

Engine Application Manual



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FOREWORD

It is vital for Honda, the OEM and the end user of the product that the engine installation and characteristic is suited for a particular application. If not, engine and/or frame damage may occur, performance will suffer, durability may be reduced and in extreme cases operator injury may result. This is of course outside the scope of the Honda warranty and product liability and can be the source of dissatisfaction to OEM and end user.

Therefore, the proper application (matching) of the engine to the end product (OEM product) is very important.

This manual on engine application deals with the general subjects of four stroke general-purpose engines and their applications.

The product designer's selection of the engine model and variation is generally made after consideration of several factors such as:

- Ø Dimensions
- Ø Weight
- Ø Power
- Ø Environmental conditions
- Ø Marketing and price

The power required to operate most types of equipment can be calculated rather accurately. Other equipment cannot be readily calculated and is usually extrapolated from similar designs equipped with an electric motor or a competitor engine.

An "oversized" engine can make an excellent engine application as it provides a lot of reserve power and assures a long lifetime. An "oversized" engine, however, has the potential for introducing vibration and other problems, particularly in single-cylinder engines.

An "undersized" engine can provide real advantages in terms of dimensions, weight and cost but can fail to fulfill the end user's expectations in terms of adequate power and engine lifetime.

Customer satisfaction is gained through both the useful engine power and the engine lifetime. These data are usually expressed in horsepower-hours or horsepower-years.

A professional user would probably be satisfied with adequate power for one or two seasons, which may be a minimum of 500 hours.

A domestic user may consider a lifetime of 10 years on his equipment to be a good service, even though at 25 to 50 hours per year, he has used it only for 250 to 500 hours.

So, in engine powered equipment design and development, it is advisable to think in horsepower-hours rather than horsepower-years in the engine selection.

ENGINE INSTALLATION CHECK PRINCIPLES

Safety in usage is of the utmost importance for a customer when working with a Honda engine powered OEM product and should always be given priority in importance over preventing trouble with the engine or equipment.

A detailed technical analysis – engine installation check, engine matching test – should be conducted on the OEM equipment during the development or test period.

A Honda engine installation check consists of a static installation and mounting check followed by a 1 hour dynamic loaded test of the equipment.

STATIC CHECK OF THE APPLICATION

Engine condition

- Engine No., model and type
- Engine equipment and optional parts mounting
- Engine external damage
- Engine fuel, oil or coolant leaks
- Engine oil, fuel and coolant level

Engine controls

- Fuel cock operation
- Throttle control operation: remote, lever type
- Choke operation: remote, lever type
- Engine stop switch
- Recoil and/or electric starter

Engine mounting

- Ease of maintenance and accessibility to related components: air cleaner, spark plug, fuel tank cap, carburetor drain bolt, oil drain bolt, oil filler cap, oil filter and valve clearance
- Mounting space between engine and surrounding components
- Visibility of caution labels and marks
- Position of exhaust system: directed away from operator and air cleaner intake, clearance from equipment
- Cooling air intake opening
- Rigidity of engine mounts
- Safety protectors on revolving components
- Safety protectors on hot components
- Electric wiring: fixing points, away from sharp edges
- Fuel tubes: fixing points, away from sharp edges, clearly separated from electric wiring routing

- Alignment of the engine PTO shaft and equipment shaft
- Engine PTO shaft coupling
- Engine inclination
- Thrust and radial load on engine PTO shaft

Application / frame components

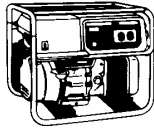
- Non standard fuel tank: position, level, filter, ventilation and safety
- Battery: size , position, connection
- Electric wire size, fuses
- Engine bed rigidity and flatness, frame rigidity

DYNAMIC CHECK OF THE APPLICATION

Full-loaded running test

- Electric starter power requirement with cold engine: cranking current
- Recoil starter pulling load
- Engine speed setting: idle and maximum operating speed
- Inclined usage operation
- Required power output, governor performance
- Cooling air flow in enclosed or semi-enclosed engine installation
- Muffler heat radiation to other parts
- Engine interference with frame or other parts during acceleration, deceleration, starting, stopping
- Installation of covers, protectors and frame parts as possible sources of resonance vibration and noise
- Flow of exhaust gas routed away from cooling air intake and air cleaner intake
- Restarting performance of engine in hot condition: vapor lock
- Engine vibration on different operating speeds
- Engine component temperatures during a 1 hour full-loaded test cycle
- Muffler afterburn at engine stop
- Backpressure of non-standard exhaust system

COMMON ENGINE APPLICATIONS



Generator

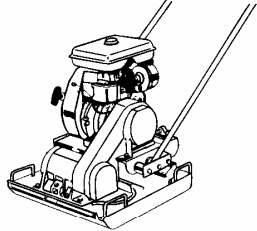
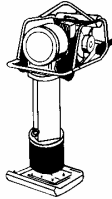
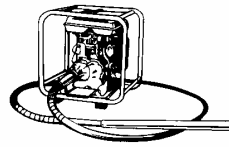


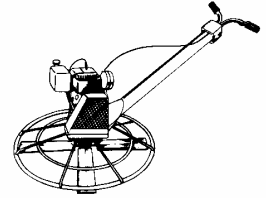
Plate compactor



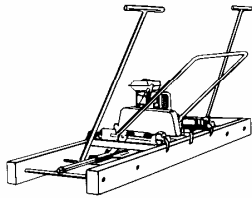
Rammer
Tamper



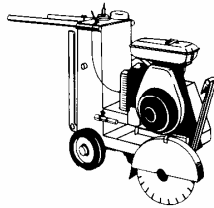
Concrete vibrator
Poker



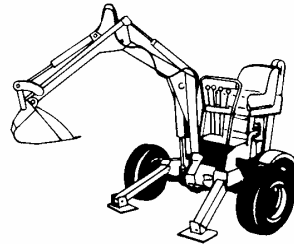
Power trowel



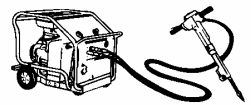
Concrete screed



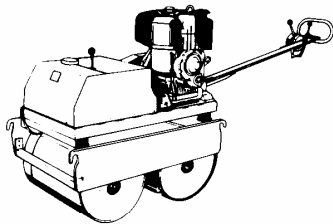
Concrete cutter



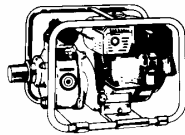
Excavator



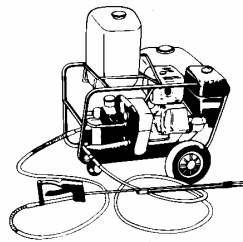
Hydraulic pack



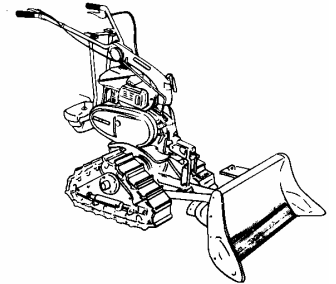
Vibrating roller



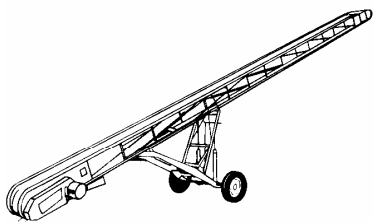
Waterpump



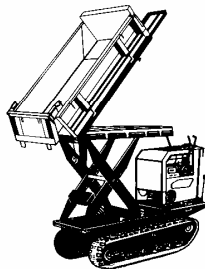
Pressure washer



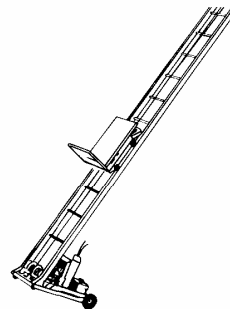
Dozer



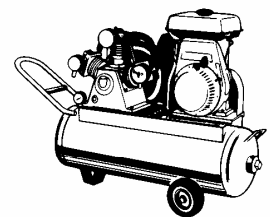
Conveyer



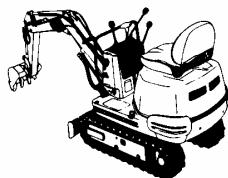
Dumper



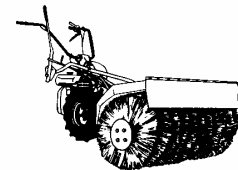
Mobile lift



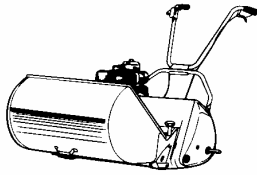
Compressor



Power shovel



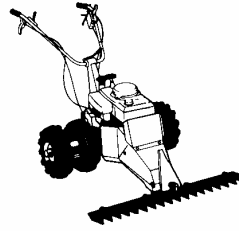
Sweeper



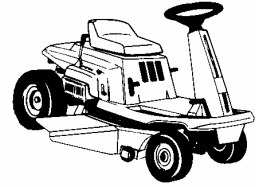
Cylinder lawnmower



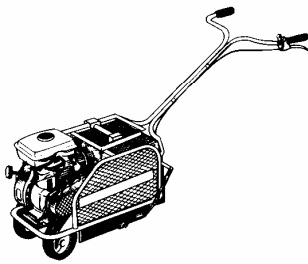
Rotary lawnmower



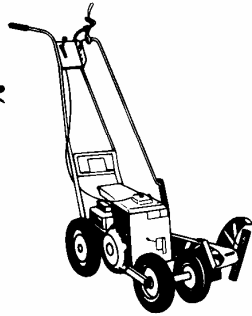
Clipping mower



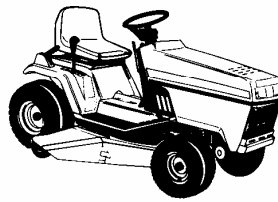
Riding mower



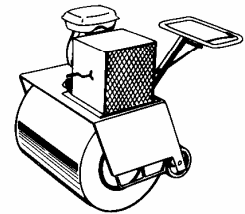
Turf cutter



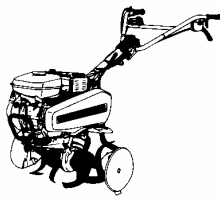
Edge trimmer



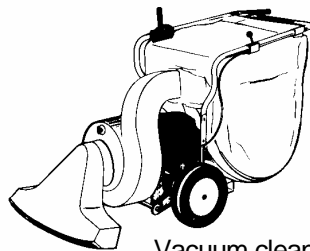
Lawn tractor



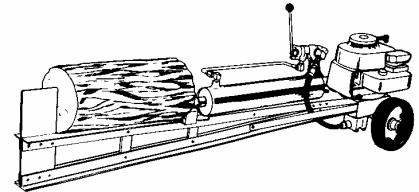
Turf roller



Tiller



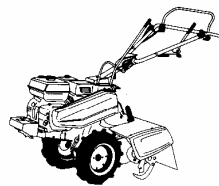
Vacuum cleaner



Log splitter



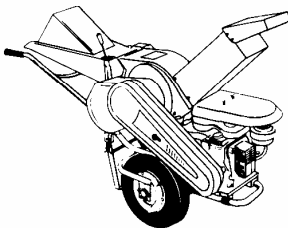
Power carrier



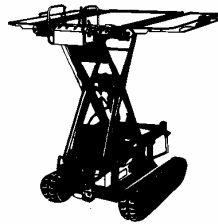
Tiller



Walk behind tractor



Shredder

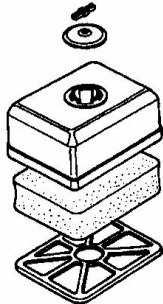
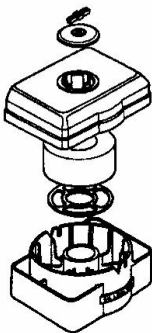
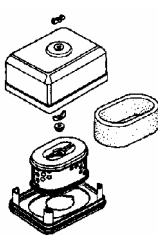
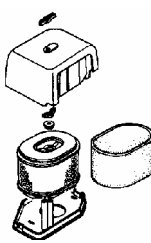
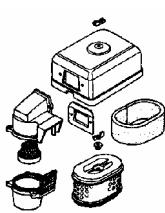


