
SECTION 2. ENGINE PERFORMANCE

- 1. Engine Perfomance 2-2
- 2. Perfomance Curves 2-3
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POWER CURVES

1. Gross Nominal gross output of engine per SAE J1995/ISO2534
(tested w/o muffler, air cleaner, alternator)
2. Net int. Output for applications with varying speed and/or intermittent load per
SAE J1349/ISO 1585 (tested with muffler, air cleaner, alternator)

examples: utility vehicle, rotary mower

3. Net cont. Output for applications with continuous load over long periods of time

examples: base load generator, irrigation pump, axial flow fan

DE-RATING FOR OPERATING ENVIRONMENT

Altitude: Naturally aspirated diesel and spark-ignited: deduct 3% from output shown on curve
for each additional 1,000 ft/300 m above 330 ft/100 m.

Turbo-diesel: deduct 1.2% from output shown on curve for each 1,000 ft/300 m above
330 ft/100m.

Temperature: Deduct 1% from output shown in curve for each 10° F/5.6° C over 77° F/2.5° C

FUEL CONSUMPTION

To estimate full load fuel consumption in gal/hr, assume the following fuel densities:

gasoline = 6.4 lb/gal

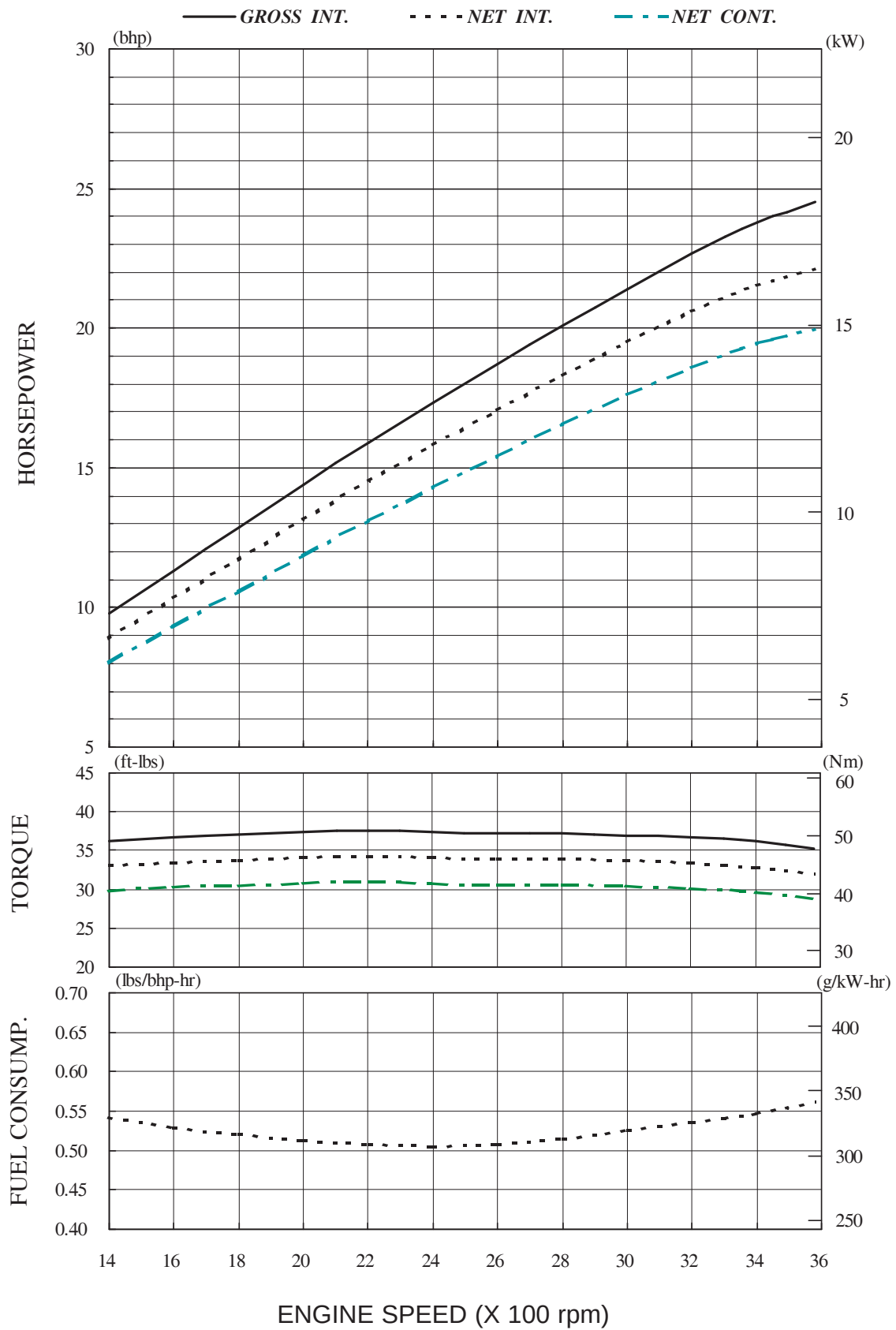
diesel fuel = 7.2 lb/gal

At a given engine speed, multiply the net intermittent hp (hp) by the bsfc (lb/hp-hr) and divide by the appropriate fuel density.

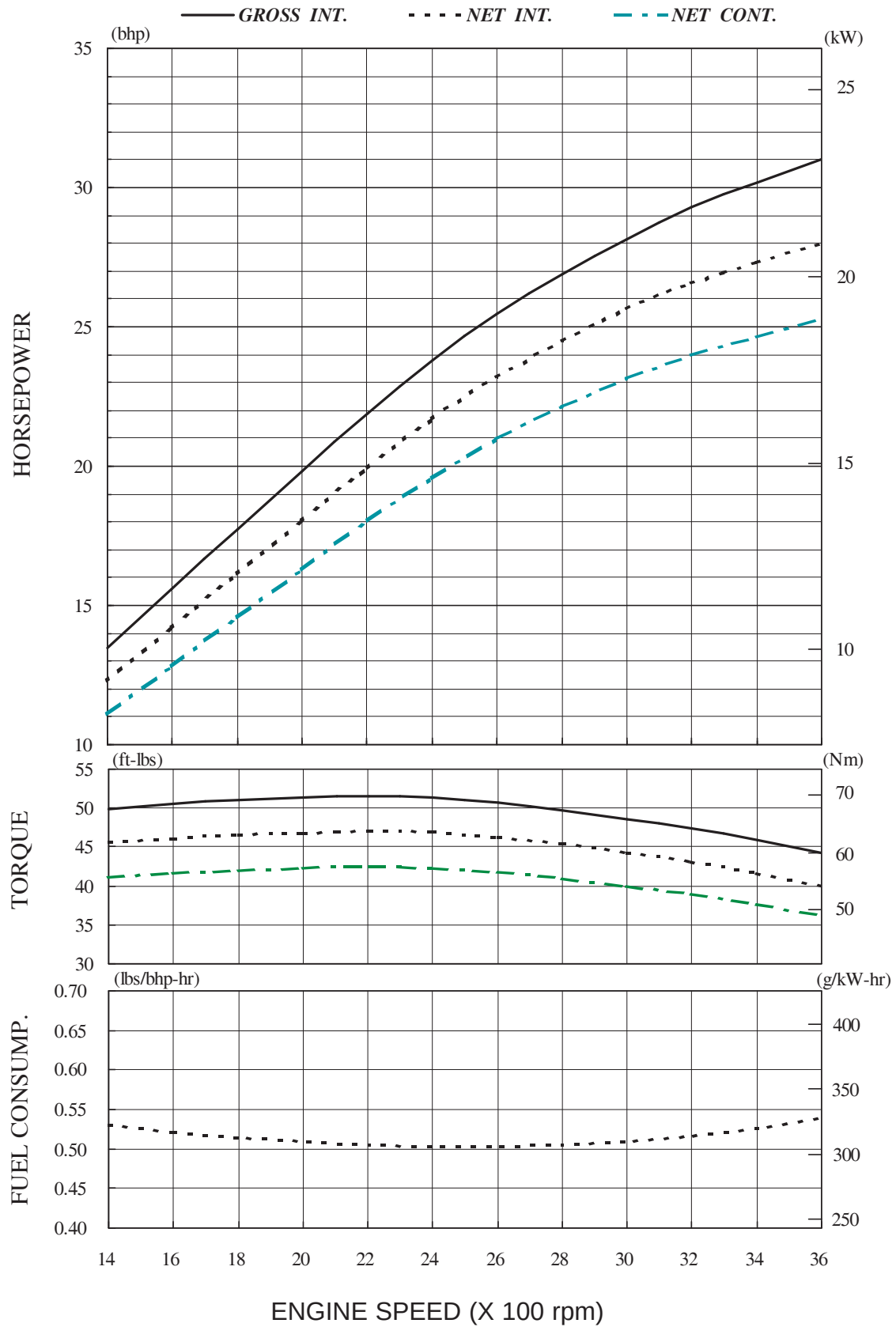
Example: DM950D @ 3600 rpm: 23.8 hp, 0.48 lb/hp-hr

