insufficient because of the time element involved.

This warrants a more closely fitted heat riser system between the exhaust and inlet manifold to reduce leakage of the heat from the exhaust gases to the surroundings other than the inlet mixture.

Unfortunately no effort has been made to isolate the inlet manifold and preheat it by some other means and determine the heat requirements for optimum performance and economy at full throttle and high piston speeds or RPM.

(2)

The preceding analysis shows that a typical 4-cylinder four-stroke engine can be made to operate satisfactorily on ethyl alcohol with relatively minor modifications.

A study by Charles Kettering (Ref. 1) shows that when the compression ratio used approaches 12:1, the actual increase in thermal efficiency is less in proportion to the theoretical fuel-air cycle efficiency. The results obtained in this thesis are of similar form. The analysis shows that the ratio of the actual indicated thermal effeciency to the theoretical fuel-air cycle thermal efficiency is lower with alcohol at a 12:1 compression ratio than that of gasoline at a compression ratio of 7.25:1. But this drop in the ratio (Nr) is not due to the fact that the actual indicated thermal efficiencies of high compression spark ignition engines do not rise as fast as the theoretical fuel-air cycle thermal efficiency as compression ratio increases, for part of it is due to the less efficient fuel distribution when alcohol is used.

According to Charles Kettering's report (Ref. 1), "if the compression ratio of an engine 6.5:1 were raised to 10:1 or 12:1, little gain in power and efficiency should be expected due to the internal friction which is brought about by their lack of rigidity. Roughness, increased friction and other mechanical problems tend to counteract any gains from high compression ratios".

This thesis disproves that statement, for the results indicate that there is a substantial gain in power and economy when the compression ratio is raised by mere addition of a block of metal on the piston head. No appreciable roughness nor decrease in mechanical efficiency is encountered.

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TABLE - I

Series "A-1" Part Throttle, 1800 rpm (945 ft/min)

Fuel - Gasoline

	BHP	IHP	BMEP	IMEP	Nm	BSFC	ISFC	Nv	△ T	Run No.
=1.3	5.25	7.27	44.75	61.5	.727	.747	.543	.377	88	26
	5.12	7.04	43.65	60.0	.727	.766	.557	.377	156	27
	5.12	7.04	43.65	60.0	.727	.747	.543	.377	197	28
	4.97	6.99	42.40	59.6	.711	.782	.556	.373	213	29
	4.77	6.97	40.75	57.9	.704	.797	.561	.365	217	30
=1.2	5.05	7.07	43.10	60.3	.714	.711	.508	.373	131	31
	4.95	6.97	42.20	59.25	.711	.715	.509	.368	162	32
	4.87	6.89	41.50	58.70	.707	.721	.510	.365	208	33
	4.82	6.84	41.00	58.25	.705	.730	.513	.365	218	34
	4.71	6.73	40.20	57.40	.700	.727	.509	.356	223	35
=1.1	4.64	6.66	39.45	56.70	.696	.710	.495	.373	125	36
	4.58	6.60	39.10	56.25	.695	.719	.500	.373	173	37
	4.51	6.53	38.40	55.75	.690	.714	.493	.365	220	38
	4.44	6.46	37.80	55.10	.687	.725	.498	.365	232	39
	4.40	6.42	37.50	54.75	.685	.732	.501	.365	239	40
=1.0	4.04	6.06	34.40	51.60	.667	.742	.495	.374	106	41
	3.98	6.00	33.90	51.10	.664	.741	.492	.368	200	42
	3.87	5.89	33.00	50.20	.657	.755	.496	.365	220	43
	3.84	5.86	32.70	50.00	.655	.762	.500	.365	225	44
	3.87	5.89	33.00	50.20	.657	.755	.496	.365	236	45
=.9	3.39	5.41	28.90	46.20	.626	.795	.498	.374	102	46
	3.47	5.49	29.55	46.80	.632	.776	.490	.374	175	47
	3.47	5.49	29.55	46.80	.632	.765	.483	.368	222	48
	3.43	5.45	29.25	46.50	.629	.767	.483	.365	237	49
	3.43	5.45	29.25	46.50	.629	.767	.483	.365	255	50

BSFC min -- .710 @ 125°△T & 1.1 F/Fc.
BMEP max -- 44.75 @ 88°△T & 1.3 F/Fc.

TABLE - II

Series "E-1" Full Throttle 2400 rpm (1260 ft/min)

Fuel - Gasoline

	BHP	IHP	BMEP	IMEP	Nm	BSFC	ISFC	Nv	ΔT	Run No.
=1.3	17.52	20.03	112.2	130.0	.864	.598	.517	.755	0	1
	17.22	19.73	110.2	126.2	.872	.598	.522	.745	27	2
	16.85	19.36	107.8	123.8	.870	.605	.526	.736	64	3
	16.78	19.29	107.4	123.7	.869	.604	.525	.730	83	4
	16.50	19.01	106.7	122.5	.869	.630	.548	.726	93	5
=1.2	17.40	19.91	111.3	127.8	.873	.550	.481	.749	0	6
	17.08	19.59	109.3	125.5	.872	.5525	.483	.738	34	7
	16.78	19.29	107.3	123.5	.870	.5550	.484	.730	65	8
	16.60	19.11	106.2	122.4	.869	.5590	.486	.726	77	9
	16.52	19.03	105.9	121.8	.869	.5580	.485	.723	104	10
=1.1	17.08	19.59	109.3	125.5	.872	.510	.444	.743	0	11
	16.69	19.20	106.0	122.0	.870	.514	.447	.735	44	12
	16.33	18.84	104.7	120.6	.866	.520	.450	.726	72	13
	16.17	18.68	103.4	119.6	.865	.524	.454	.724	85	14
	15.98	18.49	102.3	118.3	.865	.526	.455	.720	104	15
=1.0	16.15	18.66	103.3	119.5	.865	.494	.427	.748	0	16
	15.80	18.31	101.1	117.1	.864	.492	.426	.736	26	17
	15.62	18.13	100.0	116.1	.862	.494	.425	.730	67	18
	15.25	17.76	97.6	113.5	.859	.504	.433	.727	79	19
	15.18	17.69	97.1	113.1	.858	.506	.435	.722	108	20
=.9	13.73	16.24	87.9	103.8	.847	.529	.448	.759	0	21
	13.63	16.14	87.2	103.5	.844	.526	.444	.752	44	22
	13.63	16.14	87.2	103.5	.844	.522	.440	.745	74	23
	13.47	15.98	86.1	102.2	.842	.522	.440	.736	81	24
	13.56	16.07	86.7	102.8	.844	.515	.435	.730	101	25

BSFC min -- .492 @ 26° Δ T & 1.0 F/Fc.
BMEP max -- 111.3 @ 0° Δ T & 1.3 F/Fc.

TABLE III

Series "A" Part Throttle, 1800 rpm (945 ft/min)

Fuel - Alcohol

	BHP	IHP	BMEP	IMEP	Nm	BSFC	ISFC	Nv	△T	Run No.
F/Fc = 1.3	6.59	9.15	56.40	78.25	.720	1.020	.735	.383	51	80
	6.80	9.36	58.10	79.95	.726	.980	.712	.383	88	81
	6.86	9.42	58.60	80.45	.729	.972	.708	.383	121	82
	6.86	9.42	58.60	80.45	.729	.972	.708	.383	139	83
	6.94	9.50	59.25	81.10	.730	.961	.702	.383	161	84
F/Fc=1.2	6.56	9.12	56.20	78.05	.720	.960	.690	.391	43	85
	6.59	9.15	56.40	78.25	.720	.950	.684	.388	89	86
	6.66	9.22	57.00	78.85	.7225	.939	.678	.388	116	87
	6.66	9.22	57.00	78.85	.7225	.939	.678	.388	143	88
	6.66	9.22	57.00	78.85	.7225	.939	.678	.388	156	89
F/Fc =1.1	6.00	8.56	51.20	73.05	.7000	.992	.695	.404	59	90
	5.81	8.37	49.60	71.45	.6950	.998	.695	.394	80	91
	5.81	8.37	49.60	71.45	.6950	.998	.695	.394	118	92
	5.81	8.37	49.60	71.45	.6950	.998	.694	.394	135	93
	5.92	8.48	50.60	72.45	.6980	.998	.696	.394	156	94
F/Fc =1.0	5.18	7.74	44.30	66.15	.6700	1.128	.755	.441	45	95
	5.31	7.87	45.45	67.30	.6750	1.090	.735	.437	85	96
	5.27	7.83	45.20	67.05	.6720	1.095	.735	.437	96	97
	5.25	7.81	44.80	66.65	.6720	1.100	.739	.437	119	98
	5.25	7.81	44.80	66.65	.6720	1.100	.739	.437	125	99
F/Fc =.9	2.69	5.25	23.00	44.85	.5130	1.965	1.000	.443	34	100
	2.69	5.25	23.00	44.85	.5130	1.945	.996	.439	80	101
	2.69	5.25	23.00	44.85	.5130	1.935	.992	.436	97	102
	2.825	5.385	24.20	46.05	.5250	1.840	.965	.436	118	103
	2.69	5.25	23.00	44.85	.5130	1.935	.992	.436	131	104

BSFC min ---.939 @ 116° △T & 1.2 F/Fc
BMEP max ---59.25 @ 161° △T & 1.3 F/Fc

Table - IV

Series "B" Part Throttle 2000 rpm (1050 ft/min)

Fuel - Alcohol

	BHP	IHP	BMEP	IMEP	Nm	BSFC	ISFC	Nv	△ T	Run No.
'c=1.3	7.75	10.68	59.50	82.15	.726	.981	.712	.399	74	145
	7.70	11.63	58.80	81.75	.724	.980	.710	.396	97	144
	7.66	10.59	58.90	81.35	.725	.975	.706	.392	118	143
	7.66	10.59	58.90	81.35	.725	.964	.697	.387	142	142
	7.55	10.48	58.10	80.55	.720	.958	.690	.379	164	141
c=1.2	7.63	10.56	58.60	81.15	.724	.9275	.671	.401	67	150
	7.66	10.59	58.90	81.45	.724	.9180	.665	.399	97	149
	7.63	10.56	58.60	81.15	.724	.914	.660	.395	118	148
	7.63	10.56	58.60	81.15	.724	.914	.660	.395	141	147
	7.63	10.56	58.60	81.15	.724	.914	.660	.395	157	146
c=1.1	7.36	10.29	56.50	79.05	.716	.882	.632	.401	.52	155
	7.48	10.41	57.50	80.05	.719	.8625	.620	.400	92	154
	7.44	10.37	57.20	79.65	.718	.8600	.6175	.395	115	153
	7.30	10.23	56.10	78.65	.7125	.8700	.6200	.392	145	152
	7.30	10.23	56.10	78.65	.7125	.8700	.6200	.392	178	151
=1.0	7.26	10.19	55.80	78.35	.713	.8100	.5780	.404	76	160
	7.21	10.14	55.40	77.95	.710	.8020	.5700	.398	109	159
	7.10	10.03	54.60	77.15	.707	.8100	.5725	.395	131	158
	7.10	10.03	54.60	77.15	.707	.8025	.5675	.392	154	157
	7.10	10.03	54.60	77.15	.707	.7960	.5640	.389	168	156
=.9	6.21	9.14	47.75	70.30	.680	.857	.5830	.407	71	165
	6.21	9.14	47.75	70.30	.680	.850	.5780	.404	99	164
	6.10	9.03	46.90	69.45	.675	.860	.5810	.401	120	163
	6.17	9.10	47.40	69.95	.678	.850	.5760	.401	143	162
	6.14	9.07	47.10	69.65	.6775	.855	.5790	.401	169	161

BSFC min -- .85 @ 110°△T & .9 F/Fc
BMEP max -- 59.5 @ 74°△T & 1.3 F/Fc

TABLE - V

Series "C" Part Throttle, 2400 rpm (1260 ft/min)

Fuel - Alcohol

	BHP	IHP	BMEP	IMEP	Nm	BSFC	ISFC	Nv	△T	Run No.
=1.3	8.76	12.30	56.10	78.75	.712	1.033	.7375	.400	56	172
	8.84	12.38	56.60	79.25	.714	1.025	.7330	.400	90	171
	8.84	12.38	56.60	79.25	.714	1.025	.7330	.400	104	170
	8.80	12.34	56.40	79.05	.713	1.020	.7280	.398	123	169
	8.62	12.16	55.20	77.85	.708	1.032	.7320	.394	146	168
=1.2	8.98	12.52	57.50	80.15	.717	.9425	.6760	.405	51	177
	8.89	12.43	56.90	79.55	.714	.9425	.6730	.400	70	176
	8.80	12.34	56.60	79.25	.713	.9510	.6780	.400	96	175
	8.80	12.34	56.60	79.25	.713	.9510	.6780	.400	122	174
	8.84	12.38	56.60	79.25	.713	.9480	.6775	.400	152	173
=1.1	8.84	12.38	56.60	79.25	.714	.8760	.625	.405	58	182
	8.84	12.38	56.60	79.25	.714	.8700	.621	.401	91	181
	8.80	12.34	56.40	79.08	.7125	.8660	.618	.398	114	180
	8.76	12.30	56.20	78.85	.7125	.8620	.614	.394	126	179
	8.70	12.24	55.80	78.45	.7100	.8680	.617	.394	156	178
=1.0	7.08	10.62	45.40	67.85	.667	1.018	.678	.413	51	187
	7.18	10.72	46.00	68.65	.669	.993	.665	.409	91	186
	8.16	11.70	52.30	74.95	.698	.851	.594	.398	116	185
	8.16	11.70	52.30	74.95	.698	.845	.590	.395	137	184
	8.16	11.70	52.30	74.95	.698	.839	.585	.393	158	183
=0.9	6.65	10.19	42.5	65.15	.653	.975	.636	.413	30	192
	6.55	10.09	42.0	64.65	.649	.9775	.634	.408	47	191
	6.10	9.64	39.1	61.75	.633	1.0420	.660	.405	115	190
	5.475	9.015	35.1	57.75	.607	1.145	.695	.400	136	189
	5.475	9.015	35.1	57.75	.607	1.145	.695	.400	152	188

BSFC min -- .839 @ 158° △T & 1.0 F/Fc.
BMEP max -- 57.5 @ 51° △T & 1.2 F/Fc.

TABLE - VI

Series "D" Full Throttle, 2000 rpm (1050 ft/min)

Fuel - Alcohol

	BHP	IHP	BMEP	IMEP	Nm	BSFC	ISFC	Nv	ΔT	Run No.
=1.3	15.85	18.76	122.0	144.45	.845	.982	.830	.806	25	118
	16.47	19.38	126.5	148.95	.850	.938	.796	.799	68	117
	16.76	19.67	129.0	151.45	.852	.919	.781	.795	79	116
	16.96	19.87	130.05	152.45	.854	.908	.775	.795	89	115
	17.05	19.96	131.2	153.65	.854	.900	.769	.794	101	114
=1.2	15.85	18.76	122.0	144.45	.845	.915	.774	.806	30	123
	16.46	19.37	126.5	148.95	.850	.8725	.741	.798	60	122
	16.70	19.61	128.5	150.95	.851	.860	.732	.798	81	121
	16.90	19.81	130.0	152.45	.8525	.843	.710	.782	96	120
	16.96	19.87	130.5	152.95	.853	.840	.716	.782	117	119
=1.1	15.10	18.01	115.8	138.25	.838	.885	.742	.810	30	128
	16.00	18.91	123.0	145.45	.846	.830	.702	.805	57	127
	16.22	19.13	125.0	147.45	.848	.813	.689	.800	74	126
	16.46	19.37	126.5	148.95	.849	.798	.677	.798	97	125
	16.60	19.51	127.7	150.15	.850	.792	.672	.798	132	124
=1.0	14.21	17.12	109.2	131.65	.830	.860	.714	.815	30	133
	15.10	18.01	116.0	138.45	.838	.803	.674	.808	51	132
	15.50	18.41	119.6	142.05	.841	.778	.655	.805	81	131
	15.60	18.51	120.0	142.45	.842	.770	.648	.800	105	130
	15.60	18.51	120.0	142.45	.842	.770	.648	.800	127	129
=.9	12.65	15.56	97.3	119.75	.814	.873	.710	.820	30	138
	13.24	16.15	101.8	124.25	.820	.830	.680	.815	49	137
	13.82	16.73	106.4	128.85	.825	.790	.652	.810	87	136
	13.90	16.81	107.0	129.45	.827	.785	.650	.808	97	135
	14.18	17.09	109.0	131.45	.830	.770	.639	.808	119	134

BSFC min -- .765 @ 115° ΔT & 1.0 F/Fc
BMEP max -- 131 @ 100° ΔT & 1.25 F/Fc

TABLE - VII

Series "E" Full Throttle 2400 rpm (1260 ft/min)

Fuel - Alcohol

	BHP	IHP	BMEP	IMEP	Nm	BSFC	ISFC	Nv	△T	Run No.
=1.3	17.77	21.18	114.0	136.85	.840	1.017	.853	.776	9	55
	18.40	21.81	118.0	140.85	.844	.964	.813	.761	48	56
	19.05	22.46	122.0	144.85	.848	.928	.786	.760	70	57
	19.22	22.63	123.0	145.85	.847	.916	.776	.756	76	58
	19.22	22.63	123.0	145.85	.847	.916	.776	.756	80	59
=1.2	17.70	21.11	113.1	135.95	.839	.941	.790	.774	4	60
	18.50	21.91	118.5	141.35	.845	.890	.752	.766	39	61
	18.90	22.31	121.0	143.85	.848	.866	.735	.751	61	62
	19.10	22.51	122.5	145.35	.848	.854	.725	.758	86	63
	19.10	22.51	122.5	145.35	.848	.854	.725	.758	100	64
=1.1	16.60	20.01	106.5	129.35	.829	.905	.750	.773	0	65
	17.78	21.19	114.0	136.85	.839	.835	.700	.765	37	66
	18.20	21.61	116.8	139.65	.841	.828	.696	.778	45	67
	18.50	21.91	118.5	141.35	.845	.814	.689	.775	67	68
	18.50	21.91	118.5	141.35	.845	.811	.687	.774	93	69
=1.0	15.90	19.31	101.6	124.45	.822	.865	.712	.778	0	70
	16.90	20.31	108.3	131.15	.832	.807	.671	.773	29	71
	17.40	20.81	111.5	134.35	.834	.778	.650	.765	37	72
	17.70	21.11	113.2	136.05	.839	.762	.640	.763	79	73
	17.70	21.11	113.2	136.05	.839	.760	.637	.761	101	74
=0.9	13.00	16.41	83.5	106.35	.792	.962	.762	.787	12	75
	15.00	18.41	96.0	118.35	.815	.826	.673	.780	41	76
	15.15	18.56	97.2	120.05	.816	.812	.664	.773	60	77
	15.35	18.76	98.4	121.25	.819	.802	.656	.773	75	78
	15.35	18.91	99.5	122.35	.820	.792	.650	.773	89	79

BSFC min -- .760 @ 101°△T & 1.0 F/Fc.
BMEP max -- 123.0 @ 80°△T & 1.25 F/Fc.

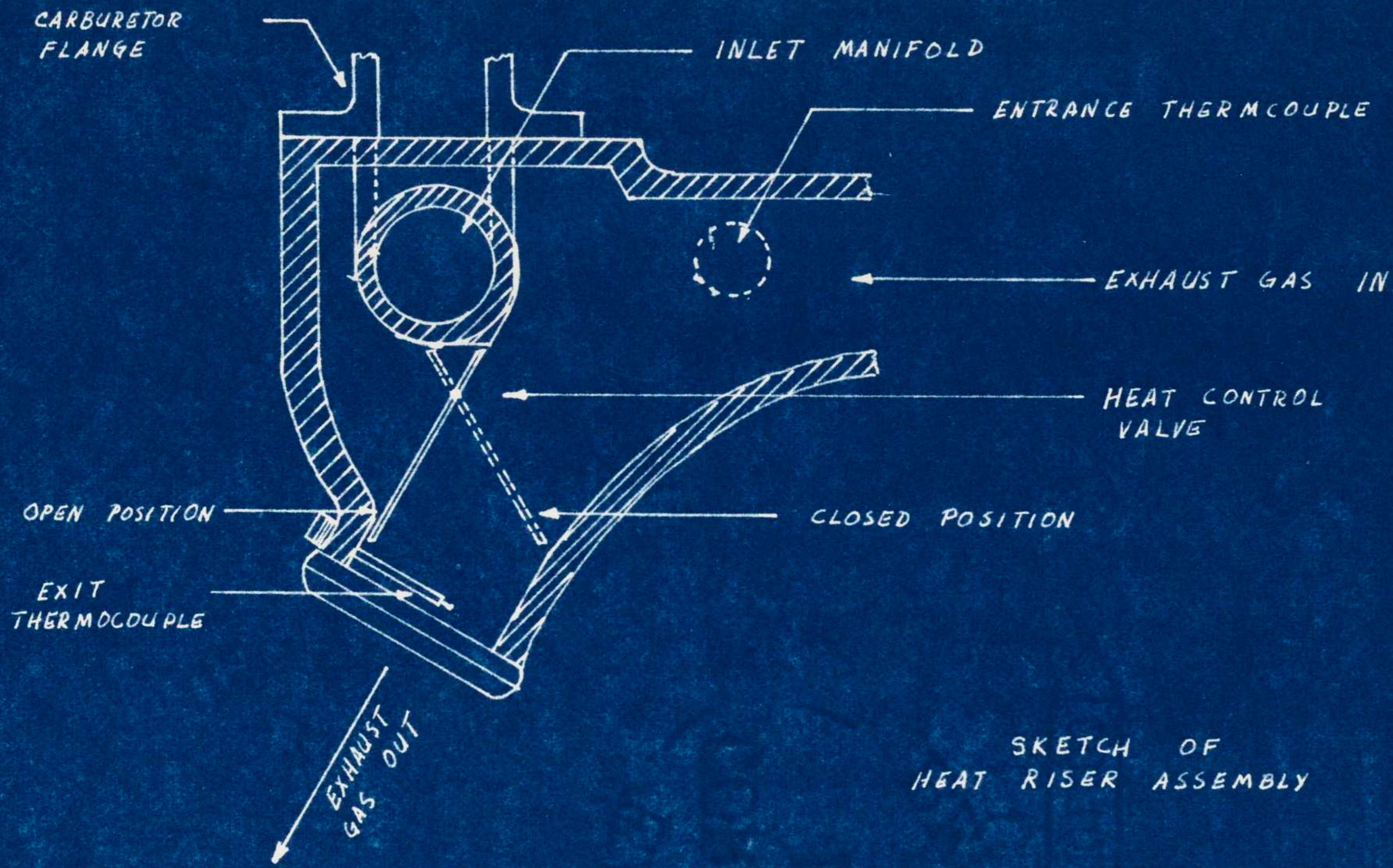
TABLE - VIII

Series "F" Full Throttle 2800 rpm (1470 ft/min)

Fuel - Alcohol

	BHP	IHP	BMEP	IMEP	Nm	BSFC	ISFC	Nv	$\triangle$ T	Run No.
=1.3	19.32	23.64	112.1	139.3	.815	1.01	.823	.727	0	199
	19.95	24.27	109.2	133.3	.821	.975	.800	.724	38	198
	20.35	24.67	111.5	135.6	.824	.949	.781	.718	47	197
	20.50	24.82	112.1	136.2	.825	.940	.775	.717	79	196
	20.60	24.92	112.5	136.6	.826	.934	.772	.715	96	195
=1.2	19.75	24.07	108.0	132.1	.820	.916	.751	.728	13	204
	20.05	24.37	110.0	134.1	.826	.898	.742	.723	35	203
	20.35	24.67	111.5	135.6	.824	.880	.725	.720	53	202
	20.60	24.92	112.5	136.6	.826	.867	.716	.718	72	201
	20.60	24.92	112.5	136.6	.828	.867	.716	.716	89	200
=1.1	19.10	23.42	104.6	128.7	.815	.875	.714	.734	0	209
	19.65	23.97	107.5	131.6	.820	.844	.691	.727	38	208
	20.07	24.39	110.0	134.1	.825	.821	.677	.723	60	207
	20.25	24.57	111.0	135.1	.826	.811	.670	.722	92	206
	20.32	24.64	111.3	135.4	.823	.808	.665	.720	105	205
=1.0	18.25	22.57	100.0	124.1	.810	.835	.676	.734	11	214
	18.83	23.15	103.0	127.1	.814	.804	.655	.731	39	213
	19.10	23.42	104.6	128.7	.815	.790	.634	.728	62	212
	19.32	23.64	106.6	130.9	.816	.776	.634	.725	74	211
	19.32	23.64	106.8	130.9	.816	.776	.634	.725	91	210

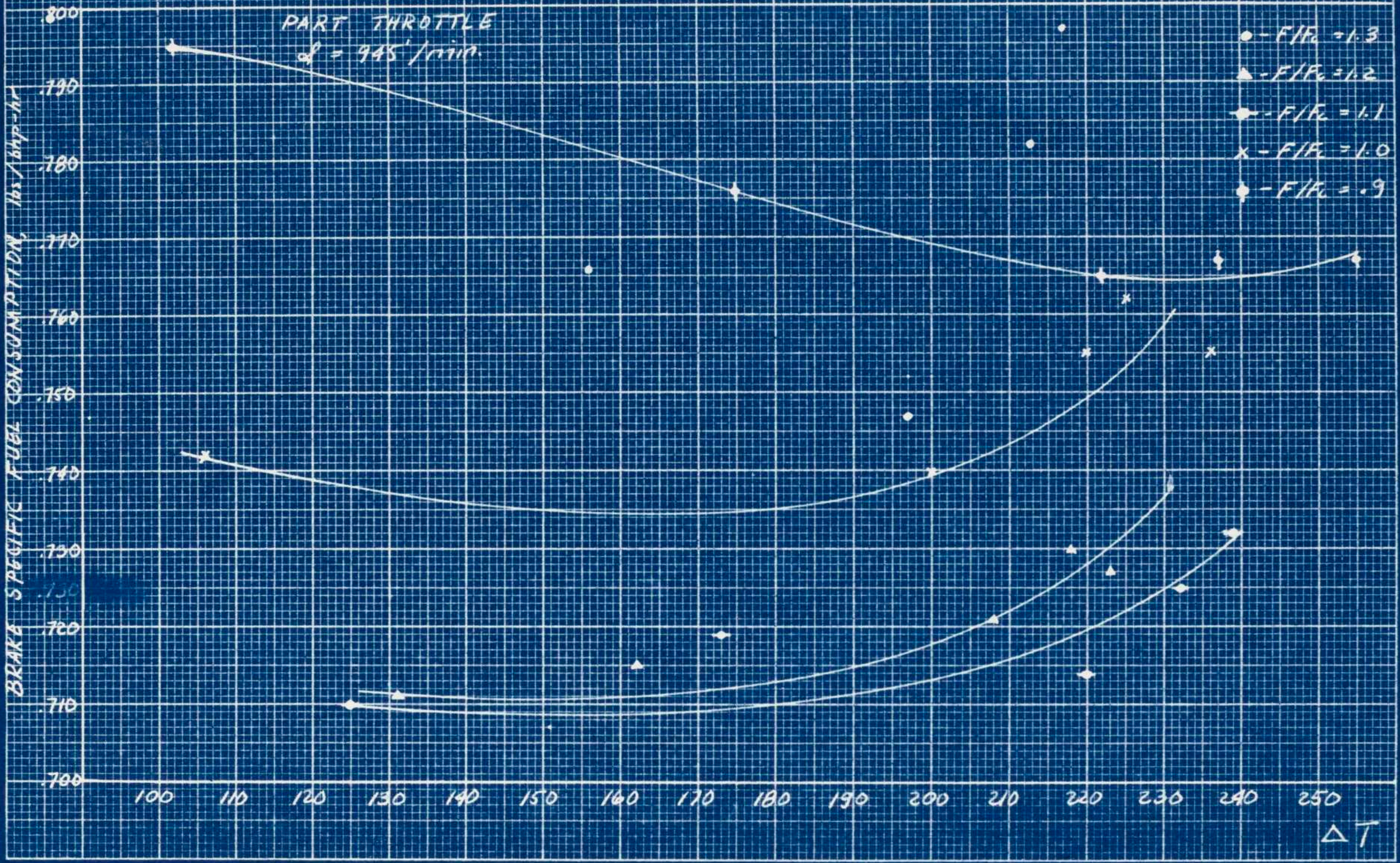
BSFC min -- .776 @ 74° $\triangle$T & 1.0 F/Fc
BMEP max -- 112.5 @ 72° $\triangle$T & 1.2 F/Fc



SKETCH OF
HEAT RISER ASSEMBLY

FIG. -O-

FIG. 1


PART THROTTLE
ℓ = 945'/min.
● - F/Fc = 1.3
▲ - F/Fc = 1.2
- F/Fc = 1.1
x - F/Fc = 1.0
- F/Fc = .9
BRAKE SPECIFIC FUEL CONSUMPTION, lbs/bhp-hr
.800
.790
.780
.770
.760
.750
.740
.730
.720
.710
.700
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
ΔT