Mobile platform



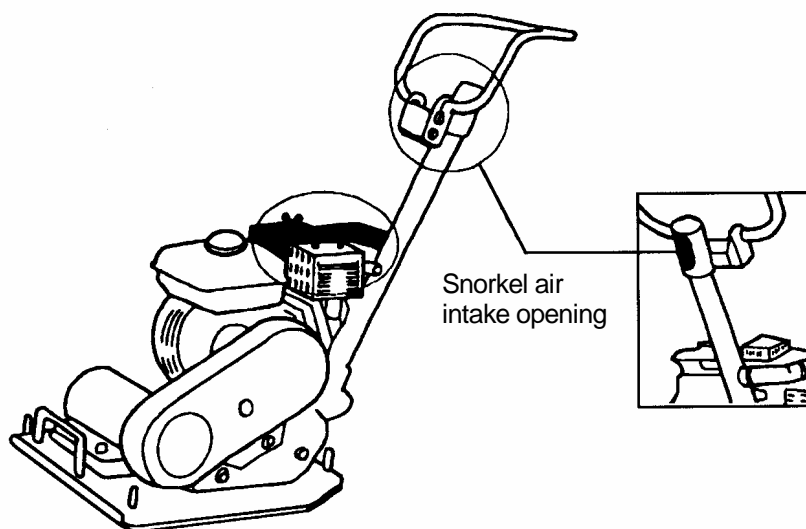
Snow thrower

TYPES OF HONDA STANDARD AIRCLEANERS

	Semi-dry	Oil bath	Dual	Silent	Cyclone
Type					
Application	No excessive dust	Excessive dust, fine dust - Not suitable for inclined operation - Leads to reduced power if not maintained regularly	Excessive dust	Excessive dust Noise reduction	Excessive dust Extension of maintenance
Filtering efficiency	99.1 %	97.8 %	99.8 %	99.8 %	99.9 %

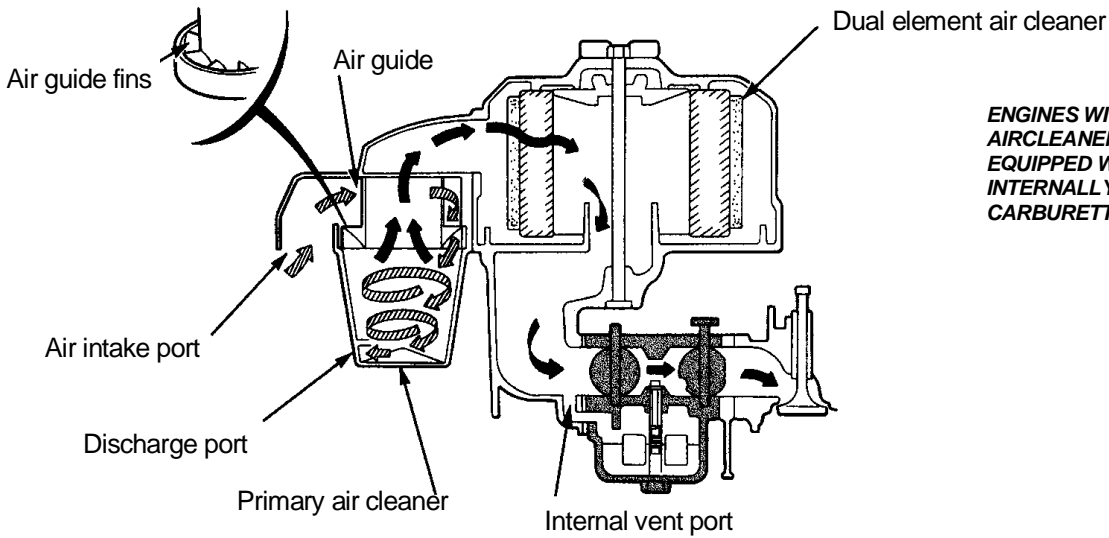
In some extreme dusty applications (concrete saws, vibrator plates) it could be advisable to change the **air intake direction**.

For this application, a commercially available snorkel, combined with a cyclone air cleaner can offer a good solution.



AIR CLEANER

The cyclone aircleaner is composed of a primary cyclone aircleaner and dual element aircleaner.



ENGINES WITH CYCLONE AIRCLEANER ARE EQUIPPED WITH INTERNALLY VENTED CARBURETTOR

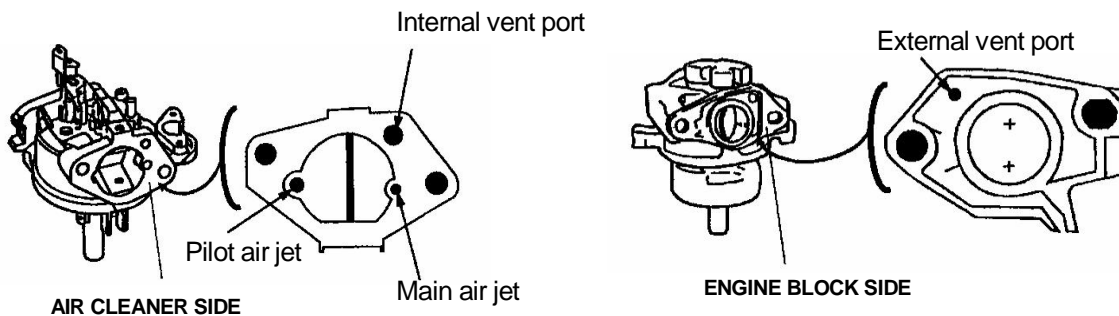
Function:

The air guide fins in the upper part of the primary aircleaner cause air from the intake air port to whirl rapidly, creating a small cyclone. Due to centrifugal force, the coarse particles of dirt or sand are forced to the sides and bottom of the primary aircleaner body, and eventually go out of the discharge port. Air speed in the middle of the cyclone is slower, enabling engine vacuum to pull the partially cleaned air up through the center of the air guide to the dual element cleaner.

This two-stage cleaning is more thorough, resulting in longer service life.

INNER VENT-TYPE CARBURETTOR

On the aircleaner side, the carburetor has an internal ventilation port to the float chamber, to equalize float chamber pressure by venturi vacuum. The result is that a more consistent amount of fuel can be supplied by the main jet without being affected by the increasing air resistance, as the dual aircleaner element becomes dirty. Both "Internal" and "External" vent ports are found on the carburetor.



Carburetors that are "Internally Vented", have the internal vent passage open to the carburetor and the external vent passage closed.

Carburetors that are "Externally Vented", have the external vent passage open to the carburetor bowl and the open air and the internal vent passage closed.

NEEDED AIR VOLUME FOR COMBUSTION

For particular engine applications such as: complete enclosure of the engine, extension of the air intake or redesign of the air cleaner, a calculation of the needed air volume for combustion is necessary.

The engine needs a certain air volume for the combustion cycle; ones for every 2 engine revolutions. Roughly, the intake air volume is equal to the volumetric displacement of the engine.

As a result, the air volume can be calculated as following:

$$\text{Air volume (m}^3\text{/min)} = \frac{\text{engine rpm (min}^{-1}\text{)}}{2} \times \frac{\text{engine capacity (cm}^3\text{)}}{1\,000\,000}$$

MODIFICATIONS TO THE AIR CLEANER ASSEMBLY: QUALITY STANDARDS AND TESTS

The Honda genuine air cleaner element is guaranteed to offer the prescribed cleaning efficiency for its full service life.

When altering the standard air cleaner system, some important quality tests have to be performed.

AIR FLOW RATE

The air cleaner element must allow a certain air flow while maintaining a good filtering efficiency.

The air flow rate must be in accordance with the needed air volume for combustion in the engine.

A standard test for checking the flow performance is an exhaust emission test with gas analyser.

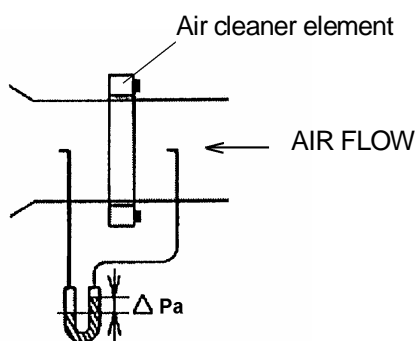
A "well performing" air cleaner system should give following results:

- CO: 3 – 5 %
- HC: as low as possible
- Lambda: 0.90 – 1.0

AIR FLOW RESISTANCE

Air flow resistance is measured as a pressure difference before and after the air cleaner element at the maximum air flow rate.

Ref: 500 – 600 Pa

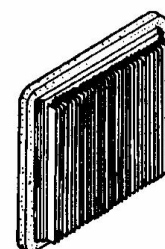


AIR CLEANER ELEMENT DESIGN

The installation direction of the paper air cleaner element is important for the self-cleaning capacity.

The element should be mounted with the paper plies in vertical direction, so that accumulated dust falls to the bottom of the air cleaner case under influence of machine vibrations.

PROTECH	
FLUX 5000	
INFRARED GAS ANALYSER	
ver. 1.3/ITA	
29 October 1999	
12:11:51	
Rpm4	3019
CO	5.140 %vol
COcor.	5.205 %vol
CO2	09.67 %vol
HC	00059 ppm
O2	02.20 %vol
NO	---- ppm
NO2	---- ppm
NOx	---- ppm
T.OIL	019.2 °C
Lambda	0.940
AFR	13.82



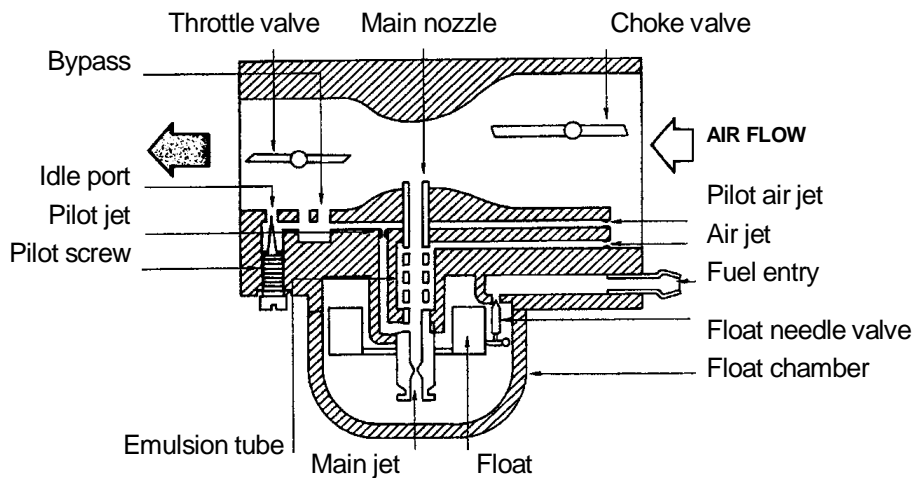
CARBURETTOR OPERATION

Choke operation

With the choke valve closed and throttle valve open, vacuum in the carburetor venturi is high. Fuel is drawn up through the pilot jet and mixed with air from the pilot air jet; this fuel/air mixture passes through the idle port and bypass port. Further enrichment of this mixture is done by fuel supplied through the main nozzle.

Slow circuit (low rpm and idling)

With the throttle valve opened slightly (idle position), a vacuum is produced in the bypass and idle port. Fuel is drawn up through the pilot jet and mixed with air from the pilot air jet; this fuel/air mixture passes through the idle port and bypass port. As this mixture discharges into the venturi, it mixes with air moving through the carburetor body, thereby producing the final mixture for slow speed operation. As the throttle valve is opened further, it frees more bypass openings and more air/fuel mixture is provided to the engine.



Main circuit (high rpm)

When the throttle valve is opened, enough air is moving through the carburetor venturi to produce a high vacuum. Since the main nozzle is centered in the venturi, the atmospheric pressure in the float chamber pushes fuel through the main jet into the main nozzle. Fuel moving up through the main jet is mixed with air from the air jet in the emulsion tube. As this mixture flows out through the main nozzle, it is mixed with air flowing through the venturi to produce the final mixture.