$(23.8 \times 0.48) / 7.2 = 1.6 \text{ gal/hr}$

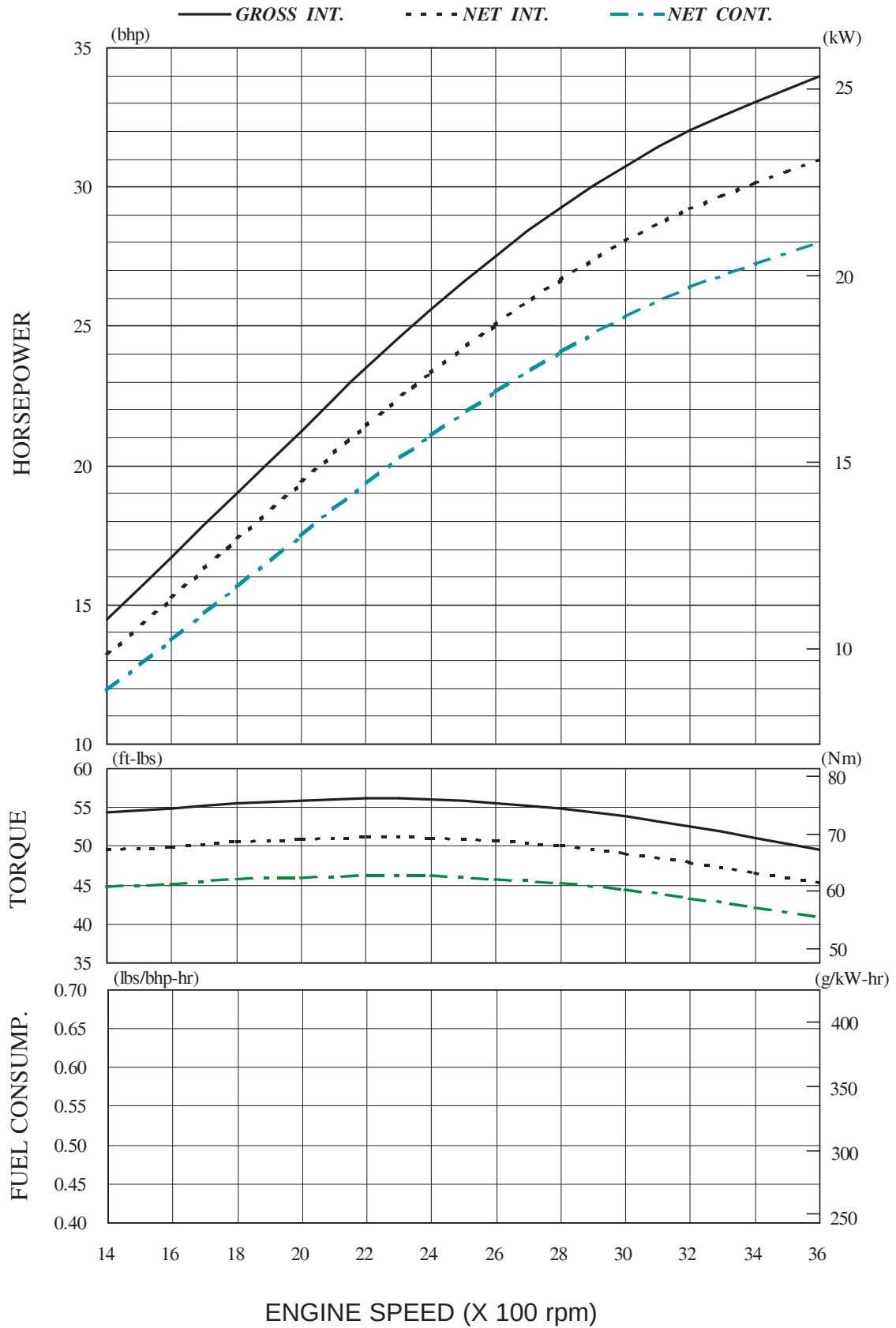
DM700G PERFORMANCE CURVES



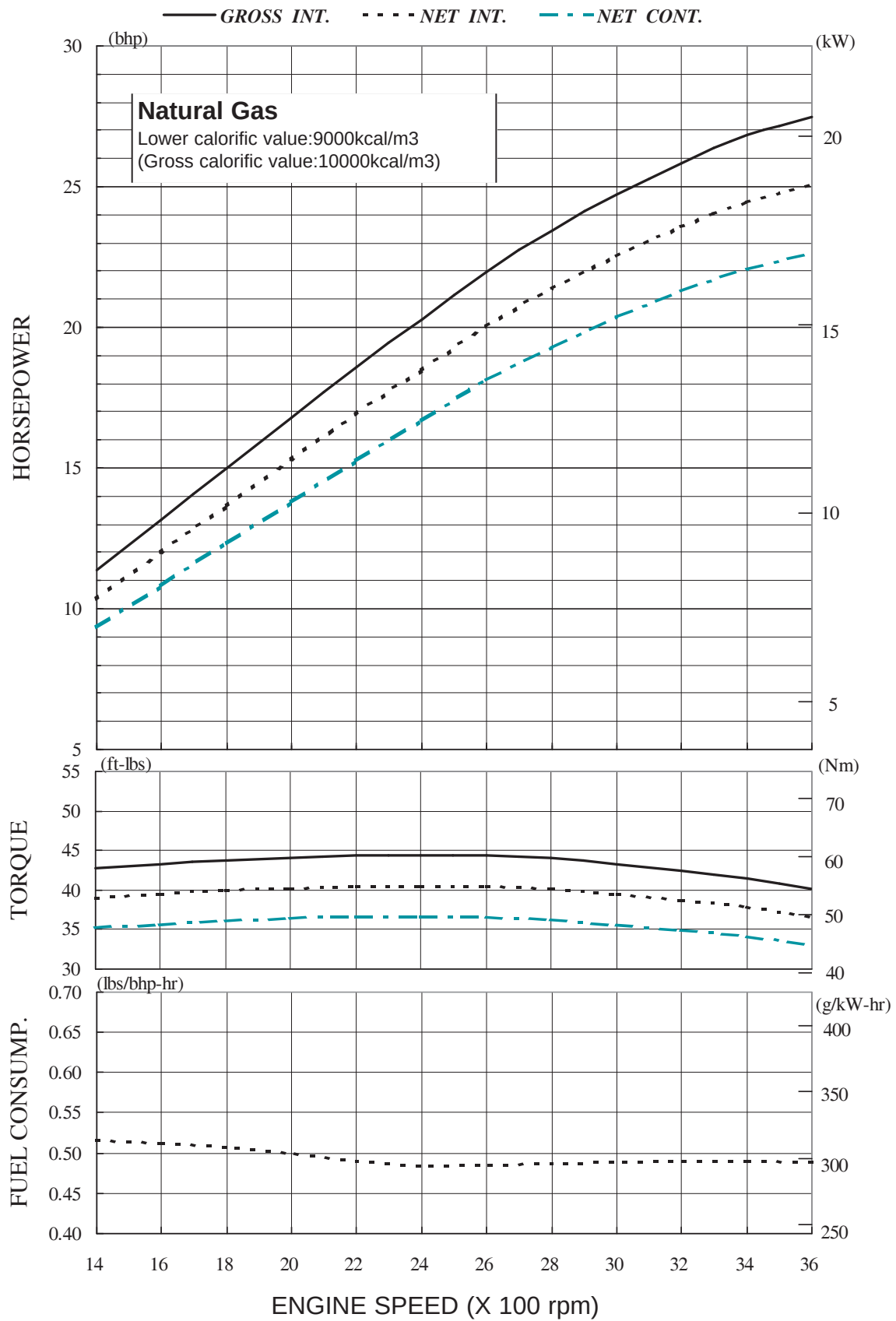
DM950G PERFORMANCE CURVES



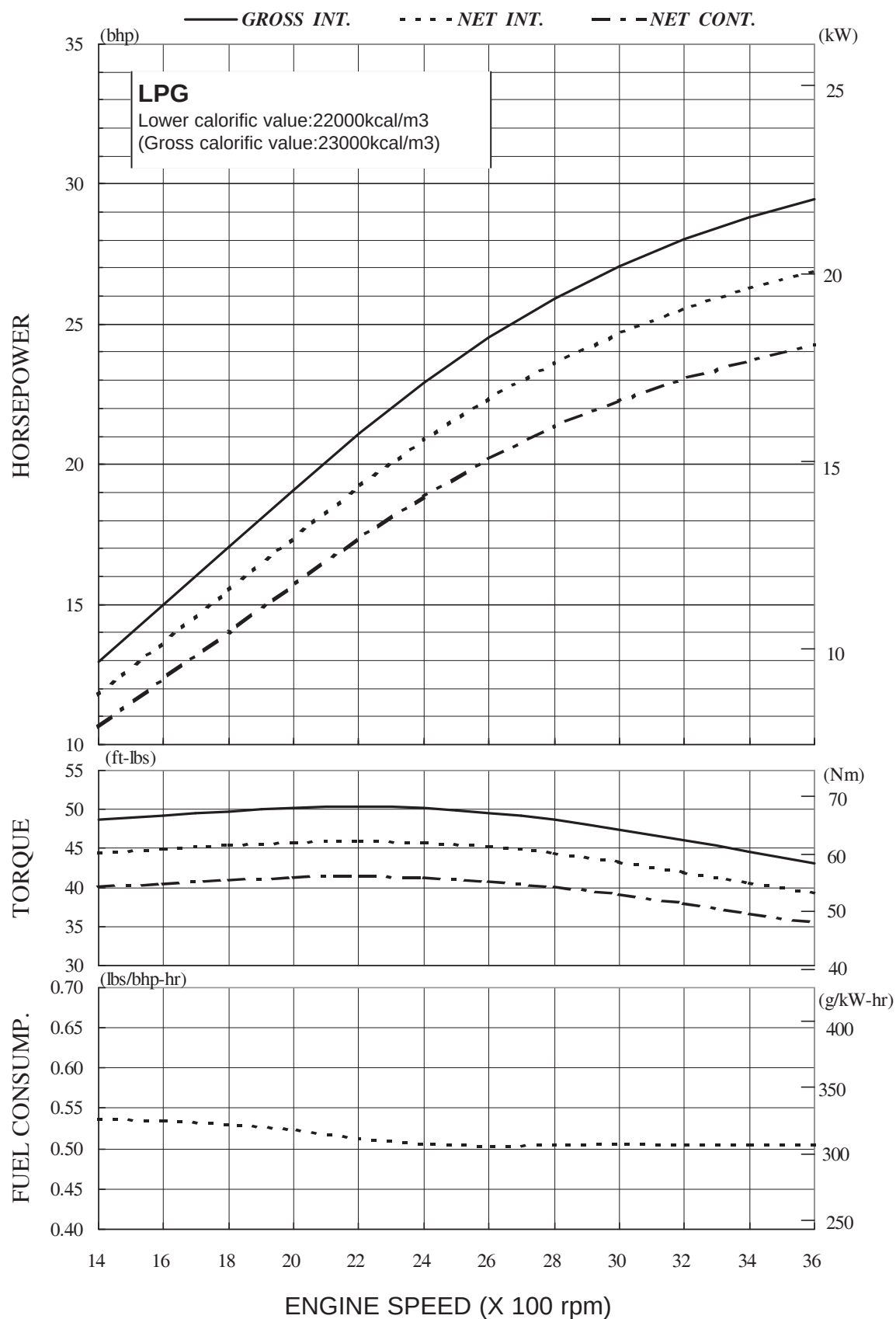
DM954G PERFORMANCE CURVES



DM950P PERFORMANCE CURVES

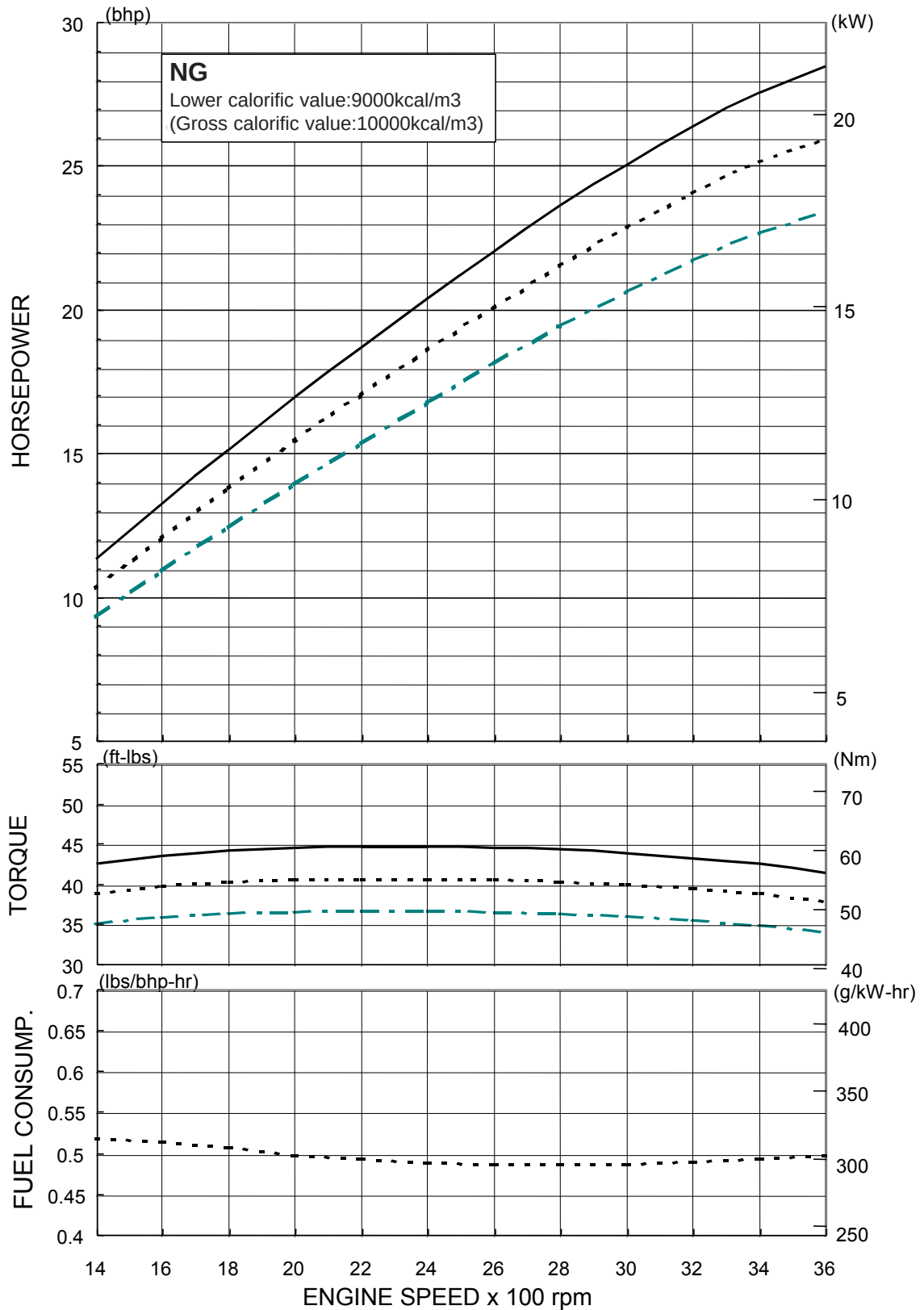


DM950P PERFORMANCE CURVES

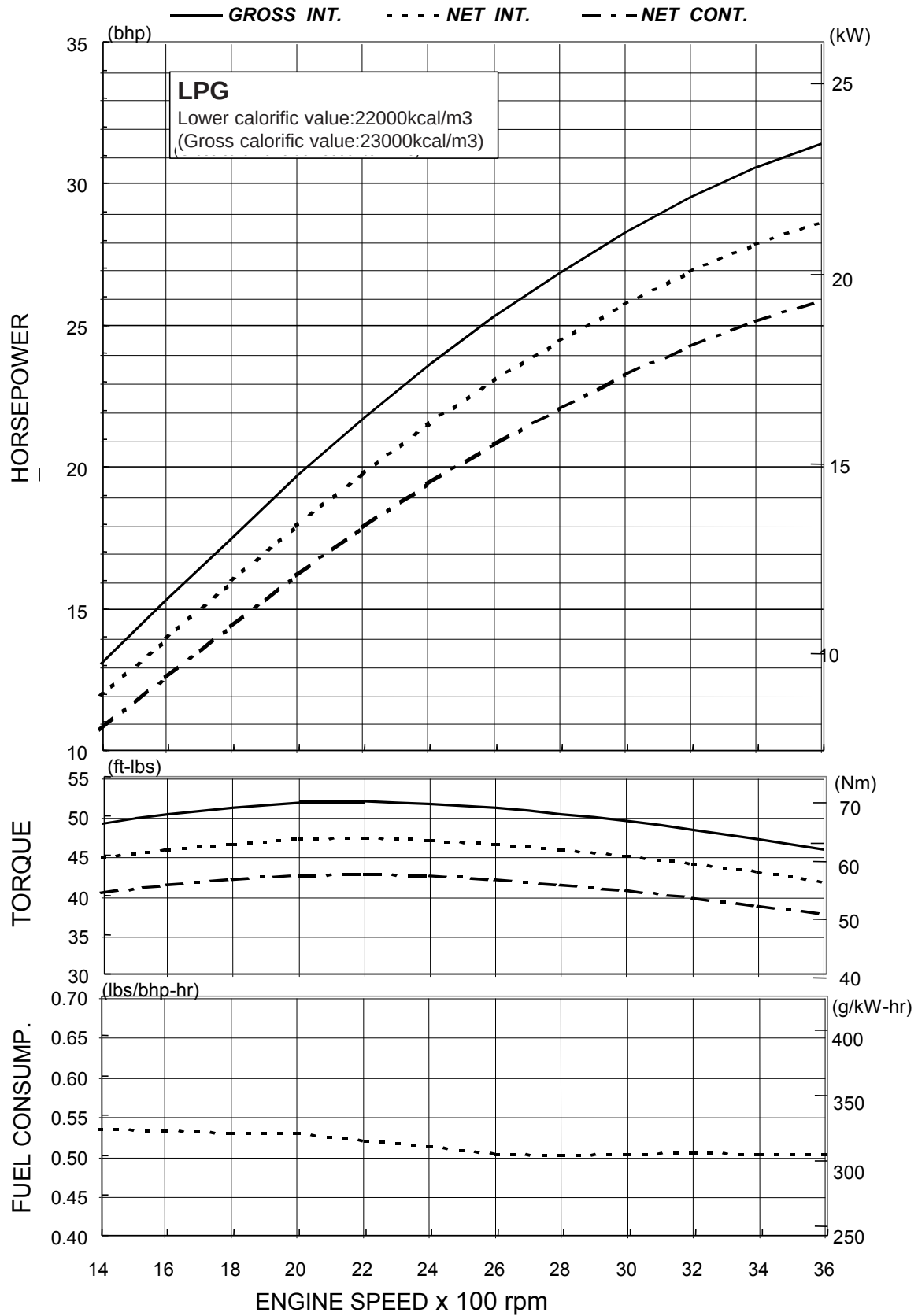


DM954P PERFORMANCE CURVES

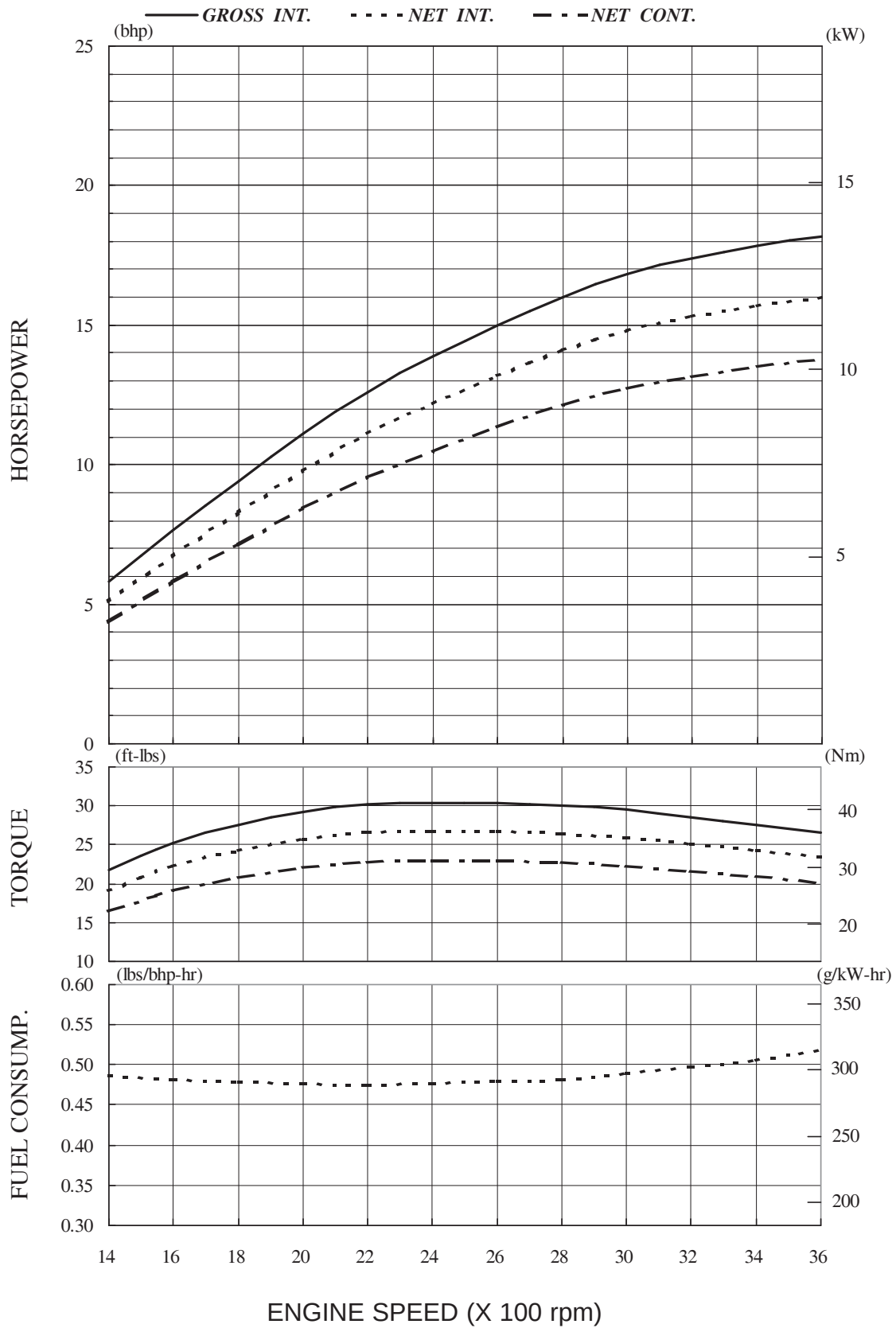
— GROSS INT. - - - NET INT. - · - NET CONT.