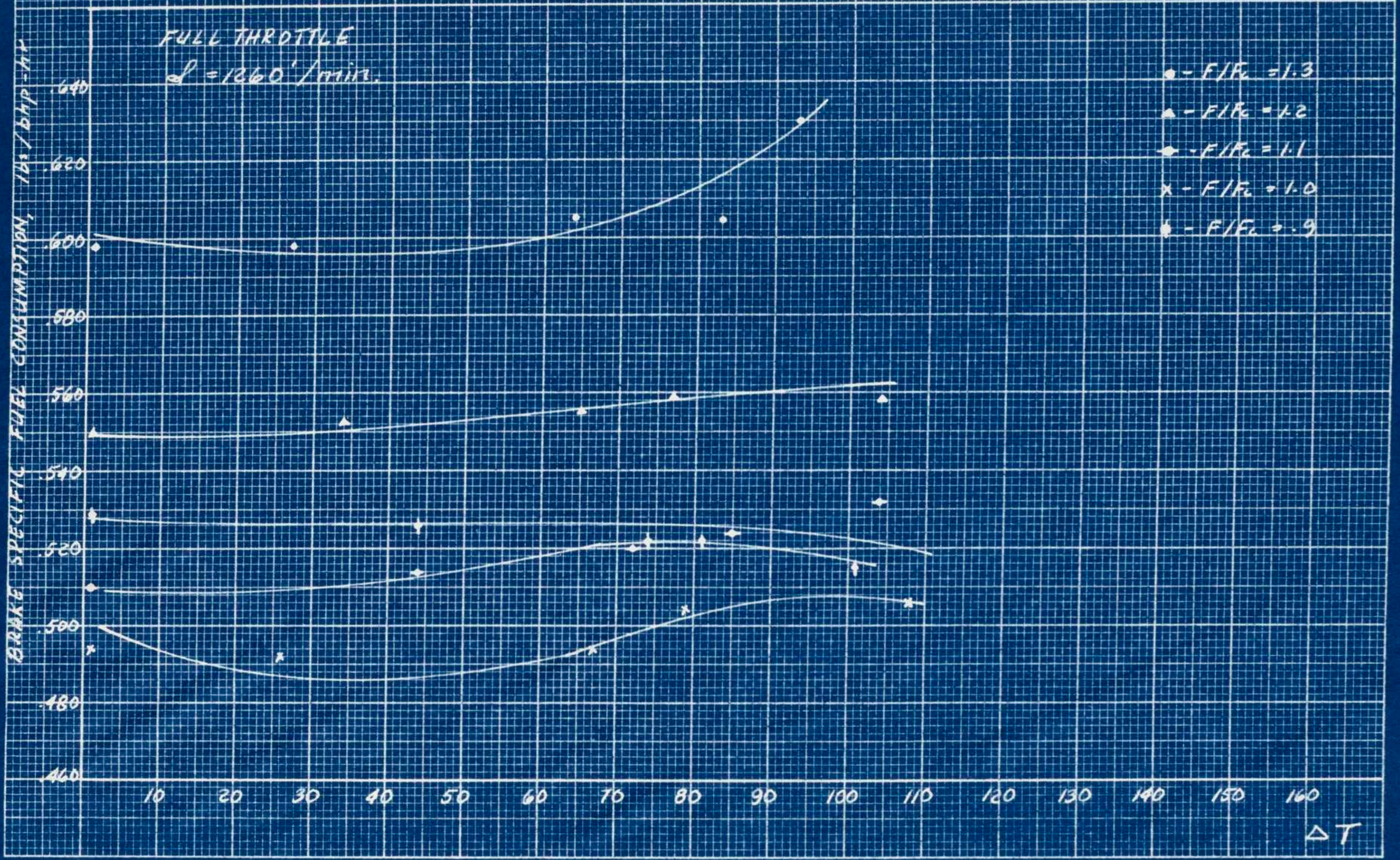

FULL THROTTLE
$\mathcal{S}$ = 1260'/min.
BRAKE SPECIFIC FUEL CONSUMPTION, lbs/bhp-hr
.640
.620
.600
.580
.560
.540
.520
.500
.480
.460
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
● - F/Fc = 1.3
▲ - F/Fc = 1.2
◆ - F/Fc = 1.1
✕ - F/Fc = 1.0
⧫ - F/Fc = .9

FIG. 2

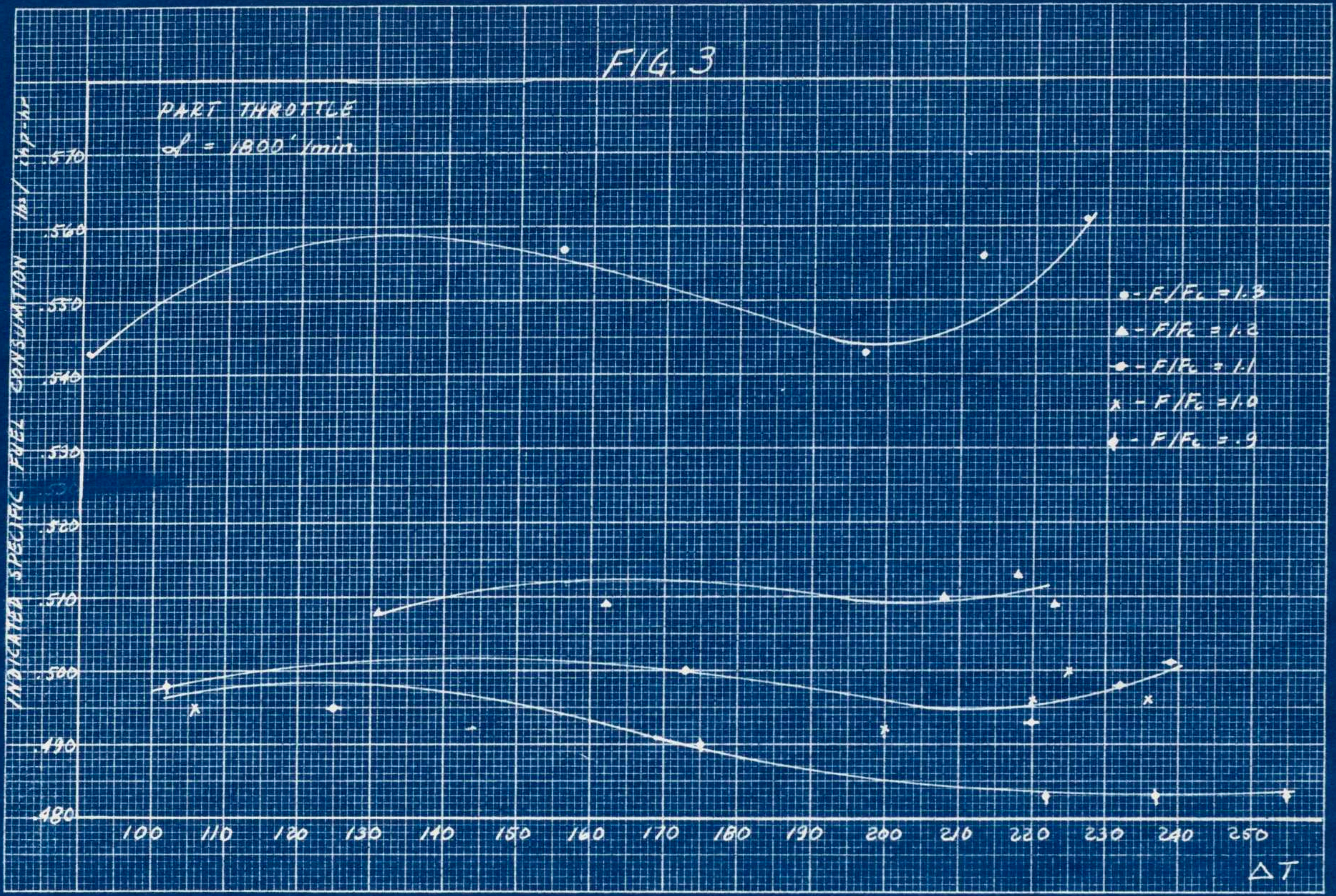


FIG. 3
PART THROTTLE
$\mathcal{L}$ = 1800'/min
INDICATED SPECIFIC FUEL CONSUMPTION lbs / ihp-hr
.570
.560
.550
.540
.530
.520
.510
.500
.490
.480
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
ΔT
● - F/Fc = 1.3
▲ - F/Fc = 1.2
● - F/Fc = 1.1
x - F/Fc = 1.0
♦ - F/Fc = .9

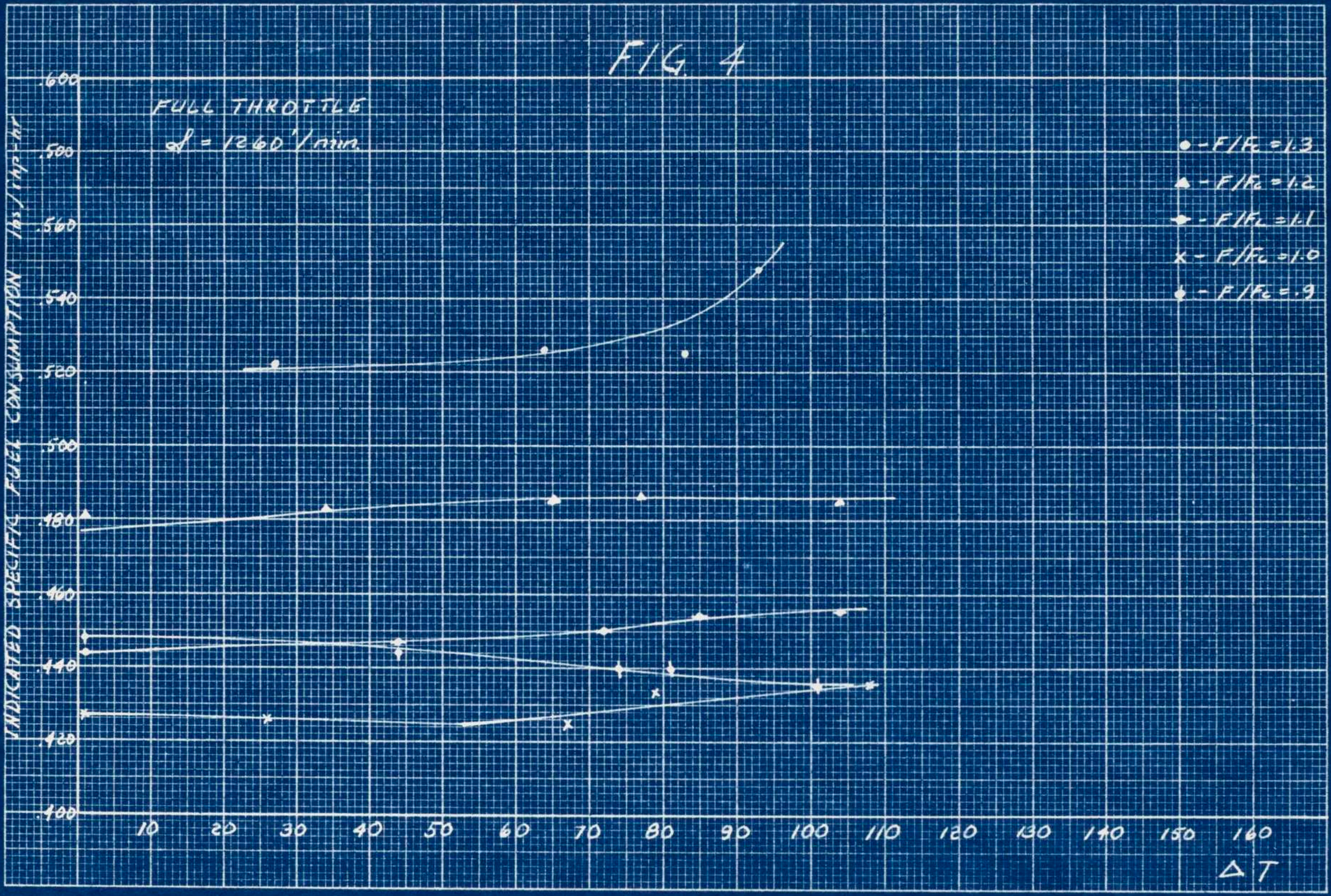


FIG. 4
FULL THROTTLE
$\mathcal{S}$ = 1260'/min.
• - F/Fc = 1.3
▲ - F/Fc = 1.2
◆ - F/Fc = 1.1
x - F/Fc = 1.0
♦ - F/Fc = .9
INDICATED SPECIFIC FUEL CONSUMPTION lbs/ihp-hr
.600
.580
.560
.540
.520
.500
.480
.460
.440
.420
.400
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
ΔT

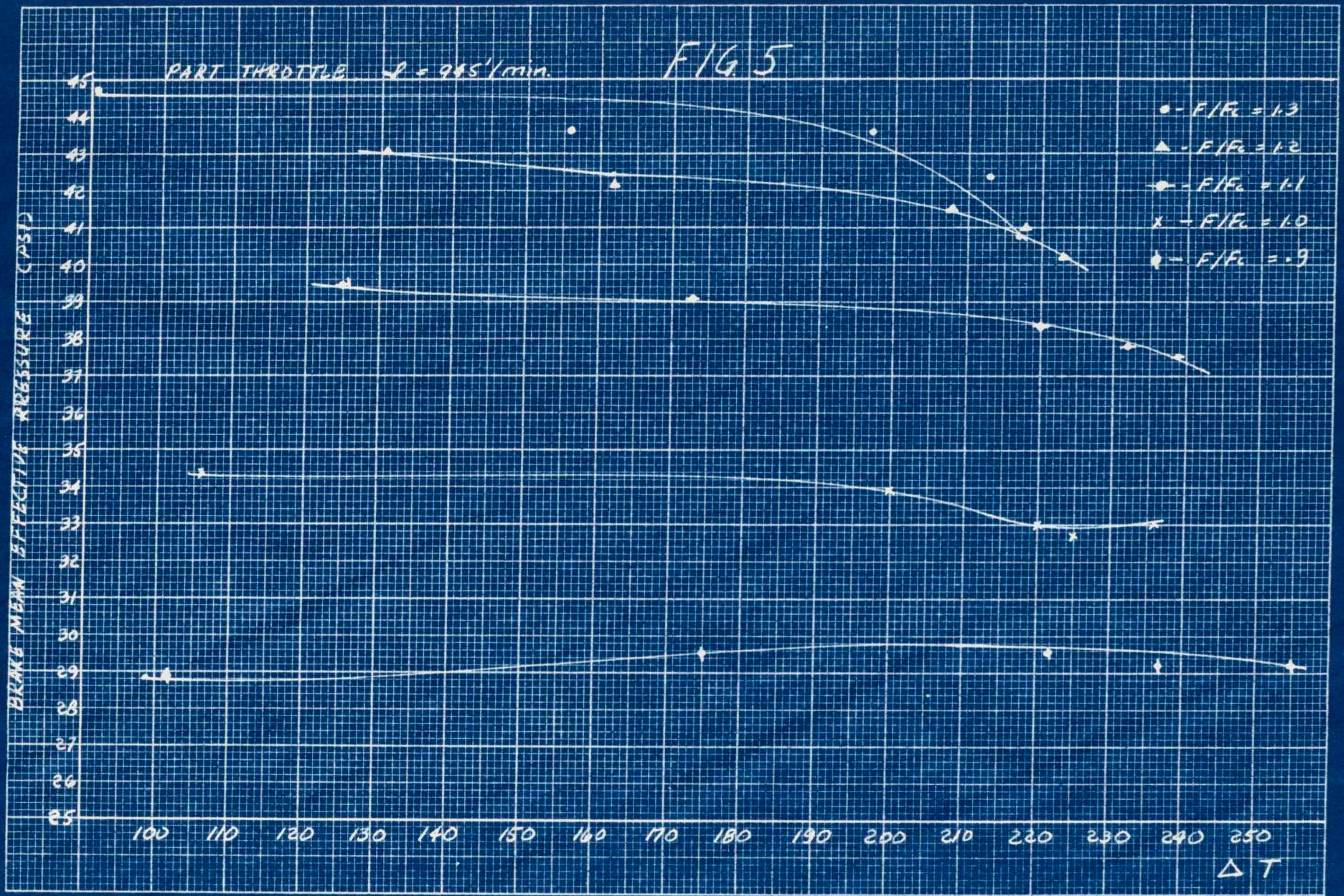
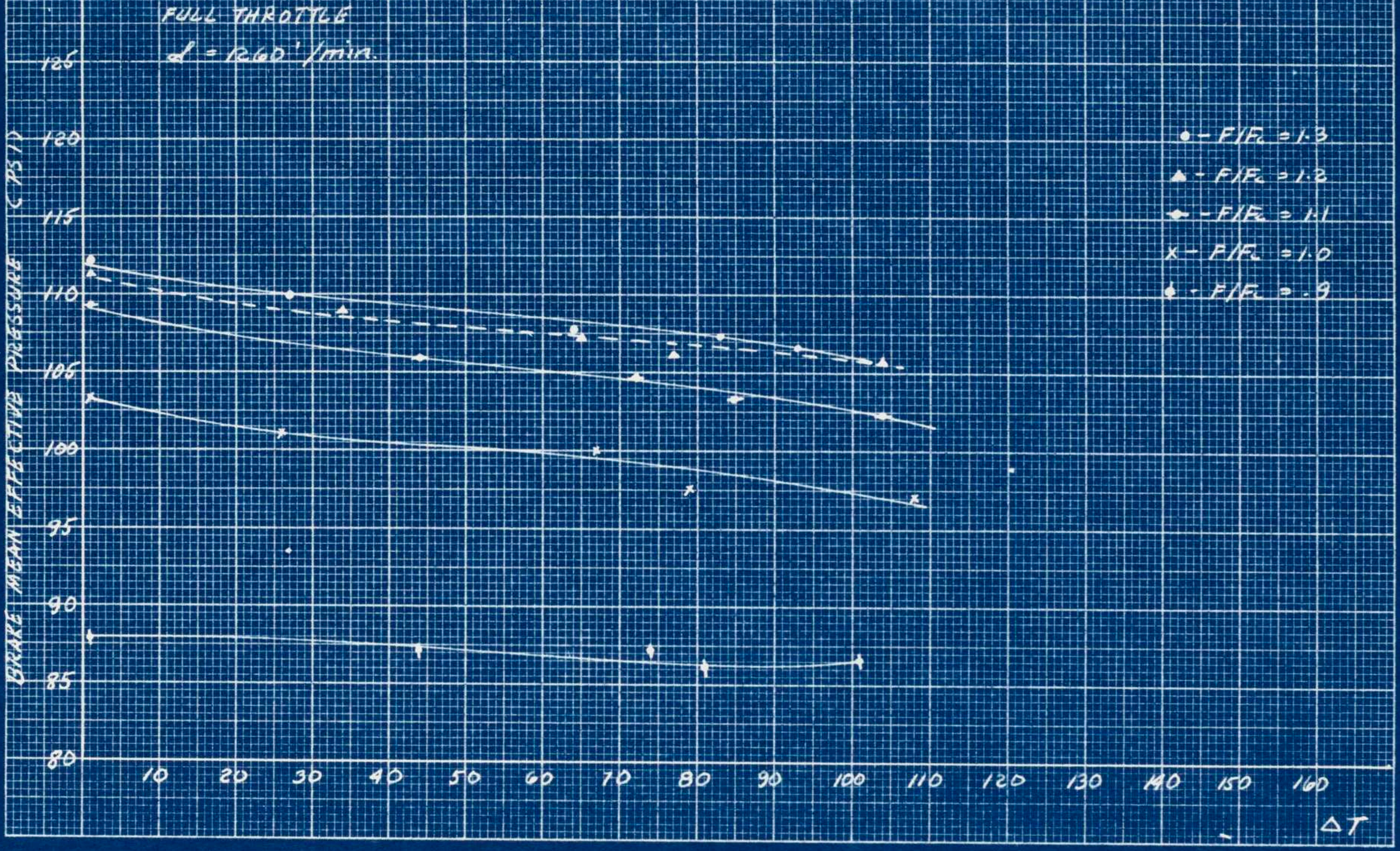

PART THROTTLE $\mathcal{S}$ = 945'/min.
BRAKE MEAN EFFECTIVE PRESSURE (PSI)
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
ΔT
• - F/Fc = 1.3
▲ - F/Fc = 1.2
F/Fc = 1.1
x - F/Fc = 1.0
F/Fc = .9

FIG 5

FIG. 6



FULL THROTTLE
d = 1260'/min.
BRAKE MEAN EFFECTIVE PRESSURE (PSI)
125
120
115
110
105
100
95
90
85
80
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
ΔT
F/Fc = 1.3
F/Fc = 1.2
F/Fc = 1.1
F/Fc = 1.0
F/Fc = .9

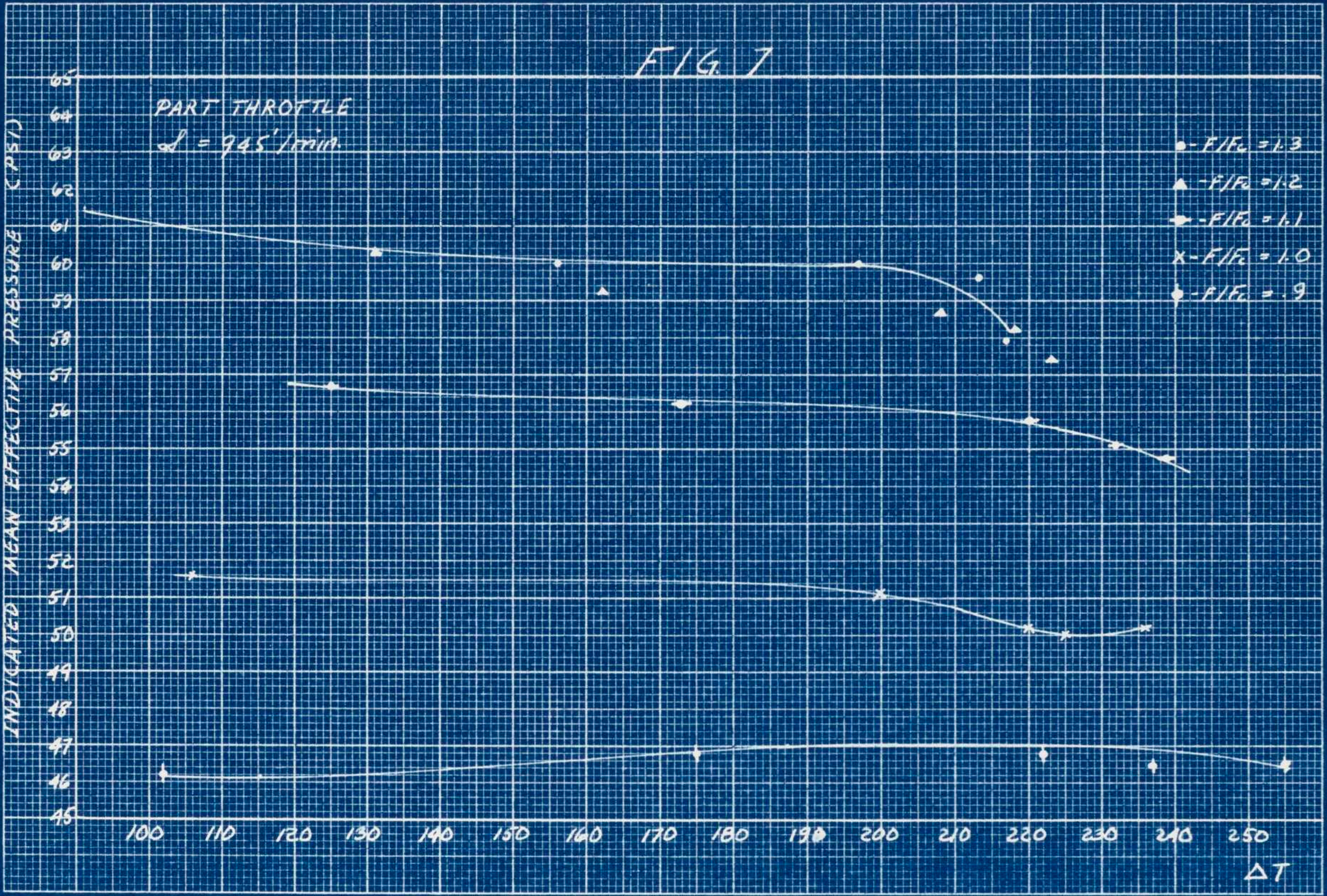
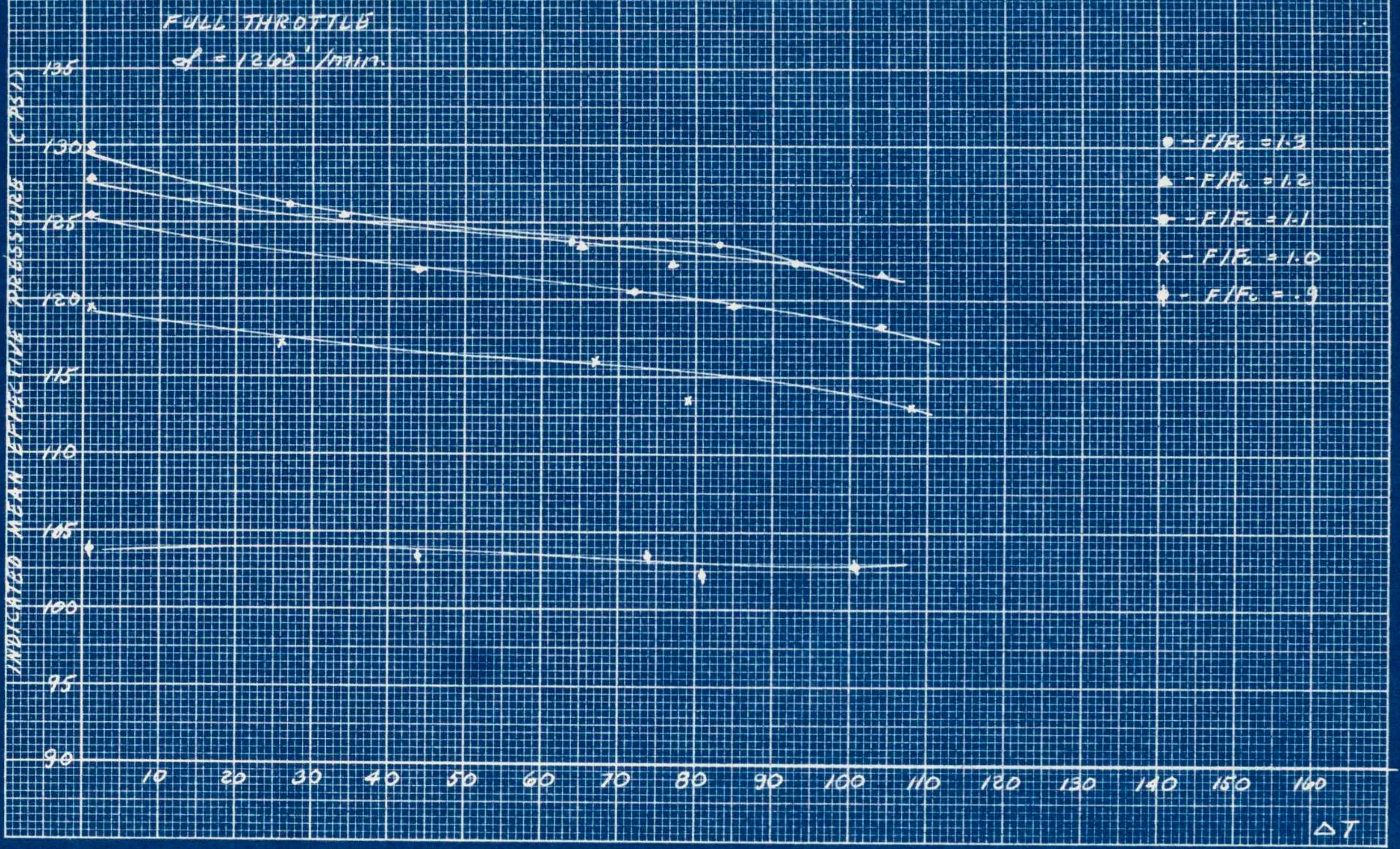


FIG. 7
PART THROTTLE
$\mathcal{L}$ = 945'/min.
INDICATED MEAN EFFECTIVE PRESSURE (PSI)
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
ΔT
• - F/Fc = 1.3
▲ - F/Fc = 1.2
- F/Fc = 1.1
X - F/Fc = 1.0
- F/Fc = .9

FIG. 8



FULL THROTTLE
= 1260'/min.
INDICATED MEAN EFFECTIVE PRESSURE (PSI)
135
130
125
120
115
110
105
100
95
90
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
ΔT
- F/Fc = 1.3
- F/Fc = 1.2
- F/Fc = 1.1
- F/Fc = 1.0
- F/Fc = .9

FIG. 9

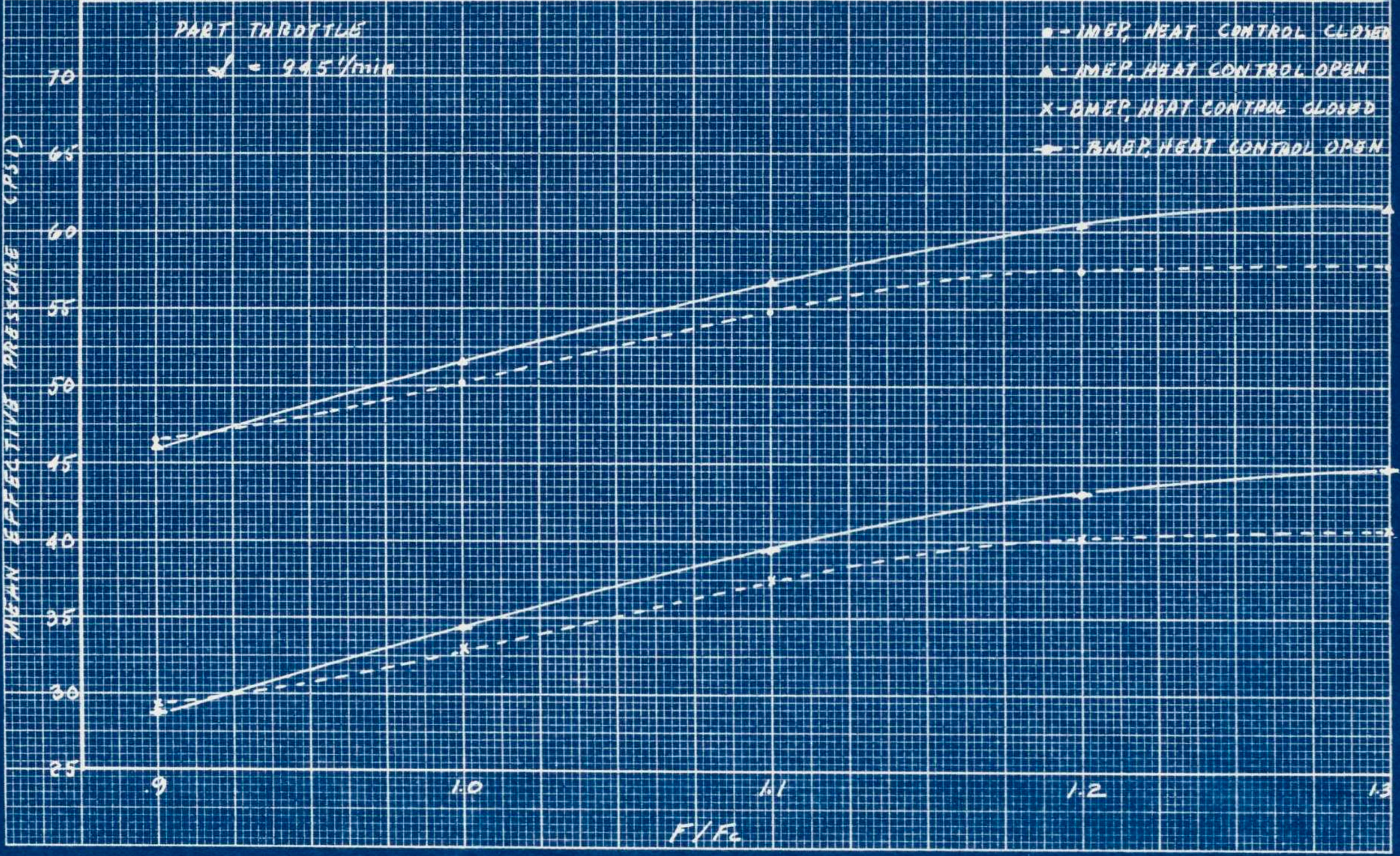
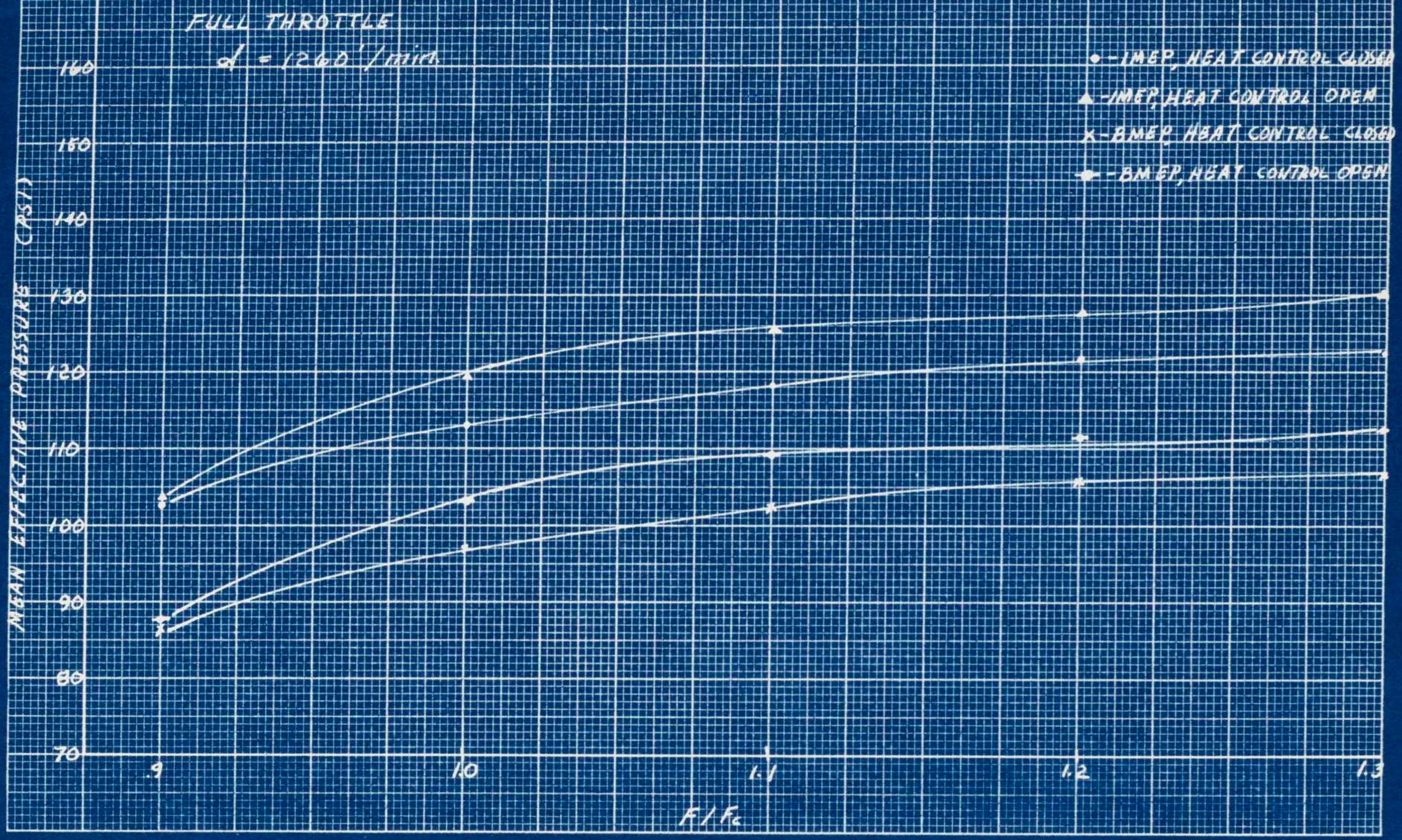