RELATION OF CARBURETTOR SETTINGS TO ENGINE PERFORMANCE

	Wide open throttle-loaded	Partial loaded	No load-high speed	Start-ability	Low temperature start	Inclined usage	Idle stability	Hot restart
Main jet	○	○	○	○				
Fuel level	○	○	○	○		○	○	○
Pilot jet		○	○				○	
Bypass holes		○	○				○	
Pilot screw adjustment			○		○		○	
Choke valve				○	○			○
Governor adjustment	○			○	○		○	○
Air vent holes	○					○		○

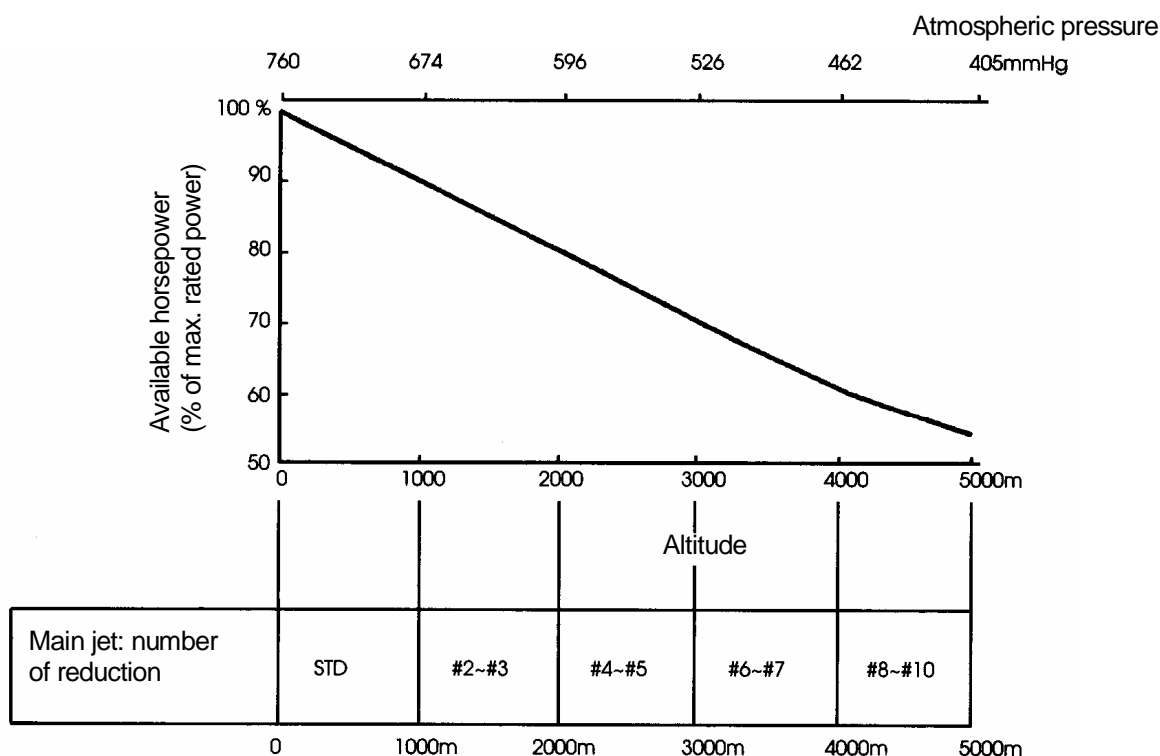
JETTING

At high altitudes, the air is less dense and the standard carburetor main jet will produce an excessively rich air-fuel mixture. Performance will decrease and fuel consumption will increase as a result.

High altitude performance can be improved by installing a smaller diameter main jet. With suitable carburetor jetting, engine horsepower will decrease approximately 10% for each 1000-meter increase in altitude. The effect of altitude on horsepower will be greater than this if a high altitude main jet is not installed.

The following chart shows the effect of altitude on horsepower when the carburetor is correctly jetted.

Before ordering or calculating optional jets, always check the mounted standard jet. For some types, variations or countries this may differ.



Example: At an altitude of 1500 meters, use a jet size correction factor of 85%. If the standard main jet is # 68, The recommended jet for an altitude of 2000 meters would be # 65 (68-3 = 65).

For quick reference, the size of a jet can be easily found through the part number.

For example: 99101-ZF5-0850 jet # 85
 99101-ZF5-0800 jet # 80
 99101-ZF5-0820 jet # 82

Note:

At an altitude of 1500 meters, a correctly jetted engine is capable of delivering approximately 85% of its sea level maximum power.
 For continuous loads, the engine should not be required to deliver more than 85% of its sea level maximum power.

FUEL CONSUMPTION

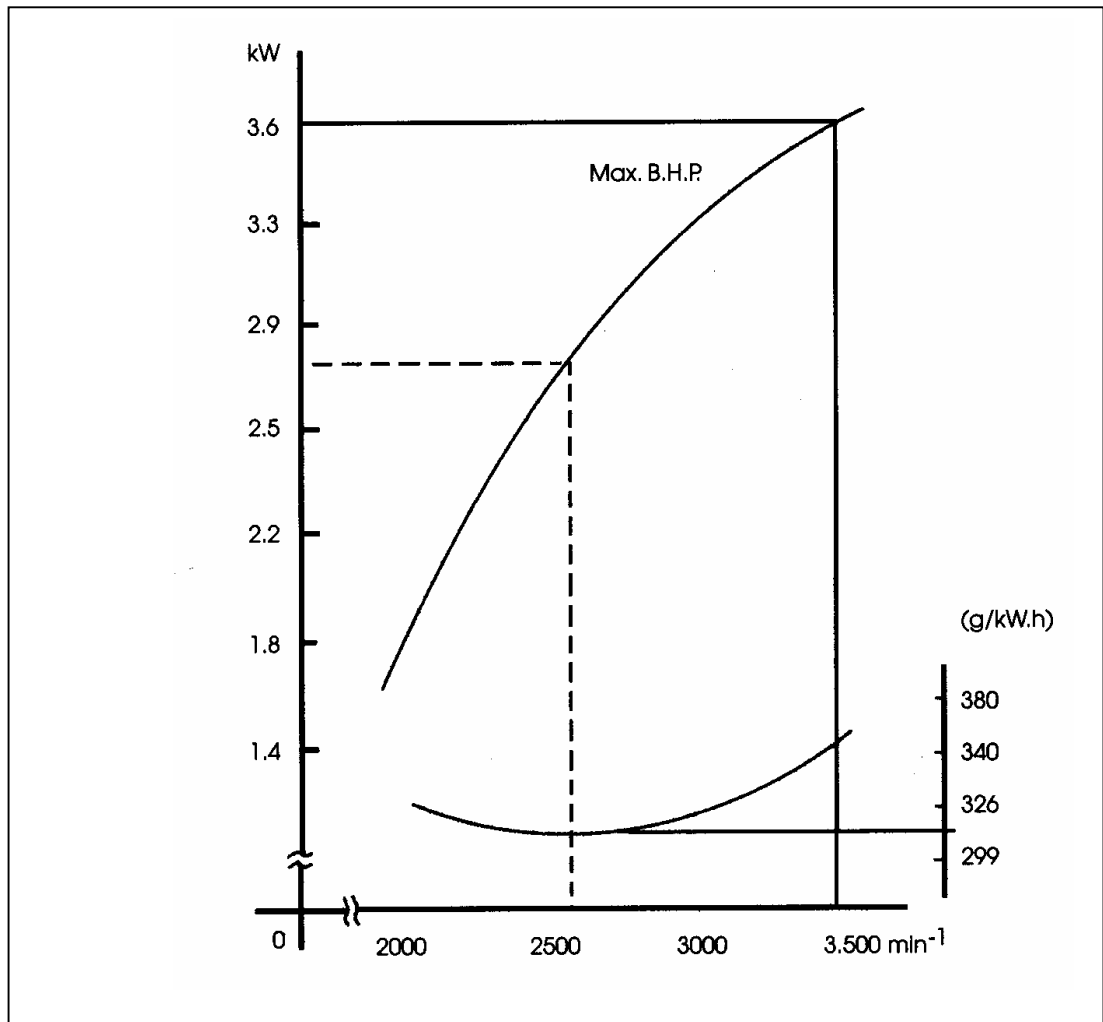
Specific fuel consumption is generally expressed in g/kWh.

Specific fuel consumption of engines can be compared by this numerical value even if the horsepower or displacement is different.

A fuel consumption of 313g/kW.h indicates that 313 grams of fuel are consumed per one kilowatt in one hour.

Sample calculation: Fuel consumption when GX160 rated output is 2.8 kW / 2600 min⁻¹
 As shown in the following graph, the fuel required for one hour of operation at 2600 min⁻¹ is 313 g/kWh x 2.8 kW = 876 g/h, assuming the specific gravity of the gasoline to be approximately 0.73 g/cm³ (diesel fuel is 0.835 g/cm³).

$$\frac{876 \text{ g/h}}{0.73 \text{ g/cm}^3} = 1200 \text{ cm}^3/\text{h} = 1.2 \text{ l/h}$$



Fuel consumption changes with loading, temperature and altitude. Since loading and rpm change during operation, actual fuel consumption may differ slightly from the calculated value.

Note

Contrary to gasoline engine, the fuel (propane gas) consumption of propane engines is generally expressed in g/h. or kg/h.

FUEL SUPPLY

FUEL TANK POSITION

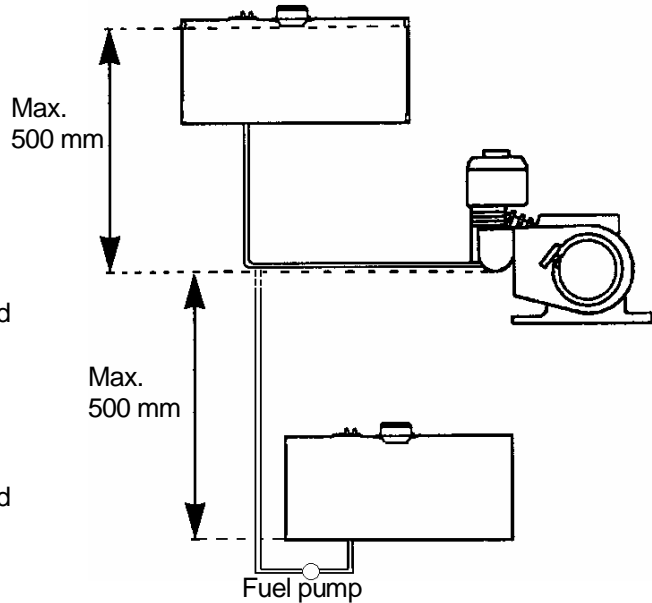
The fuel from the fuel tank flows through the float needle valve into the carburetor's float chamber.

Gravity feed

To assure a correct operation of the float needle valve (opening / closing pressure), the maximum level difference between a separately mounted fuel tank and the carburetor float level should be kept within 150 to 500mm.

Pressure feed

In case a fuel pump is used, the maximum level difference between a separately mounted fuel tank and the carburetor float level should be kept within 500mm above or below.



FUEL FILTER

The standard fuel tank is provided with a fuel strainer: micro mesh nylon filter (mesh horizontal # 300, mesh vertical # 180-200).

To protect the carburetor's narrow passages from blocking, this filter should always be incorporated in the fuel system between carburetor and tank.

FUEL PUMP

A standard carburetor inlet float valve has a closing pressure of 0.2 kg/cm².

A standard fuel pump provides a fuel pressure of 0.1 kg/cm² and delivers 15 l/h.

To avoid carburetor flooding, fuel pressures higher than 0.1 kg/cm² should be avoided.

A T-joint and fuel tank return tube can lower the fuel pressure in the fuel system.

FUEL LINE

Use a weather resistant fuel tube rated for gasoline use.

The fuel tube inner diameter should be 5.5 mm.

FUEL LINE INSTALLATION

Route the fuel line away from hot components, sharp surfaces and electrical wiring and components.

Secure the fuel line with clamps to prevent pinching and rubbing.

If the fuel line passes through a surface, protect it with a rubber grommet.

VAPOR LOCK

When fuel is heated, fuel vapor is generated. Normally there is a balance between vapor generation and vapor discharge through the fuel tank ventilation system.

Vapor generation rapidly increases from a temperature of 60°C on.

Vapor may accumulate in the carburetor float chamber and fuel lines disturbing fuel flow and causing engine malfunctioning and stalling.