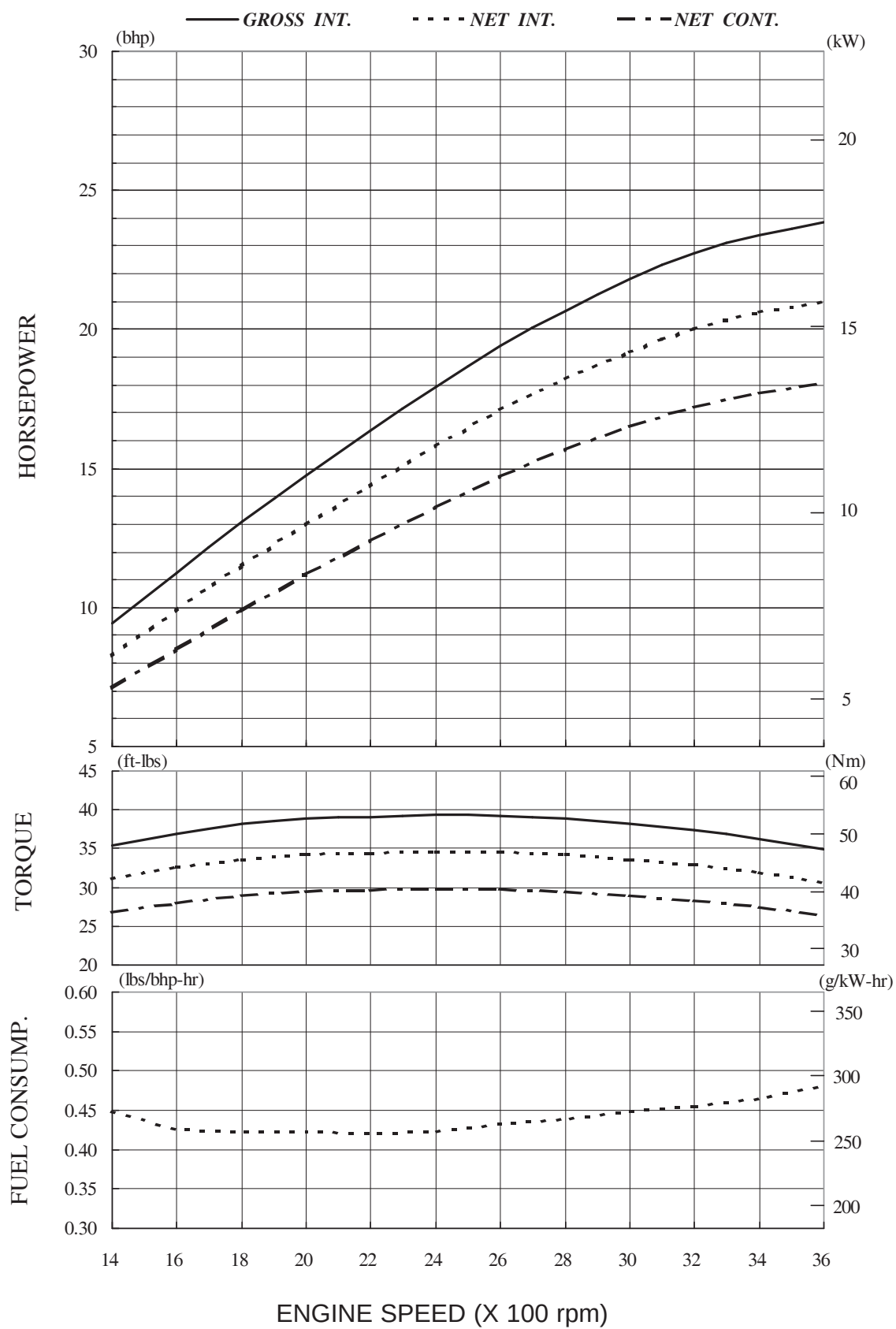
DM954P PERFORMANCE CURVES



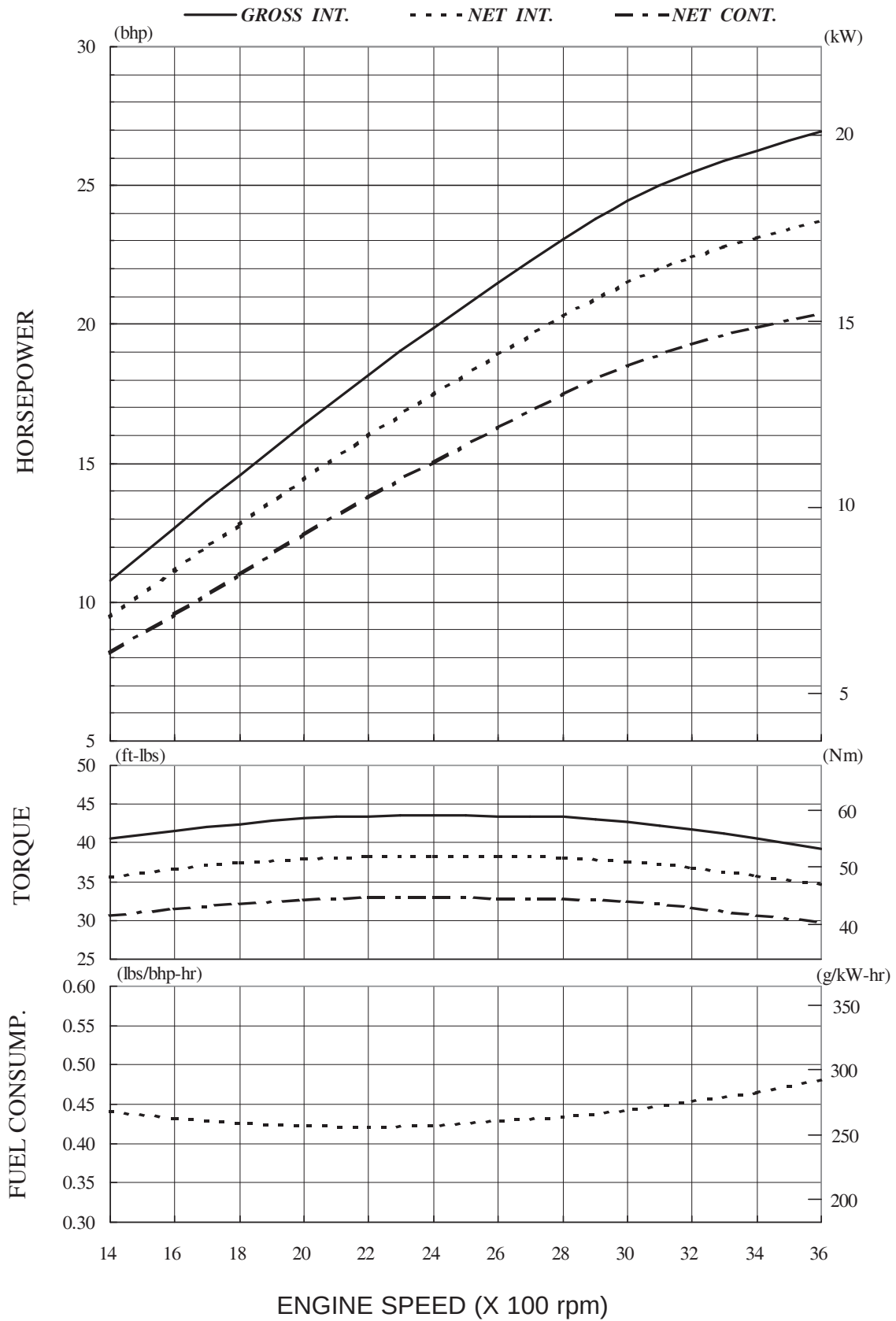
DM700D PERFORMANCE CURVES



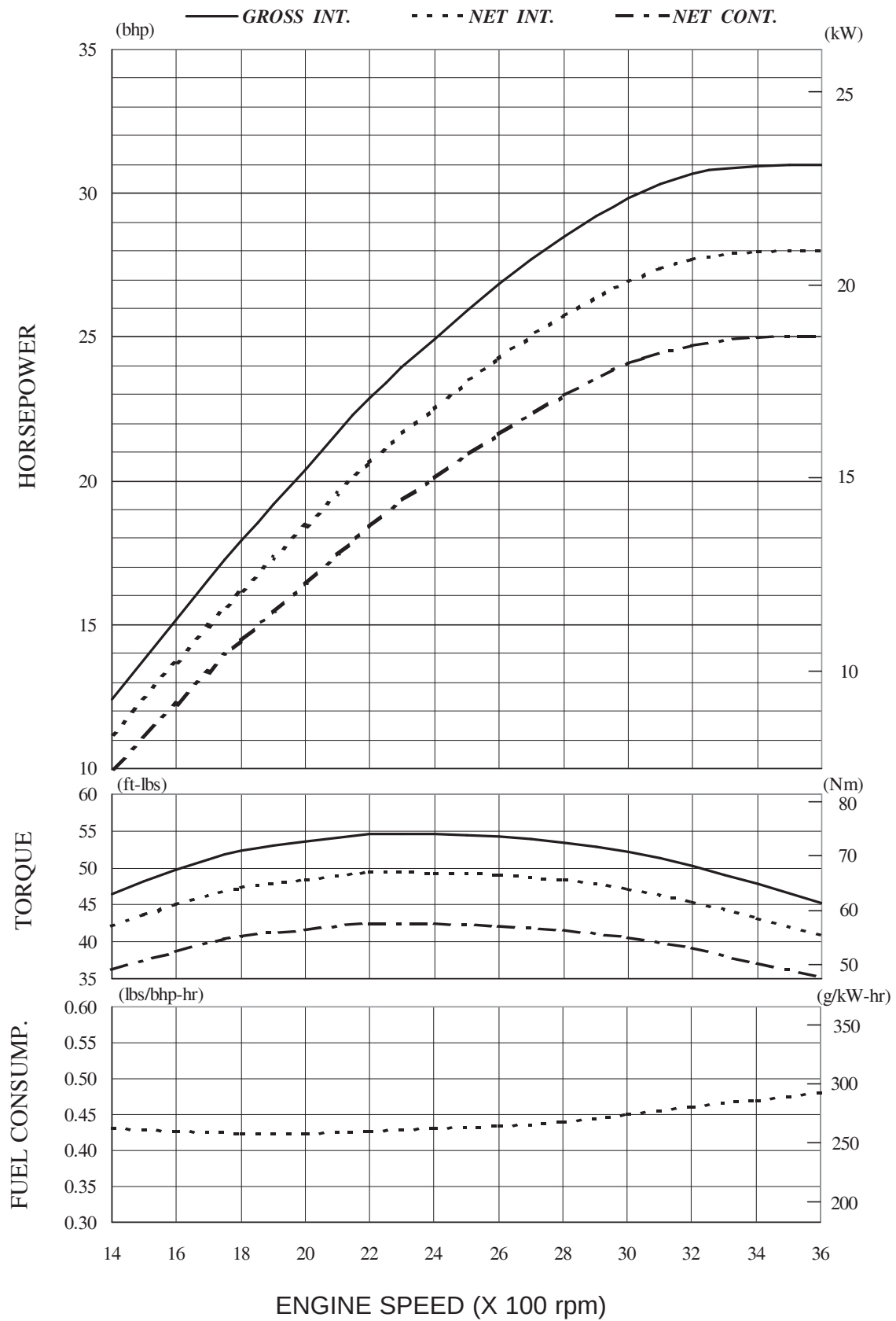
DM850D PERFORMANCE CURVES



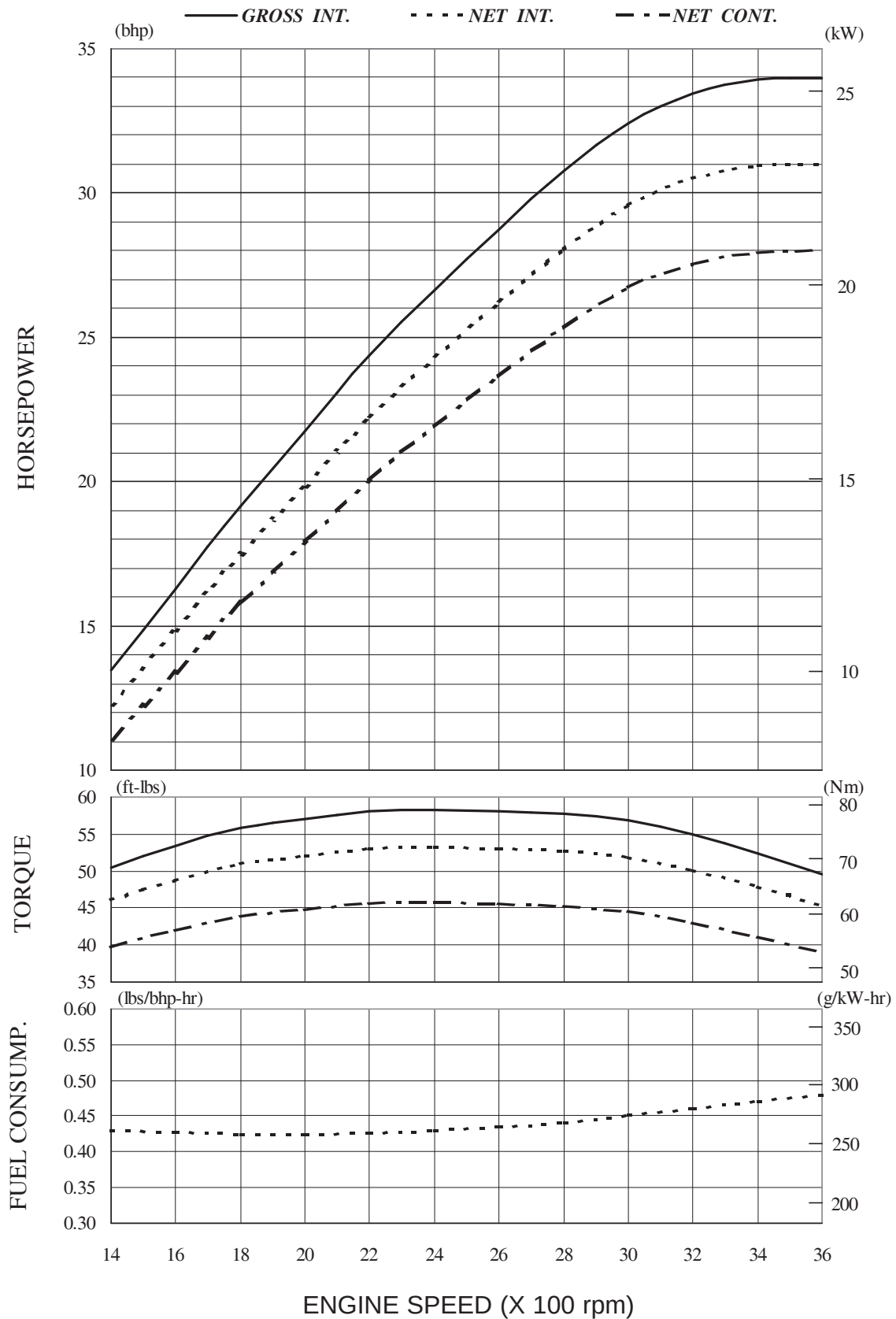
DM950D PERFORMANCE CURVES



DM950DT PERFORMANCE CURVES



DM954DT PERFORMANCE CURVES



Generator

$$\text{Horsepower (hp)} = \frac{\text{Kilowatts} \times 1.34}{\text{generator efficiency}}$$

Note: If generator efficiency is not known use 70 percent (.70).

Welder

$$\text{hp} = \frac{\text{Volts} \times \text{amperes}}{746 \times \text{efficiency}}$$

Note: If welder efficiency is not known use 70 percent (.70).

Water Pump

$$\begin{aligned} \text{hp} &= \frac{\text{Gallons per minute} \times \text{total dynamic head (feet)}}{3960 \times \text{efficiency}} \\ \text{or} \quad \text{hp} &= \frac{\text{GPM} \times \text{pressure (psi)}}{1714 \times \text{efficiency}} \end{aligned}$$

Note: If efficiency is not known use 50 percent (.50).

Trash Pump

$$\begin{aligned} \text{hp} &= \frac{\text{GPM} \times \text{head} \times \text{specific gravity}}{3960 \times \text{efficiency}} \\ \text{or} \quad \text{hp} &= \frac{\text{GPM} \times \text{psi} \times \text{specific gravity}}{1714 \times \text{efficiency}} \end{aligned}$$

Note: If efficiency is not known use 40 percent (.40).

Hydraulic Pump

$$\text{hp} = \frac{\text{GPM} \times \text{pressure (psi)}}{1714 \times \text{efficiency}}$$

Note: If efficiency is not known use 80 percent (.80).

Air Compressor

Allow 0.25 horsepower for each cubic foot of free air when operating at a pressure of 75 or 100 psi. This applies to driving single or two stage air compressors of the piston-type.

Higher operating pressures will require more power and for low pressures less power.