PART THROTTLE
N = 945'/min
• - IMEP, HEAT CONTROL CLOSED
▲ - IMEP, HEAT CONTROL OPEN
X - BMEP, HEAT CONTROL CLOSED
- - BMEP, HEAT CONTROL OPEN
MEAN EFFECTIVE PRESSURE (PSI)
70
65
60
55
50
45
40
35
30
25
.9
1.0
1.1
1.2
1.3
F/Fc

FIG. 10



FULL THROTTLE
s = 1200'/min
• - IMEP, HEAT CONTROL CLOSED
▲ - IMEP, HEAT CONTROL OPEN
x - BMEP, HEAT CONTROL CLOSED
- BMEP, HEAT CONTROL OPEN
MEAN EFFECTIVE PRESSURE (PSI)
160
150
140
130
120
110
100
90
80
70
.9
1.0
1.1
1.2
1.3
F/Fc

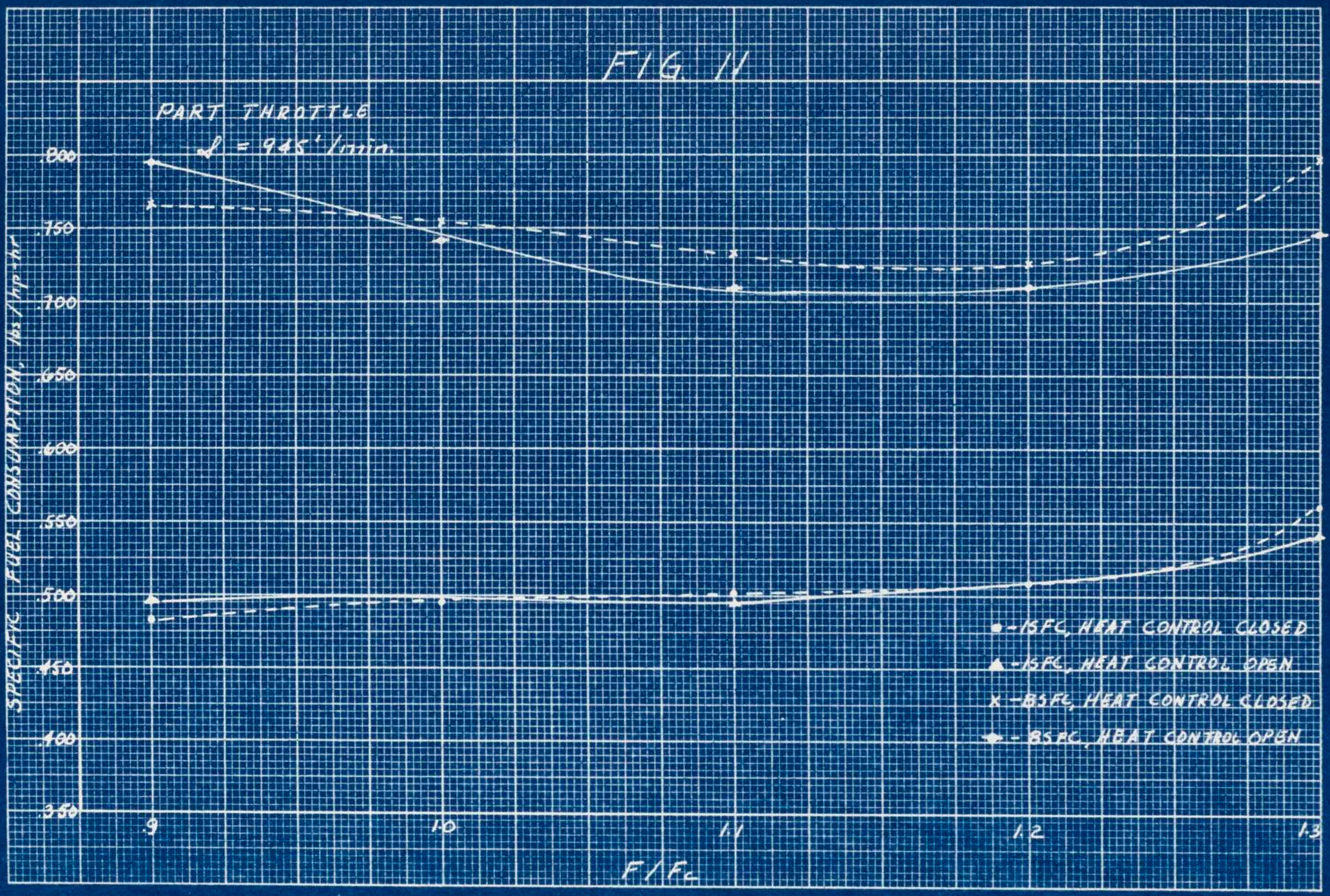


FIG. 11
PART THROTTLE
$\mathcal{S}$ = 945'/min.
SPECIFIC FUEL CONSUMPTION, lbs / hp-hr
.800
.750
.700
.650
.600
.550
.500
.450
.400
.350
.9
1.0
1.1
1.2
1.3
F / Fc
● - ISFC, HEAT CONTROL CLOSED
▲ - ISFC, HEAT CONTROL OPEN
x - BSFC, HEAT CONTROL CLOSED
◆ - BSFC, HEAT CONTROL OPEN

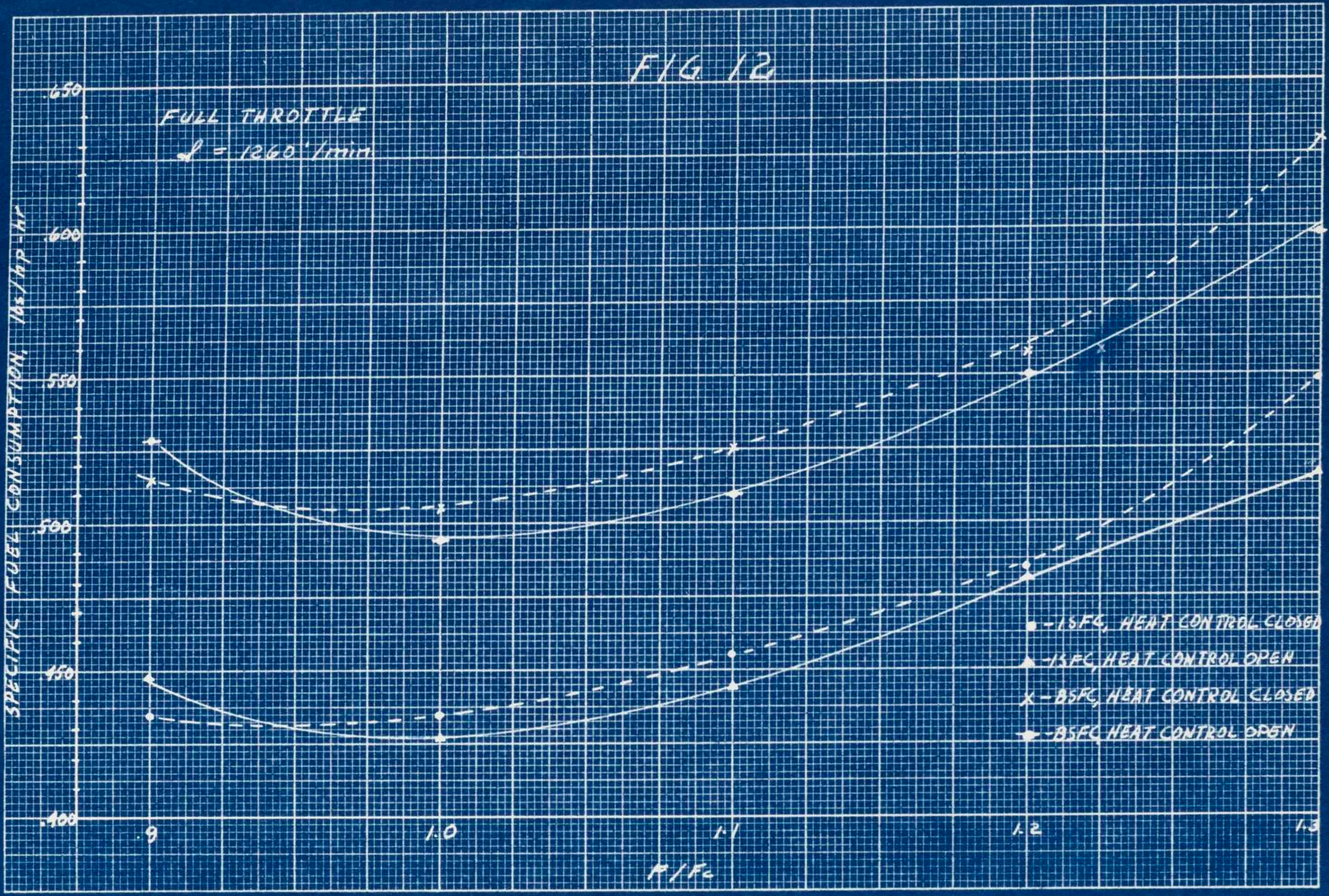


FIG 12
FULL THROTTLE
= 1260'/min
SPECIFIC FUEL CONSUMPTION, lbs/hp-hr
.650
.600
.550
.500
.450
.400
.9
1.0
1.1
1.2
1.3
F/Fc
- ISFC, HEAT CONTROL CLOSED
- ISFC, HEAT CONTROL OPEN
- BSFC, HEAT CONTROL CLOSED
- BSFC, HEAT CONTROL OPEN

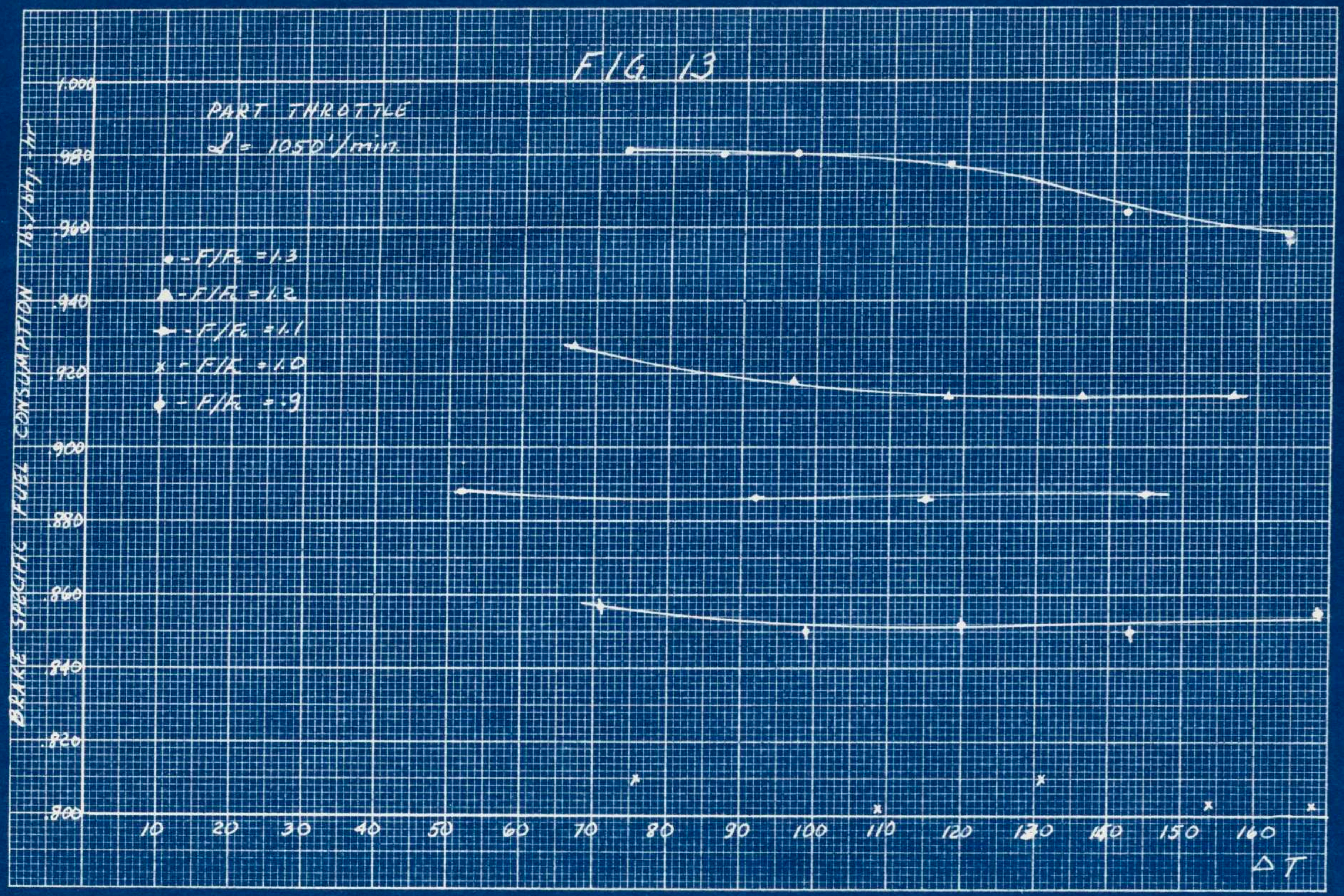
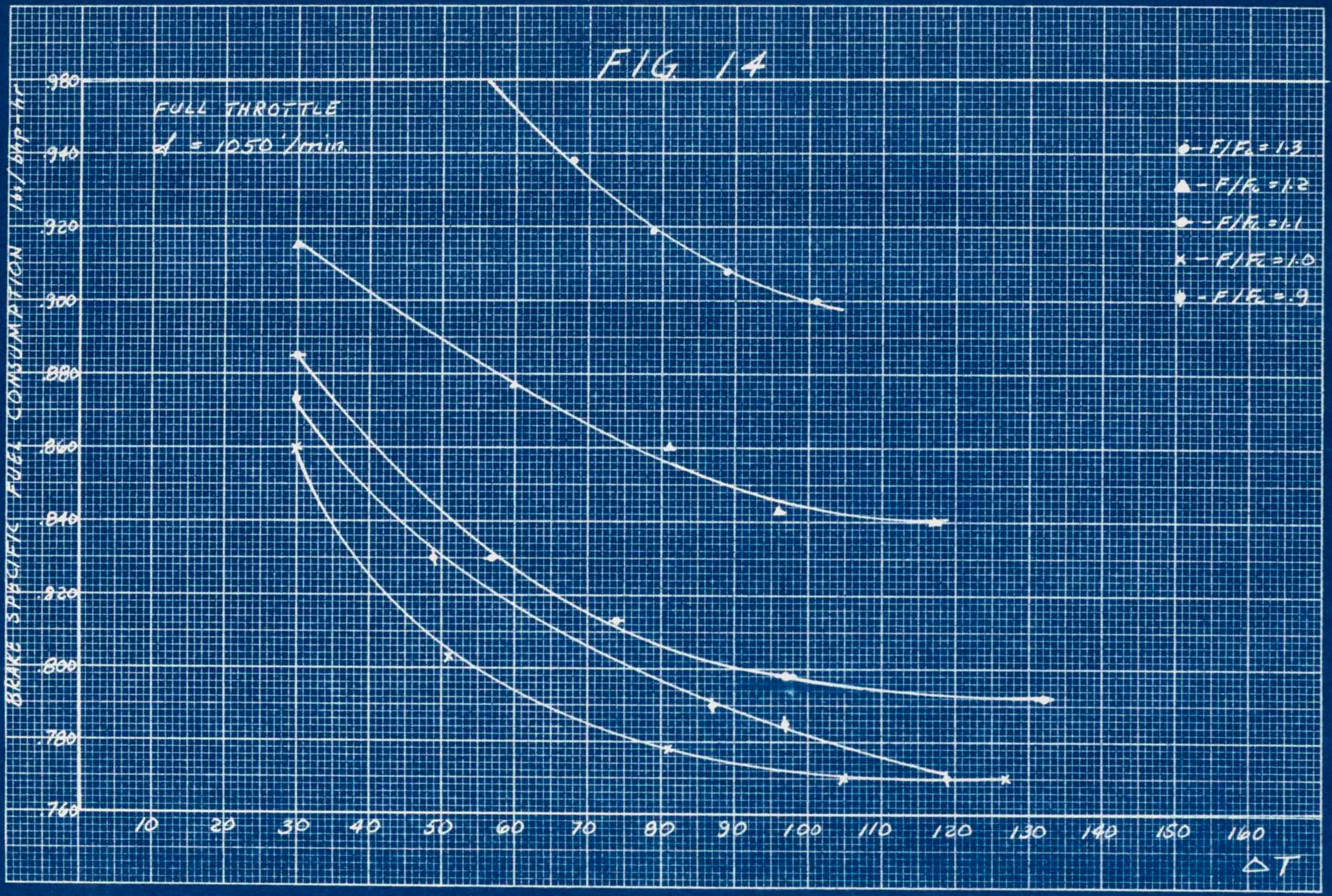


FIG. 13
PART THROTTLE
S = 1050'/min.
• - F/Fc = 1.3
▲ - F/Fc = 1.2
- F/Fc = 1.1
x - F/Fc = 1.0
- F/Fc = .9
BRAKE SPECIFIC FUEL CONSUMPTION lbs/bhp - hr
1.000
.980
.960
.940
.920
.900
.880
.860
.840
.820
.800
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
ΔT

FIG 14



FULL THROTTLE
= 1050'/min.
BRAKE SPECIFIC FUEL CONSUMPTION lbs/Bhp-hr
.980
.940
.920
.900
.880
.860
.840
.820
.800
.780
.760
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
ΔT
- F/Fc = 1.3
- F/Fc = 1.2
- F/Fc = 1.1
- F/Fc = 1.0
- F/Fc = .9

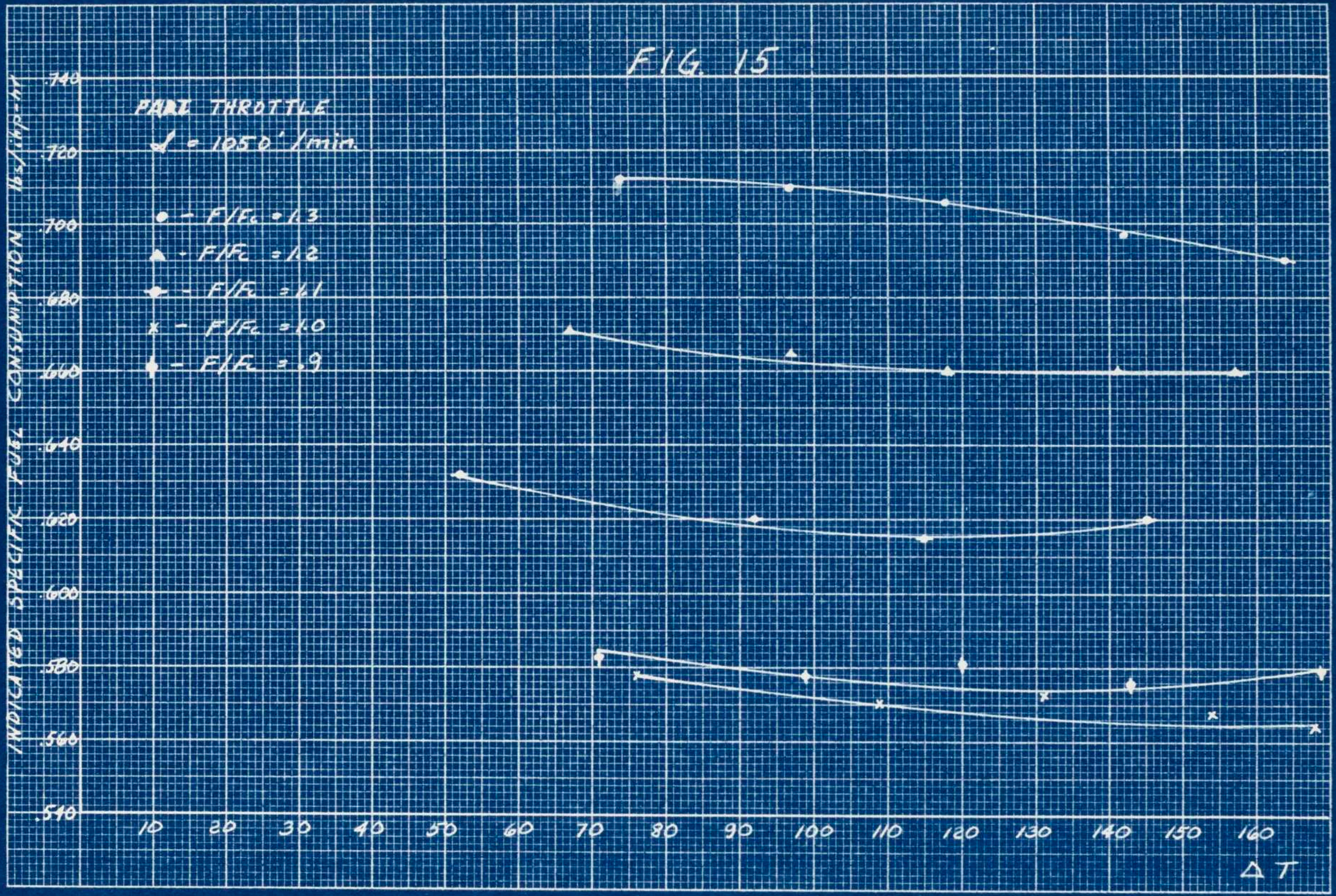


FIG. 15
PART THROTTLE
√ = 1050'/min.
● - F/Fc = 1.3
▲ - F/Fc = 1.2
- F/Fc = 1.1
x - F/Fc = 1.0
- F/Fc = .9
INDICATED SPECIFIC FUEL CONSUMPTION lbs/ihp-hr
.740
.720
.700
.680
.660
.640
.620
.600
.580
.560
.540
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
ΔT

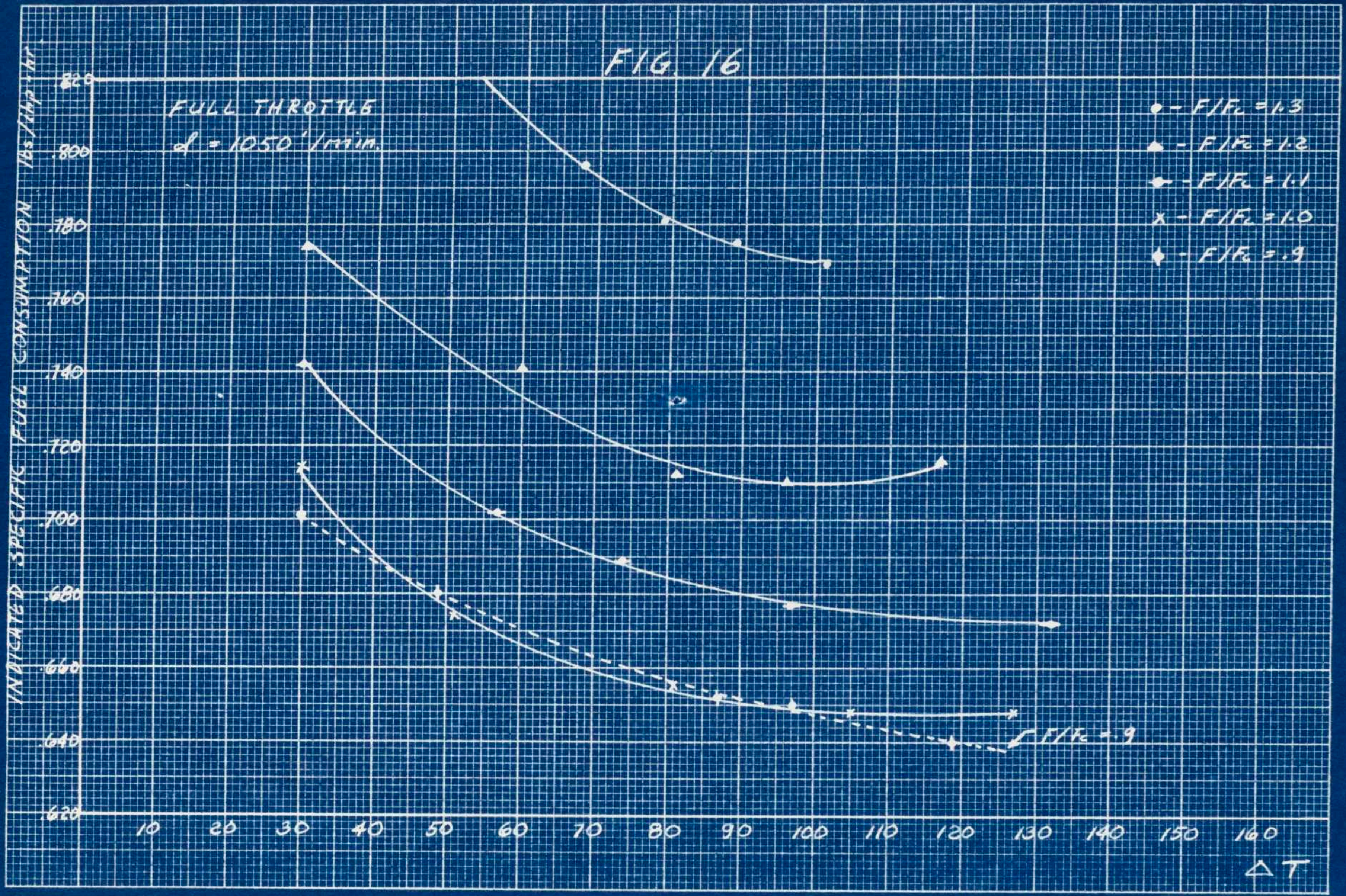


FIG. 16
FULL THROTTLE
$\mathcal{L}$ = 1050'/min.
● - F/Fc = 1.3
▲ - F/Fc = 1.2
● - F/Fc = 1.1
x - F/Fc = 1.0
♦ - F/Fc = .9
F/Fc = .9
INDICATED SPECIFIC FUEL CONSUMPTION lbs/ihp-hr
.820
.800
.780
.760
.740
.720
.700
.680
.660
.640
.620
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
ΔT