VAPOR LOCK PREVENTION

The temperature of fuel system components should be kept under 60°C.

Fuel pipes should have the minimum length.

High bends should be avoided in the fuel pipe routing.

An adequate fuel tank ventilation system has to be provided.

PROPANE FUELED ENGINES

Propane is a by-product of the petroleum refining process. It is an extremely clean burning and relatively efficient fuel. Because of this, it can be used in engines operated in well ventilated indoor areas.

But, propane isn't without its disadvantages:

- it causes engines to run at higher operating temperatures
- it reduces lubrication to the valve guide area because it is a dry gas, not a liquid
- it reduces the engines power output: the calorific value of propane is higher than that of gasoline,

Gasoline 42.7 MJ/kg

Propane 46.3 MJ/kg

Butane 45.6 MJ/kg

but the stoichiometric ratio (air / fuel ratio) for propane is higher than for gasoline (the volumetric efficiency of the engine decreases with propane use because 5% more oxygen is needed for combustion).

Gasoline 14.7

Propane 15.5

Compared to gasoline, propane produces less carbon as well as reduced carbon monoxide giving cleaner exhaust gasses.

LPG is Liquefied Petroleum Gas comprised mainly of propane and butane. The main component of LPG is propane, but the percentage of propane content can vary from day to day production.

Some considerations on propane fueled engines:

- Ventilated indoor use is possible.
- CO and HC emissions are drastically reduced.
- A minimum carbon deposit in the combustion chamber leads to a long term guaranteed power output.
- Long operation time is possible with large propane tank.
- The engine is approved for propane use by the manufacturer (minimum 95% propane content).
- The specific fuel consumption is low.
- Up to 26% better fuel efficiency compared to a similar gasoline engine.
- The engine power output is about 5% lower.
- The propane gas octane rating of ± 100 gives troublefree engine operation.
- The propane engines meet the emission regulations
- Only propane fuel to be utilized.

If gasoline (producing considerable more carbon) is utilized in a propane-spec engine, carbon may lodge between the larger valve seat and valve face reducing compression and causing other problems.

- Recommended oil for propane engine usage

API service category: SE/SF/CC

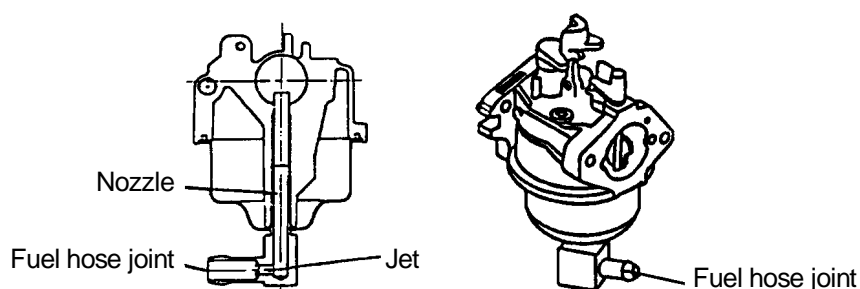
SAE viscosity grade: over 0°C single grade SAE30

Under 0°C multi grade SAE 5W30

As valve cooling and lubrication is critical in a propane engine, use of normal engine multi-grade oils may cause valve sticking, increased oil consumption and reduced oil life.

SUMMARY OF PROPANE ENGINE DESIGN FEATURES

- Valve seats:
Both intake and exhaust seat width are increased for better heat transfer.
- Intake valve
Outside diameter of the valve head increased to allow for greater seat width.
- Exhaust valve:
Head diameter increased to allow for greater seat width and a stellite coating added to the face for improved wear resistance.
- Exhaust valve rotor:
removed to eliminate abrasion to the valve face and seat caused by the rotating valve and the poorer lubricating quality of the propane fuel.
- Propane gas carburetor:
The gas mixer (nozzle) and gas hose joint have been factory installed and the mixer jet dimension has been fixed for propane use, according to the engine's displacement. The vacuum port connection has been factory installed too.



- Conversion
The propane engine conversion does not include the regulator and hoses; they have to be obtained locally.

NOTE

Propane valves are marked with a "P" on the head to indicate they are designed for propane. The gasoline valves are marked with a "Z". The propane exhaust valve face has a stellite coating. This is to help prevent burning and erosion of the valve face due to the higher combustion temperature and lubricating quality of the propane fuel. Do not grind or excessively lap the exhaust valve when rebuilding; it will destroy the protective coating.

FUEL TANK VAPORIZING CAPACITY

Stationary engine applications can use either a propane gas vapor or liquid withdrawal system.

A vapor withdrawal system uses fuel vaporized in the tank and needs only a **dry-gas regulator** for control.

If space permits only a relatively small fuel tank, then use liquid withdrawal where the fuel is taken from the tank in liquid form and changed to vapor in a **Vaporizer-regulator**.

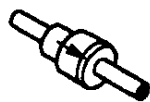
Only if an adequate size fuel tank is installed, a vapor withdrawal system can be used.

Note:

Butane freezes at 0°C and therefore can not be used where the supply tank is subjected to temperatures below the freezing point. For this reason, plus the fact that the system recommended for Honda engines are "vapor" systems, we recommend primarily propane gas to be used in Honda engines.

MATCHING AND INSTALLATION RECOMMENDATIONS FOR PROPANE ENGINES

- Engine stops at high engine speed should be avoided, it can cause afterburn because of higher engine operating temperature. First lower the engine speed before stopping the engine.
- Cooling is critical for propane engines.
Install the engine so that the sufficient volume of cooling air can be drawn in under the normal operation conditions. Be sure that the engine meets the temperature matching requirements.
When the electric starter motor is not mounted, be sure that the fan cover opening is blocked. If not, cooling air will leak and the engine becomes overheated.
- In some applications, the engine speed can drop low because of the sudden change of the load. The vacuum at the carburetor venturi drops, resulting in the fuel cut by the vacuum lock mechanism in the regulator.
To prevent this, a dashpot valve available as spare part, can be integrated in the vacuum hose.
Dashpot check valve: 36135-PH3-004

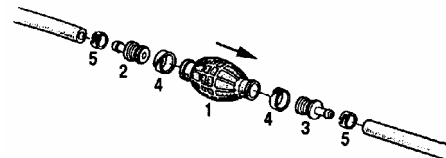


Wind seal tape at both ends of the dash pot valve and use hose clips.

- In case of small displacement engines like GX160/200 whose discharge by pulling the recoil starter is small, use the primer to discharge the air and create sufficient vacuum in order to release the vacuum lock mechanism of the regulator (full release: less than -20 mm Hg).

The indicated primer bulb from spare parts can be used:

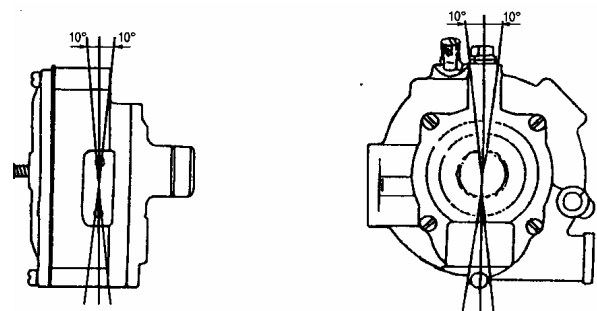
1. 17661-921-000 bulb primer
2. 17665-ZV5-000 valve comp, in
3. 17680-ZV4-000 valve comp, out
4. 17703-921-000 tube clip 20 mm
5. 17704-ZV4-000 tube clip 12.5 mm



- In order to meet the emission regulations, use IMPCO's regulator model 50(B).
In addition, if UL (fuel lock) is necessary, use model 50. In this case, make sure that the cranking revolution is more than 600 min⁻¹ for starting.

- The length of the fuel hose between the engine and the regulator must be as follows for the engine matching.

GXV340/390	457 – 914 mm
GX610/620, GXV610/620	610 – 1067 mm
GX160/200/240/ 270/340/390	610 – 1067 mm



Install the regulator **upright** as shown

- Fuel mixture adjustment.

Adjust the mixture on the regulator so that exhaust emissions CO value is:

- At idle speed +/- 5%
- At full load +/- 2%

POWER

Power (P) is the amount of work done in a certain period of time.

Is expressed in Watts : $1W = 1 \text{ N (ewton) } \times \text{ m (eter) } / \text{ s (ec)}$
 $1kW = 1000 \text{ W}$

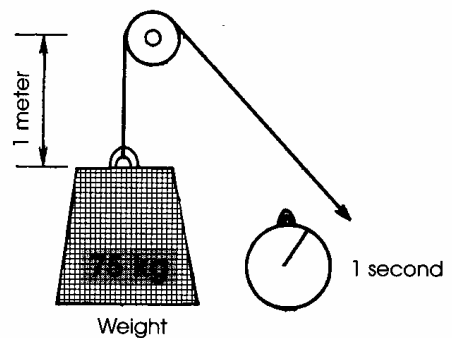
The old unit is HP (Horse Power)

1 horsepower (HP) is the power required to raise a 75 kg weight to a height of 1 meter in 1 second.

1 HP = 75 kg-m/sec

1HP = 745.7 W

1kW = 1.341 HP

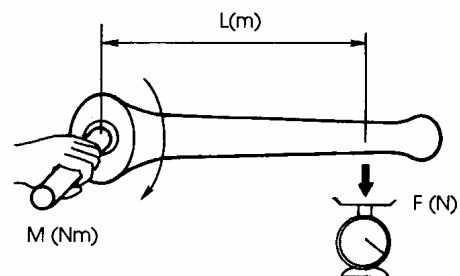


TORQUE

Torque (M) is the turning force exerted on one object by another.

Torque (M) = Force (N) x Length (m).

The old unit is kgm.



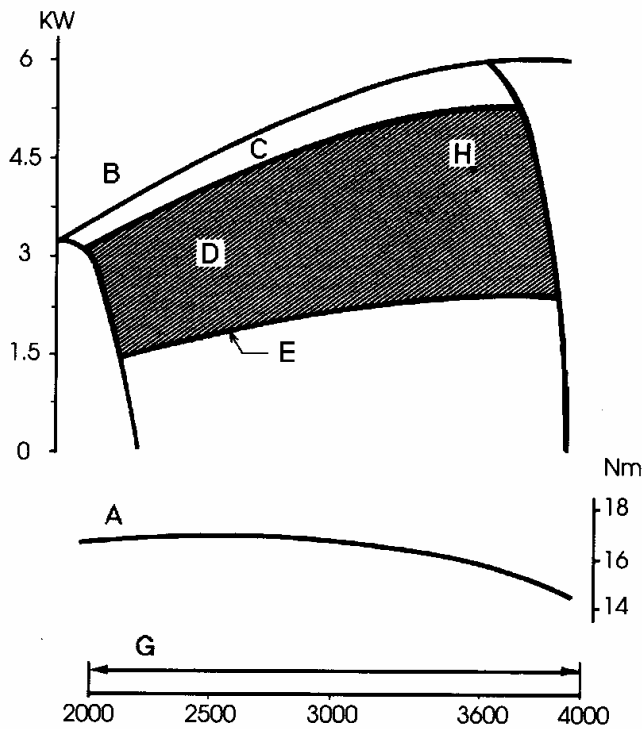
Engine efficiency, fuel consumption is optimized in the rpm range of an engine's maximum torque output.

RELATIONSHIP POWER & TORQUE

Power and torque are related in the following way:

$$P = \frac{M \cdot n}{9550} \quad \text{and} \quad M = \frac{P \cdot 9550}{n}$$

PERFORMANCE CURVES



- A: Maximum torque curve
- B: Maximum B.H.P. curve
- C: Recommended operating max. B.H.P.
- D: Recommended output range
- E: Recommended minimum output curve
- G: Recommended operating speed range
- H: Continuous rated output

Power curves are of standard test engines.

Power output will decrease 3.5 % for each 300m elevation increase above sea level and decrease 1 % for each 5.6°C increase above the standard temperature of 15.6°C.

As shipped, production engines will develop not less than 90 % of the "Maximum B.H.P."
After running-in, they will develop not less than 95 % of the "Maximum B.H.P."