The displacement of a multi-cylinder single stage compressor is the total displacement volumes of all of its cylinders.

The displacement of a two-stage compressor is the total displacement volumes of only the low pressure cylinders.

Refrigerating and Air Conditioning Compressors

Rule of Thumb

For modern compressors smaller than 15 tons refrigerating capacity allow two (2) horsepower per ton of compressor rating.

Air Fan (Blower and Vacuum)

Air fans do not permit simple calculation of power absorbed as do water pumps. However, air fans allow quite simple checking of engine load, and power reserve by the following test calculation where:

Load = engine load as a percentage of maximum power available

Load speed = engine rpm at normal governed speed

Maximum speed = engine rpm with throttle held wide open

$$\text{therefore: Load} = \frac{(\text{load speed})^3}{(\text{maximum speed})^3} \times 100$$

Air fans and impellor-type centrifugal water pumps follow similar laws that may be useful when adjusting for optimum performance and for testing. These are:

1. Volume varies directly with speed (rpm)

$$\text{Volume}_2 = \text{Volume}_1 \times \frac{\text{rpm}_2}{\text{rpm}_1}$$

2. Pressure varies with speed (rpm) squared

$$\text{Pressure}_2 = \text{Pressure}_1 \times \frac{(\text{rpm}_2)^2}{(\text{rpm}_1)^2}$$

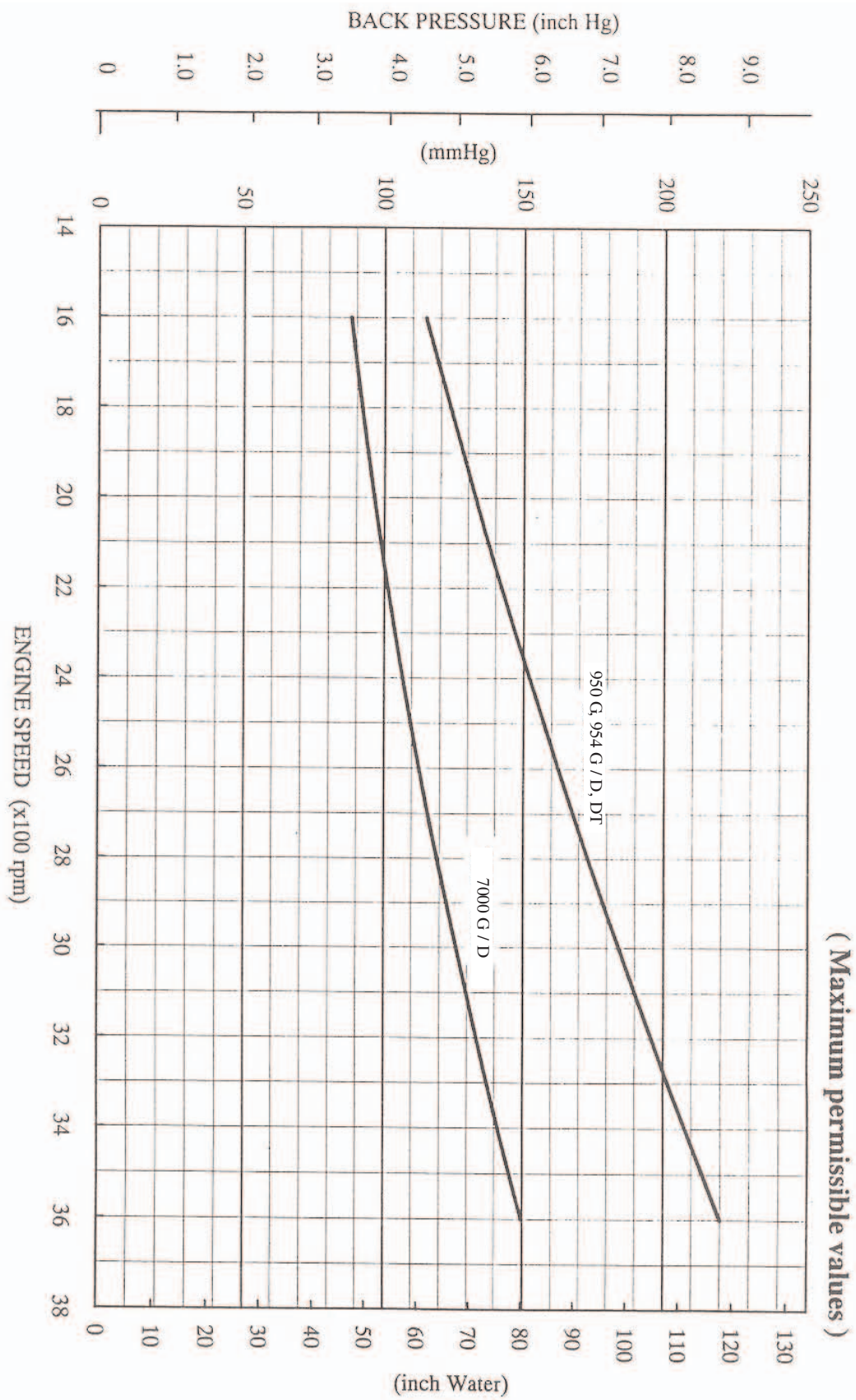
3. Power required varies with speed (rpm) cubed

$$\text{hp}_2 = \text{hp}_1 \times \frac{(\text{rpm}_2)^3}{(\text{rpm}_1)^3}$$

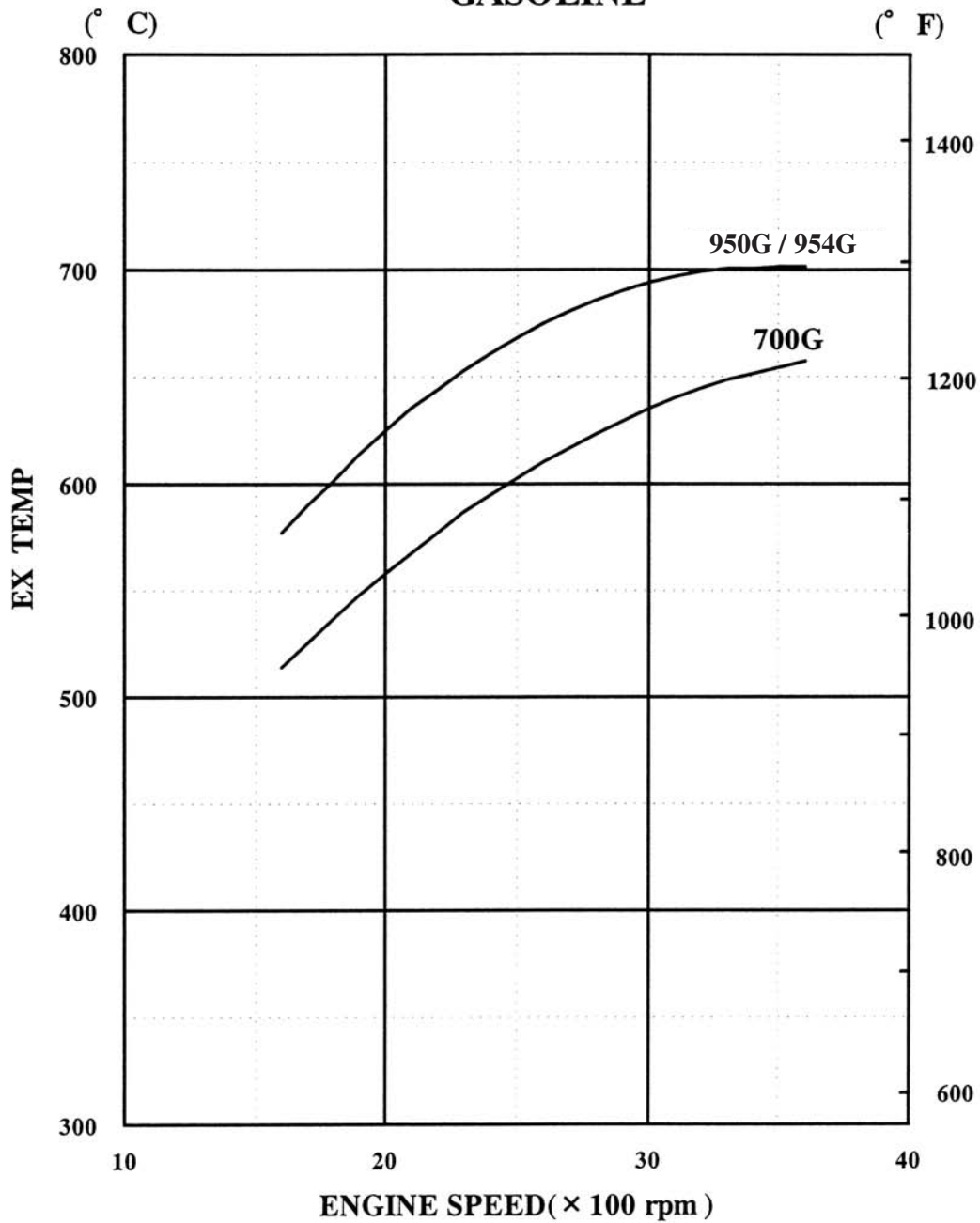
SECTION 3. EXHAUST SYSTEM

- 1. Back Pressure Limits 3-2
- 2. Full Load Exhaust Gasoline Temperatures 3-3
- 3. Full Load Exhaust Gaseous Temperatures 3-4
- 4. Full Load Exhaust Diesel Temperatures 3-5