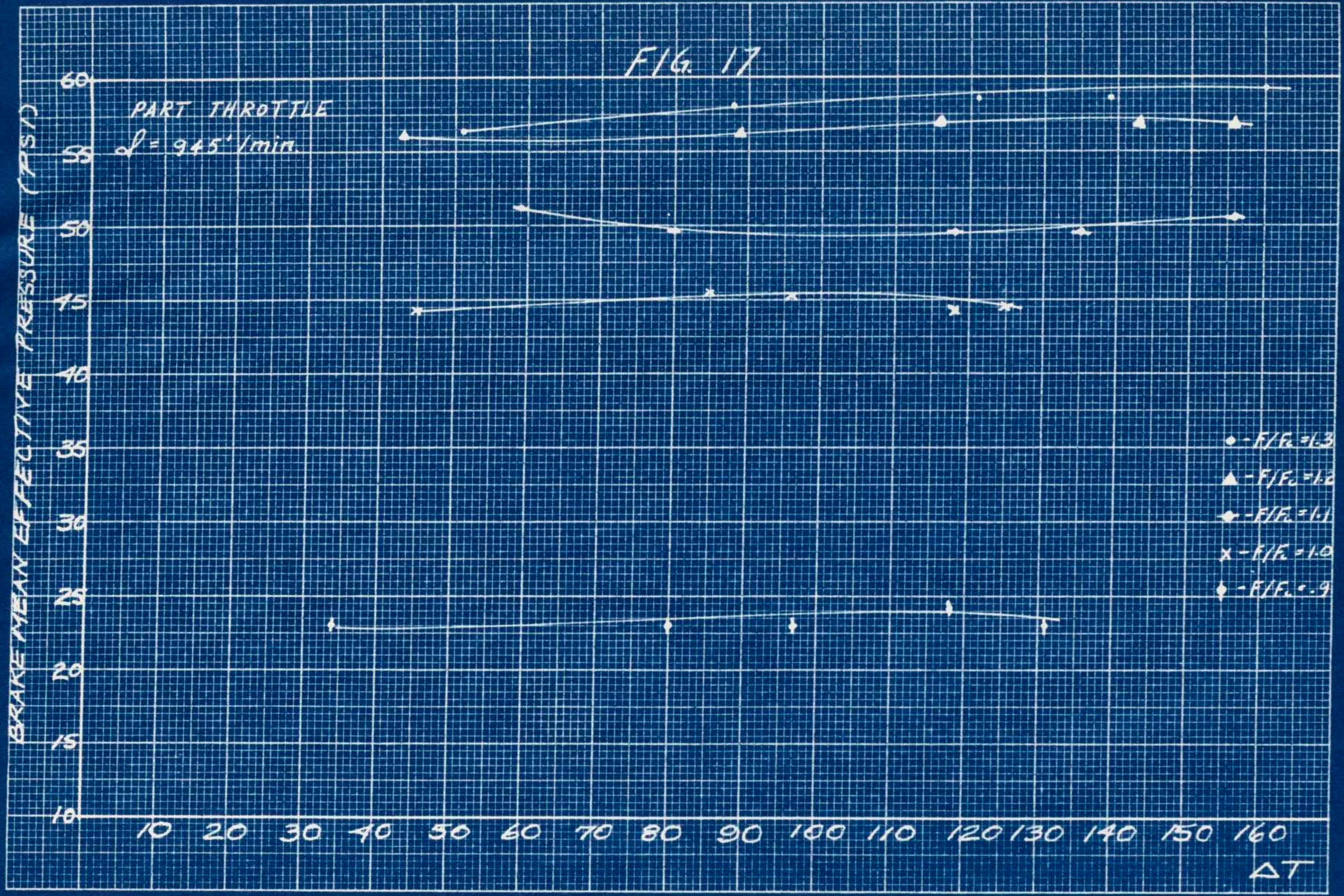


FIG. 17
PART THROTTLE
S = 945'/min.
BRAKE MEAN EFFECTIVE PRESSURE (PSI)
60
55
50
45
40
35
30
25
20
15
10
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
- F/Fc = 1.3
- F/Fc = 1.2
- F/Fc = 1.1
x - F/Fc = 1.0
- F/Fc = .9

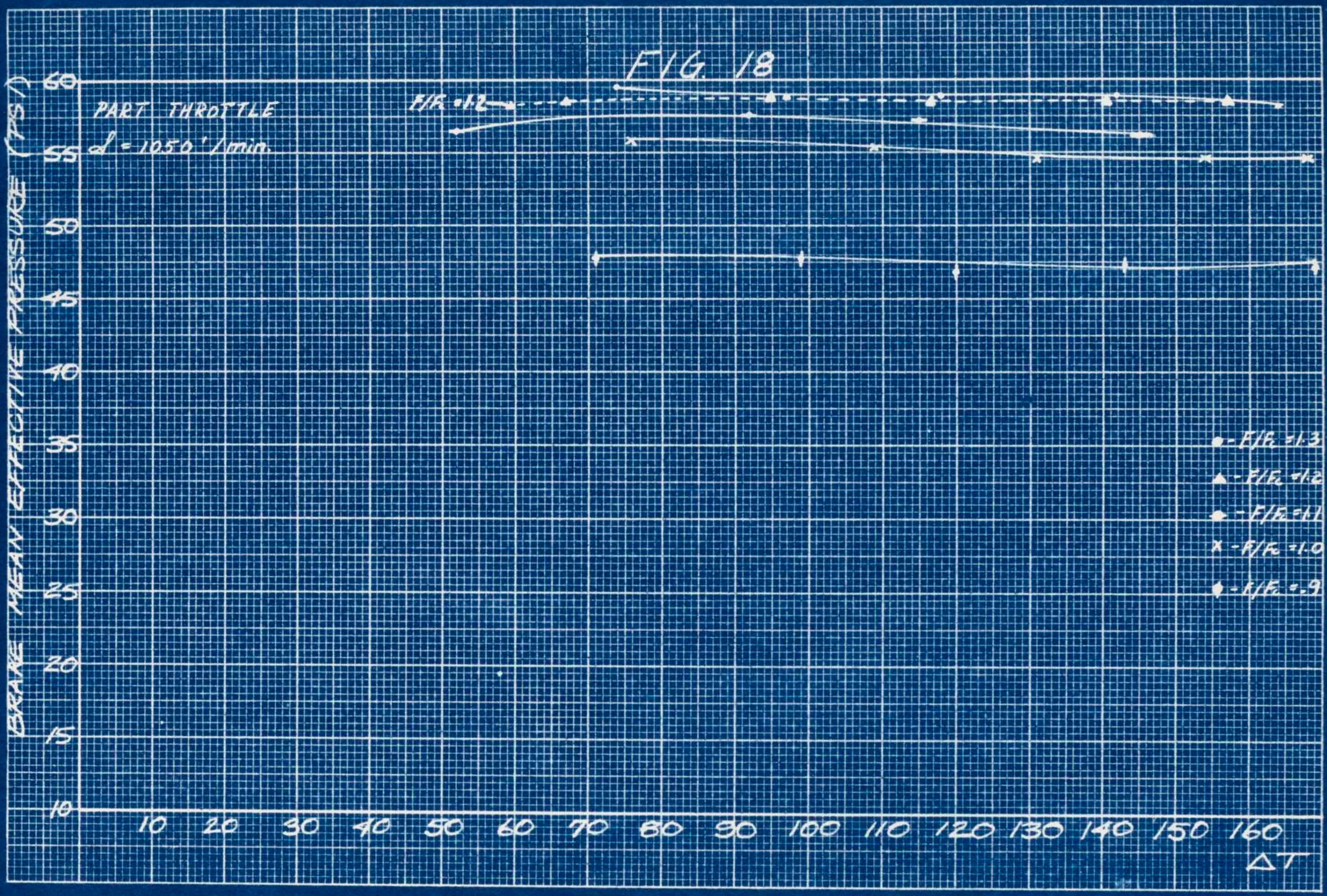


FIG. 18
PART THROTTLE
α = 1050'/min.
F/Fc = 1.2
BRAKE MEAN EFFECTIVE PRESSURE (PSI)
60
55
50
45
40
35
30
25
20
15
10
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
● - F/Fc = 1.3
▲ - F/Fc = 1.2
■ - F/Fc = 1.1
X - F/Fc = 1.0
♦ - F/Fc = .9

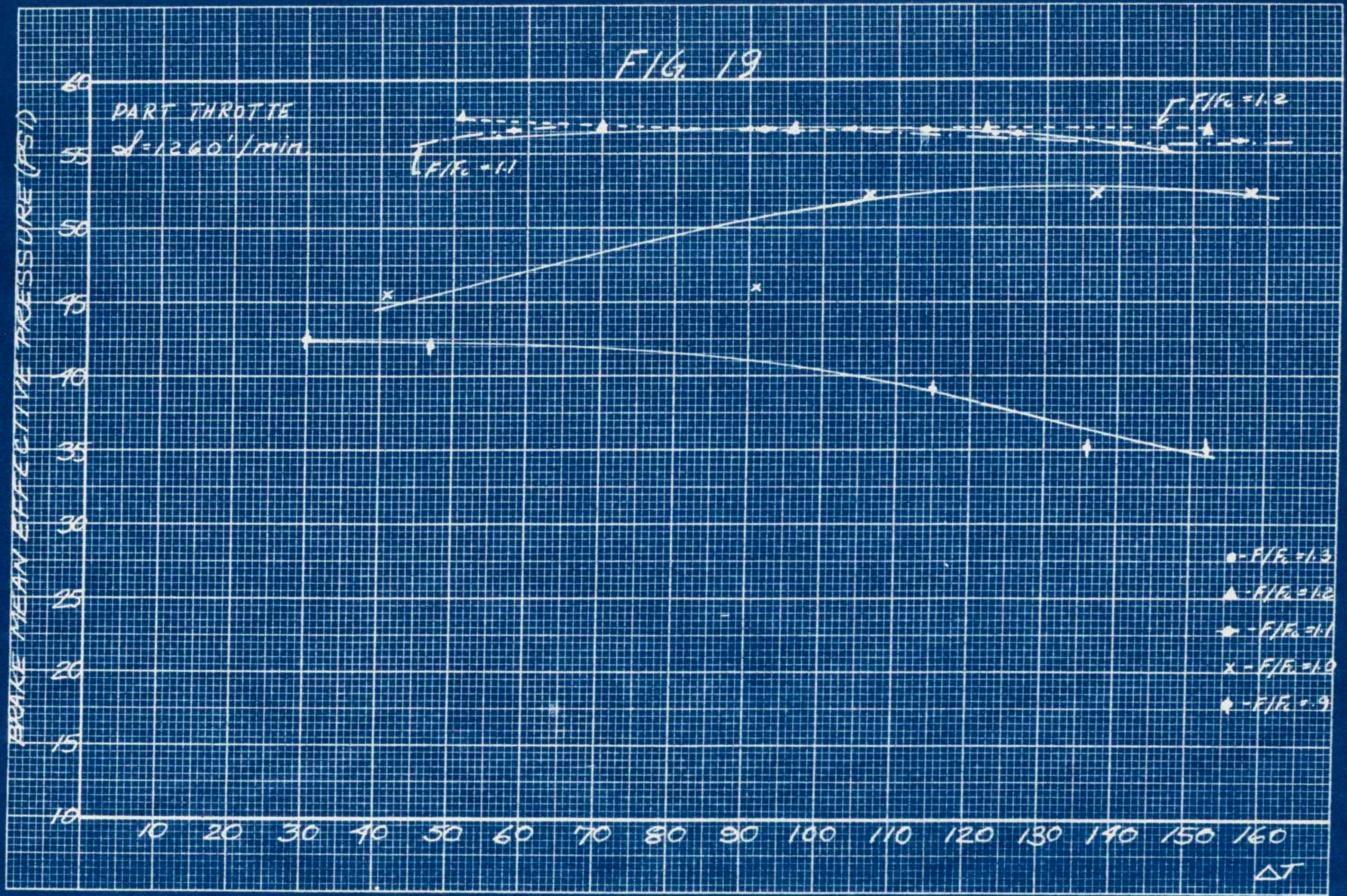
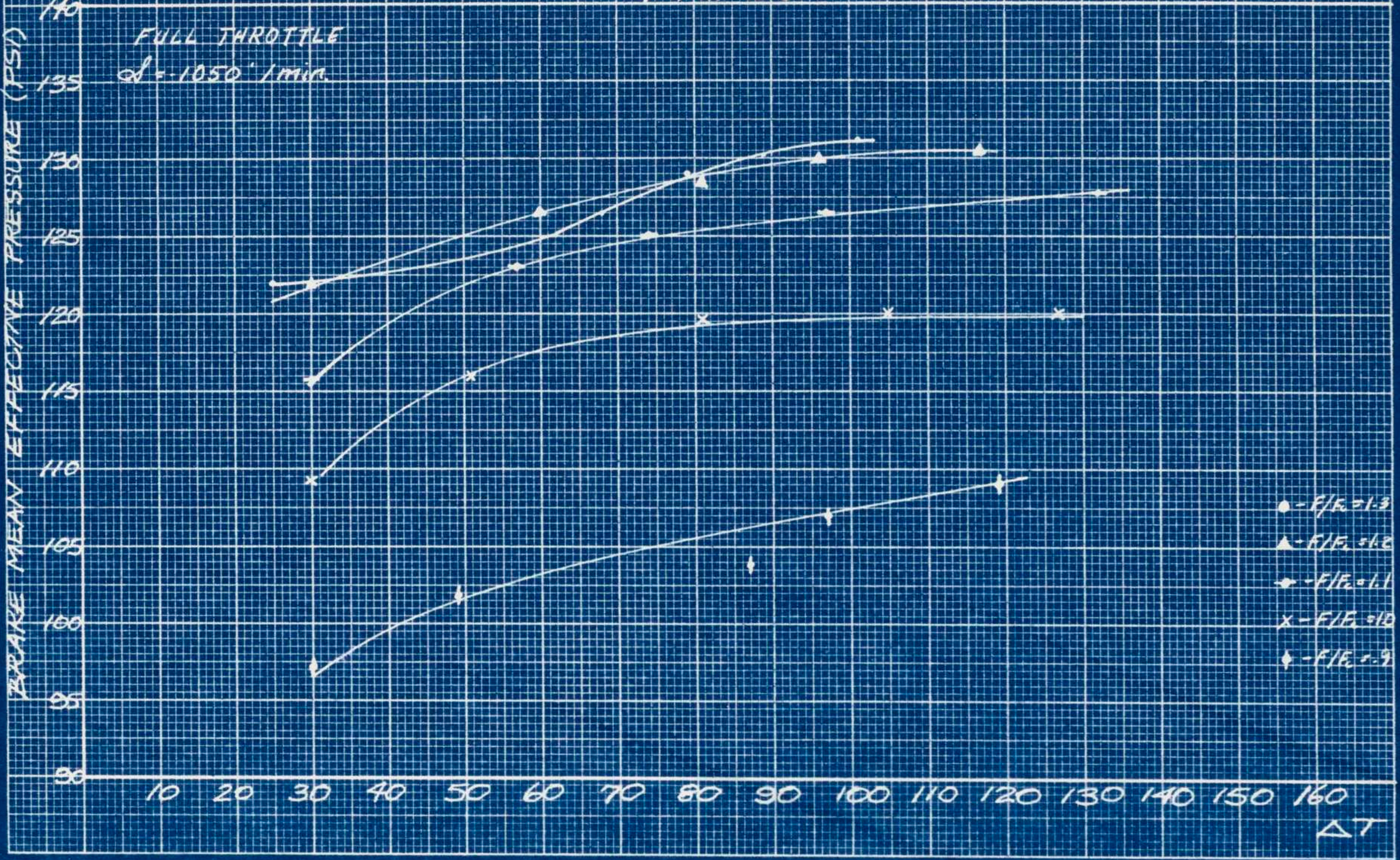


FIG. 19
PART THROTTLE
$\mathscr{L}$=1260'/min
F/F_c=1.2
F/F_c=1.1
BRAKE MEAN EFFECTIVE PRESSURE (PSI)
60
55
50
45
40
35
30
25
20
15
10
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
ΔT
● - F/F_c=1.3
▲ - F/F_c=1.2
● - F/F_c=1.1
x - F/F_c=1.0
● - F/F_c=.9

FIG. 20



FULL THROTTLE
S = 1050' /min.
BRAKE MEAN EFFECTIVE PRESSURE (PSI)
140
135
130
125
120
115
110
105
100
95
90
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
● - F/Fc = 1.3
▲ - F/Fc = 1.2
◆ - F/Fc = 1.1
x - F/Fc = 1.0
♦ - F/Fc = .9

FIG. 21

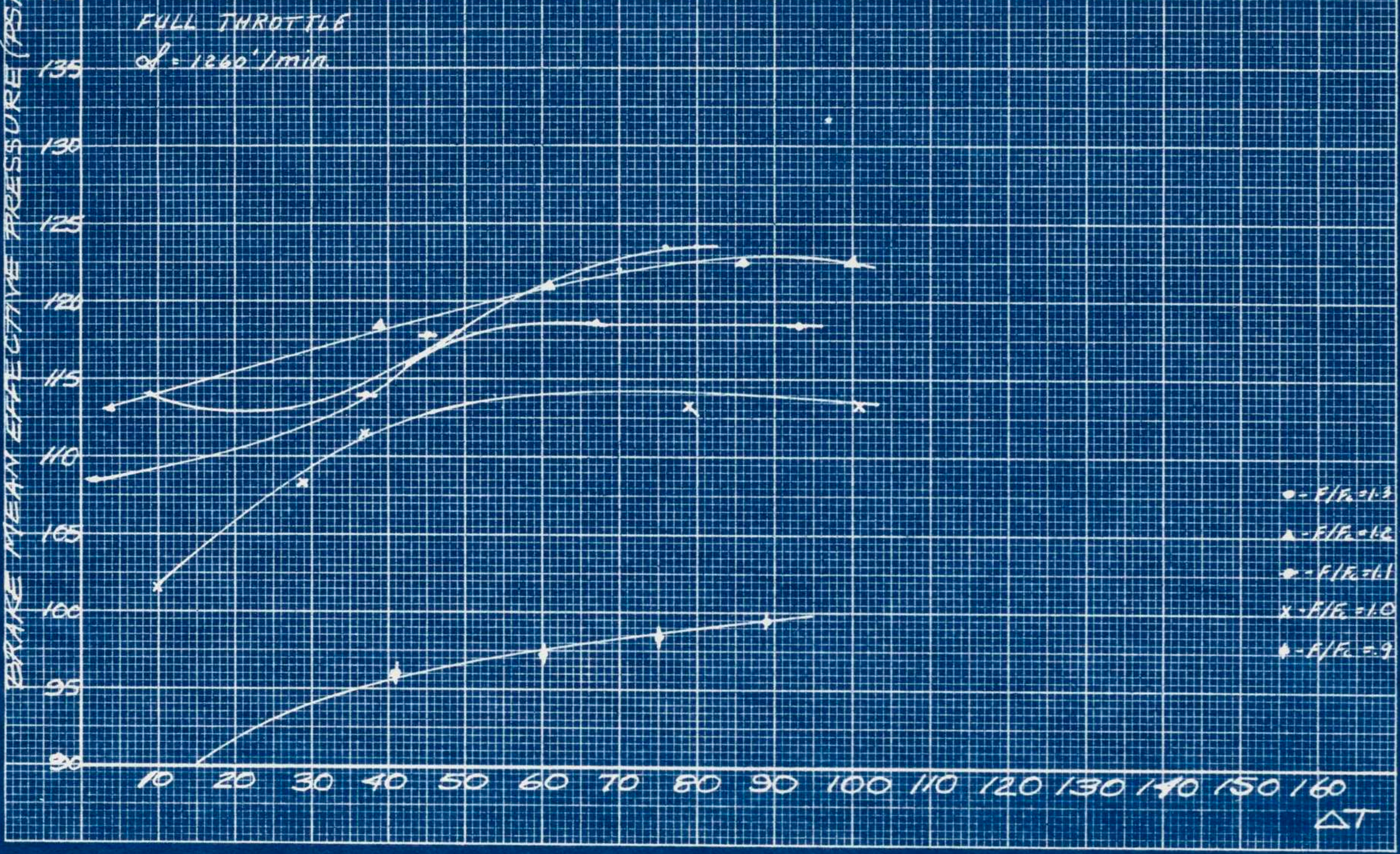
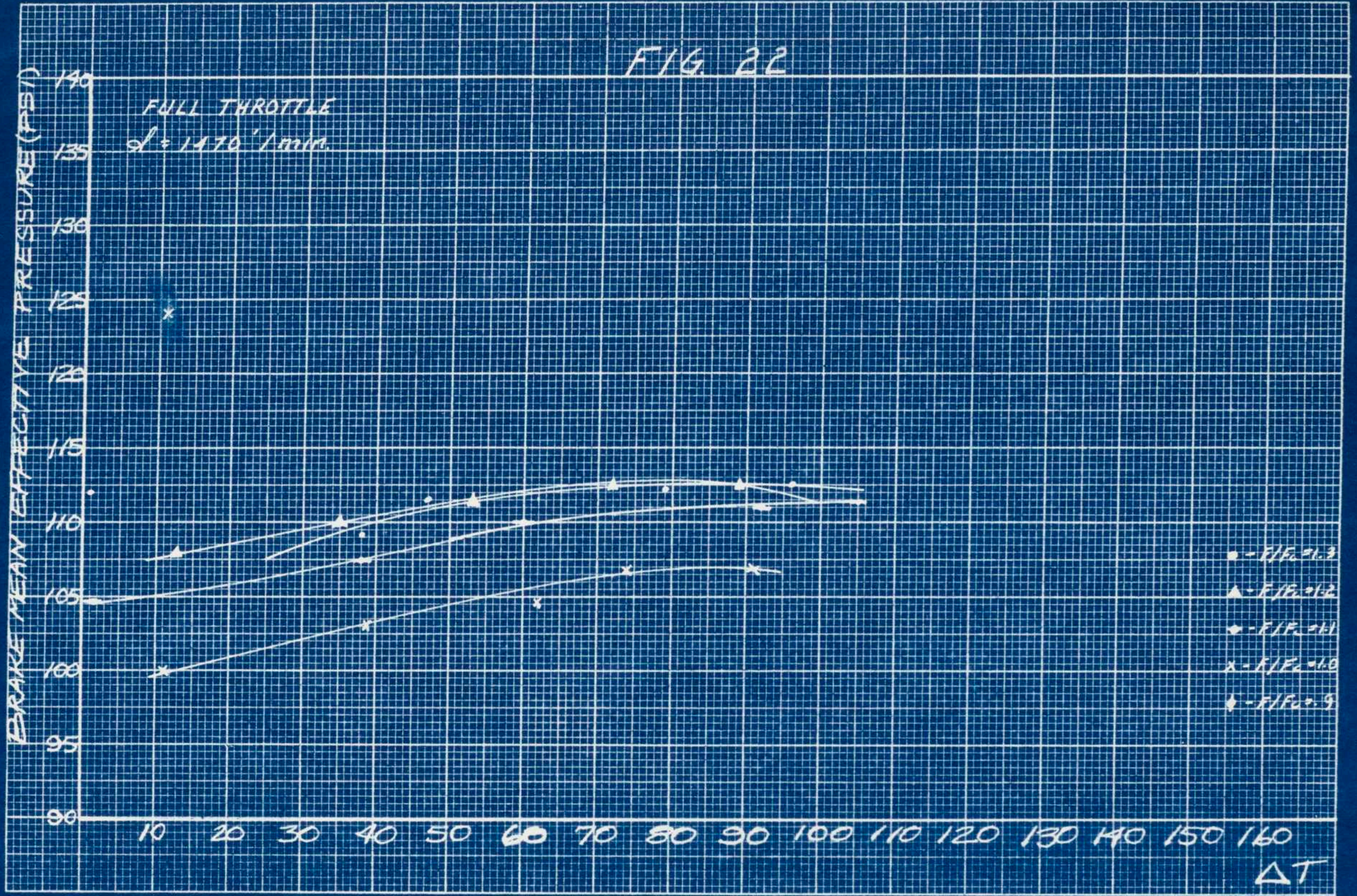

FULL THROTTLE
ω = 1260'/min
BRAKE MEAN EFFECTIVE PRESSURE (PSI)
140
135
130
125
120
115
110
105
100
95
90
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
● - F/Fc = 1.3
▲ - F/Fc = 1.2
● - F/Fc = 1.1
x - F/Fc = 1.0
♦ - F/Fc = .9

FIG. 22


FULL THROTTLE
ω = 1470 '/min.
BRAKE MEAN EFFECTIVE PRESSURE (PSI)
140
135
130
125
120
115
110
105
100
95
90
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
● - F/Fc = 1.3
▲ - F/Fc = 1.2
● - F/Fc = 1.1
x - F/Fc = 1.0
♦ - F/Fc = .9

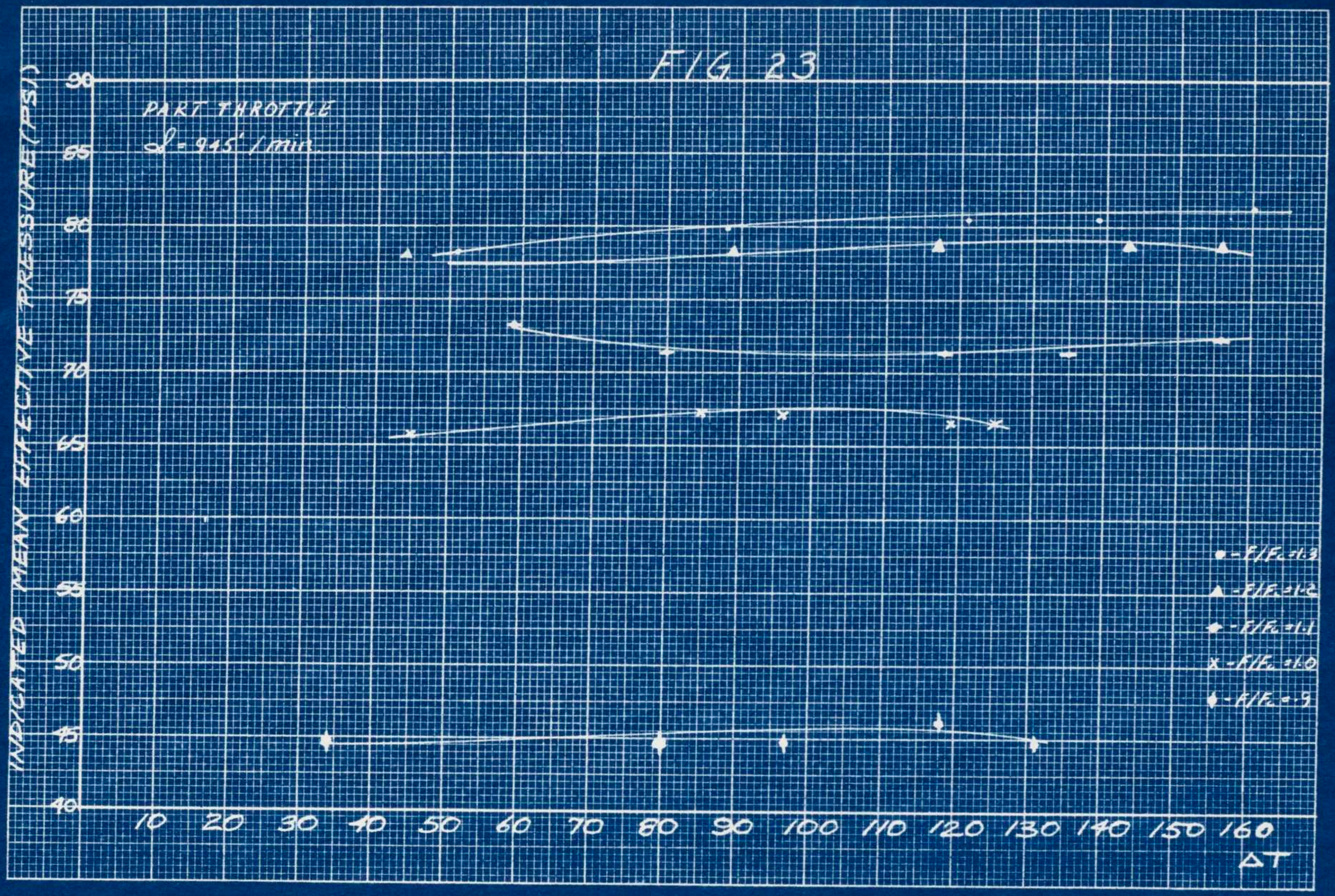
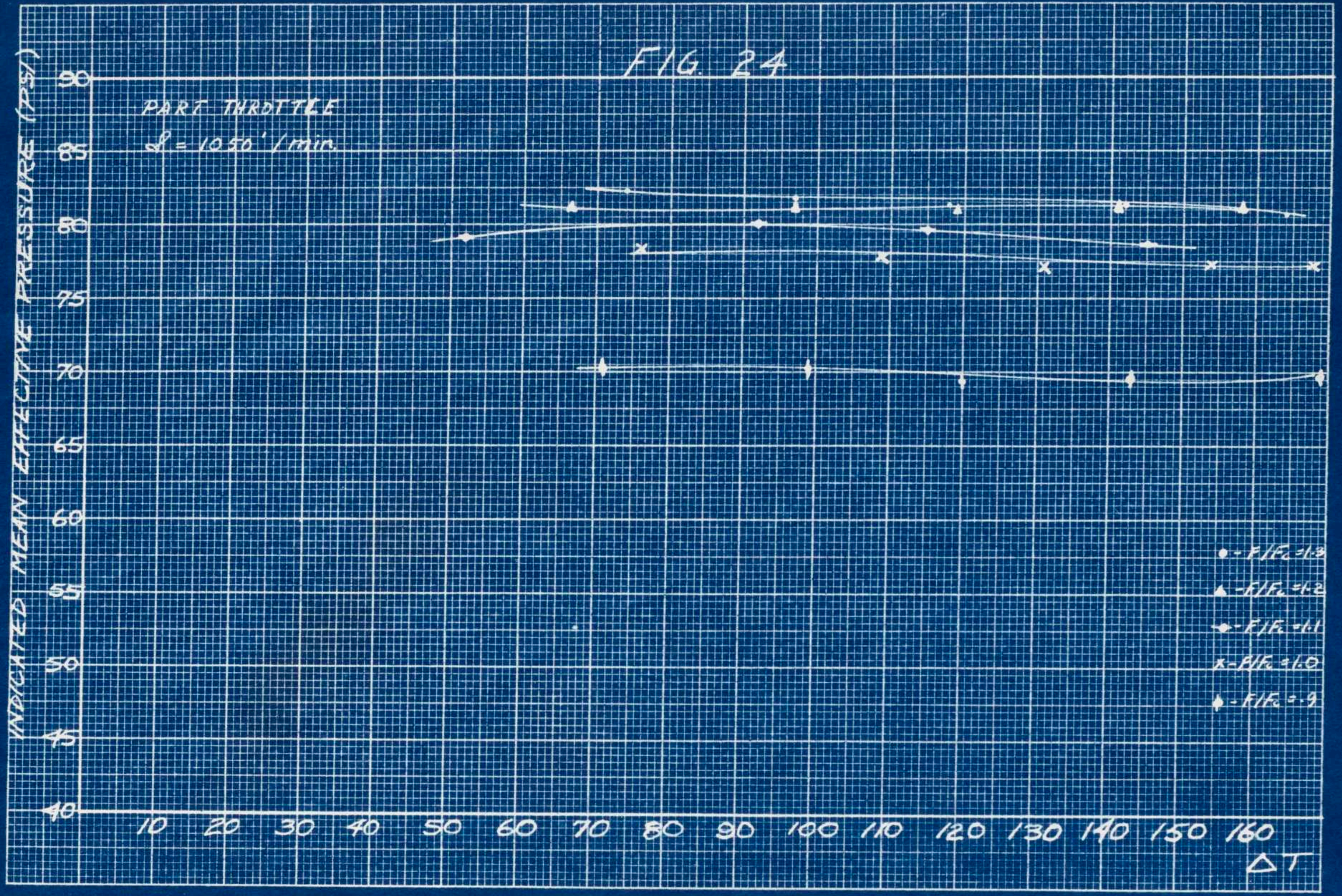


FIG 23
PART THROTTLE
INDICATED MEAN EFFECTIVE PRESSURE (PSI)
90
85
80
75
70
65
60
55
50
45
40
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT

FIG. 24



PART THROTTLE
S = 1050'/min.
INDICATED MEAN EFFECTIVE PRESSURE (PSI)
90
85
80
75
70
65
60
55
50
45
40
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
● - F/Fc = 1.3
▲ - F/Fc = 1.2
- F/Fc = 1.1
x - F/Fc = 1.0
- F/Fc = .9

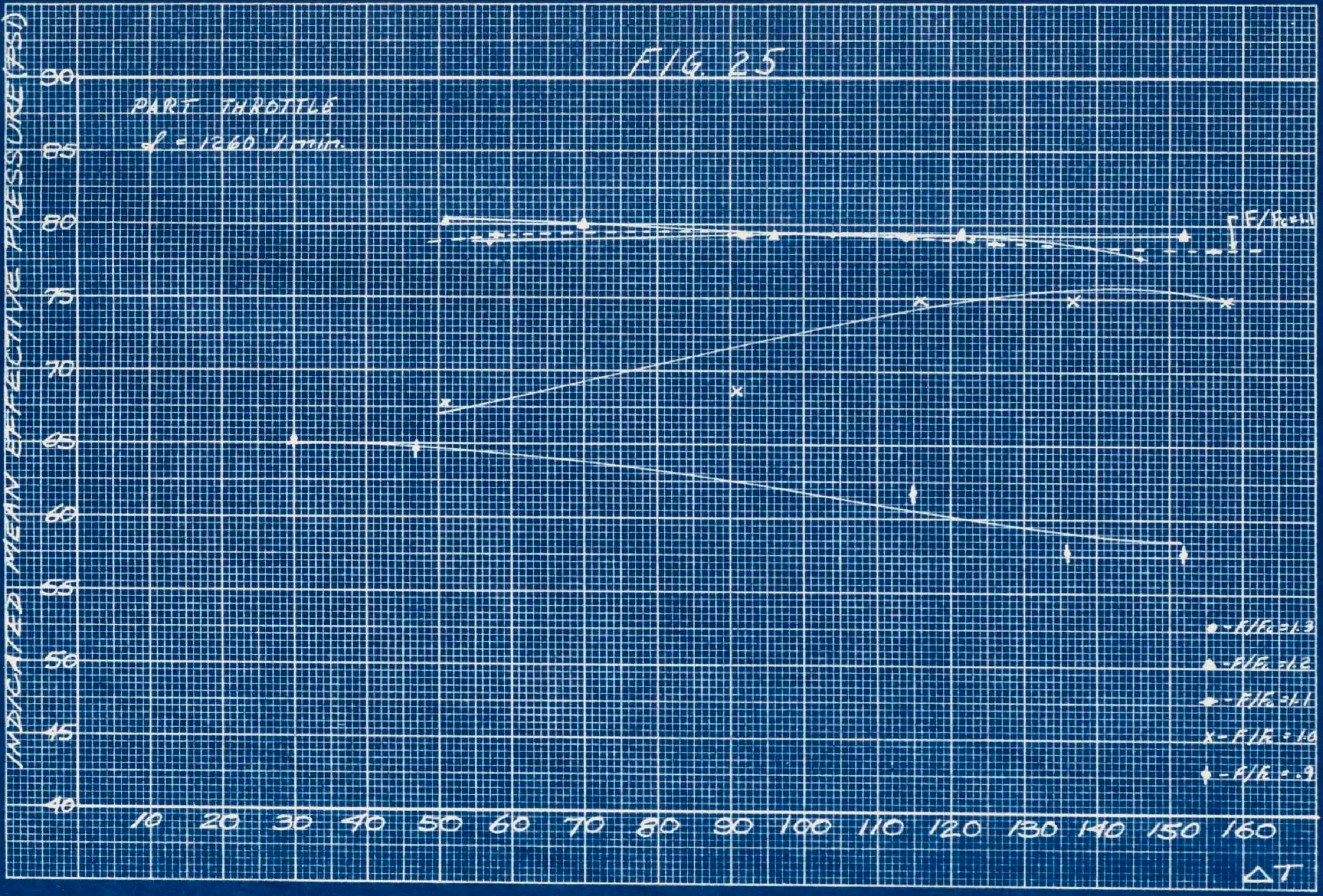


FIG. 25
PART THROTTLE
ℓ = 1260'/min.
INDICATED MEAN EFFECTIVE PRESSURE (PSI)
90
85
80
75
70
65
60
55
50
45
40
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
F/Fc = 1.1
• – F/Fc = 1.3
▲ – F/Fc = 1.2
• – F/Fc = 1.1
x – F/Fc = 1.0
♦ – F/Fc = .9

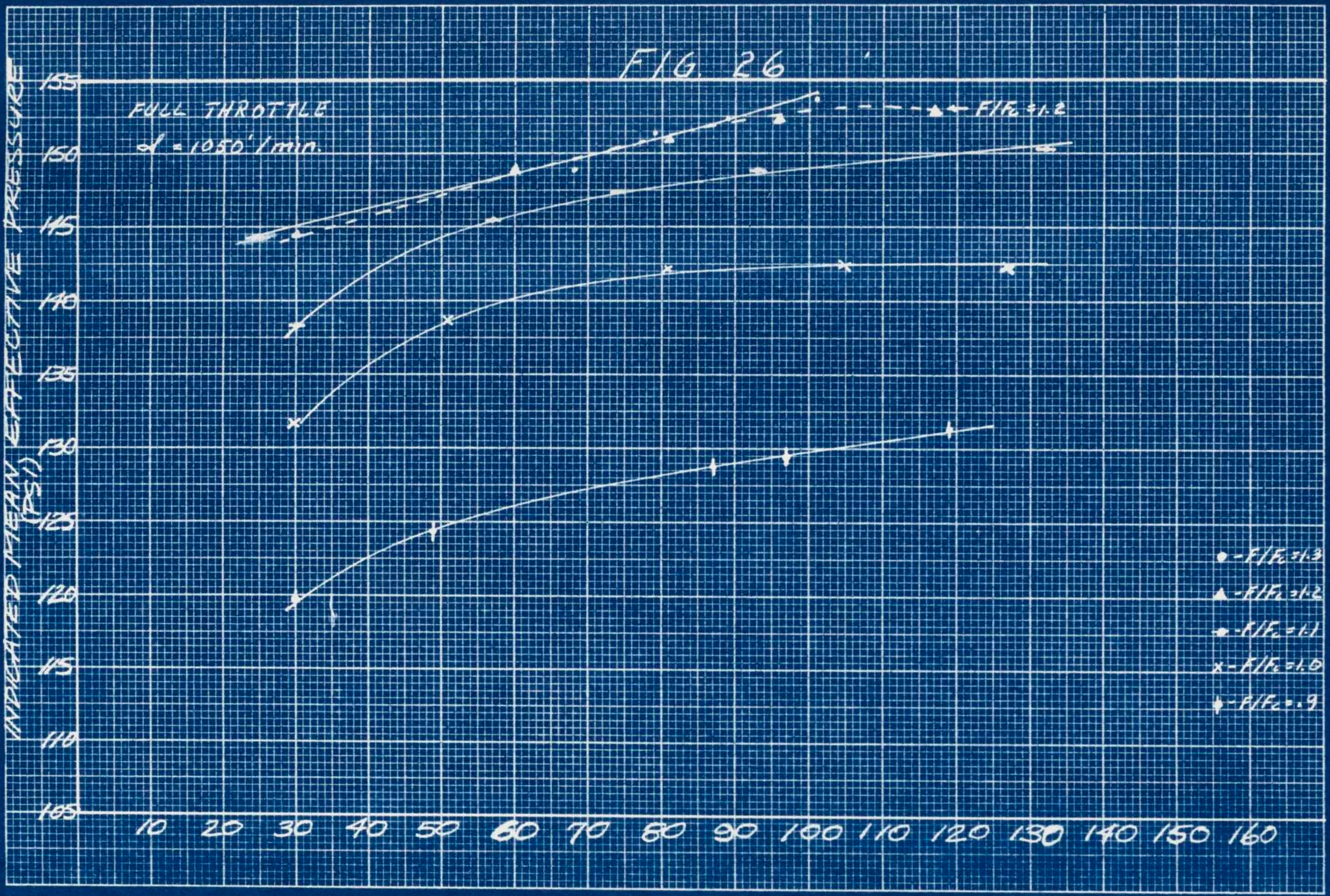

FULL THROTTLE
α = 1050'/min.
F/Fc = 1.2
INDICATED MEAN EFFECTIVE PRESSURE (PSI)
155
150
145
140
135
130
125
120
115
110
105
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
● - F/Fc = 1.3
▲ - F/Fc = 1.2
■ - F/Fc = 1.1
x - F/Fc = 1.0
ϕ - F/Fc = .9

FIG. 26

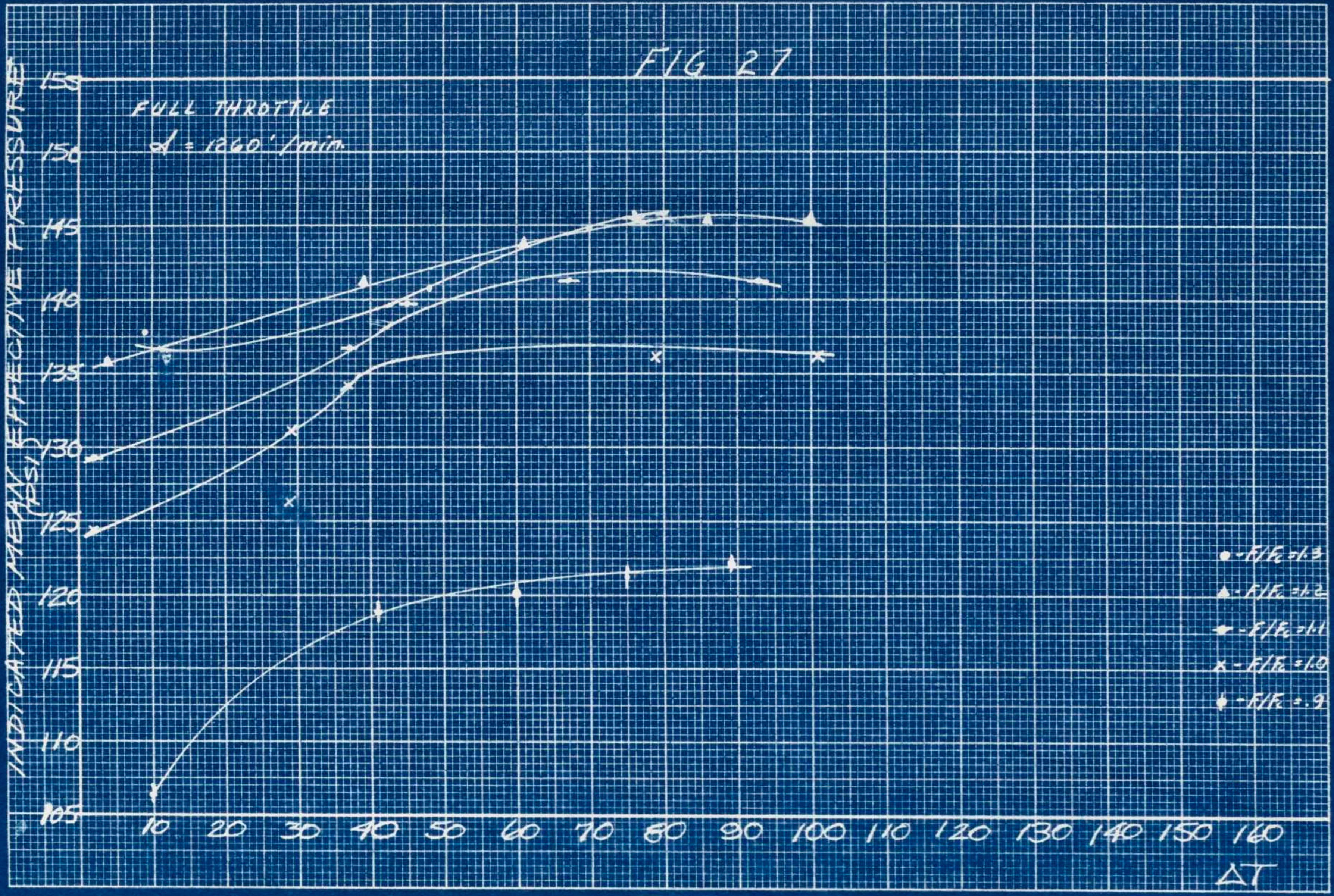


FIG. 27
FULL THROTTLE
Δ = 1260'/min
INDICATED MEAN EFFECTIVE PRESSURE (PSI)
105
110
115
120
125
130
135
140
145
150
155
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
• - F/Fc = 1.3
▲ - F/Fc = 1.2
- F/Fc = 1.1
x - F/Fc = 1.0
- F/Fc = .9

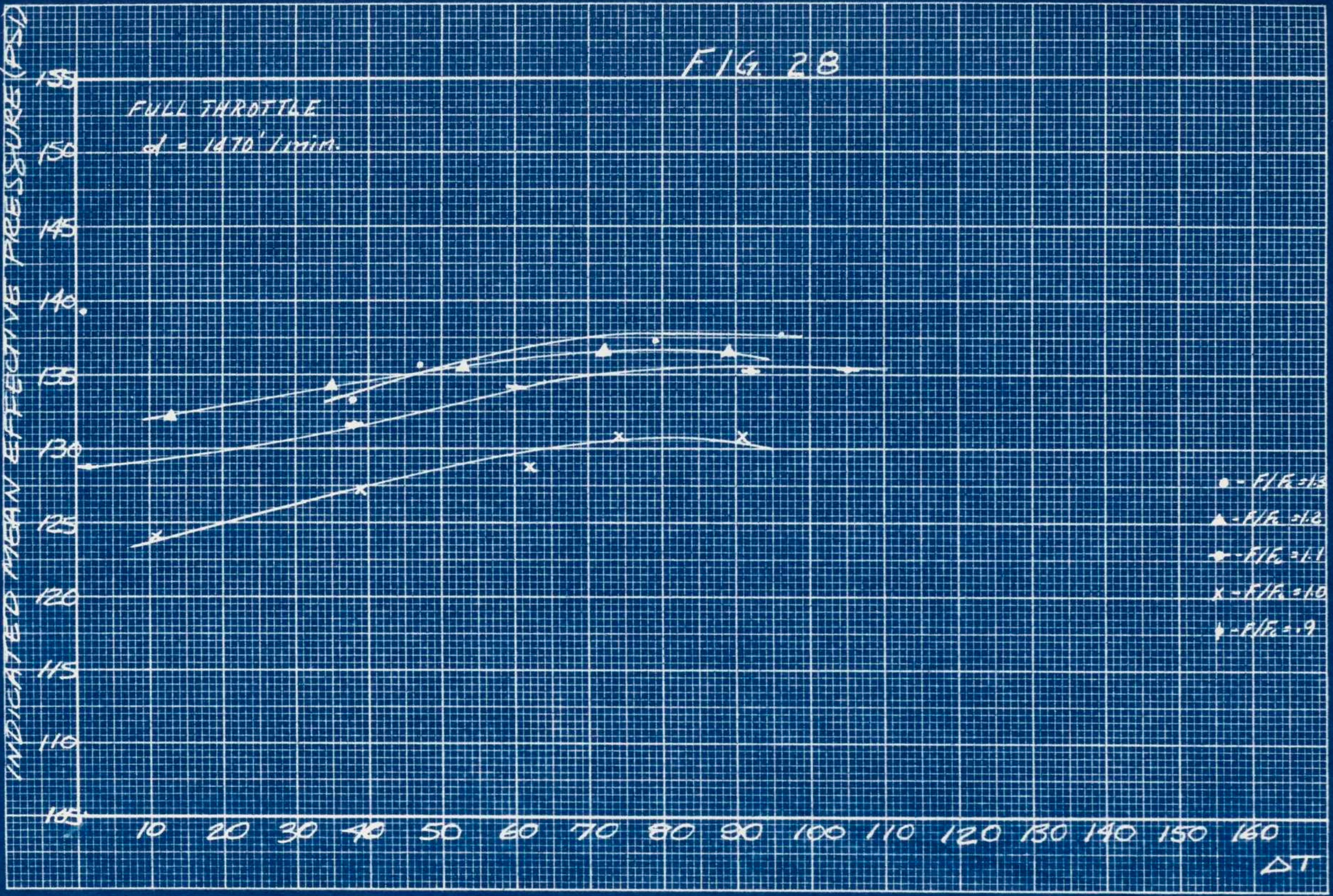
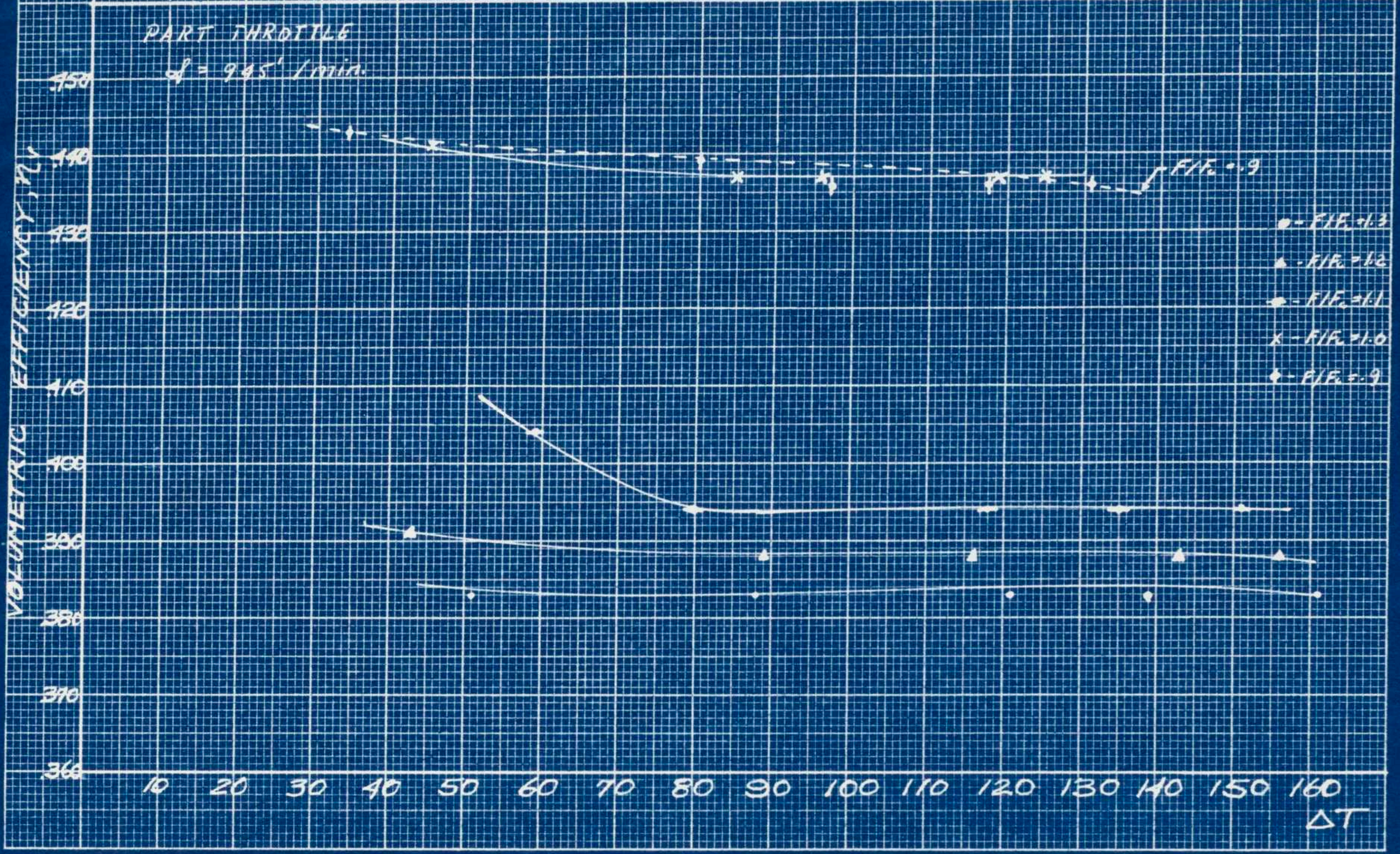

FULL THROTTLE
α = 1470' / min.
INDICATED MEAN EFFECTIVE PRESSURE (PSI)
155
150
145
140
135
130
125
120
115
110
105
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
• - F/Fc = 1.3
▲ - F/Fc = 1.2
- F/Fc = 1.1
x - F/Fc = 1.0
- F/Fc = .9

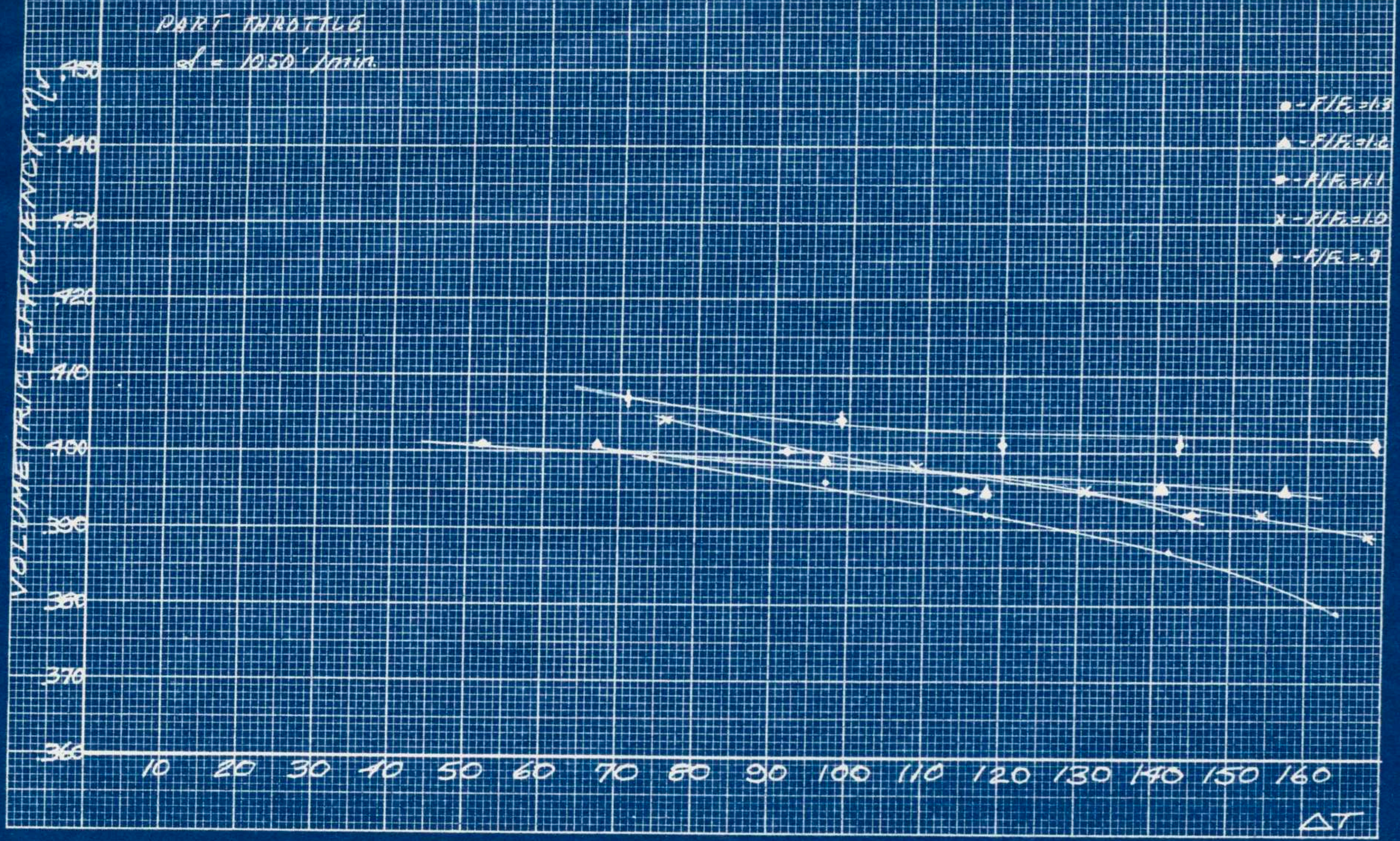
FIG. 28

FIG. 29



PART THROTTLE
S = 995'/min.
VOLUMETRIC EFFICIENCY, ηv
450
440
430
420
410
400
390
380
370
360
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
F/Fc = .9
● - F/Fc = 1.3
▲ - F/Fc = 1.2
● - F/Fc = 1.1
x - F/Fc = 1.0
♦ - F/Fc = .9

FIG. 30


PART THROTTLE
S = 1050'/min.
VOLUMETRIC EFFICIENCY, η_v
.450
.440
.430
.420
.410
.400
.390
.380
.370
.360
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
● - F/Fc = 1.3
▲ - F/Fc = 1.2
◆ - F/Fc = 1.1
x - F/Fc = 1.0
✦ - F/Fc = .9

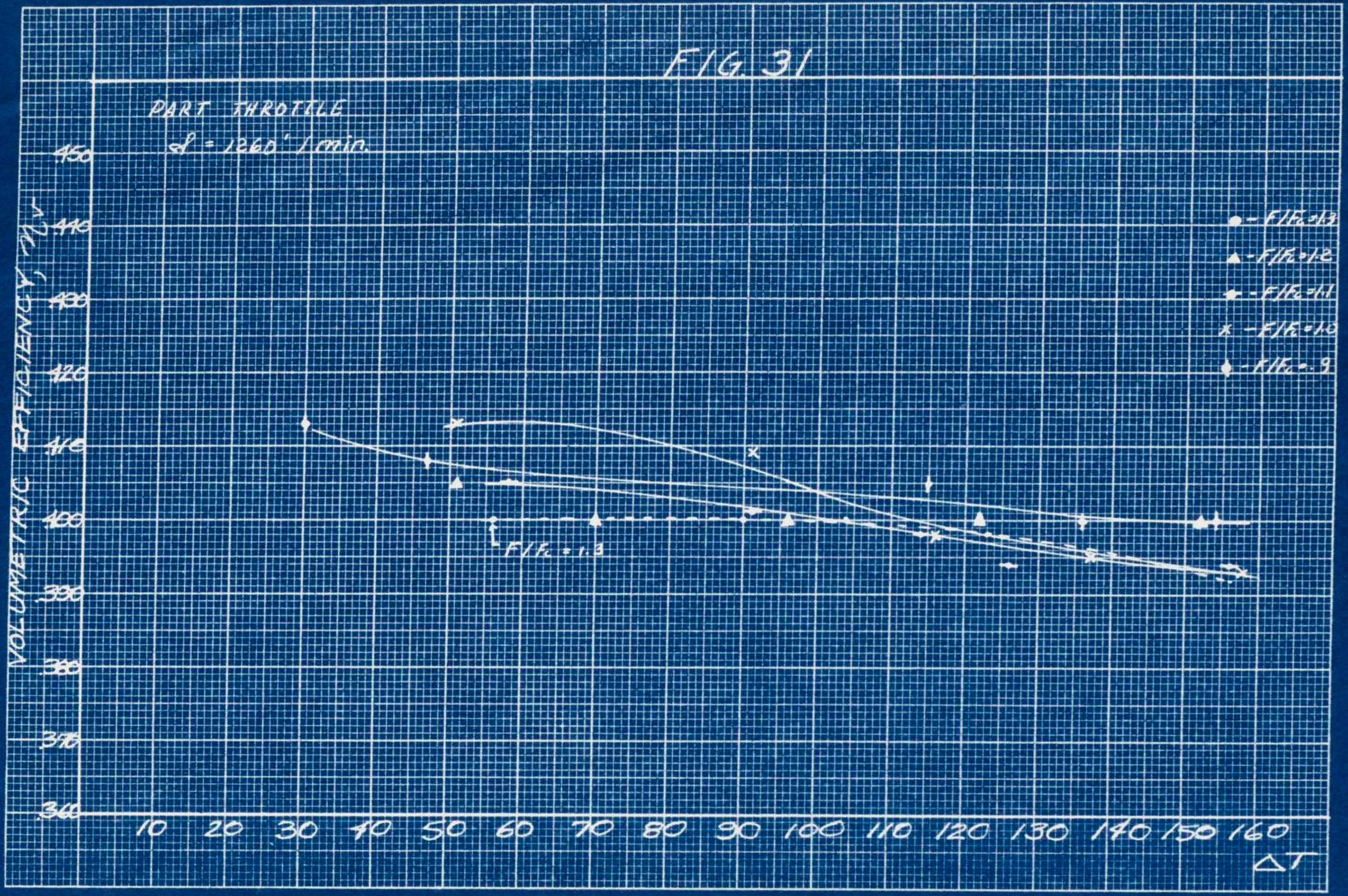
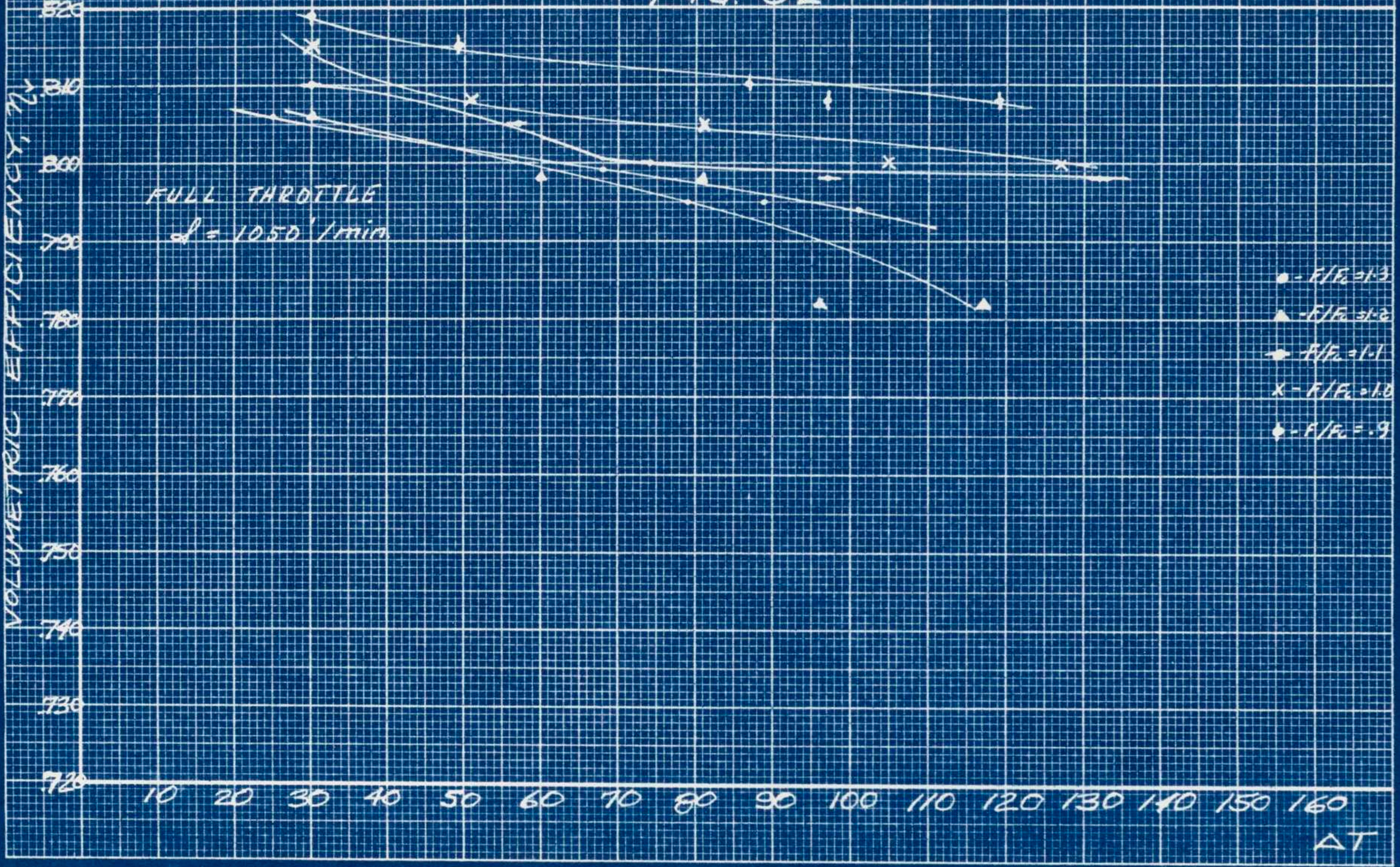