For practical operation, the B.H.P. load and engine speed should be within the limits defined by the "Recommended maximum operating B.H.P." curve (below 90 % of the "Maximum B.H.P.")

For optimum engine service life in generator, pump and other continuous constant-load applications, operation should be within 85 % of the "Maximum B.H.P."

* 80 % for GX(V) 610/620/670, for GC(V) 135/160 and for GCV/GXV 520/530.

Continuous operation with light load at low rpm is not economical. Such operation conditions can lead to incomplete combustion of the fuel mixture, resulting in excessive exhaust smoke and carbon build-up. Fuel consumption will increase under such operating conditions.

Running at low rpm limits the engine power and cooling performance of the fan and can cause engine overheating and shortened engine service life.

With fluctuating loads (tillers, compressors, etc.) the engine should be run within the recommended maximum operating B.H.P.

The engine speed setting must be chosen so that even if maximum load is suddenly applied, the engine speed may not drop below the point where maximum torque is developed; this speed setting assures good performance and fuel economy.

PERFORMANCE TESTS

- SAE in USA
Performance tests are conducted according to SAE standard measured at carburetor entrance.

Nr. J607a : Temperature : 16 °C
Pressure : 760 mmHg
Humidity : 0 %

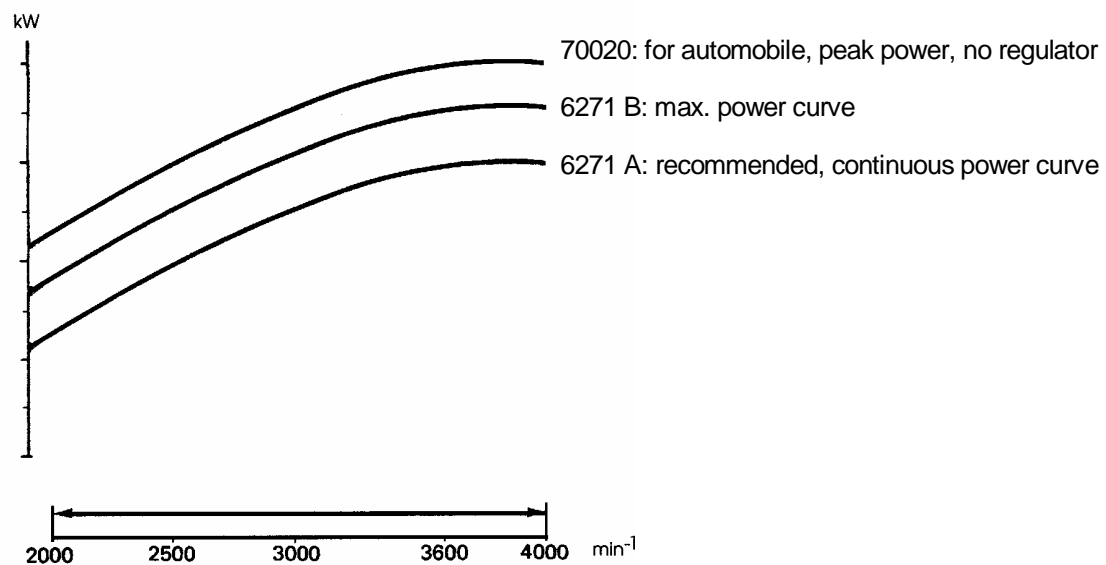
Note

The SAE standard SAE J607a has been replaced by SAE J1349 and later by SAE J1995

SAE J607a and SAE J1349 treat NET power, where as SAE J1995 mentions GROSS power.

- JIS in Japan
Standards are: Temperature : 20 °C (ambient air temp)
 Pressure : 760 mmHg
 Humidity : 0 %
- DIN in Germany
Standards are : Temperature : 20 °C (ambient air temp)
 Pressure : 760 mmHg
 Humidity : 80 %

3 standards are used for gasoline engines.



Other correction factors between the different standards are the use of : standard air filter, muffler charge coil, etc.

Generally we can say that :

- SAE standard gives 3 – 5 % more power output than JIS standard
- SAE standard gives 5 – 10 % more power than DIN standard

GOVERNOR SYSTEM

The governor system automatically maintains a constant engine speed regardless of changes in engine loading.

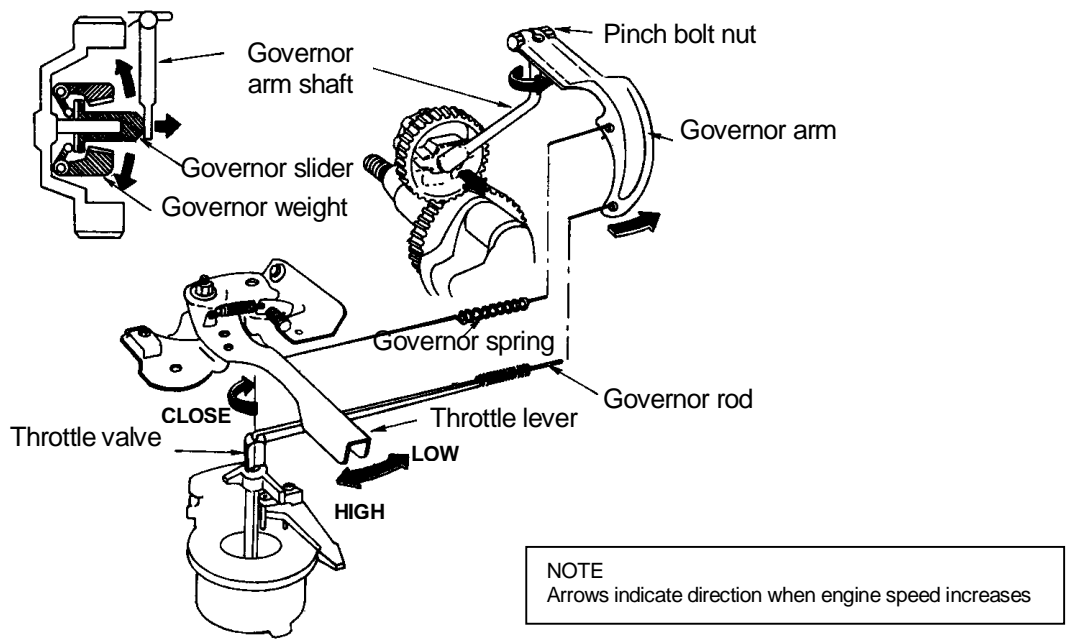
Three types of governor systems are commonly used: centrifugal, air-vane or electric governor. Honda general purpose engines use a centrifugal governor system.

At a certain engine speed setting (by the control lever) there is a balance between the governor spring force and the centrifugal force of the governor weights exerted on the governor arm.

When engine speed increases due to reduced loading, the governor weight is moved by centrifugal force towards the outer end of the radius.

This in turn closes the throttle valve via the link rod and engine speed is reduced.

When engine speed decreases, the action of the governor is opposite to the above and engine rpm is increased. The two sequences occur repeatedly to maintain constant speed regardless of changes in engine loading.



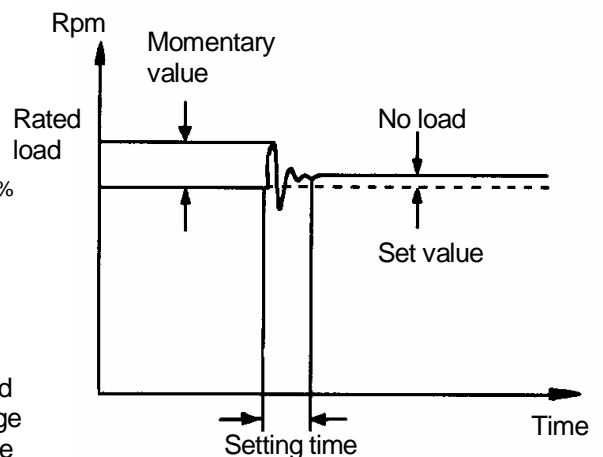
COEFFICIENT OF GOVERNOR FLUCTUATION

This chart shows engine speed changes when the load (rated load) is suddenly removed during operation.

The following 3 items are to be considered when checking governor function.

- a. $\text{Momentary value} = \frac{\text{Momentary max. speed} - \text{Speed with rated load}}{\text{Speed with rated load}} \times 100\%$
- b. $\text{Set value} = \frac{\text{Speed with no load} - \text{Speed with rated load}}{\text{Speed with rated load}} \times 100\%$
- c. Setting time = t (sec)

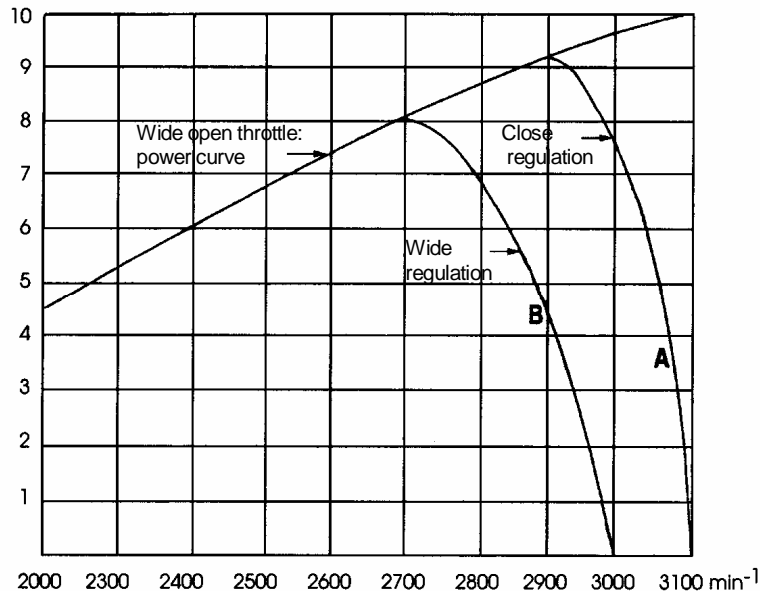
A good governor characteristic will show small values for a, b and c. An engine equipped with such a governor will show little change in rpm and will return immediately to the set value when a change in load occurs.



GOVERNOR PERFORMANCE

The governor is usually associated with controlling the engine speed, but it also effects the available power output of the engine.

For this reason, the effect of the governor control must also be considered in the application of the engine.

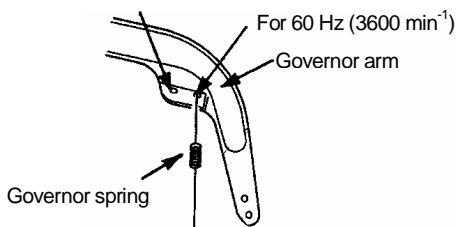


Curve A shows a typical governor performance curve. Engine speed at no-load starts at 3100 min⁻¹. When the load is applied, engine speed drops and reaches 2900 min⁻¹ where full power is delivered. This is a typical close regulation curve with an engine speed drop of 200 min⁻¹; a generator set may require a closer regulation.

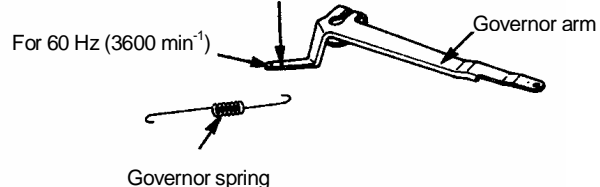
As you obtain closer regulation and a more sensitive governor, it tends to become unstable. Much of the powered equipment that has rapidly changing load, and is subject to bouncing around, can not tolerate very close governing, as the speed surges (hunts) too much. For this case, more stable governing (wider regulation) is generally preferred.

Curve B shows a wide regulation governor curve. Engine speed at no-load starts at 3000 min⁻¹ and drops at 2700 min⁻¹ when load is applied. The wide regulation curve shows less power available, about 11% less power compared to the close regulation.

For 50 Hz (3000 min⁻¹)



For 50 Hz (3000 min⁻¹)



A weaker spring or a hook position closer to the governor shaft makes the governor operation more “close regulated”.

A stronger spring or a spring hook position further from the governor arm makes the governor operation more “wide regulated”.