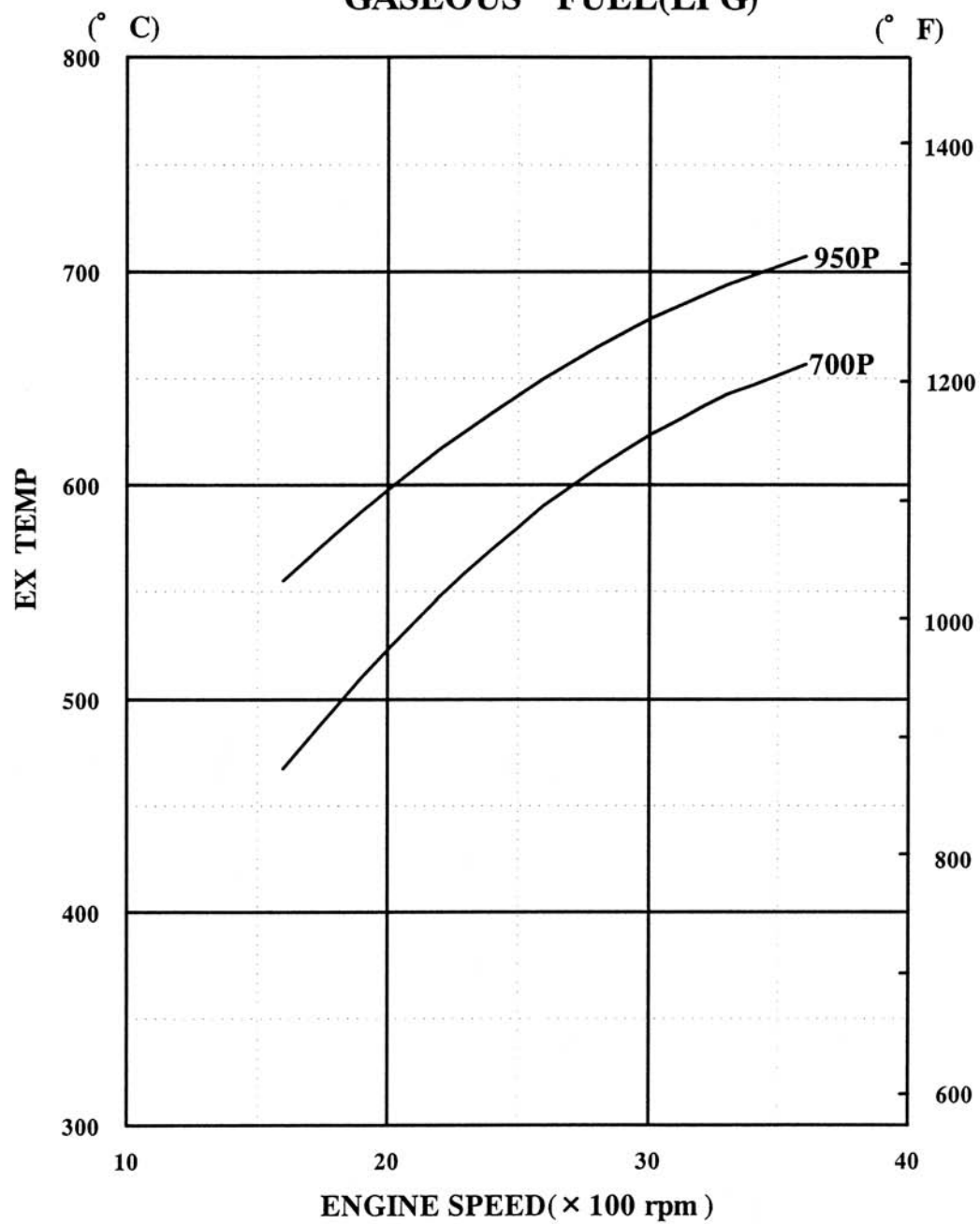
Muffler Back Pressure Limit



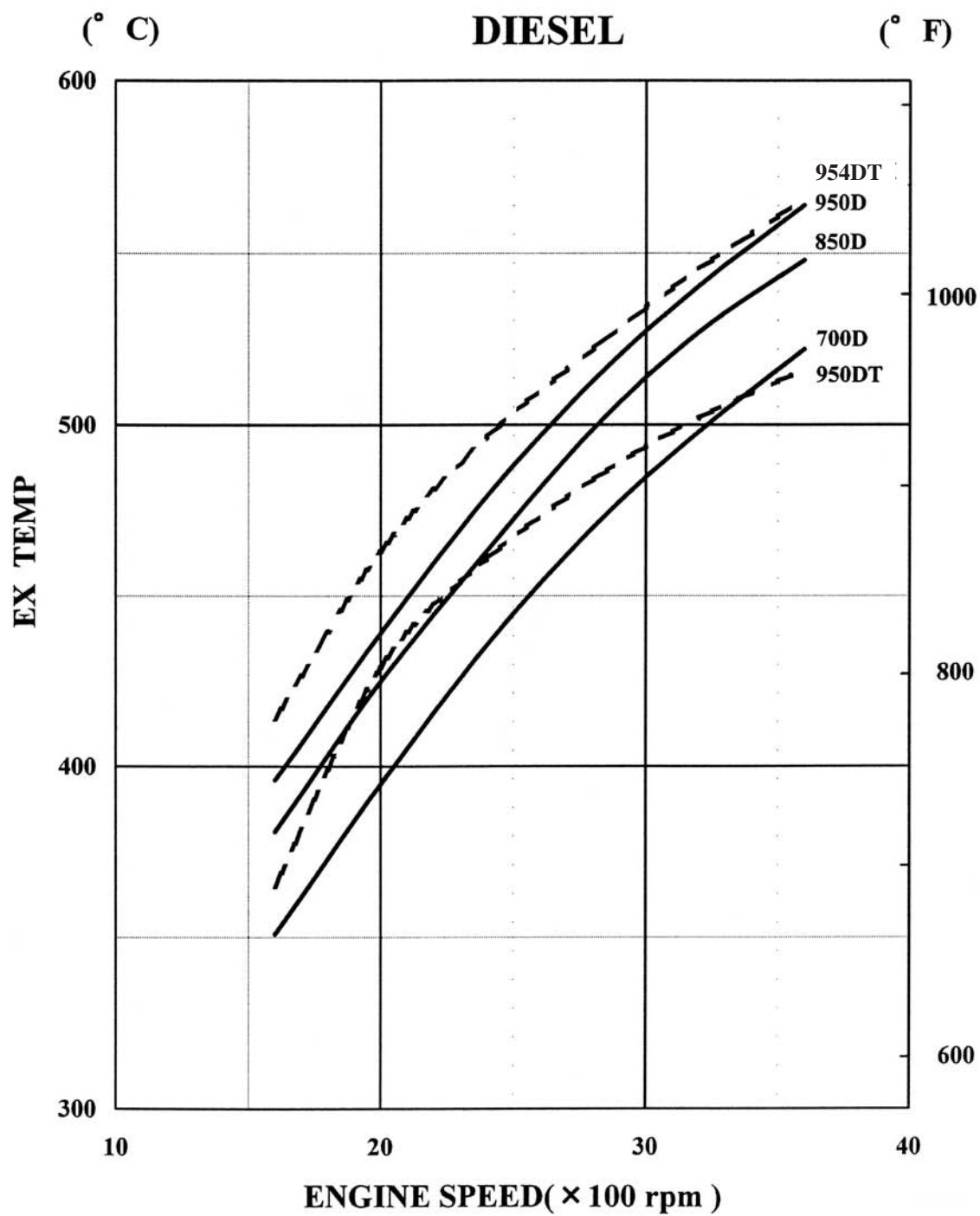
**EXHAUST TEMPERATURE
GASOLINE**



**EXHAUST TEMPERATURE
GASEOUS FUEL(LPG)**



EXHAUST TEMPERATURE DIESEL



EXHAUST GAS FLOW RATE

Approximate exhaust flow rate may be calculated as follows:

Intake air consumption rate:

$$\left\{ \frac{\text{engine displacement (in}^3\text{)} \times \text{rpm}}{3456} \right\} \times \text{volumetric efficiency} = \text{intake air flow (ft}^3\text{/min)}$$

$$\left\{ \frac{\text{engine displacement (cc)} \times \text{rpm}}{2 \times 10^6} \right\} \times \text{volumetric efficiency} = \text{intake air flow (m}^3\text{/min)}$$

Volumetric Efficiency:

naturally aspirated spark ignition	0.75
naturally aspirated compression ignition (diesel)	0.90
turbocharged compression ignition (diesel)	1.35

Exhaust gas flow rate:

$$\text{intake air flow (ft}^3\text{/min)} \times \left\{ \frac{\text{exhaust gas temp (}^\circ\text{F)} + 460}{540} \right\} = \text{exhaust flow rate (ft}^3\text{/min)}$$

$$\text{intake air flow (m}^3\text{/min)} \times \left\{ \frac{\text{exhaust gas temp (}^\circ\text{C)} + 273}{294} \right\} = \text{exhaust flow rate (m}^3\text{/min)}$$

SECTION 4. COOLING SYSTEM

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- 3. Cooling Fan Performance Data 4-6
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AIR-TO-BOIL (ATB) TEST

SUBJECT

Heat Test Procedure for Applications Powered by Liquid Cooled Engines.

PURPOSE

To determine if an application's cooling system can maintain acceptable engine operating temperatures under the appropriate loads.

SCOPE

This test is to be performed on all new applications powered by liquid cooled engines.

REFERENCES

SAE J81 9 - Engine Cooling System Field Test

SAE J312 - Fuel Requirements

"Temperature Guidelines" section in Engine Installation Manual

SET-UP

- 1) The test machine will be free of dirt and debris, and be thoroughly cleaned before the test. Special attention must be given to the engine, radiator and grill.
- 2) It is preferred that laboratory tests are conducted in cells where the ambient temperature can be stabilized to $100^{\circ}\text{F} \pm 5^{\circ}$. Outdoor tests should be conducted with the ambient temperature above 70°F .
- 3) The engine crankcase is to be filled with fresh SAE 30 oil.
- 4) The engine coolant will be drained. The thermostat will be blocked in the open position. The cooling system will be refilled with water. **WARNING:** Engine damage can result if units with pure water for coolant are exposed to temperatures below freezing.
- 5) The fuel tank will be full at the beginning of the test. For gasoline fueled engines, the fuel volatility should be 10 Rvp. For diesel fueled engines, #2 fuel should be used.
- 6) Automated data acquisition should be arranged so as to make measurements at a minimum of every two minutes. If data has to be taken manually, it should be recorded every 5 minutes until temperatures appear to stabilize. Then 2 sets of data should be taken at 2 minute intervals to confirm stabilization.

INSTRUMENTATION

With automated data acquisition, thermocouples should be installed to measure:

- 1) Cell ambient.
- 2) Fuel in the tank.
- 3) Fuel at the carburetor or injection pump.
- 4) Air on the clean side of the air filter.
- 5) Air into the radiator. Two thermocouples shall be placed such that:
 - they lie on a line that intersects the fan center and is parallel to the cell floor
 - they are 1/2" away from the forward edge of the radiator fins
 - they are located on each side of the fan center a distance of 0.75 times the fan radius

-
- 6) Air into the grill. Two thermocouples shall be placed such that:
 - they are midway between the top and bottom of the air inlet opening
 - they are 1/2" away from the grill surface
 - they are located at each side of the air inlet opening a distance of 0.25 times the width of the opening
 - 7) Engine compartment.
 - 8) Engine oil. It is preferable to install a thermocouple in an oil galley rather than through the drain plug or at the tip of the dipstick.
 - 9) Exhaust gas for diesel engines. Thermocouple to be located 6" downstream of the exhaust manifold outlet or turbocharger.
 - 10) Spark plug bases on gasoline engines.
 - 11) Radiator top tank. This shall be measured at the radiator inlet. With the hose removed, a thermocouple wire may be formed to place the tip at the center of the opening. With the wire lying on the outside of the tube the hose can then be slipped over the tube and clamped.
 - 12) Radiator bottom tank. This shall be measured at the radiator outlet. Instrument as for the top tank.
 - 13) Others, depending on application configuration and data requirements.

An exhaust gas analyzer shall be used to measure the combined CO concentration of gasoline fueled engines. The cylinders should not be measured individually.

Engine speed should be measured using a suitable tachometer. It should be recorded throughout the test.

With manual data acquisition, the minimum data set must include thermocouples in locations 1,11 and 12 above. Additional data may be taken at other locations with a hand-held thermocouple.

LABORATORY PROCEDURE

- 1) Elevate the test cell temperature to $100^{\circ}\text{F} \pm 5^{\circ}$.
- 2) Some means of circulating the test cell air should be utilized to keep the temperature uniform throughout the cell. This should not blow directly into the radiator or engine compartment.
- 3) Run under full load until all temperatures have stabilized (temperature does not change more than one degree in two minutes). Lower loads may be appropriate for certain applications such as vehicles.
- 4) Heat soak gasoline fueled application for 10 minutes at conclusion of test run. Continue to record temperatures.
- 5) Restart gasoline fueled applications following the standard restart procedure and note results accordingly.

FIELD PROCEDURE

- 1) Operate the application as intended, keeping the load as high and constant as feasible until all temperatures stabilize.
- 2) Heat soak gasoline fueled application for 10 minutes at conclusion of test run. Continue to record temperatures.
- 3) Restart engine gasoline fueled applications following the standard restart procedure and note results accordingly.

PRESENTATION OF RESULTS

Data should be presented as is done for air cooled engine heat tests. Ambient temperature and the ΔT for each thermocouple location should be noted at consistent intervals throughout the run. The interval length will be determined by the length of the run and events during the run. High speed no load rpm should be noted for the beginning and end of the run. Engine speed under tested load should be noted throughout the run. Notes on the test configuration (fan size, grill area, etc.) should be included for each run.