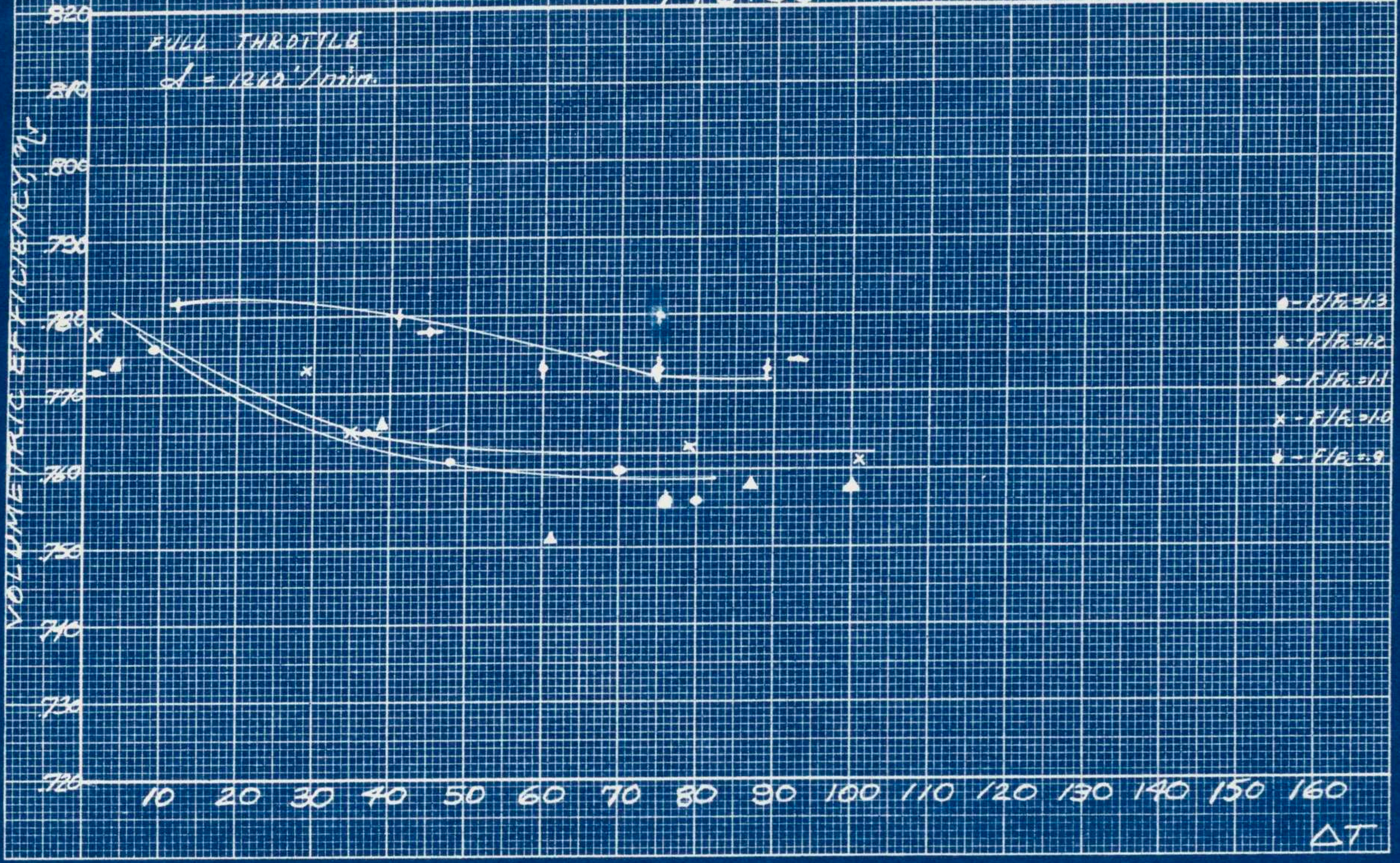
FIG. 31
PART THROTTLE
ϑ = 1260' / min.
VOLUMETRIC EFFICIENCY, ηv
450
440
430
420
410
400
390
380
370
360
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
F/Fc = 1.3
● - F/Fc = 1.3
▲ - F/Fc = 1.2
- F/Fc = 1.1
× - F/Fc = 1.0
- F/Fc = .9

FIG. 32



VOLUMETRIC EFFICIENCY, η_v
.820
.810
.800
.790
.780
.770
.760
.750
.740
.730
.720
FULL THROTTLE
$\mathcal{S}$ = 1050'/min
● - F/Fc = 1.3
▲ - F/Fc = 1.2
- F/Fc = 1.1
X - F/Fc = 1.0
- F/Fc = .9
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT

FIG. 33.


FULL THROTTLE
$\mathcal{L}$ = 1260'/min.
VOLUMETRIC EFFICIENCY, η_v
.820
.810
.800
.790
.780
.770
.760
.750
.740
.730
.720
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
F/Fc = 1.3
F/Fc = 1.2
F/Fc = 1.1
F/Fc = 1.0
F/Fc = .9

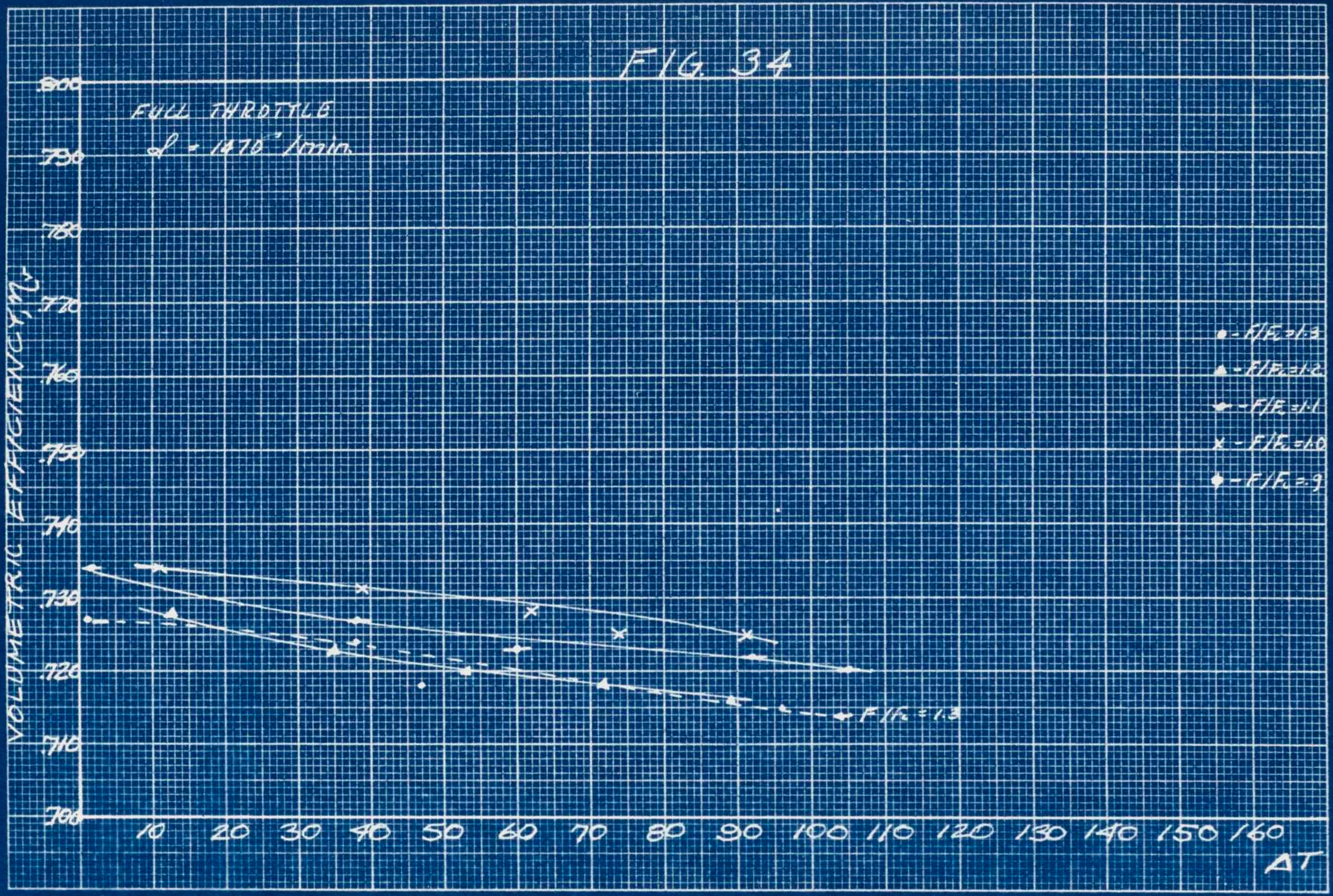


FIG. 34
FULL THROTTLE
= 1470 /min.
VOLUMETRIC EFFICIENCY
.800
.790
.780
.770
.760
.750
.740
.730
.720
.710
.700
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
ΔT
F/Fc = 1.3
- F/Fc = 1.3
- F/Fc = 1.2
- F/Fc = 1.1
- F/Fc = 1.0
- F/Fc = .9

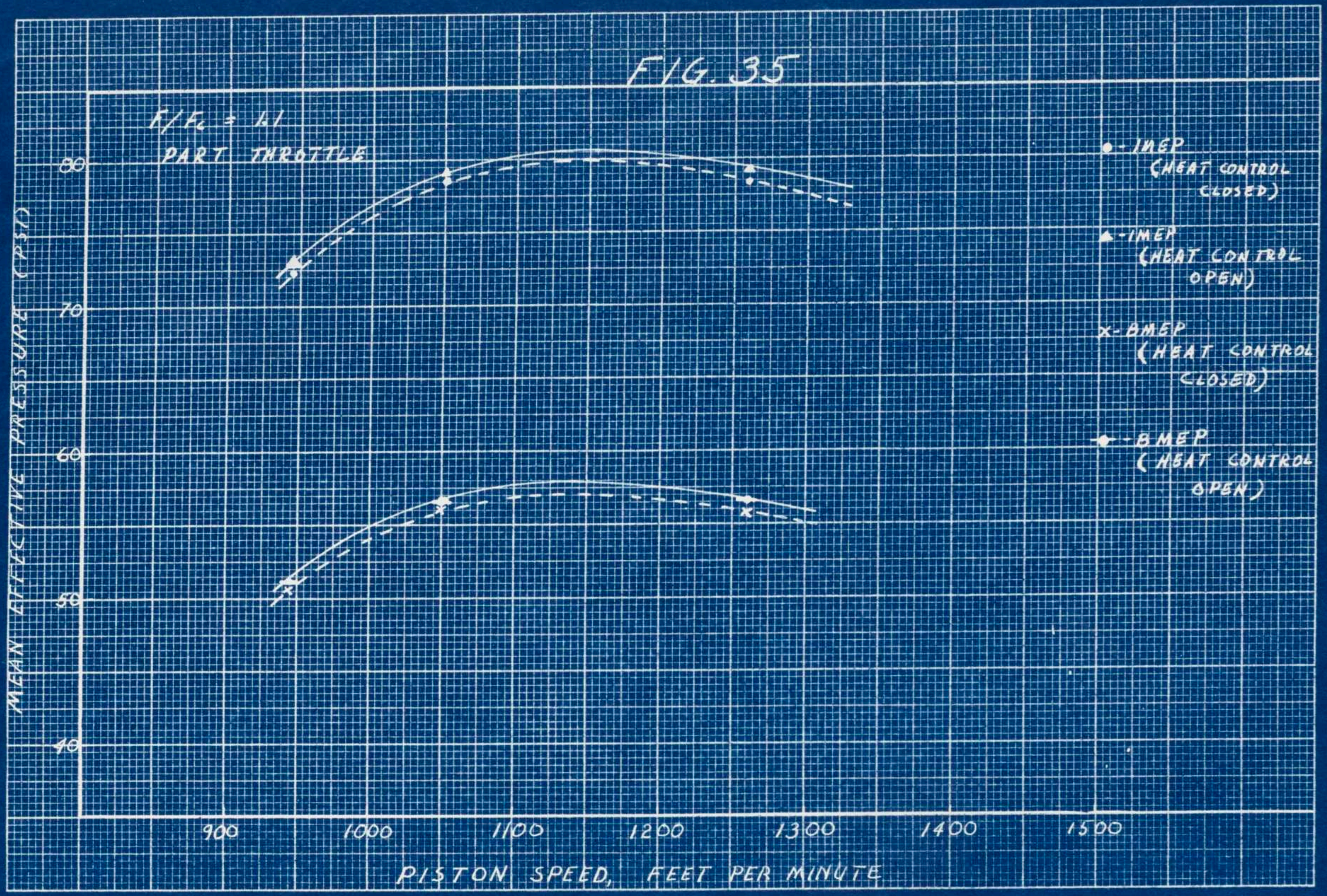
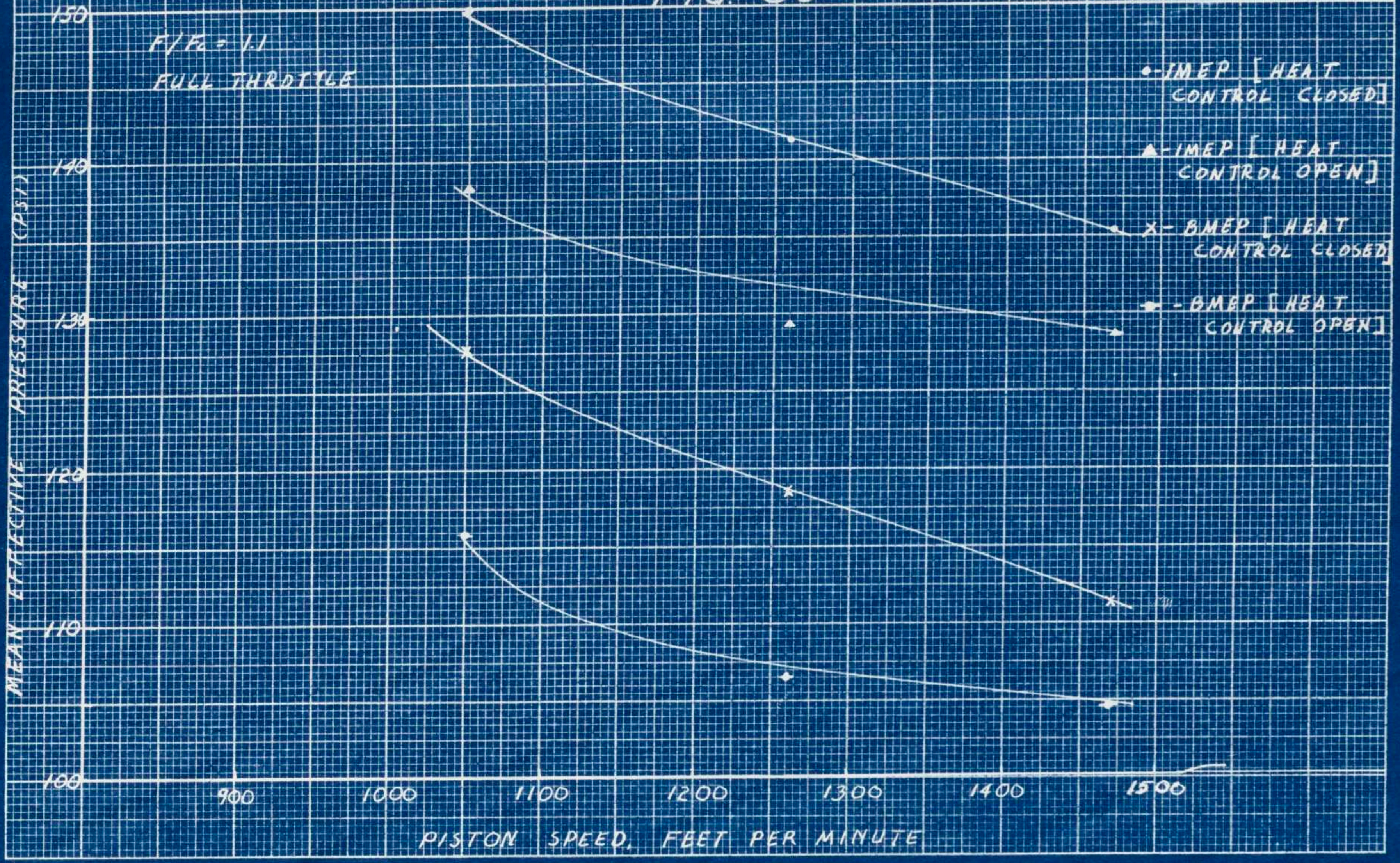


FIG. 35
F/Fc = 1.1
PART THROTTLE
• - IMEP (HEAT CONTROL CLOSED)
▲ - IMEP (HEAT CONTROL OPEN)
x - BMEP (HEAT CONTROL CLOSED)
• - BMEP (HEAT CONTROL OPEN)
MEAN EFFECTIVE PRESSURE (PSI)
80
70
60
50
40
900
1000
1100
1200
1300
1400
1500
PISTON SPEED, FEET PER MINUTE

FIG. 36



F/Fc = 1.1
FULL THROTTLE
• - IMEP [HEAT CONTROL CLOSED]
▲ - IMEP [HEAT CONTROL OPEN]
X - BMEP [HEAT CONTROL CLOSED]
◆ - BMEP [HEAT CONTROL OPEN]
MEAN EFFECTIVE PRESSURE (PSI)
150
140
130
120
110
100
900
1000
1100
1200
1300
1400
1500
PISTON SPEED, FEET PER MINUTE

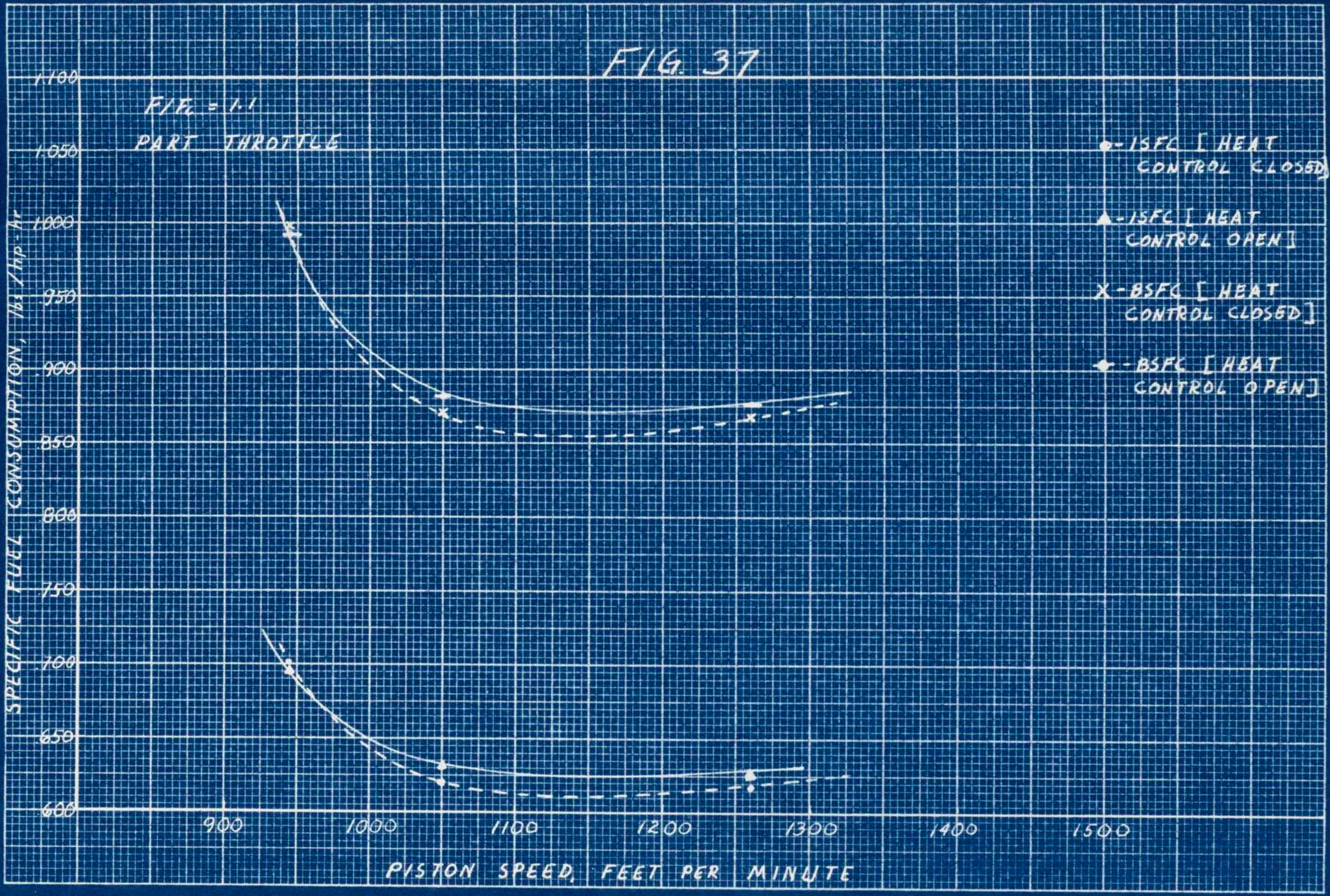


FIG. 37
F/Fc = 1.1
PART THROTTLE
1.100
1.050
1.000
.950
.900
.850
.800
.750
.700
.650
.600
SPECIFIC FUEL CONSUMPTION, lbs./hp-hr
900
1000
1100
1200
1300
1400
1500
PISTON SPEED, FEET PER MINUTE
● - ISFC [HEAT CONTROL CLOSED]
▲ - ISFC [HEAT CONTROL OPEN]
X - BSFC [HEAT CONTROL CLOSED]
◆ - BSFC [HEAT CONTROL OPEN]

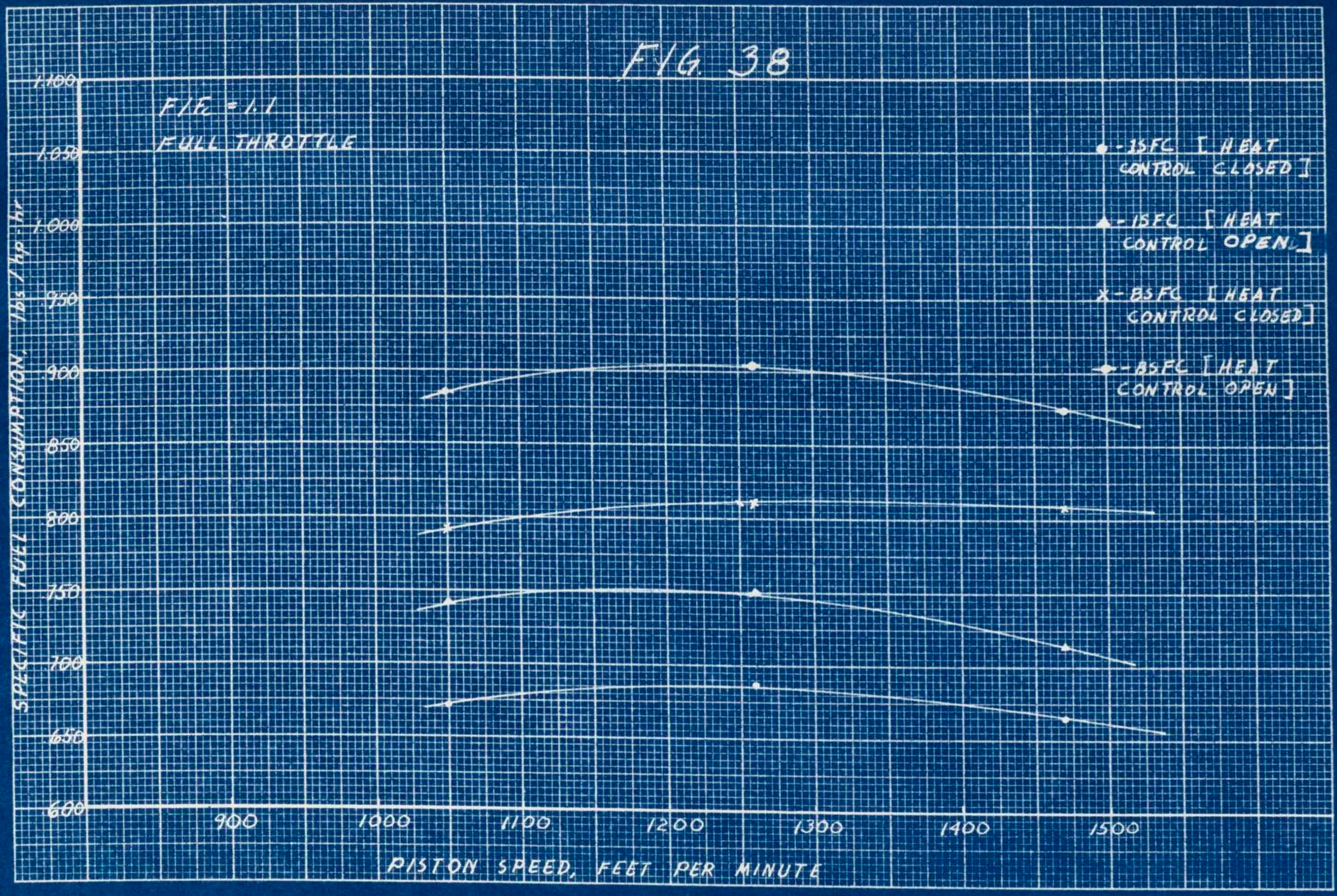


FIG. 38
F/E = 1.1
FULL THROTTLE
• - ISFC [HEAT CONTROL CLOSED]
▲ - ISFC [HEAT CONTROL OPEN]
X - BSFC [HEAT CONTROL CLOSED]
-•- - BSFC [HEAT CONTROL OPEN]
SPECIFIC FUEL CONSUMPTION, lbs / hp · hr
1.100
1.050
1.000
.950
.900
.850
.800
.750
.700
.650
.600
900
1000
1100
1200
1300
1400
1500
PISTON SPEED, FEET PER MINUTE