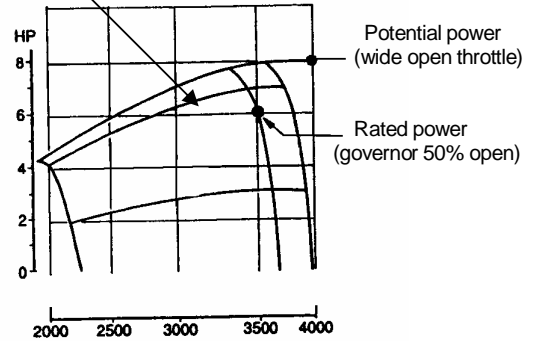
MAXIMUM ENGINE POWER – GOVERNORED ENGINE POWER

The governor system is designed in a way that even at the engine's maximum "governed" power delivery, there is enough residual power to stabilize power fluctuations and keep engine speed stable.

The ratio between the engine wide open throttle (WOT) maximum power and the governed maximum power is generally 85% (80% for GC(V)135/160 and GX(V) 610/620/670).

If the governor system is well adjusted and matching the application, the engine must be able to produce 85% (or 80%) of the maximum power at a stable engine speed.

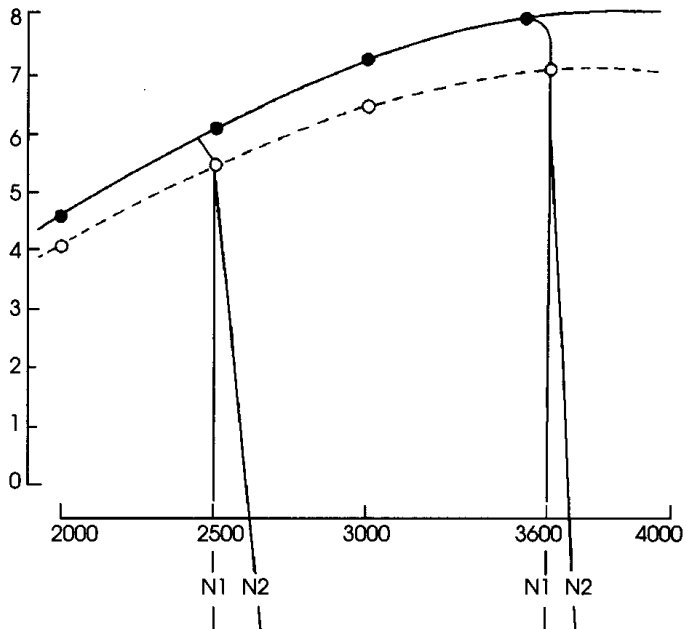
Governored maximum power curve



POWER OUTPUT CONFIRMATION METHOD BY ENGINE SPEED DROP

Changes in the working load of an engine cause changes in engine speed (speed drop). An indication on required power output when the engine is loaded is given by the engine speed drop calculation. Honda's standard for speed drop is 5% for high speed applications and up to 8% for low speed applications. Exceeding this 5% or 8% speed drop will extend into the maximum up to the wide open throttle power range.

- (N1) Measured engine rotation speed under actual operating conditions (stable condition - loaded).
- (N2) Measured engine rotation speed under the same condition with load removed (stable condition – unloaded)

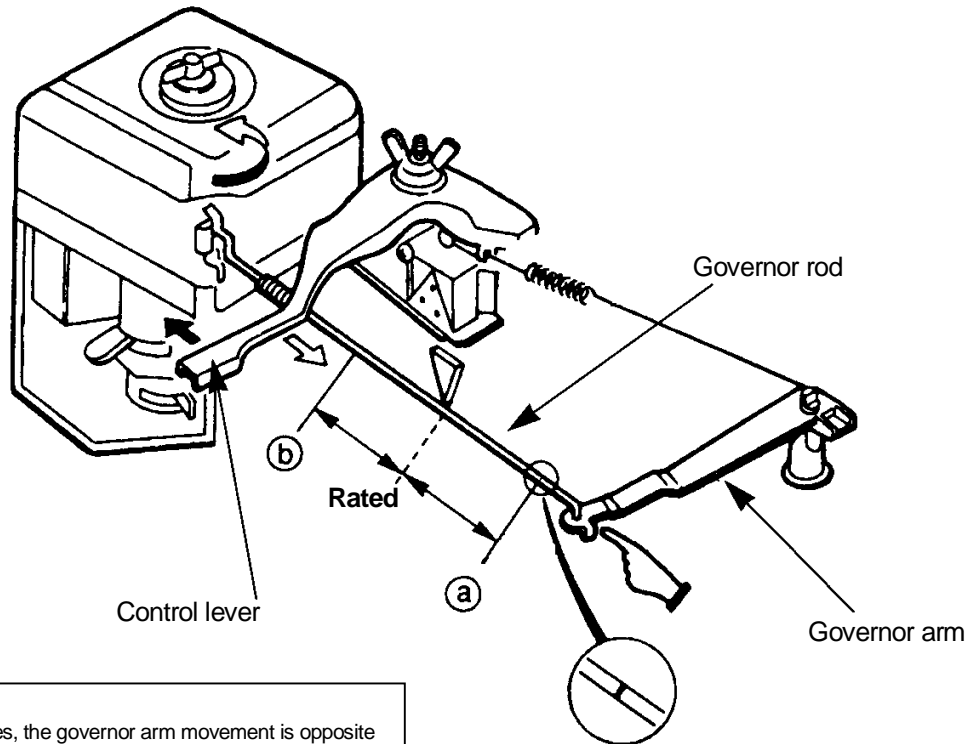


Speed drop calculation:

$$\frac{N2 - N1}{N1} \times 100 \% = \text{is within } 5 \% \text{ (or } 8\%)$$

OUTPUT CONFIRMATION METHOD

True power output of an engine should be measured on a power bench; a simplified power measurement method on the application is introduced here.



NOTE
For some engine types, the governor arm movement is opposite

Procedure

Initially, adjust the engine speed to the maximum required speed without load and block the throttle lever in this position.

Set the throttle valve in the fully closed position; governor arm moved completely to the right. In this position, place a mark (line) on the governor rod and a mark (line) directly below on the fan cover. Designate this position as (a).

Set the throttle valve in the fully open position; governor arm moved completely to the left. Place a mark on the fan cover directly below the mark on the governor rod. Designate this position as (b).

Finally make a dotted line on the fan cover at the mid-point between (a) and (b).

This position will be the intermediate point (balance between the load and the governor) between the full open and full close position of the throttle valve (recommended output range).

Output confirmation by the governor rod movement.

Operate the equipment and apply load after sufficient warm-up. If the mark (line) on the governor rod is moving within the range of the center point (ζ) located between the full open position (b) and the full close position (a), the engine is operating at approximately the recommended rated output. However, if the speed occasionally drops near the full open position, it is an indication of overloading.

DIESEL ENGINE POWER OUTPUT

Determine power output by checking exhaust gas temperature and/or specific fuel consumption at the specified engine speed.

Power output can be approximately determined by comparing the measured data with the data given for the specific model, type and operating speed range.

Always ensure that power output is within the specified limits.

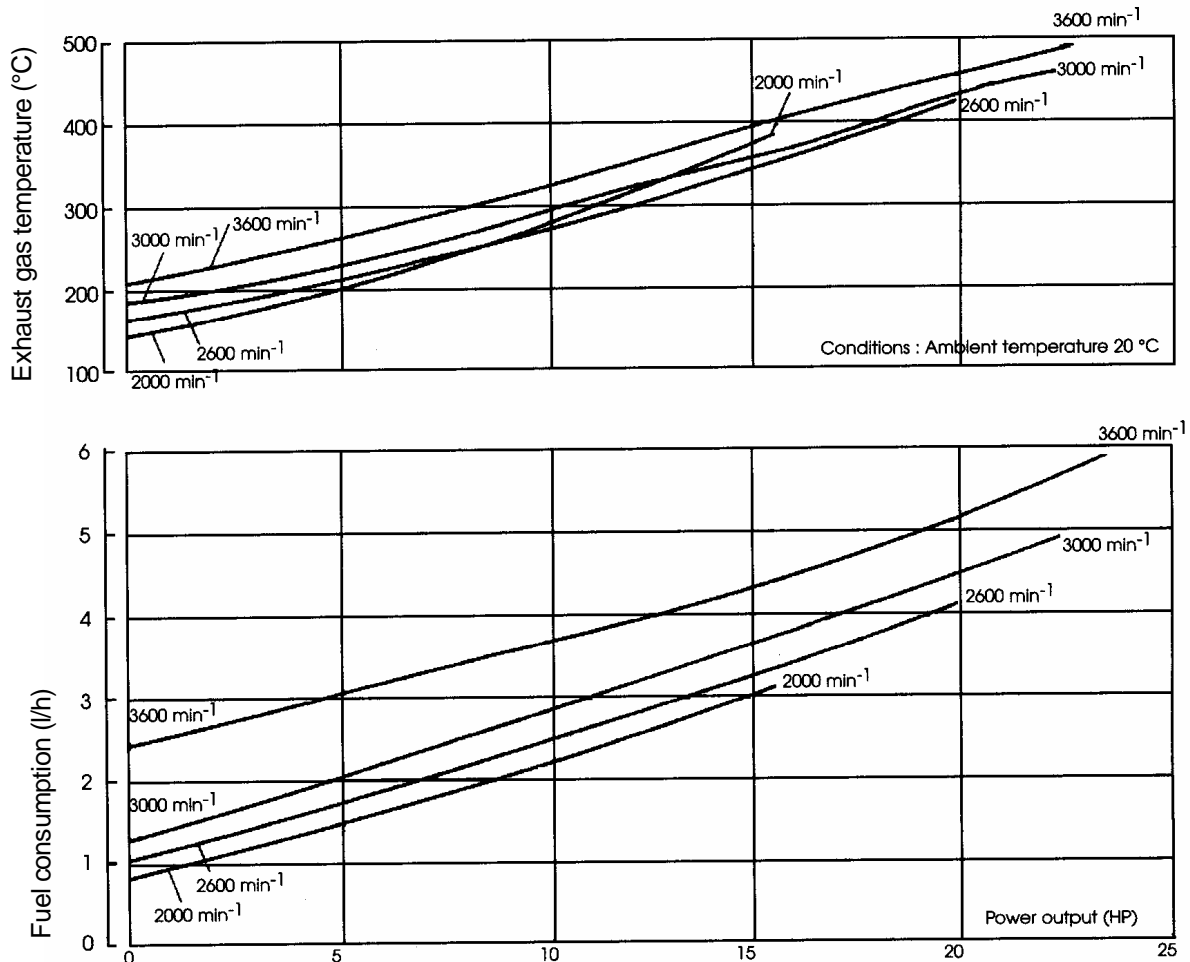
1. Exhaust gas temperature

Always ensure exhaust gas temperature is below the maximum recommended operating temperature. For more details on the measuring method, see the section "temperature".

2. Measurement of specific fuel consumption (l/h)

- Fill the fuel tank with a specified amount of fuel. Run the engine at the rated load for 1 hour and measure the fuel leftover in the fuel tank.
- Specific fuel consumption varies with engine load, ambient temperature, altitude and other changes in operating conditions. Likewise, fluctuations in engine loading during actual operation will result in slightly different consumption figures.
- If the specific fuel consumption figure obtained in each application closely approximates that shown in the specifications, it can be assumed the engine is running at maximum continuous rated power output.
- For the data and graph, consult the engine technical data tables.

Example of exhaust gas temperature / specific fuel consumption graph.



TYPES OF THREADS

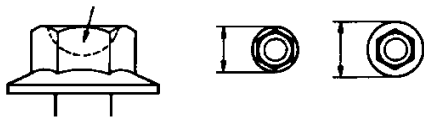
Metric threads, as specified by the International Standards Organization (ISO), are used on Honda products.

Few parts do not have conventional (ISO) metric threads, for example:

- spark plugs
- oil pressure switch
- thermosensor
- etc...

Diameter (mm)	Pitch (mm)
3	0.5
4	0.7
5	0.8
6	1.0
8	1.25
10	1.25
12	1.25
14	1.5
16	1.5
18	1.5
20	1.5

DR – TYPE BOLTS



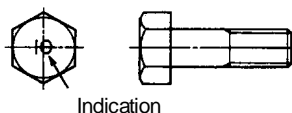
DR – type (dish-headed) bolts, without strength markings are classified by outer flange diameters. Be careful about the installation points and the torque of high-tension bolts, having the same hexagon dimensions as standard bolts but having larger flanges.