The ATB (air to boil) temperature should be calculated with the stabilized data. The calculation is:

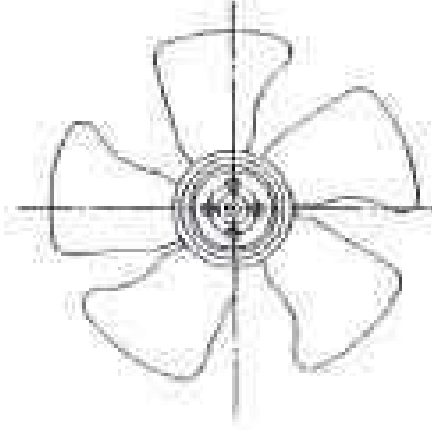
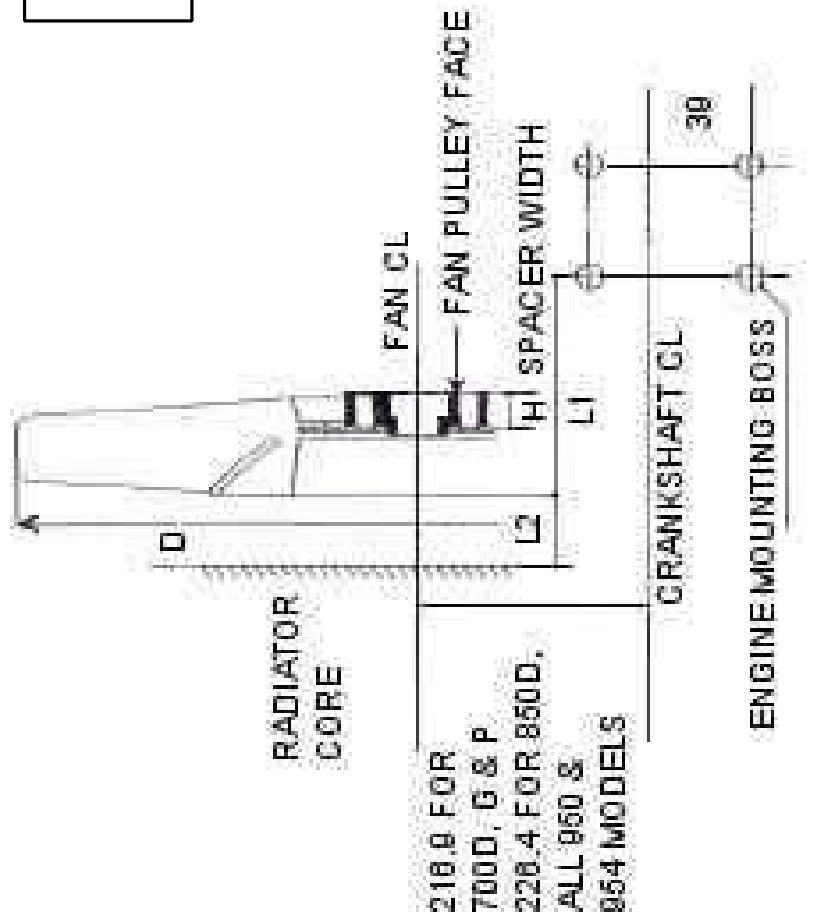
$$\text{ATB } (^{\circ}\text{F}) = 212^{\circ}\text{ F} - \text{radiator top tank temperature } (^{\circ}\text{F}) + \text{cell ambient temperature } (^{\circ}\text{F})$$

Example: T ambient = 100° F
 T top tank = 192° F

$$\begin{aligned}\text{ATB} &= 212 - 192 + 100 \\ &= 120^{\circ}\text{ F}\end{aligned}$$

The ATB temperature should exceed 120° F under the load appropriate for the application.

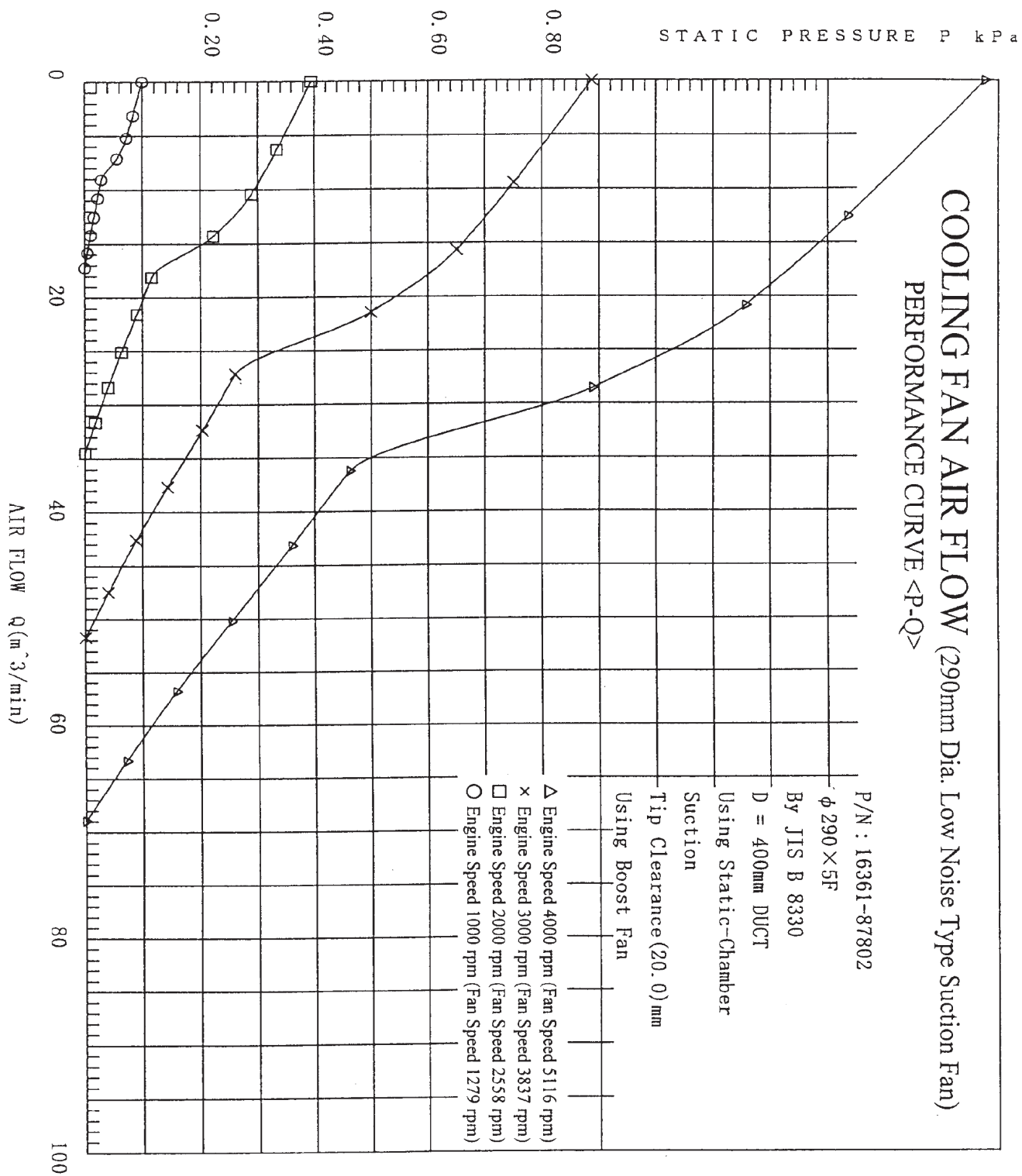
COOLING FAN OPTIONS

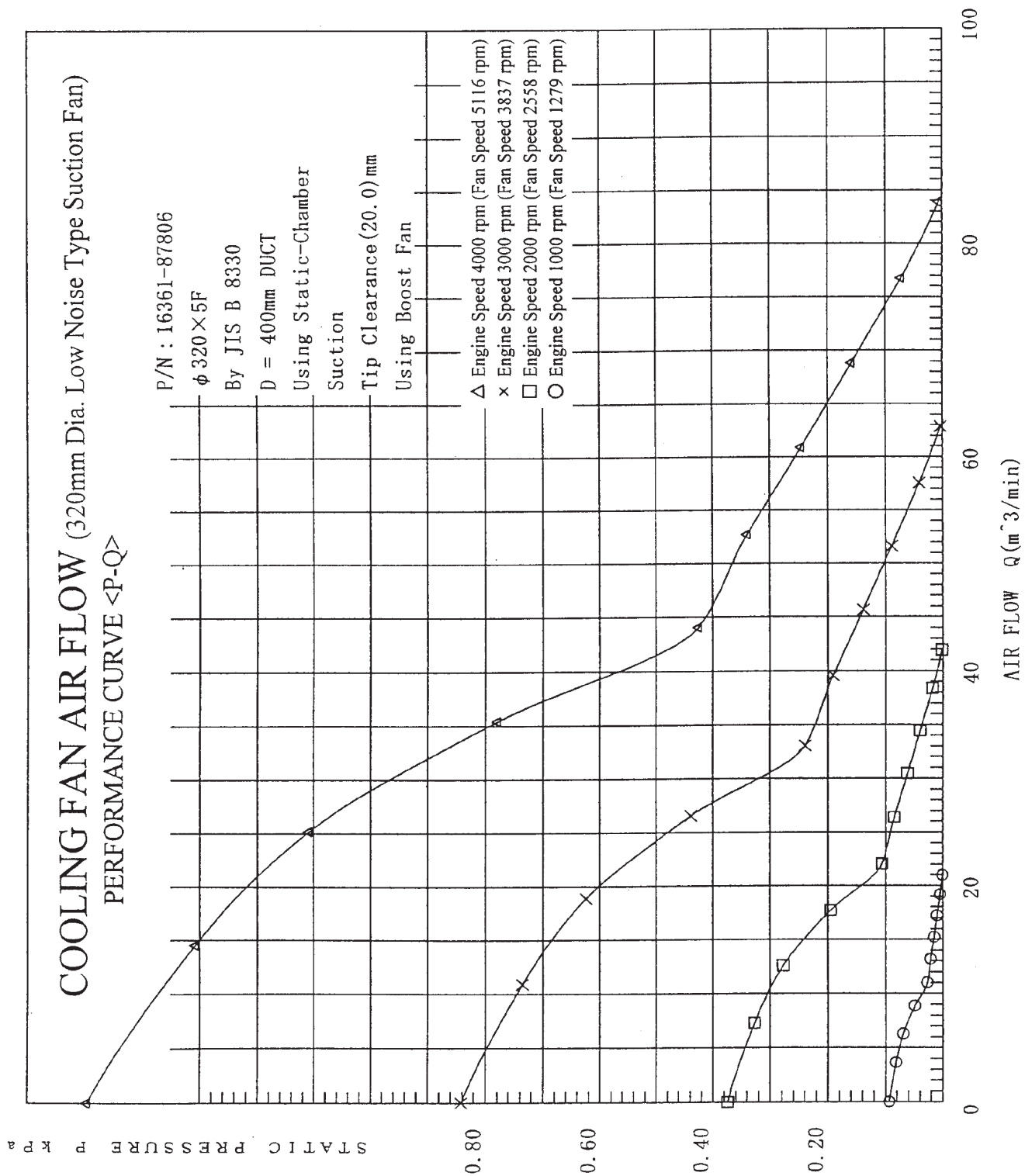


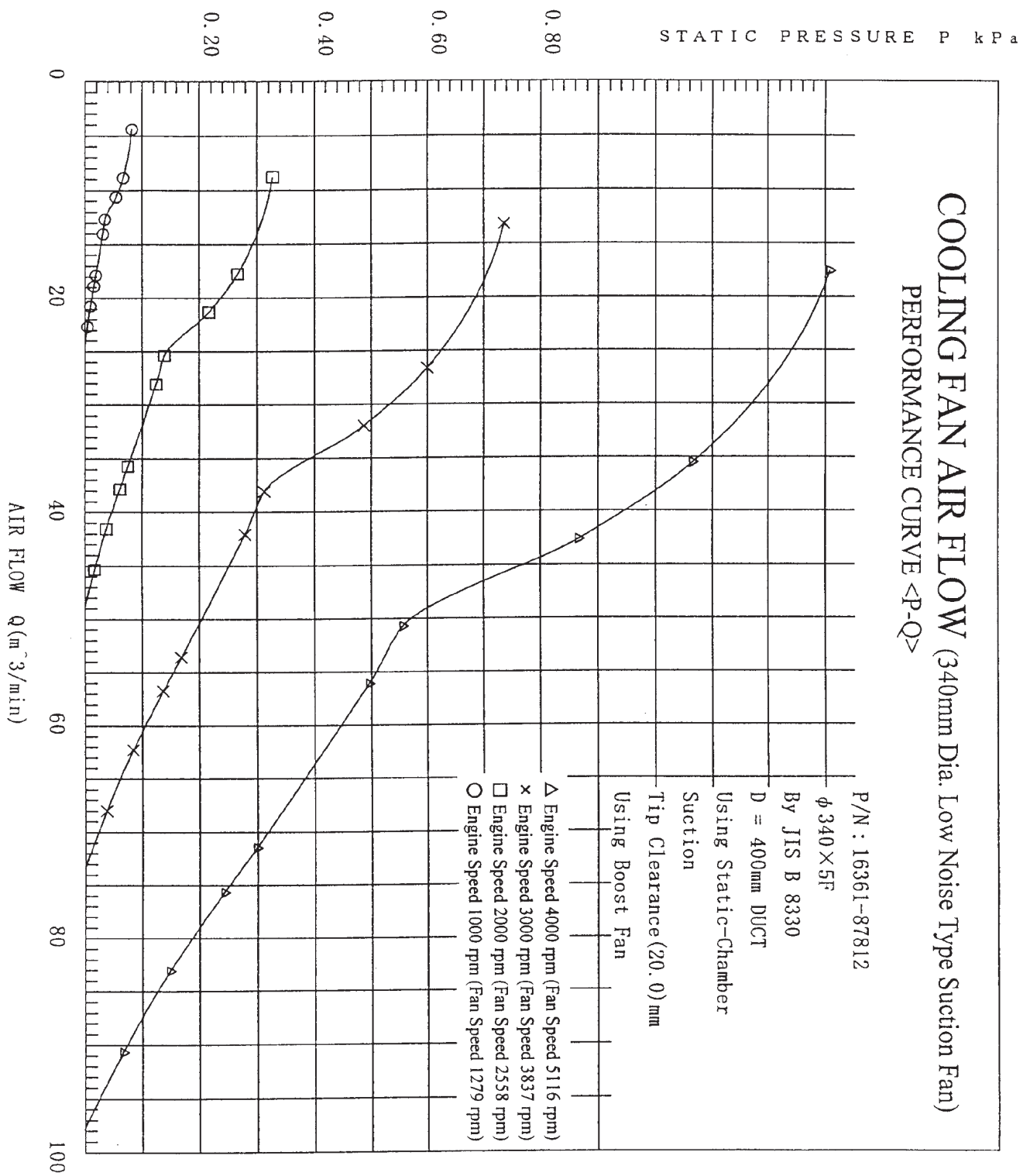
LOW NOISE FAN

ALL DIMENSIONS IN mm

fan type	D	H	L1	L2	# blades	notes
suction	290	NA	159.8	36	5	std 700D & G
	320	NA	152.4	43.4	5	std 850D, 950D & G, 954G
	340	NA	152.4	43.4	5	std 950DT, 954DT
	360	15	151.4	44.4	7	option
pusher	290	15	176.4	19.4	5	option
	310	10	179.4	16.4	5	option
	350	10 x 2	184.4	11.4	6	option