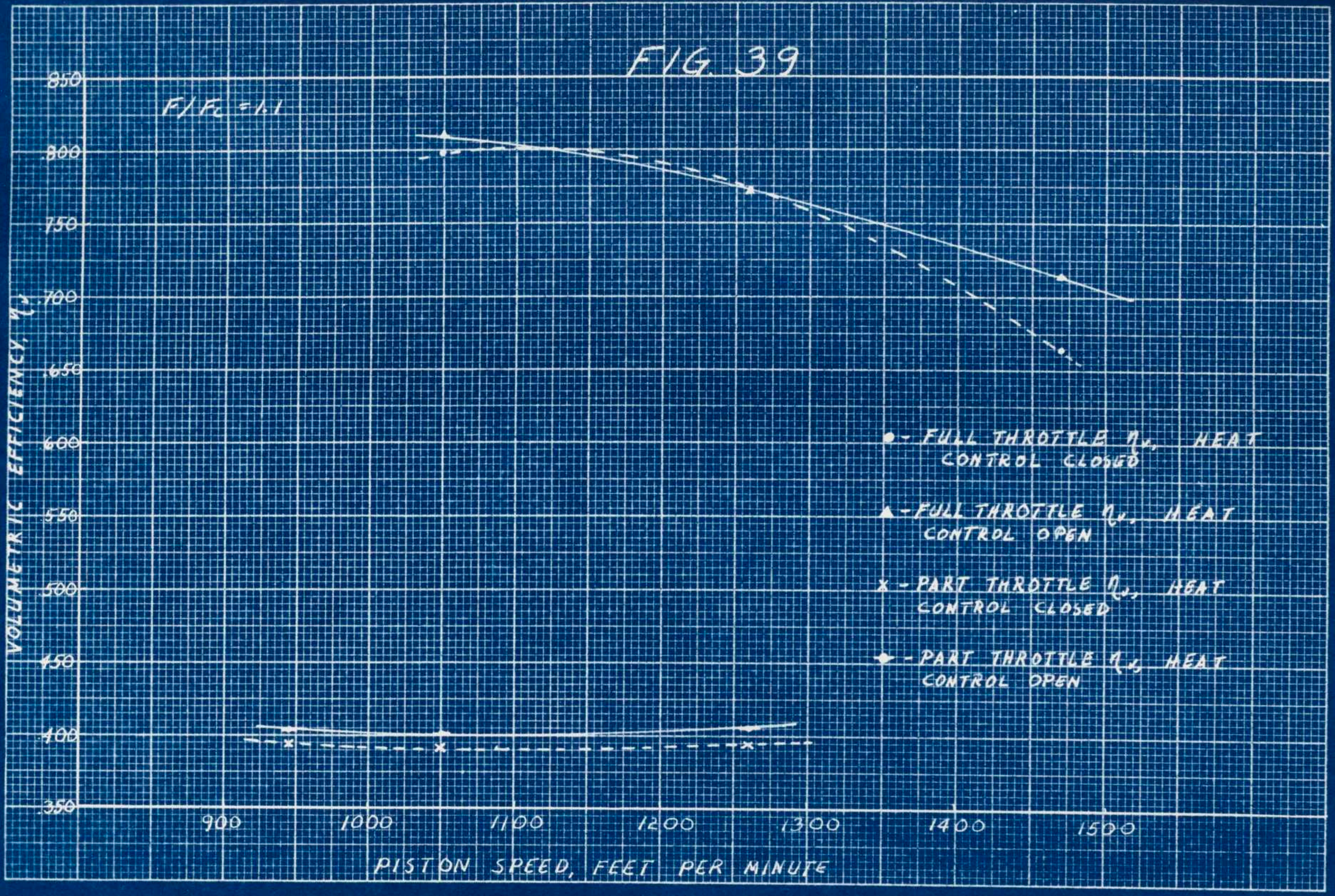
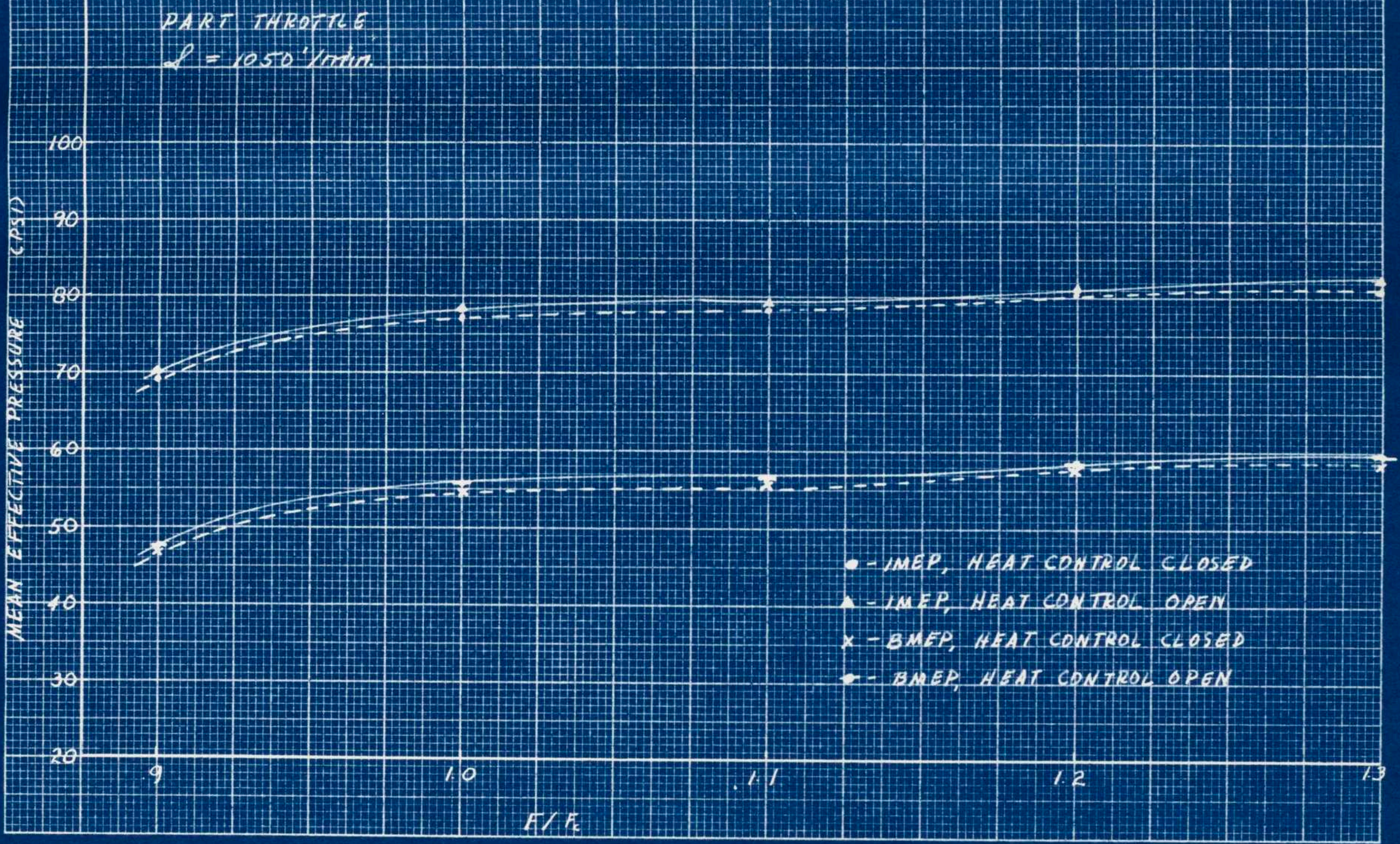


FIG. 39
F/Fc = 1.1
850
800
750
.700
.650
.600
.550
.500
.450
.400
.350
VOLUMETRIC EFFICIENCY, ηv
900
1000
1100
1200
1300
1400
1500
PISTON SPEED, FEET PER MINUTE
● - FULL THROTTLE ηv. HEAT CONTROL CLOSED
▲ - FULL THROTTLE ηv. HEAT CONTROL OPEN
x - PART THROTTLE ηv. HEAT CONTROL CLOSED
◆ - PART THROTTLE ηv. HEAT CONTROL OPEN



PART THROTTLE
$\mathcal{S}$ = 1050'/min.
MEAN EFFECTIVE PRESSURE (PSI)
100
90
80
70
60
50
40
30
20
.9
1.0
1.1
1.2
1.3
F/Fc
● - IMEP, HEAT CONTROL CLOSED
▲ - IMEP, HEAT CONTROL OPEN
x - BMEP, HEAT CONTROL CLOSED
✦ - BMEP, HEAT CONTROL OPEN

FIG. 40

FIG. 41

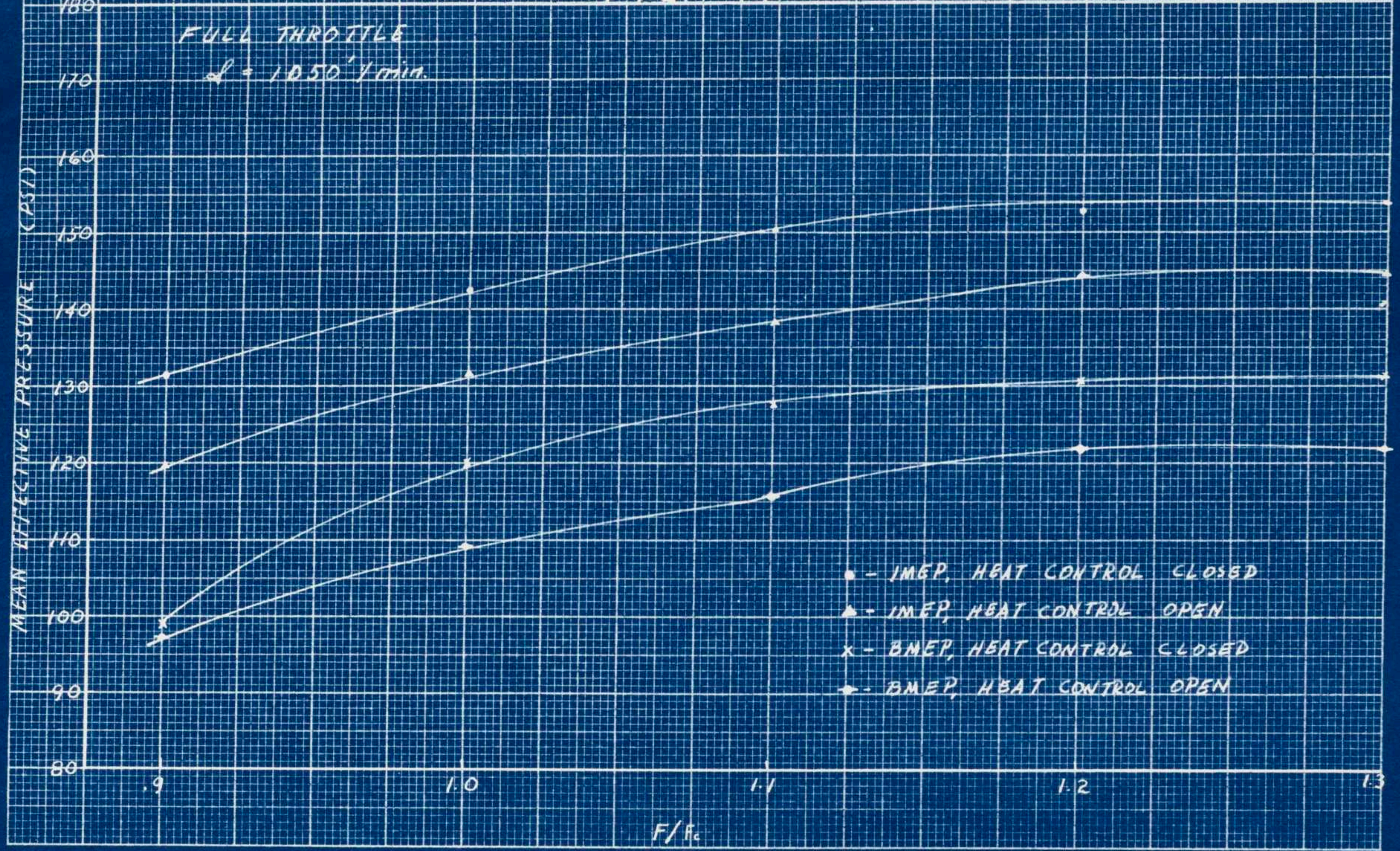
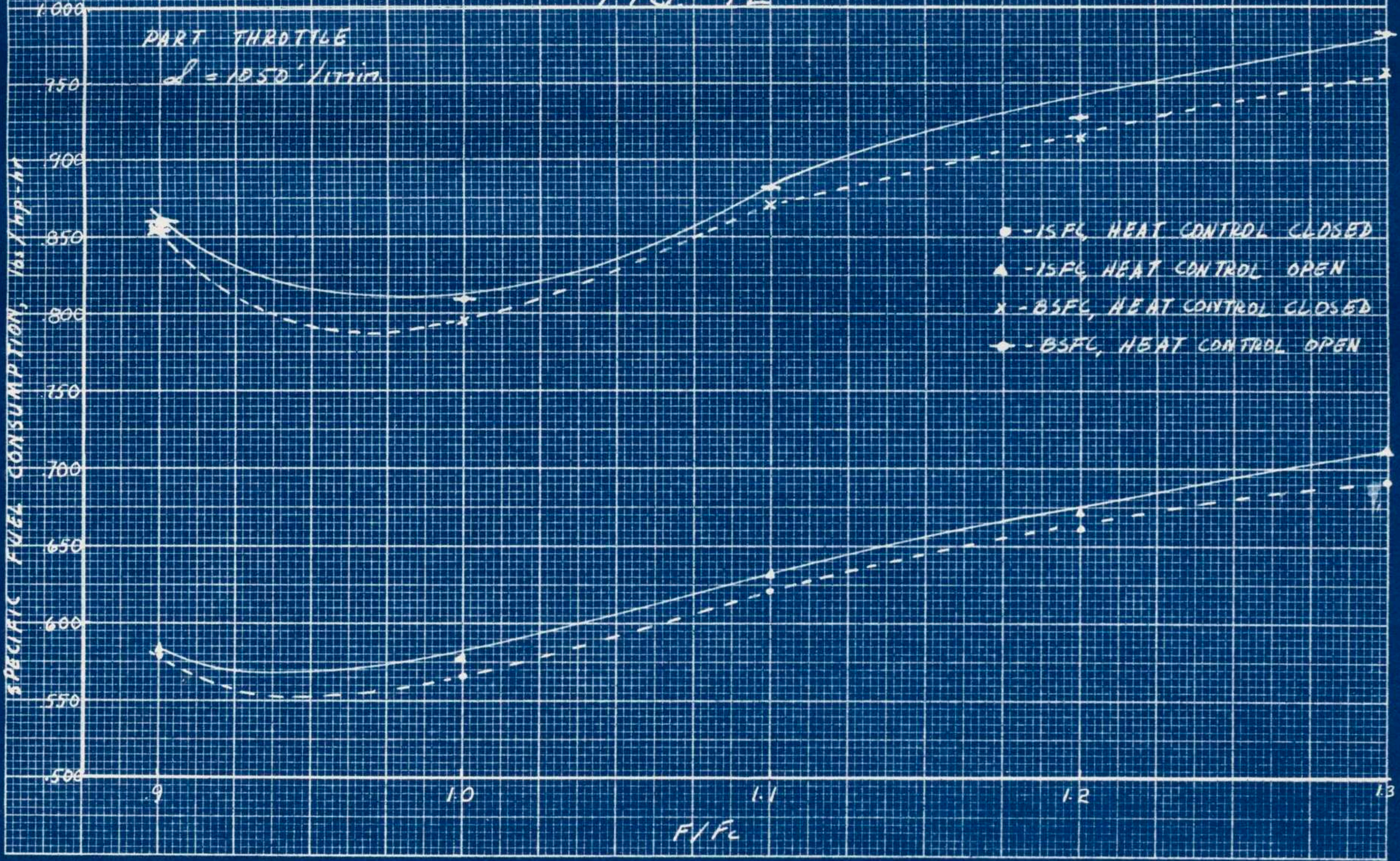

FULL THROTTLE
s = 1050'/min.
MEAN EFFECTIVE PRESSURE (PSI)
180
170
160
150
140
130
120
110
100
90
80
.9
1.0
1.1
1.2
1.3
F/Fc
• - IMEP, HEAT CONTROL CLOSED
▲ - IMEP, HEAT CONTROL OPEN
x - BMEP, HEAT CONTROL CLOSED
◆ - BMEP, HEAT CONTROL OPEN

FIG. 42



PART THROTTLE
$\mathcal{L}$ = 1050'/min.
1.000
.950
.900
.850
.800
.750
.700
.650
.600
.550
.500
SPECIFIC FUEL CONSUMPTION, lbs / hp-hr
- ISFC, HEAT CONTROL CLOSED
- ISFC, HEAT CONTROL OPEN
- BSFC, HEAT CONTROL CLOSED
- BSFC, HEAT CONTROL OPEN
.9
1.0
1.1
1.2
1.3
F / Fc

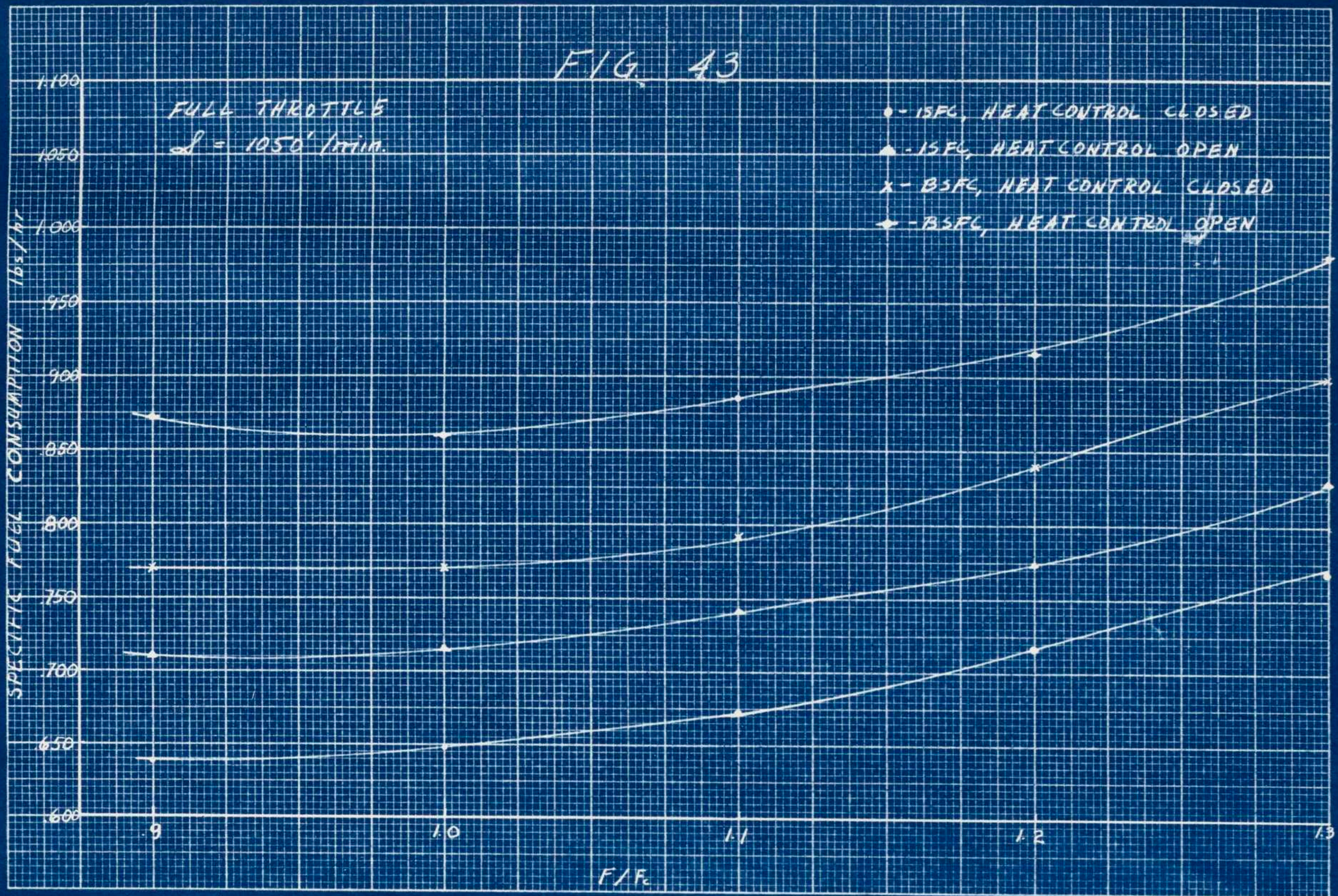


FIG. 43
FULL THROTTLE
S = 1050'/min.
• - ISFC, HEAT CONTROL CLOSED
▲ - ISFC, HEAT CONTROL OPEN
x - BSFC, HEAT CONTROL CLOSED
♦ - BSFC, HEAT CONTROL OPEN
SPECIFIC FUEL CONSUMPTION lbs/hr
1.100
1.050
1.000
.950
.900
.850
.800
.750
.700
.650
.600
.9
1.0
1.1
1.2
1.3
F/Fc

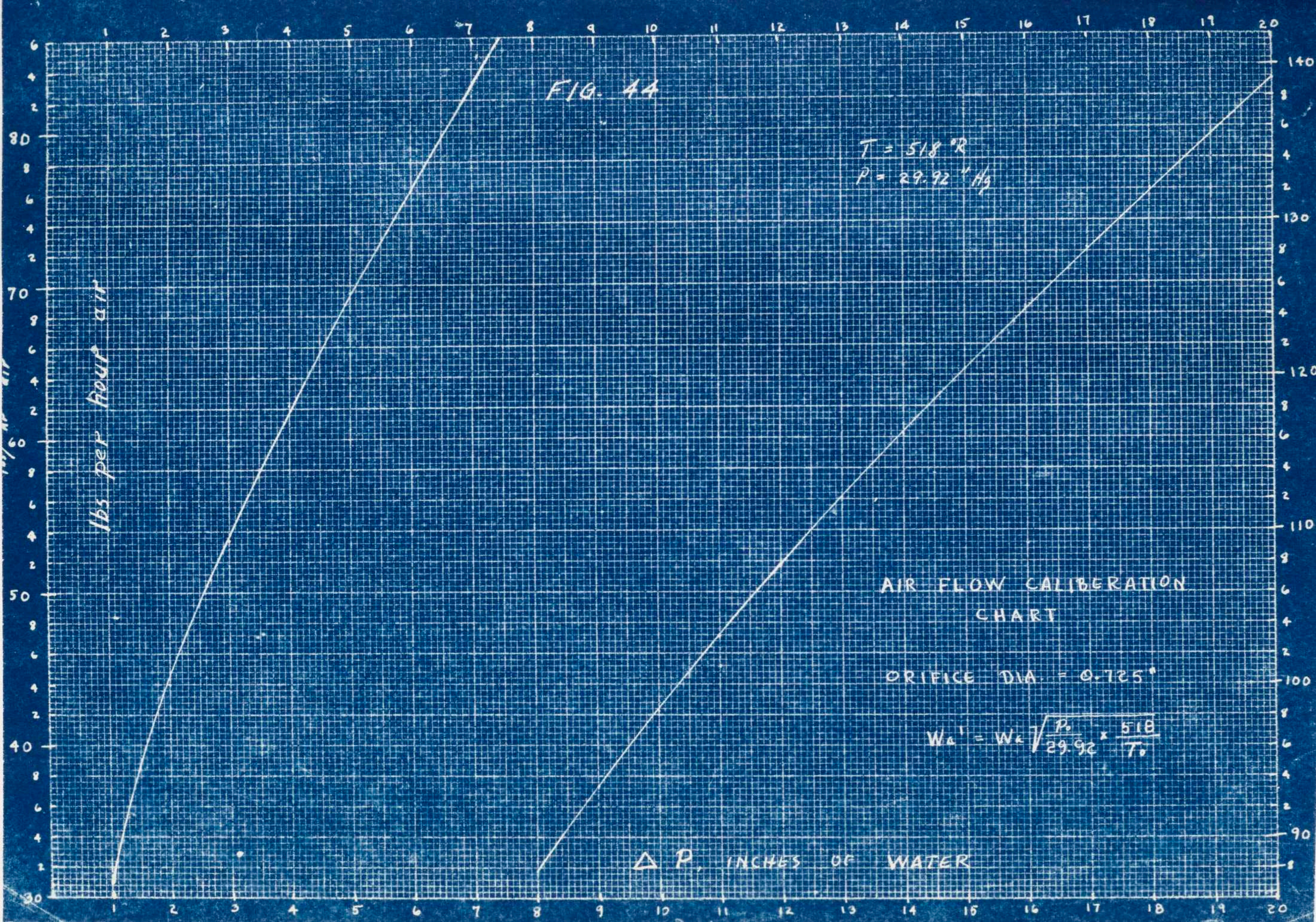


FIG. 44
T = 518 °R
P = 29.92 " Hg
lbs per hour air
AIR FLOW CALIBERATION
CHART
ORIFICE DIA = 0.725"
Wa' = Wa √(P₀/29.92 × 518/T₀)
Δ P, INCHES OF WATER

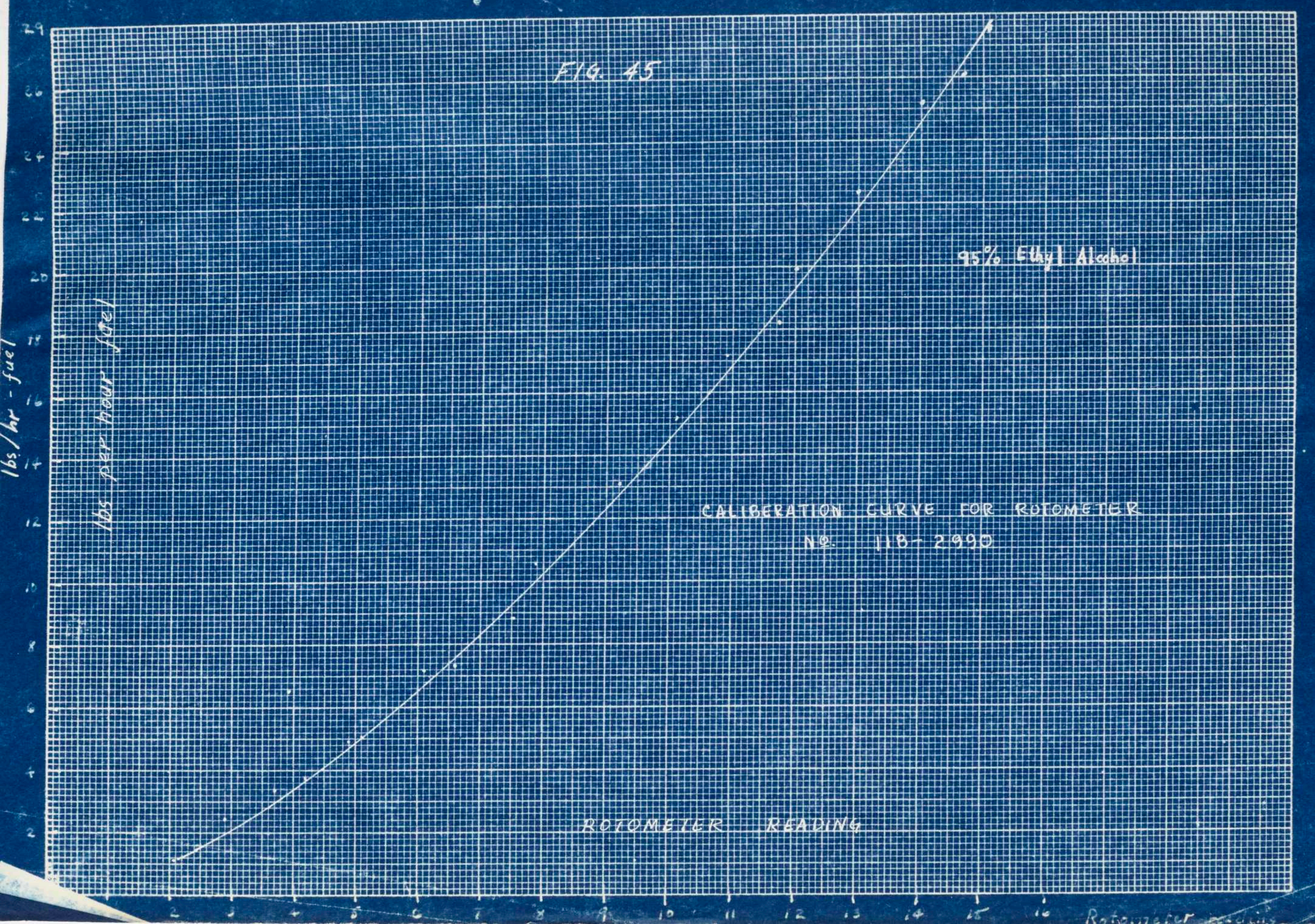
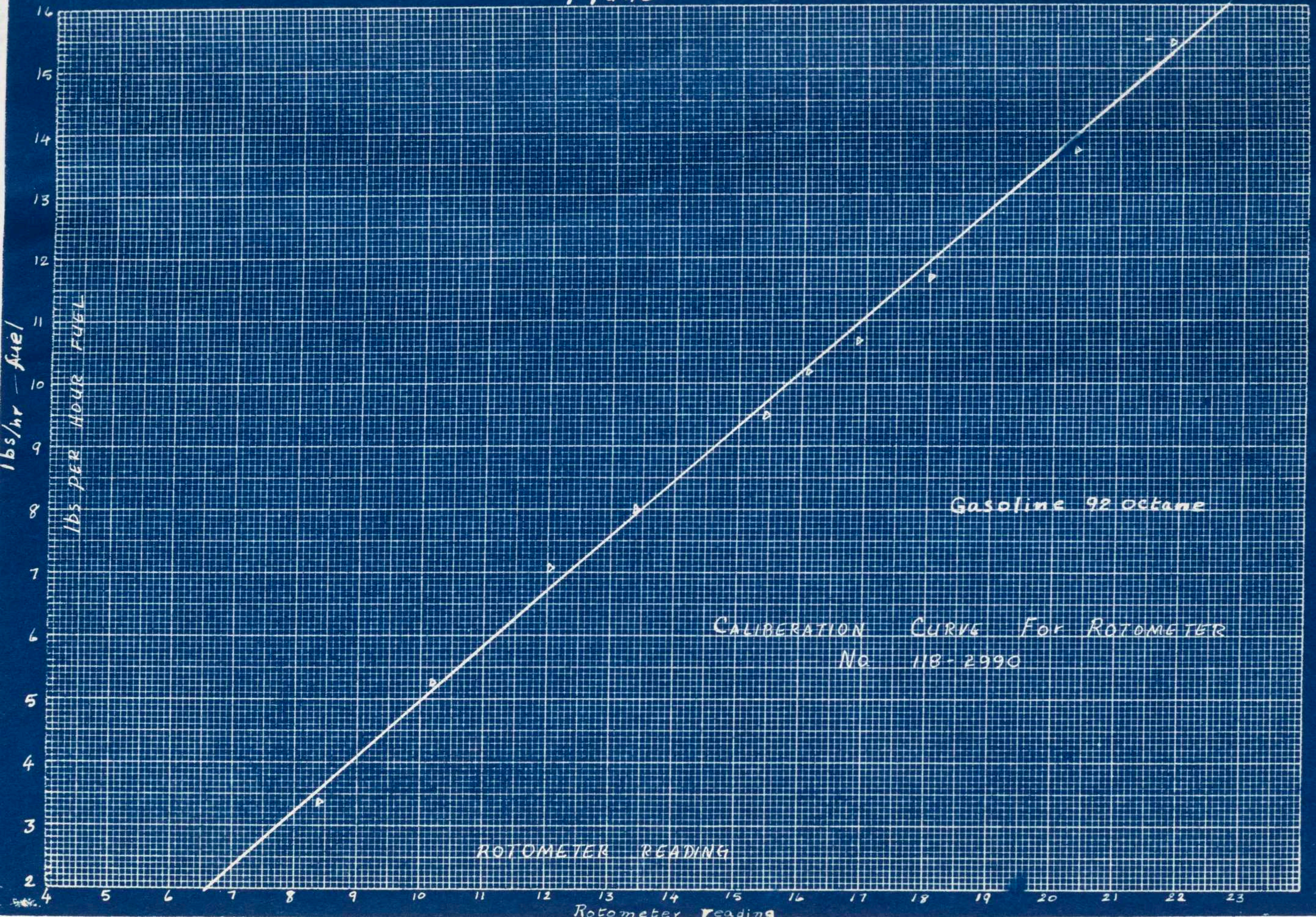

95% Ethyl Alcohol
CALIBRATION CURVE FOR ROTOMETER
No. 118-2990
ROTOMETER READING
lbs per hour fuel
lbs/hr - fuel

FIG. 45

Fig 46


lbs/hr — fuel
lbs PER HOUR FUEL
Gasoline 92 octane
CALIBERATION CURVE FOR ROTOMETER
NO 118-2990
ROTOMETER READING
Rotometer reading
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
4
5
6
7
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9
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EXPERIMENT NO. 1 **TITLE** ENGINE PERFORMANCE & ECONOMY TEST - FULL THROTTLE **DATE** FEBRUARY 24, 1960 **SLOAN LABORATORY**

ENGINE RENAULT DAUPHINE, 4 CYL **FUEL** 92 Octane Gasoline **S.G.** ______ **WET BULB** ______ **DRY BULB** 72 °F

BORE 58 mm **STROKE** 80 mm **COMPRESSION RATIO** 7.25 : 1 **BAROMETER (ACT.)** ______ **(CORR.)** 76.09 cm. Hg.