THREAD DIAMETER AND PITCH

Hexagon portion	Width across flats	Thread diam. x pitch
	8	5 x 0.8
	8	6 x 1.0
	10	6 x 1.0
	12	8 x 1.25
	14	10 x 1.25
	17	12 x 1.25
	19	14 x 1.5
	5	6 x 1.0
	6	8 x 1.25
	8	10 x 1.25
	10	12 x 1.25

STRENGTH INDICATION

Mark	No mark		10 or	12 or
Strength class	5.8	8.8	10.9	12.9
Tension strength	50 - 70 kg/mm ²	80 - 100 kg/mm ²	100 - 120 kg/mm ²	120 - 140 kg/mm ²
Class	Standard bolt	Standard bolt	High tension	High tension



INDICATION ON BOLT HEAD



UNC (CORSE THREAD)

Ex: 1/4 – 20 UNC
Nominal thread diameter 1/4 inch; 20 threads/inch

UNF (FINE THREAD)

Ex: 3/8 – 24 UNC
Nominal thread diameter 3/8 inch; 24 threads/inch

STANDARD Honda TORQUE VALUES (for reference)

Size	M5	M6	M8	M10	M12
Torque (Nm)	6 - 9	8 - 12	20 - 28	40 - 50	70 - 85

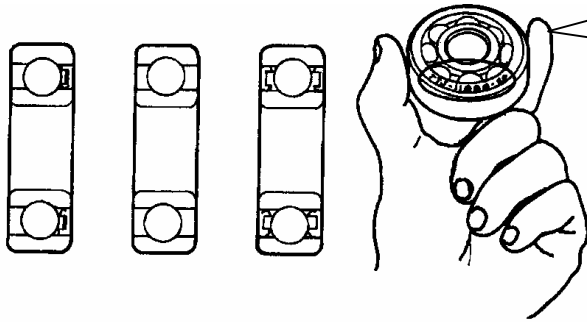
Note
As torque values vary according to bolt material, type and application; care must be taken

ROLLING ELEMENT BEARINGS

Rolling element bearings are classified by design features and usage.

- | | | |
|--|--|---|
| <p>1. Direction of the predominant load</p> <ul style="list-style-type: none"> - radial bearings - thrust bearings | <p>2. The rolling element</p> <ul style="list-style-type: none"> - ball - roller | <p>3. Design feature</p> <ul style="list-style-type: none"> - angular movement - angular misalignment |
|--|--|---|

BEARING CLEARANCE



A "U" or "Z" indicates a bearing with a metal shield or rubber seal respectively. These letters have no connection with bearing size.

- U : single metal sealed type
- Z : single rubber sealed type
- UU : double metal sealed type
- ZZ : double rubber sealed type

Radial clearance is marked on a face of the bearing, preceded with the letter C.

Rolling bearing advantages :

- Low coefficient of friction
- Low maintenance
- Low lubricant consumption
- Small bearing width
- High precision

Rolling bearing disadvantages :

- Sensitive to impact loads
- Sensitive to dirt
- Bearing noise is high
- A 1-piece bearing limits The design of the bearing holder

- C1: radial clearance smaller than C2
- C1: radial clearance smaller than normal
- . . : radial clearance normal
- C3 : radial clearance greater than normal
- C4 : radial clearance greater than C3
- C5 : radial clearance greater than C4

PLAIN BEARINGS

The plain bearing, sometimes called journal bearing, exists in three versions:

- A sleeve bearing
- A flange bearing (combination of sleeve and thrust)
- A thrust bearing

Plain bearings are made from a variety of materials or combination of materials, each having their own specific properties: resistance to seizure, corrosion resistance or strength.

The first category of plain bearings is class I.

Class I bearings have outside sourced lubrication systems.
 Class II bearings contain within their own surface the necessary lubricant.
 Class III bearings include all PTFE bearings and plastic bearing that have PTFE additives (Teflon).

The motion between the plain bearings and another part may take place:

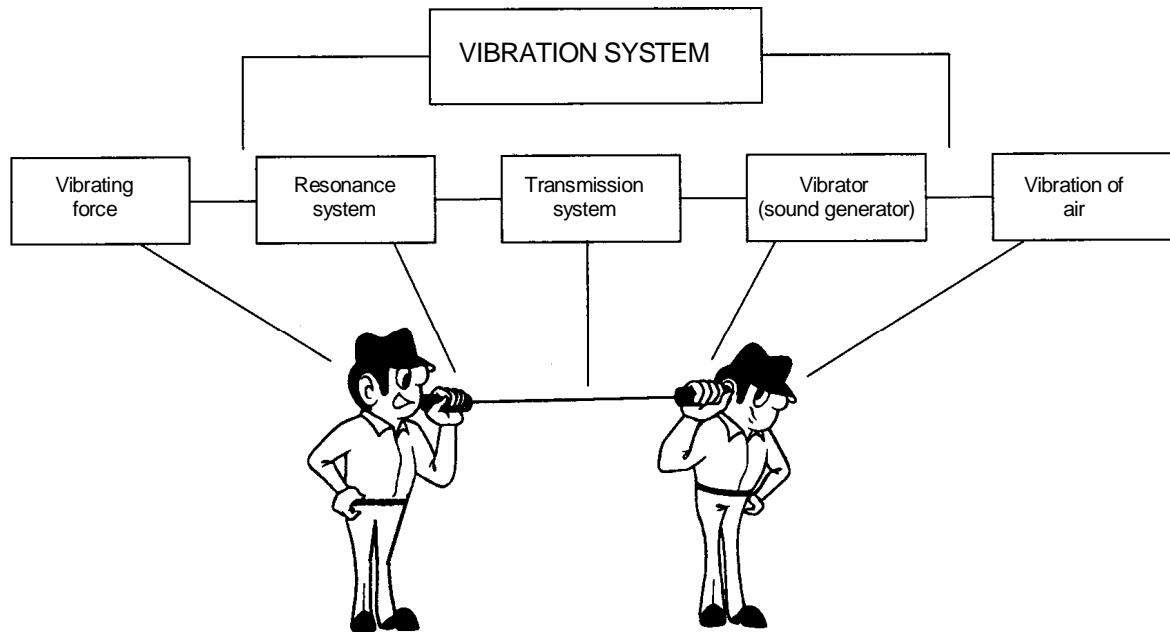
- as pure sliding without benefit of a lubricating medium
- with hydrodynamic lubrication where a lubricant film partially or completely separates the bearing surfaces
- with hydrostatic lubrication where lubricant is fed under pressure and separates the surfaces
- as a combination of hydrostatic and hydrodynamic

Some advantages and disadvantages of plain bearings (sliding) compared with rolling bearings (antifriction).

- Advantages:
- require less space
 - quiet in operation
 - less cost
 - greater rigidity
 - life not limited by fatigue

- Disadvantages:
- higher friction: more power consumption
 - more sensitive to damage from foreign material in lubrication system
 - requires good lubrication
 - more susceptible to damage from interrupted lubrication supply

5 Vibrations and sounds are transmitted in basically the same way.

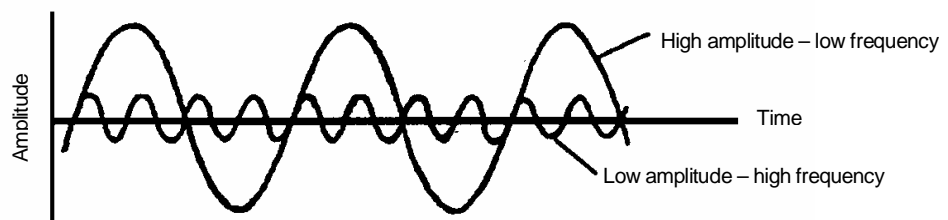
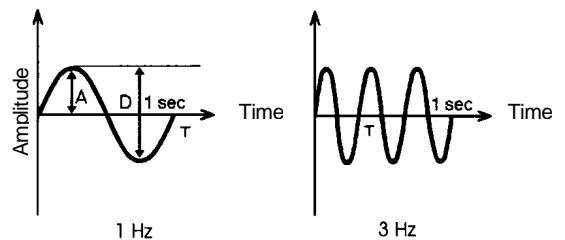


The vibration system is a general term for all components that should be considered when troubleshooting and preventing vibrations and sounds.

CHARACTERISTIC OF VIBRATIONS

- Amplitude D, A (micrometer)
Is the side of the wave: - total amplitude D
- half amplitude A
- Frequency F (Hertz : Hz)
The frequency is the number of waves that occur per second.
The time in which a wave (negative + positive) is formed is called a period T.

A period $T = \frac{1}{F}$



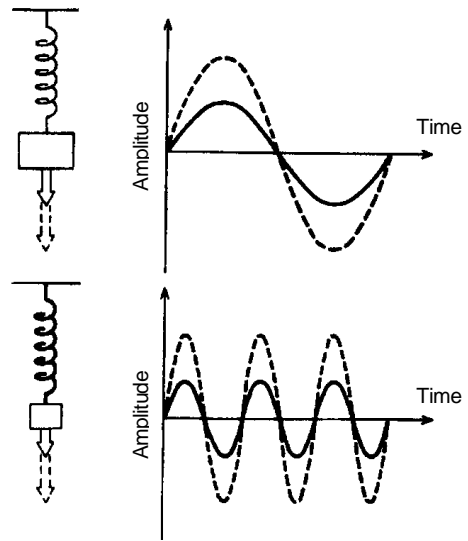
NATURAL FREQUENCY

The frequency of a vibration system (spring + weight) is determined by the strength of the spring and the weight. This frequency is unique to that particular vibration system and is called a natural frequency.

The stronger the spring, the higher the natural frequency.

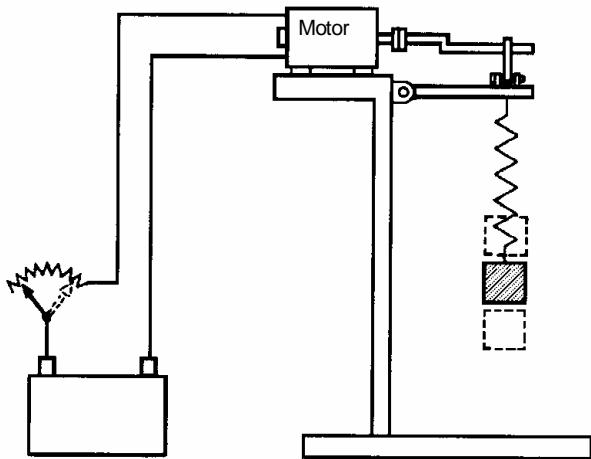
The lighter the weight, the higher the natural frequency.

The amplitude varies by the external force exerted on the weight: the natural frequency does not.



RESONANCE

Resonance is a condition in which the frequency of the vibrating force coincides with the natural frequency of the vibration system.



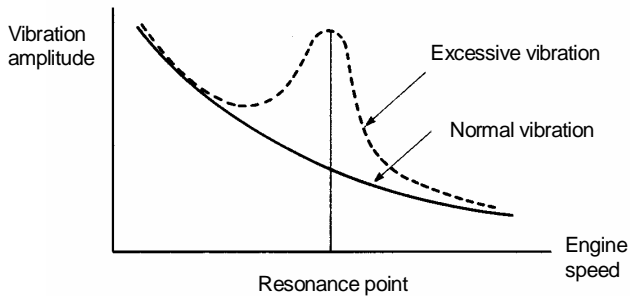
The amplitude of the weight movement is relatively small when the frequency of the vibrating force is low.

The amplitude increases as the frequency is increased.

When increasing the frequency, the amplitude reaches the maximum at the specified frequency; the natural frequency of the vibration system. This is the state of resonance and the frequency at that state is called the resonant point.