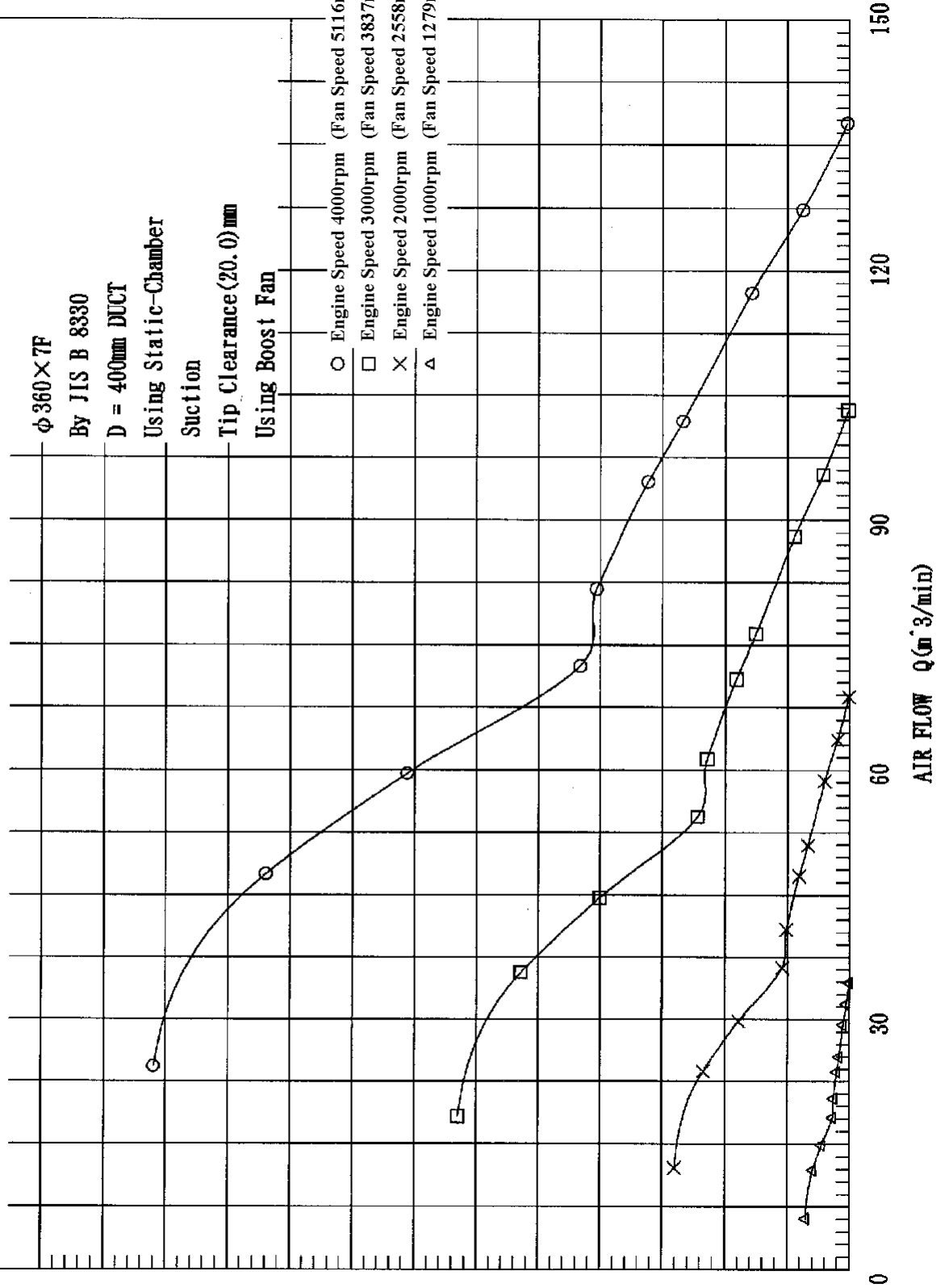


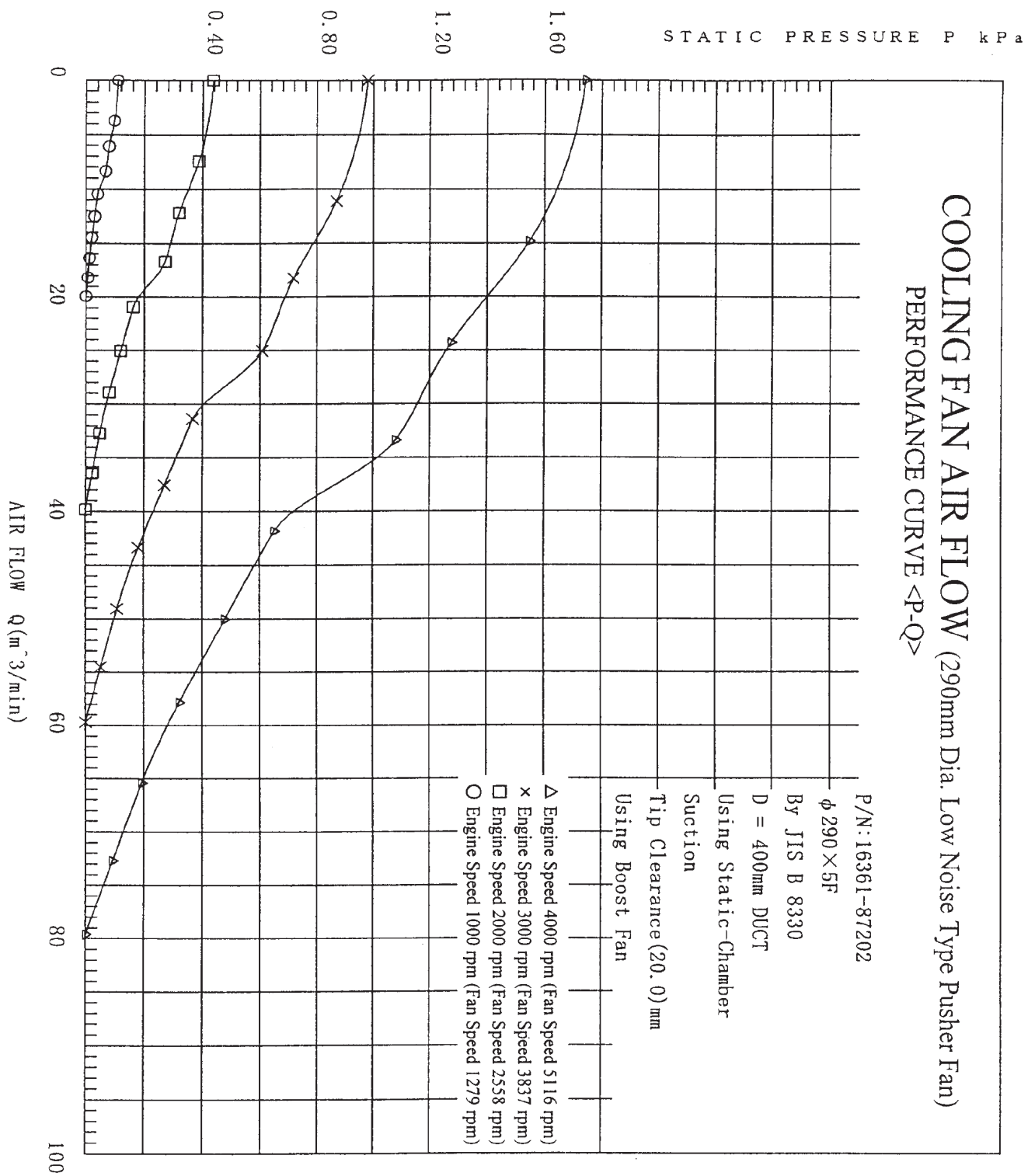
STATIC PRESSURE P kPa

COOLING FAN AIR FLOW (360mm Dia. Suction Fan) PERFORMANCE CURVE <P-Q>

$\phi 360 \times 7F$
 By JIS B 8330
 D = 400mm DUCT
 Using Static-Chamber
 Suction
 Tip Clearance (20.0)mm
 Using Boost Fan

- Engine Speed 4000rpm (Fan Speed 5116rpm)
- Engine Speed 3000rpm (Fan Speed 3837rpm)
- × Engine Speed 2000rpm (Fan Speed 2558rpm)
- △ Engine Speed 1000rpm (Fan Speed 1279rpm)





STATIC PRESSURE P kPa

COOLING FAN AIR FLOW (310mm Dia. Low Noise Type Pusher Fan) PERFORMANCE CURVE <P-Q>