CONSTANTS BMEP = B.L. X 11.5 BHP = $\frac{\text{B.L. X RPM}}{1530}$

REMARKS	TIME	RUN	RPM	B.L.	F.L.	TEMP. OIL	TEMP. JAC	OIL PRES.	P_1	P_E	T_1	AIR CONS.	FUEL CONS.	F/A	S.A.	ΔP	Rotometer Reading	F/Fc	t_i	t_o	Man. Vac.	Corr. Factor
HEAT CONTROL - FULLY OPEN		1	2400	9.75	1.5	150	180							.0865	17	15.6	16.3	1.3	1171	1171	1.5	.985
3/4 "		2		9.6												15.15	16.1		1175	1148		
1/2 "		3		9.4												14.8	16.0		1171	1107		
1/4 "		4		9.35												14.6	15.9		1167	1084		
FULLY CLOSED		5	↓	9.2	↓	↓	↓							↓		14.4	15.8	↓	1167	1074	↓	↓
FULLY OPEN		6	2400	9.7	1.5	150	180							.0798		15.3	15.25	1.2	1218	1218	1.5	.985
3/4 "		7		9.5												14.9	15.15		1218	1184		
1/2 "		8		9.35												14.55	15.0		1205	1140		
1/4 "		9		9.25												14.4	14.9		1201	1124		
FULLY CLOSED		10	↓	9.2	↓	↓	↓							↓		14.2	14.85	↓	1226	1122	↓	↓
FULLY OPEN		11	2400	9.5	1.5	150	180							.0731		15.1	14.3	1.1	1247	1247	1.5	.985
3/4 "		12		9.3												14.65	14.15		1247	1203		
1/2 "		13		9.1												14.4	14.0		1247	1175		
1/4 "		14		9.0												14.3	13.96		1247	1162		
FULLY CLOSED		15	↓	8.9	↓	↓	↓							↓		14.1	13.9	↓	1262	1158	↓	↓
FULLY OPEN		16	2400	9.0	1.5	150	180							.0677		15.3	13.45	1.0	1227	1227	1.5	.985
3/4 "		17		8.8												14.85	13.35		1227	1201		
1/2 "		18		8.7												14.6	13.2		1227	1160		
1/4 "		19		8.5												14.4	13.17		1227	1148		
FULLY CLOSED		20	↓	8.45	↓	↓	↓							↓		14.2	13.07	↓	1246	1138	↓	↓
FULLY OPEN		21	2400	7.65	1.5	150	180							.0558		15.7	12.65	.9	1201	1201	1.5	.985
3/4 "		22		7.6												15	12.57		1190	1146		
1/2 "		23		7.6												15	12.5		1181	1107		
1/4 "		24		7.5												14	12.4		1171	1090		
FULLY CLOSED		25	↓	7.55	↓	↓	↓							↓		14	12.35	↓	1192	1091	↓	↓

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EXPERIMENT NO. 2 **TITLE** ENGINE PERFORMANCE & ECONOMY TEST - PART THROTTLE **DATE** FEBRUARY 25, 1960 **SLOAN LABORATORY**

ENGINE RENAULT DAUPHINE, 4 CYL. **FUEL** 92 Octane Gasoline **S.G.** ______ **WET BULB** ______ **DRY BULB** 75 °F

BORE 58 mm **STROKE** 80 mm **COMPRESSION RATIO** 7.25:1 **BAROMETER (ACT.)** ______ **(CORR.)** 76.8 cm. Hg.

CONSTANTS BMEP = B.L. X 11.5 BHP = $\frac{\text{B.L. x RPM}}{1336}$

REMARKS	TIME	RUN	RPM	B.L.	F.L.	TEMP. OIL	TEMP. JAC	OIL PRES.	P_I	P_E	T_I	AIR CONS.	FUEL CONS.	F/A	S.A.	ΔP	Rotometer Reading	F/Fc	t_i	t_o	Man. Vac.	Corr. Factor
EAT CONTROL - FULLY OPEN		26	1800	3.9	1.5	150	180							.0865	16	2.15	8.85	1.3	1103	1015	13.2	.986
3/4 "		27		3.8												2.15	8.85		1124	968		
1/2 "		28		3.8												2.15	8.85		1124	927		
1/4 "		29		3.7												2.1	8.82		1122	909		
FULLY CLOSED		30	↓	3.65	↓	↓	↓							↓	↓	2.0	8.76	↓	1122	905	↓	↓
FULLY OPEN		31	1800	3.75	1.5	150	180							.0798	16	2.1	8.5	1.2	1150	1019	13.2	.986
3/4 "		32		3.68												2.05	8.47		1151	989		
1/2 "		33		3.62												2.0	8.42		1151	943		
1/4 "		34		3.58												2.0	8.42		1146	928		
FULLY CLOSED		35	↓	3.5	↓	↓	↓							↓	↓	1.9	8.35	↓	1150	927	↓	↓
FULLY OPEN		36	1800	3.45	1.5	150	180							.0731	16	2.1	8.00	1.1	1213	1188	12.6	.980
3/4 "		37		3.4												2.1	8.00		1226	1055		
1/2 "		38		3.35												2.0	7.95		1226	1006		
1/4 "		39		3.3												2.0	7.95		1215	983		
FULLY CLOSED		40	↓	3.27	↓	↓	↓							↓	↓	2.0	7.95	↓	1215	976	↓	↓
FULLY OPEN		41	1800	3	1.5	150	180							.0677	16	2.1	7.75	1.0	1218	1112	12.6	.980
3/4 "		42		2.96												2.05	7.70		1221	1021		
1/2 "		43		2.88												2.0	7.60		1219	999		
1/4 "		44		2.85												2.0	7.60		1215	990		
FULLY CLOSED		45	↓	2.88	↓	↓	↓							↓	↓	2.0	7.60	↓	1210	974	↓	↓
FULLY OPEN		46	1800	2.52	1.5	150	180							.0598	16	2.1	7.4	.9	1218	1116	12.6	.980
3/4 "		47		2.58												2.1	7.4		1219	1044		
1/2 "		48		2.58												2.05	7.37		1214	992		
1/4 "		49		2.55												2.0	7.35		1210	973		
FULLY CLOSED		50	↓	2.55	↓	↓	↓							↓	↓	2.0	7.35	↓	1210	965	↓	↓

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February 26, 1960
T dry bulb = 76
Barometer = 75.4 cm. Hg.

EXPERIMENT NO. 3 **TITLE** ENGINE PERFORMANCE & ECONOMY TEST – FULL THROTTLE **DATE** APRIL 23, 1960 **SLOAN LABORATORY**

ENGINE RENAULT DAUPHINE, 4 CYL. **FUEL** ETHYL ALCOHOL **S.G.** ______ **WET BULB** ______ **DRY BULB** 68°F

BORE 58mm **STROKE** 80mm **COMPRESSION RATIO** 12 : 1 **BAROMETER (ACT.)** ______ **(CORR.)** 76.2 cm. Hg.

CONSTANTS BMEP = B.L. X 11.5 BHP = $\frac{\text{B.L. x RPM}}{1336}$

REMARKS	TIME	RUN	RPM	B.L.	F.L.	TEMP. OIL	TEMP. JAC	OIL PRES.	P_1	P_E	T_1	AIR CONS.	FUEL CONS.	F/A	S.A.	ΔP	Rotometer Reading	F/F_c	t_i	t_o	Man. Vac.	Corr. Factor
HEAT CONTROL: Fully Open		55	2400	9.9	1.9	150	180							.1447	18	16.2	11.3	1.3	1049	1040	1.7	1.0
3/4 "		56	↓	10.25	↓	↓	↓							↓	↓	15.65	11.25	↓	1058	1010	↓	↓
1/2 "		57	↓	10.6	↓	↓	↓							↓	↓	15.5	11.25	↓	1053	983	↓	↓
1/4 "		58	↓	10.7	↓	↓	↓							↓	↓	15.35	11.2	↓	1048	972	↓	↓
Fully Closed		59	↓	10.7	↓	↓	↓							↓	↓	15.35	11.2	↓	1044	964	↓	↓
FULLY OPEN		60	2400	9.58	1.9	150	180							.1338	16	16	10.72	1.2	1055	1049	1.7	1.0
3/4 "		61	↓	10.3	↓	↓	↓							↓	↓	15.75	10.65	↓	1041	1002	↓	↓
1/2 "		62	↓	10.52	↓	↓	↓							↓	↓	15.5	10.55	↓	1061	1000	↓	↓
1/4 "		63	↓	10.65	↓	↓	↓							↓	↓	15.4	10.55	↓	1065	979	↓	↓
FULLY CLOSED		64	↓	10.65	↓	↓	↓							↓	↓	15.4	10.55	↓	1065	965	↓	↓
FULLY OPEN		65	2400	9.25	1.9	150	180							.1225	16	16.1	10.0	1.1	1120	1120	1.7	.984
3/4 "		66	↓	9.9	↓	↓	↓							↓	↓	15.75	9.9	↓	1110	1073	↓	↓
1/2 "		67	↓	10.15	↓	↓	↓							↓	↓	15.75	10	↓	1063	1018	↓	↓
1/4 "		68	↓	10.3	↓	↓	↓							↓	↓	15.65	9.95	↓	1065	998	↓	↓
FULLY CLOSED		69	↓	10.3	↓	↓	↓							↓	↓	15.6	9.95	↓	1082	989	↓	↓
FULLY OPEN		70	2400	8.85	1.9	150	180							.1114	16	16.3	9.47	1.0	1105	1105	1.7	.984
3/4 "		71	↓	9.42	↓	↓	↓							↓		16	9.4	↓	1099	1070	↓	↓
1/2 "		72	↓	9.7	↓	↓	↓							↓		15.8	9.35	↓	1099	1062	↓	↓
1/4 "		73	↓	9.85	↓	↓	↓							↓		15.7	9.3	↓	1120	1041	↓	↓
FULLY CLOSED		74	↓	9.85	↓	↓	↓							↓		15.65	9.3	↓	1120	1019	↓	↓
FULLY OPEN		75	2400	7.25	1.9	150	180							.1002	16	16.7	8.82	.9	1006	994	1.7	.984
3/4 "		76	↓	8.35	↓	↓	↓							↓	↓	16.3	8.75	↓	1150	1109	↓	↓
1/2 "		77	↓	8.45	↓	↓	↓							↓	↓	16.2	8.75	↓	1154	1094	↓	↓
1/4 "		78	↓	8.55	↓	↓	↓							↓	↓	16.1	8.7	↓	1142	1067	↓	↓
FULLY CLOSED		79	↓	8.65	↓	↓	↓							↓	↓	16.05	8.7	↓	1148	1059	↓	↓

(Runs 65–79:) April 25, 1960
Barometer (corr) = 75.37 cm

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EXPERIMENT NO. 4 **TITLE** ENGINE PERFORMANCE AND ECONOMY TEST - PART THROTTLE **DATE** MAY 2, 1960 **SLOAN LABORATORY**

ENGINE RENAULT DAUPHINE, 4 CYL. **FUEL** ETHYL ALCOHOL **S.G.** ______ **WET BULB** ______ **DRY BULB** 76 °F

BORE 58 mm **STROKE** 80 mm **COMPRESSION RATIO** 12 : 1 **BAROMETER (ACT.)** ______ **(CORR.)** 77.01 cm Hg

CONSTANTS BMEP = B.L. X 11.5 BHP = $\frac{\text{B.L. x RPM}}{1336}$

REMARKS	TIME	RUN	RPM	B.L.	F.L.	TEMP. OIL	TEMP. JAC	OIL PRES.	P_1	P_E	T_1	AIR CONS.	FUEL CONS.	F/A	S.A.	ΔP	Rotameter Reading	F/F_c	t_i	t_o	Man. Vac.	Corr Factor
HEAT-CONTROL: FULLY OPEN		80	1800	4.9	1.9	150	180							.1467	16	2.25	5.9	1.3	932	881	13.3	.982
3/4 "		81	↓	5.05	↓	↓	↓							↓		2.25	5.9	↓	951	863	↓	↓
1/2 "		82	↓	5.1	↓	↓	↓							↓		2.25	5.9	↓	958	837	↓	↓
1/4 "		83	↓	5.1	↓	↓	↓							↓		2.25	5.9	↓	964	825	↓	↓
FULLY CLOSED		84	↓	5.15	↓	↓	↓							↓		2.25	5.9	↓	964	803	↓	↓
FULLY OPEN		85	1800	4.88	1.9	150	180							.1338		2.33	5.84	1.2	932	889	13.3	.982
3/4 "		86	↓	4.9	↓	↓	↓							↓		2.3	5.8	↓	960	871	↓	↓
1/2 "		87	↓	4.95	↓	↓	↓							↓		2.3	5.8	↓	972	856	↓	↓
1/4 "		88	↓	4.95	↓	↓	↓							↓		2.3	5.8	↓	972	829	↓	↓
FULLY CLOSED		89	↓	4.95	↓	↓	↓							↓		2.3	5.8	↓	972	816	↓	↓
FULLY OPEN		90	1800	4.95	1.9	150	180							.1225		2.5	5.5	1.1	947	888	13.3	.982
3/4 "		91	↓	4.32	↓	↓	↓							↓		2.4	5.45	↓	943	863	↓	↓
1/2 "		92	↓	4.32	↓	↓	↓							↓		2.4	5.45	↓	947	829	↓	↓
1/4 "		93	↓	4.32	↓	↓	↓							↓		2.4	5.45	↓	947	812	↓	↓
FULLY CLOSED		94	↓	4.4	↓	↓	↓							↓		2.4	5.45	↓	947	791	↓	↓
FULLY OPEN		95	1800	3.85	1.9	150	180							.1114		3.0	5.42	1.0	885	840	12.0	.983
3/4 "		96	↓	3.95	↓	↓	↓							↓		2.9	5.4	↓	882	797	↓	↓
COURSE 1/2 "		97	↓	3.92	↓	↓	↓							↓		2.9	5.4	↓	882	786	↓	↓
GROUP 1/4 "		98	↓	3.9	↓	↓	↓							↓		2.9	5.4	↓	882	763	↓	↓
NAMES FULLY CLOSED		99	↓	3.9	↓	↓	↓							↓		2.9	5.4	↓	882	757	↓	↓
FULLY OPEN		100	1800	2	1.9	150	180							.1002		3	5.1	.9	897	863	12.0	.983
3/4 "		101	↓	2	↓	↓	↓							↓		2.95	5.08	↓	900	820	↓	↓
1/2 "		102	↓	2	↓	↓	↓							↓		2.9	5.05	↓	900	803	↓	↓
1/4 "		103	↓	2.1	↓	↓	↓							↓		2.9	5.05	↓	900	782	↓	↓
FULLY CLOSED		104	↓	2	↓	↓	↓							↓		2.9	5.05	↓	892	761	↓	↓

(Runs 95–104:) May · 1960

Barometer = 76.09 cm. Hg

T dry bulb = 76°F

EXPERIMENT NO. 5 **TITLE** ENGINE PERFORMANCE & ECONOMY TEST - FULL THROTTLE **DATE** JUNE 9, 1960 **SLOAN LABORATORY**

ENGINE RENAULT DAUPHINE 4 CYL. **FUEL** ETHYL ALCOHOL **S.G.** ______ **WET BULB** ______ **DRY BULB** 74 °F

BORE ____ **STROKE** ____ **COMPRESSION RATIO** 12:1 **BAROMETER (ACT.)** ______ **(CORR.)** 76.78 cm. Hg.

CONSTANTS **BMEP = B.L. X** 11.5 **BHP =** $\frac{B.L. \times RPM}{1336}$

REMARKS	TIME	RUN	RPM	B.L.	F.L.	TEMP. OIL	TEMP. JAC	OIL PRES.	P_1	P_E	T_1	AIR CONS.	FUEL CONS.	$\frac{F}{A}$	S.A.	ΔP	Rotometer Reading	F/F_c	t_i	t_o	Man. Vac.	Corr. Factor
HEAT CONTROL - FULLY CLOSED		114	2000	11.4	1.95	150	180							.1447	13	11.90	10.2	1.3	964	863	1.4	.99
1/4 OPEN		115	↓	11.35	↓	↓	↓							↓	↓	11.95	10.2	↓	964	875	↓	↓
1/2 "		116	↓	11.2	↓	↓	↓							↓	↓	11.95	10.2	↓	964	885	↓	↓
3/4 "		117	↓	11.0	↓	↓	↓							↓	↓	12.1	10.25	↓	952	894	↓	↓
FULLY OPEN		118	↓	10.6	↓	↓	↓							↓	↓	12.25	10.3	↓	947	922	↓	↓
FULLY CLOSED		119	2000	11.35	1.95	150	180							.1338	13	11.95	9.56	1.2	1013	896	1.4	.99
1/4 OPEN		120	↓	11.3	↓	↓	↓							↓	↓	11.95	9.65	↓	1007	911	↓	↓
1/2 "		121	↓	11.18	↓	↓	↓							↓	↓	12.1	9.7	↓	1007	926	↓	↓
3/4 "		122	↓	11.0	↓	↓	↓							↓	↓	12.1	9.7	↓	990	930	↓	↓
FULLY OPEN		123	↓	10.6	↓	↓	↓							↓	↓	12.35	9.75	↓	990	960	↓	↓
FULLY CLOSED		124	2000	11.1	1.95	150	180							.1225	13	12.1	9.05	1.1	1032	900	1.4	.991
1/4 OPEN		125	↓	11.0	↓	↓	↓							↓	↓	12.1	9.05	↓	1023	926	↓	↓
1/2 "		126	↓	10.85	↓	↓	↓							↓	↓	12.2	9.1	↓	1023	949	↓	↓
3/4 "		127	↓	10.7	↓	↓	↓							↓	↓	12.3	9.14	↓	1013	956	↓	↓
FULLY OPEN		128	↓	10.1	↓	↓	↓							↓	↓	12.5	9.2	↓	10.10	980	↓	↓
FULLY CLOSED		129	2000	10.45	1.95	150	180							.1114	13	12.2	8.55	1.0	1046	919	1.4	.991
1/4 OPEN		130	↓	10.45	↓	↓	↓							↓	↓	12.2	8.55	↓	1040	935	↓	↓
1/2 OPEN		131	↓	10.4	↓	↓	↓							↓	↓	12.3	8.58	↓	1040	959	↓	↓
3/4 OPEN		132	↓	10.1	↓	↓	↓							↓	↓	12.45	8.62	↓	1021	970	↓	↓
FULLY OPEN		133	↓	9.5	↓	↓	↓							↓	↓	12.65	8.72	↓	1021	991	↓	↓
FULLY CLOSED		134	2000	9.48	1.95	150	180							.1002	13	12.45	8.15	.9	1053	934	1.4	.991
1/4 OPEN		135	↓	9.3	↓	↓	↓							↓	↓	12.45	8.15	↓	1053	956	↓	↓
1/2 "		136	↓	9.25	↓	↓	↓							↓	↓	12.5	8.15	↓	1061	974	↓	↓
3/4 "		137	↓	8.85	↓	↓	↓							↓	↓	12.7	8.2	↓	1053	1004	↓	↓
FULLY OPEN		138	↓	8.45	↓	↓	↓							↓	↓	12.8	8.2	↓	1053	1023	↓	↓

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EXPERIMENT NO. 6 **TITLE** ENGINE PERFORMANCE & ECONOMY TEST - PART THROTTLE **DATE** JUNE 13, 1960 **SLOAN LABORATORY**

ENGINE RENAULT DAUPHINE, 4 CYL **FUEL** ETHYL ALCOHOL **S.G.** ______ **WET BULB** ______ **DRY BULB** 76 °F

BORE 58 mm **STROKE** 80 mm **COMPRESSION RATIO** 12 : 1 **BAROMETER (ACT.)** ______ **(CORR.)** 75.87 cm. Hg.

CONSTANTS BMEP = B.L. X 11.5 BHP = $\frac{\text{B.L. X RPM}}{1336}$

REMARKS	TIME	RUN	RPM	B.L.	F.L.	TEMP. OIL	TEMP. JAC	OIL PRES.	P_I	P_E	T_I	AIR CONS.	FUEL CONS.	F/A	S.A.	ΔP	Rotameter Reading	F/F_c	t_1	t_0	Man. Vac.	Corr. Factor
HEAT CONTROL - FULLY CLOSED		141	2000	5.05	1.96	150	180							.1447	18	2.7	6.22	1.3	899	735	12.9	.983
1/4 OPEN		142	↓	5.12	↓	↓	↓							↓	↓	2.8	6.3	↓	909	767	↓	↓
1/2 "		143	↓	5.12	↓	↓	↓							↓	↓	2.9	6.4	↓	909	791	↓	↓
3/4 "		144	↓	5.15	↓	↓	↓							↓	↓	2.95	6.45	↓	905	808	↓	↓
FULLY OPEN		145	↓	5.18	↓	↓	↓							↓	↓	3.0	6.5	↓	892	822	↓	↓
FULLY CLOSED		146	2000	5.1	1.96	150	180							.1338	18	2.95	6.1	1.2	922	765	12.9	.983
1/4 OPEN		147	↓	5.1	↓	↓	↓							↓	↓	2.95	6.1	↓	927	786	↓	↓
1/2 OPEN		148	↓	5.1	↓	↓	↓							↓	↓	2.95	6.1	↓	922	804	↓	↓
3/4 OPEN		149	↓	5.12	↓	↓	↓							↓	↓	3.0	6.15	↓	922 ~~905~~	825	↓	↓
FULLY OPEN		150	↓	5.1	↓	↓	↓							↓	↓	3.05	6.2	↓	905	838	↓	↓
FULLY CLOSED		151	2000	4.88	1.96	150	180							.1225	18	2.9	5.7	1.1	943	765	12.9	.983
1/4 OPEN		152	↓	4.88	↓	↓	↓							↓	↓	2.9	5.7	↓	940	795	↓	↓
1/2 "		153	↓	4.97	↓	↓	↓							↓	↓	2.95	5.75	↓	940	825	↓	↓
3/4 "		154	↓	5.0	↓	↓	↓							↓	↓	3.0	5.8	↓	926	834	↓	↓
FULLY OPEN		155	↓	4.92	↓	↓	↓							↓	↓	3.02	5.82	↓	915	863	↓	↓
FULLY CLOSED		156	2000	4.75	1.96	150	180							.1114	16	2.8	5.35	1.0	946	778	12.9	.977
1/4 OPEN		157	↓	4.75	↓	↓	↓							↓	↓	2.85	5.35	↓	951	797	↓	↓
1/2 "		158	↓	4.75	↓	↓	↓							↓	↓	2.9	5.4	↓	956	825	↓	↓
3/4 "		159	↓	4.82	↓	↓	↓							↓	↓	2.95	5.4	↓	951	842	↓	↓
FULLY OPEN		160	↓	4.85	↓	↓	↓							↓	↓	3.05	5.45	↓	943	867	↓	↓
FULLY CLOSED		161	2000	4.1	1.96	150	180							.1002	16	3.08	5.05	.9	932	763	12.9	.977
1/4 OPEN		162	↓	4.12	↓	↓	↓							↓	↓	3.00	5.05	↓	932	789	↓	↓
1/2 "		163	↓	4.08	↓	↓	↓							↓	↓	3.00	5.05	↓	932	812	↓	↓
3/4 "		164	↓	4.15	↓	↓	↓							↓	↓	3.05	5.08	↓	932	833	↓	↓
FULLY OPEN		165	↓	4.15	↓	↓	↓							↓	↓	3.1	5.12	↓	934	863	↓	↓

(Runs 156–165, bracketed:) July 12, 1960
Barometer : 75.94 cm. Hg.
T dry bulb = 82°F

COURSE
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EXPERIMENT NO. 7 **TITLE** ENGINE PERFORMANCE & ECONOMY TEST - PART THROTTLE **DATE** JULY 12, 1960 **SLOAN LABORATORY**

ENGINE RENAULT DAUPHINE **FUEL** ETHYL ALCOHOL **S.G.** ____ **WET BULB** ____ **DRY BULB** 82°F

BORE 58 mm **STROKE** 80 mm **COMPRESSION RATIO** 12 : 1 **BAROMETER (ACT.)** ____ **(CORR.)** 79.94 cm. Hg.

CONSTANTS BMEP = B.L. X 11.5 BHP = $\frac{\text{B.L. x RPM}}{1336}$

REMARKS	TIME	RUN	RPM	B.L.	F.L.	TEMP. OIL	TEMP. JAC	OIL PRES.	P_I	P_E	T_I	AIR CONS.	FUEL CONS.	F/A	S.A.	ΔP	Rotometer Reading	F/Fc	t_i	t_e	Man. Vac.	Corr. Factor
HEAT CONTROL - FULLY CLOSED		168	2400	4.8	1.97	150	180							.1447	18	4.2	7.1	1.3	928	782	12.9	.977
1/4 OPEN		169	↓	4.9	↓	↓	↓							↓	↓	4.25	7.15	↓	918	795	↓	↓
1/2 "		170	↓	4.92	↓	↓	↓							↓	↓	4.3	7.2	↓	918	814	↓	↓
3/4 "		171	↓	4.92	↓	↓	↓							↓	↓	4.3	7.2	↓	923	833	↓	↓
FULLY OPEN		172	↓	4.88	↓	↓	↓							↓	↓	4.3	7.2	↓	923	867	↓	↓
FULLY CLOSED		173	2400	4.92	1.97	150	180							.1338	18	4.3	6.8	1.2	947	795	12.9	.977
1/4 OPEN		174	↓	4.90	↓	↓	↓							↓	↓	4.3	6.8	↓	947	825	↓	↓
1/2 "		175	↓	4.90	↓	↓	↓							↓	↓	4.3	6.8	↓	939	843	↓	↓
3/4 "		176	↓	4.95	↓	↓	↓							↓	↓	4.3	6.8	↓	943	873	↓	↓
FULLY OPEN		177	↓	5.0	↓	↓	↓							↓	↓	4.4	6.85	↓	943	892	↓	↓
FULLY CLOSED		178	2400	4.85	1.97	150	180							.1225	18	4.2	6.40	1.1	989	833	12.9	.977
1/4 OPEN		179	↓	4.88	↓	↓	↓							↓	↓	4.2	6.45	↓	981	855	↓	↓
1/2 "		180	↓	4.9	↓	↓	↓							↓	↓	4.25	6.45	↓	989	875	↓	↓
3/4 "		181	↓	4.92	↓	↓	↓							↓	↓	4.35	6.50	↓	989	898	↓	↓
FULLY OPEN		182	↓	4.92	↓	↓	↓							↓	↓	4.4	6.50	↓	981	923	↓	↓
FULLY CLOSED		183	2400	4.55	1.97	150	180							.1114	16	4.2	6.00	1.0	1059	901	12.9	.974
1/4 OPEN		184	↓	4.55	↓	↓	↓							↓	↓	4.25	6.05	↓	1059	922	↓	↓
1/2 OPEN		185	↓	4.55	↓	↓	↓							↓	↓	4.3	6.08	↓	1059	943	↓	↓
3/4 OPEN		186	↓	4.0	↓	↓	↓							↓	↓	4.5	6.2	↓	1053	962	↓	↓
FULLY OPEN		187	↓	3.95	↓	↓	↓							↓	↓	4.6	6.23	↓	1053	1002	↓	↓
FULLY CLOSED		188	2400	3.05	1.97	150	180							.1002	16	4.35	5.70	.9	1053	901	12.9	.974
1/4 OPEN		189	↓	3.05	↓	↓	↓							↓	↓	4.35	5.70	↓	1053	917	↓	↓
1/2 "		190	↓	3.4	↓	↓	↓							↓	↓	4.45	5.70	↓	1045	930	↓	↓
3/4 "		191	↓	3.65	↓	↓	↓							↓	↓	4.5	5.75	↓	1045	998	↓	↓
FULLY OPEN		192	↓	3.7	↓	↓	↓							↓	↓	4.6	5.8	↓	1053	1023	↓	↓

(Runs 183–192:) July 13, 1960
Barometer = 75.92 cm. Hg.
T dry bulb = 84°F

COURSE GROUP NAMES

EXPERIMENT NO. 8 **TITLE** ENGINE PERFORMANCE & ECONOMY TEST - FULL THROTTLE **DATE** JULY 26, 1960 **SLOAN LABORATORY**

ENGINE RENAULT DAUPHINE, 4 CYL. **FUEL** ETHYL ALCOHOL **S.G.** ______ **WET BULB** ______ **DRY BULB** 80 °F

BORE 58 mm **STROKE** 80 mm **COMPRESSION RATIO** 12 : 1 **BAROMETER (ACT.)** ______ **(CORR.)** 76.7 cm. Hg.

CONSTANTS BMEP = B.L. X 11.5 BHP = $\frac{\text{B.L.} \times \text{RPM}}{1336}$

REMARKS	TIME	RUN	RPM	B.L.	F.L.	TEMP. OIL	TEMP. JAC	OIL PRES.	P_I	P_E	T_I	AIR CONS.	FUEL CONS.	F/A	S.A.	ΔP	Rotometer Reading	F/Fc	t_i	t_o	Man. Vac.	Corr. Factor
HEAT CONTROL - FULLY CLOSED		195	2800	9.8	2.06	150	180							.1447	16	18.9	11.75	1.3	1119	1023	2	.983
1/4 OPEN		196	↓	9.76	↓	↓	↓							↓	↓	19.0	11.8	↓	1112	1033	↓	↓
1/2 "		197	↓	9.7	↓	↓	↓							↓	↓	19.1	11.85	↓	1112	1065	↓	↓
3/4 "		198	↓	9.5	↓	↓	↓							↓	↓	19.3	11.9	↓	1112	1074	↓	↓
FULLY OPEN		199	↓	9.20	↓	↓	↓							↓	↓	19.6	11.95	↓	1110	1110	↓	↓
FULLY CLOSED		200	2800	9.8	2.06	150	180							.1338	16	19.1	11.2	1.2	1116	1027	2	.983
1/4 OPEN		201	↓	9.8	↓	↓	↓							↓	↓	19.1	11.2	↓	1112	1040	↓	↓
1/2 "		202	↓	9.7	↓	↓	↓							↓	↓	19.2	11.2	↓	1108	1055	↓	↓
3/4 "		203	↓	9.55	↓	↓	↓							↓	↓	19.35	11.25	↓	1100	1065	↓	↓
FULLY OPEN		204	↓	9.4	↓	↓	↓							↓	↓	19.65	11.3	↓	1091	1078	↓	↓
FULLY CLOSED		205	2800	9.68	2.06	150	180							.1225	16	19.2	10.6	1.1	1145	1040	2	.983
1/4 OPEN		206	↓	9.65	↓	↓	↓							↓	↓	19.25	10.6	↓	1141	1049	↓	↓
1/2 "		207	↓	9.55	↓	↓	↓							↓	↓	19.3	10.65	↓	1134	1074	↓	↓
3/4 "		208	↓	9.35	↓	↓	↓							↓	↓	19.6	10.7	↓	1116	1078	↓	↓
FULLY OPEN		209	↓	9.1	↓	↓	↓							↓	↓	20.0	10.75	↓	1108	1108	↓	↓
FULLY CLOSED		210	2800	9.2	2.06	150	180							.1114	16	19.5	10.0	1.0	1137	1046	2	.983
1/4 OPEN		211	↓	9.2	↓	↓	↓							↓	↓	19.5	10.0	↓	1133	1059	↓	↓
1/2 "		212	↓	9.1	↓	↓	↓							↓	↓	19.6	10.05	↓	1133	1071	↓	↓
3/4 "		213	↓	8.97	↓	↓	↓							↓	↓	19.75	10.1	↓	1133	1094	↓	↓
FULLY OPEN		214	↓	8.7	↓	↓	↓							↓	↓	20.0	10.15	↓	1133	1124	↓	↓

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