P/N : 16361-87811

φ 310×5F

By JIS B 8330

D = 400mm DUCT

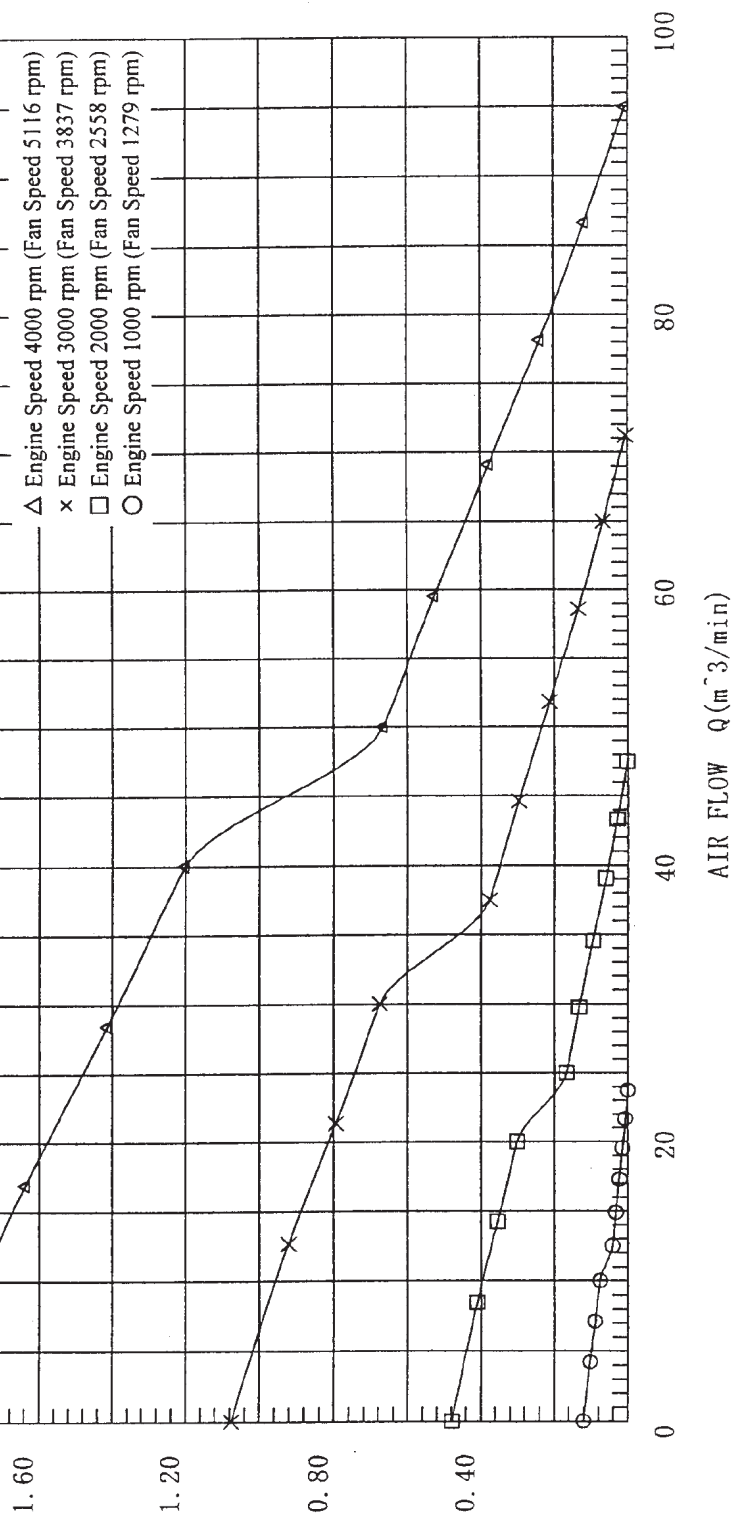
Using Static-Chamber

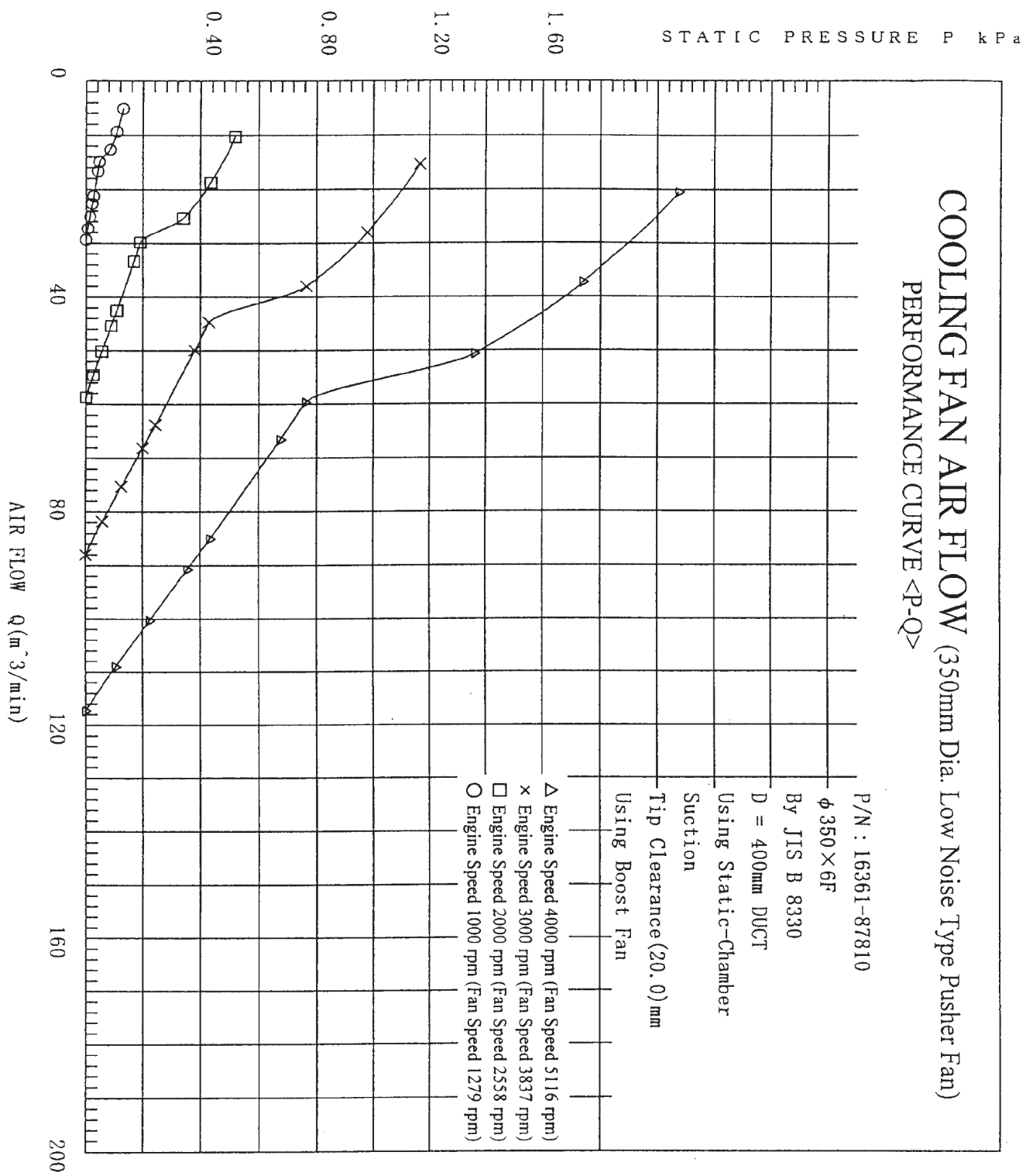
Suction

Tip Clearance(20.0) mm

Using Boost Fan

- △ Engine Speed 4000 rpm (Fan Speed 5116 rpm)
- × Engine Speed 3000 rpm (Fan Speed 3837 rpm)
- Engine Speed 2000 rpm (Fan Speed 2558 rpm)
- Engine Speed 1000 rpm (Fan Speed 1279 rpm)



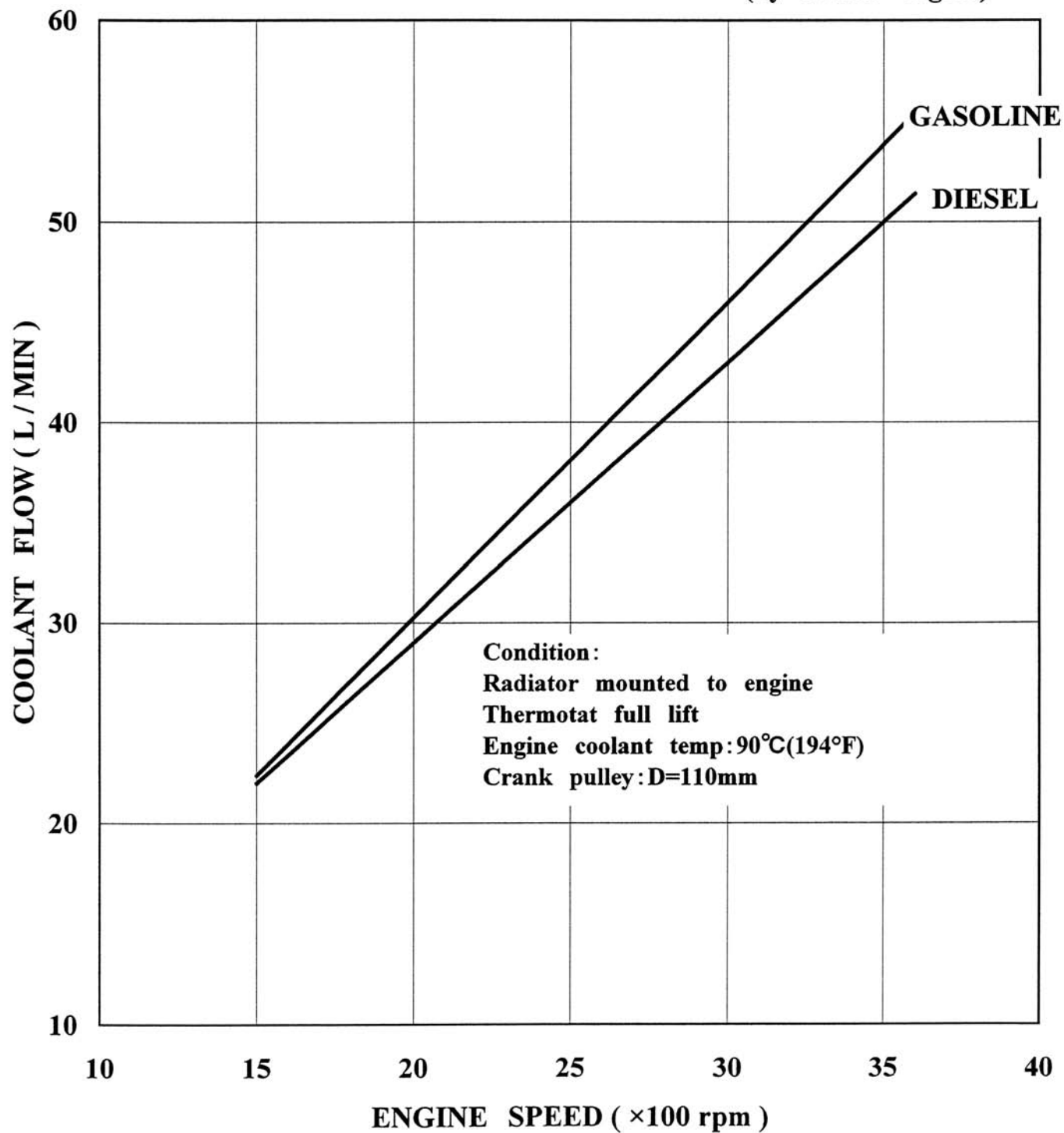


axial power (kW) vs air flow (m³/min)

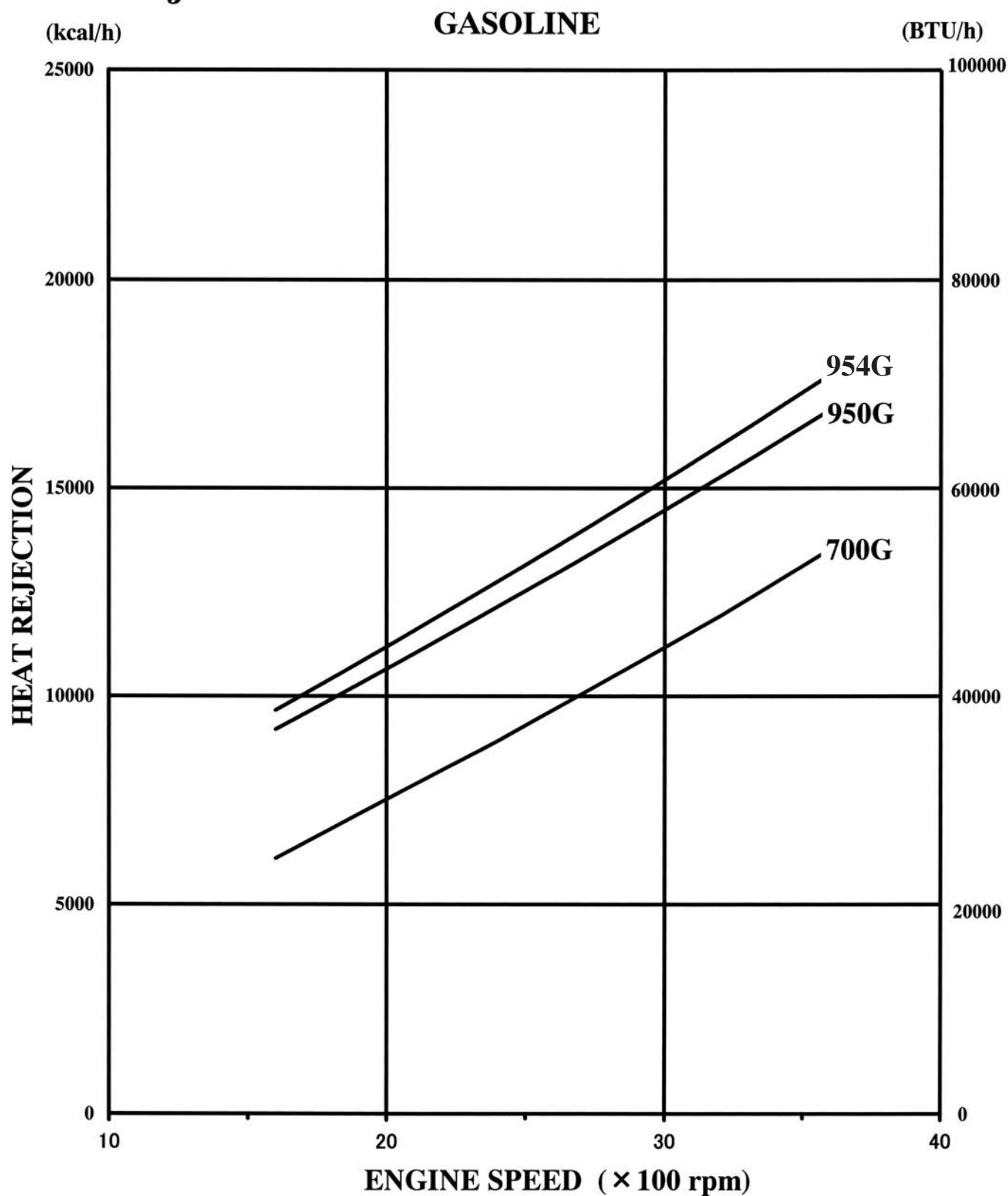
1000 rpm fan speed			air flow										
fan type		dia. (mm)	0	2	4	6	8	10	12	14	16	18	20
suction	low noise	290	0.019	0.017	0.016	0.013	0.013	0.013	0.012				
	low noise	320	0.021	0.02	0.018	0.015	0.014	0.015	0.015	0.015	0.015		
	low noise	340			0.023	0.021	0.018	0.018	0.021	0.021	0.02	0.02	
	low noise	360											
pusher	low noise	290	0.023	0.022	0.021	0.018	0.018	0.019	0.018	0.017			
	low noise	310	0.034	0.032	0.03	0.028	0.026	0.023	0.026	0.026	0.026	0.026	
	low noise	350			0.05	0.049	0.043	0.036	0.036	0.037	0.039	0.04	0.041
2000 rpm fan speed			air flow										
fan type		dia. (mm)	0	4	8	12	16	20	24	28	32	36	40
suction	low noise	290	0.15	0.135	0.123	0.1	0.102	0.101	0.096				
	low noise	320	0.168	0.157	0.144	0.117	0.114	0.122	0.123	0.122	0.115		
	low noise	340			0.183	0.169	0.144	0.146	0.168	0.17	0.163	0.163	
	low noise	360				0.724	0.68	0.651	0.629	0.581	0.535	0.539	0.543
pusher	low noise	290	0.186	0.179	0.168	0.148	0.145	0.148	0.144	0.14			
	low noise	310	0.27	0.256	0.244	0.228	0.207	0.185	0.208	0.209	0.21	0.208	
	low noise	350			0.402	0.392	0.348	0.281	0.29	0.298	0.314	0.323	0.325
3000 rpm fan speed			air flow										
fan type		dia. (mm)	0	5	10	15	20	25	30	35	40	45	50
suction	low noise	290	0.508	0.464	0.429	0.373	0.333	0.345	0.339	0.328	0.31		
	low noise	320	0.57	0.534	0.5	0.459	0.358	0.395	0.41	0.415	0.41	0.403	
	low noise	340			0.183	0.599	0.554	0.469	0.49	0.565	0.582	0.56	0.55
	low noise	360						1.79	1.69	1.62	1.55	1.52	1.48
pusher	low noise	290	0.63	0.609	0.575	0.544	0.49	0.49	0.5	0.49	0.475	0.468	
	low noise	310	0.91	0.873	0.83	0.8	0.745	0.683	0.625	0.7	0.705	0.705	0.705
	low noise	350				1.354	1.29	1.125	0.945	0.976	0.99	1.03	1.07
4000 rpm fan speed			air flow										
fan type		dia. (mm)	0	10	20	30	40	50	60	70	80	90	100
suction	low noise	290	1.2	1.059	0.88	0.799	0.802	0.759					
	low noise	320	1.355	1.231	1.085	0.86	0.975	0.98	0.958				
	low noise	340			1.424	1.225	1.165	1.37	1.329	1.3			
	low noise	360				3.36	3.04	2.76	2.73	2.83	2.95	2.96	2.86
pusher	low noise	290	1.49	1.4	1.28	1.15	1.18	1.14	1.1				
	low noise	310	2.16	2.02	1.9	1.69	1.48	1.66	1.67	1.67			
	low noise	350			3.21	2.94	2.25	2.32	2.45	2.57	2.61	2.64	
5000 rpm fan speed			air flow										
fan type		dia. (mm)	0	10	20	30	40	50	60	70	80	90	100
suction	low noise	290	2.35	2.13	1.93	1.57	1.58	1.58	1.5				
	low noise	320	2.64	2.45	2.24	1.83	1.76	1.9	1.92	1.88	1.84		
	low noise	340			2.85	2.66	2.24	2.26	2.64	2.67	2.54	2.54	
	low noise	360				6.83	6.52	6.03	5.11	5.12	5.31	5.53	5.81
pusher	low noise	290	3.91	2.79	2.61	2.3	2.27	2.3	2.27	2.2			
	low noise	310	4.42	4	3.79	3.58	3.2	2.9	3.25	3.25	3.25	3.26	
	low noise	350			6.28	6.14	5.43	4.39	4.52	4.65	4.92	5.05	5.09

COOLANT FLOW

(by actual engine)



Heat Rejection



Heat Rejection