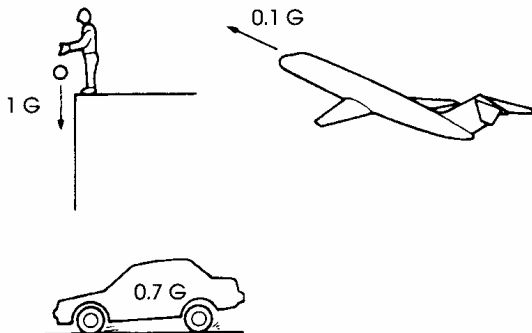
If the frequency is increased further beyond the resonant point, the amplitude starts to decrease gradually.

On engine powered applications, it is indispensable to identify the resonant frequency and to separate it far from the working speed and idling speed range of the equipment.



VIBRATION ACCELERATION

Acceleration means an amount of change in velocity within a specific period of time (cm/s², m/s²).



“G” is a unit of vibration acceleration based on gravitational acceleration.

$$980 \text{ cm/s}^2 = 9.8 \text{ m/s}^2 = 1\text{G}$$

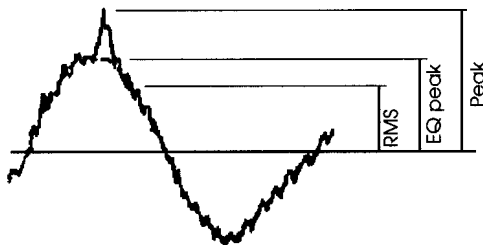
INDICATION CHARACTERISTICS OF VIBRATION METERS

A vibration is expressed by the amplitude, vibration speed and vibration acceleration.

Vibrations in machines are most often discussed in terms of their vibration acceleration, which is indicated by units G and dB.

PEAK

The peak is used for measuring impulsive vibrations and directly follows the peak value of the waveform. Therefore a peak represents the value at the top (half amplitude) of the wave.



EQ PEAK (EQUIVALENT PEAK)

The equivalent peak is the peak value obtained when the actual waveform is corrected as a sinusoidal vibration. It is used commonly when discussing vibrations in automobiles and engines.

RMS (ROOT MEANS SQUARE)

The RMS is the Root Means Square, and is equal to $1 / \sqrt{2}$ of the equivalent peak.

LOW PASS FILTER

The important features of vibration are the level (measured in terms of velocity or acceleration) and the frequency at which the vibration occurs; the closer vibration occurs to the natural or resonant frequency, the greater the effect will be.

The natural frequency of engines running at maximum speeds of 10 000 rpm is below the 200 Hz level; therefore high frequency vibration measurement is not used for vibration analysis.

For vibration measurement on engine driven applications, a 500 Hz low pass filter should be used to filter out the influence of high frequency vibration.

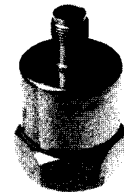
FREQUENCY PICK-UP

Many different kinds of pick-ups are available, although only two types: the electrokinetic (velocity type) pick-up and the piezoelectric (acceleration type) pick-up are most commonly used because of their outstanding ease of use and stability.

The piezoelectric pick-up is most commonly used for measuring vibration acceleration of automobiles and engines.

Important notes to remember:

- Align the direction of vibration of the pick-up with that of the vibrator.
- Select a pick-up which is as light as possible compared to the weight of the item being measured. If the pick-up is too heavy, its weight itself will act as a mass damper.



VIBRATION MEASURING METHOD

Install the piezo-electric acceleration pick-up on the engine mount base at the center position of the engine mount bolts.

* mount base can be crankcase cover or flange in case of engine direct mount to application (tamper, brushcutter).

Remove any dirt and oil from the measuring surface of the engine and bond the pick-up with instant adhesive.

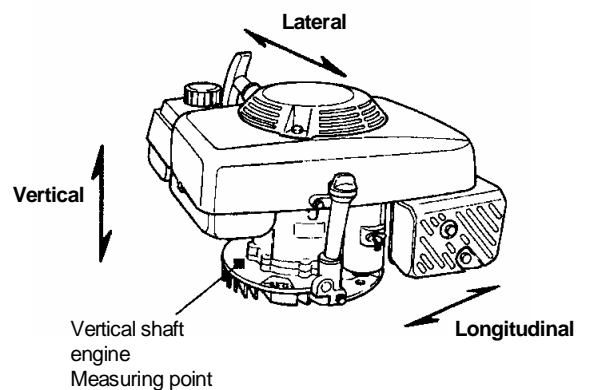
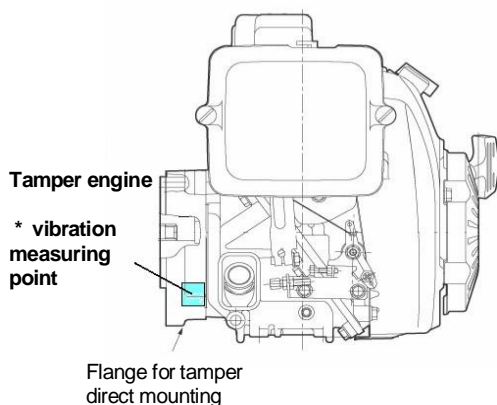
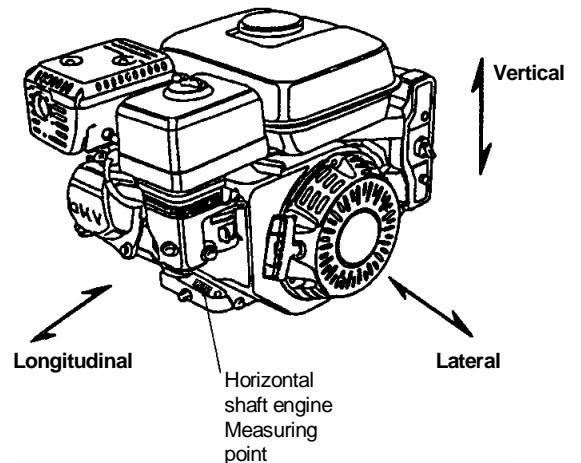
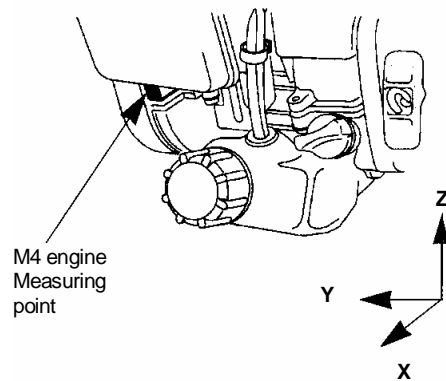
Use a handheld, digital display vibration meter and measure the RMS or EQ Peak values along the three axis: vertical, longitudinal and lateral at the entire engine rpm operating range.

Vibration is measured with the low pass filter (500Hz) switched ON.

Note

Be sure that old layers of adhesive are removed from the pick-up; these layers can form an insulant for vibrations.

Removal of the pick-up can be easily done by inserting a small screwdriver under the pick-up.

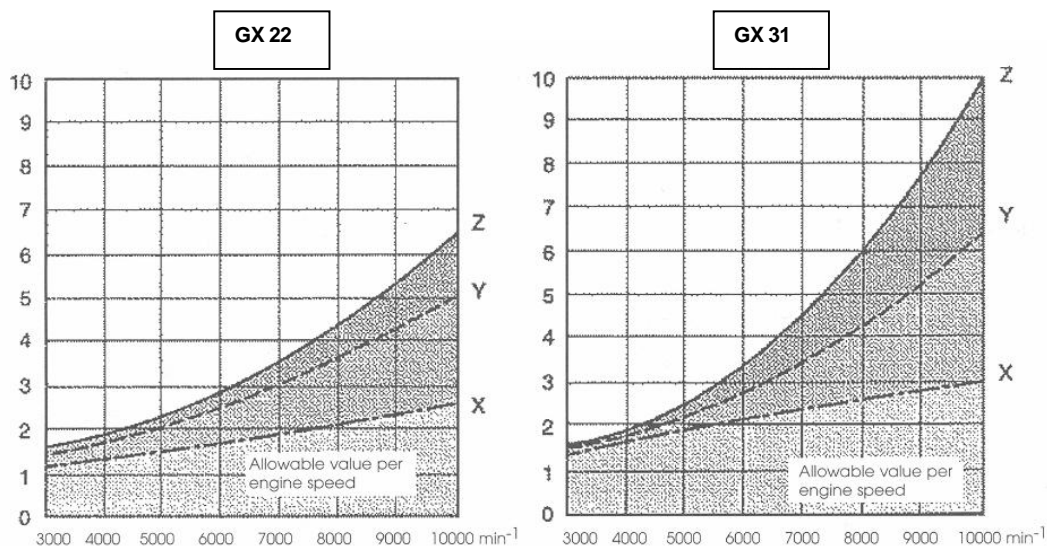


Allowable G value for GX(V) / GC(V) engines

Engine	direction	Allowable G value: EQ Peak	Allowable G value: RMS
GX 120 – 390	vertical	10	7.1
	longitudinal	6	4.3
	lateral	7	4.9
GX 100 standard	vertical	5	3.5
	longitudinal	3.5	2.5
	lateral	5	3.5
GX 100 tamper type		50	35
GXH 50 GXV 50 – 390		5	3.5
GX(V) 610 / 620 / 670		5	3.5
GCV 520/530 GXV 520/530		5	3.5
GC 135/160 GCV 135/160		7	5

Allowable G value for M4 engine: GX22 / GX25 / GX31

Vibration acceleration G (RMS value) in three directions at each engine speed must be below the following values.



GX 22			
RPM	Z - axis	Y - axis	X - axis
5000	2.5	2.0	1.5
8000	4.0	3.5	2.0
10000	6.5	5.0	2.5

GX 31			
RPM	Z - axis	Y - axis	X - axis
5000	2.5	2.5	2.0
8000	6.0	4.0	2.5
10000	10	6.5	3.0

GX 25 / 35			
RPM	Z - axis	Y - axis	X - axis
5000	2.5 / 3.5	2.5 / 2.5	2.0 / 2.0
8000	6.0 / 6.0	4.0 / 6.5	2.5 / 3.5
10000	10 / 13.5	6.5 / 10	4.0 / 7.0

Vibration analysis and visualization

A useful tool for solving vibration problems is a stroboscope.

This instrument connected to the ignition system of the engine causes the motion of elements vibrating at the same frequency of the ignition to become optically frozen.

Therefore this instrument can be of great assistance when placing stiffening members on the equipment.



VIBRATION ISOLATING TECHNIQUES

Rigid mount engine bed

In case the engine is mounted on a solid frame or engine base following point should be considered.

- the dimensions (length and width) of the engine base / frame should be as small as possible to avoid vibration amplification
- the thickness of the engine bed should be kept to a minimum of 6 mm to avoid bending by weight or belt tension.
- If increased engine bed thickness is not possible, reinforcements should be added to increase rigidity.
- Flatness of the engine bed should be kept to a maximum to avoid stress tightening.

Common engine bed with rubber insulator

In case the engine and application are mounted on a common bed or frame supported by rubber insulators, the insulators absorb the vibrations and transmit these to the sub-frame. Incorrectly chosen rubber insulators may generate rocking motions of the engine bed and high resonance vibration.

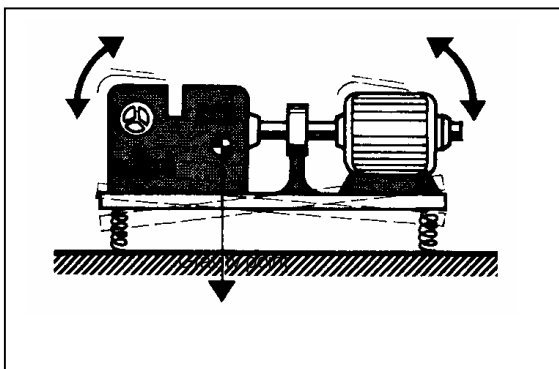
The location and the hardness of the rubber insulators is important; the static deflection of each rubber mount should be equal.

On a machine with non-uniform weight distribution, mountings nearer to the center of gravity must be stiffer than those more remote from it.

The most efficient isolation is obtained if the rubber mountings are fixed so that their individual distance to the engine bed's center of gravity is equal.

A longer span length gives less vibration and moves the resonant frequency to another level.

If an application spends a significant amount of time at resonance, e.g. because of frequent stop, start or acceleration, rubber mountings should be adapted to avoid these resonance points.



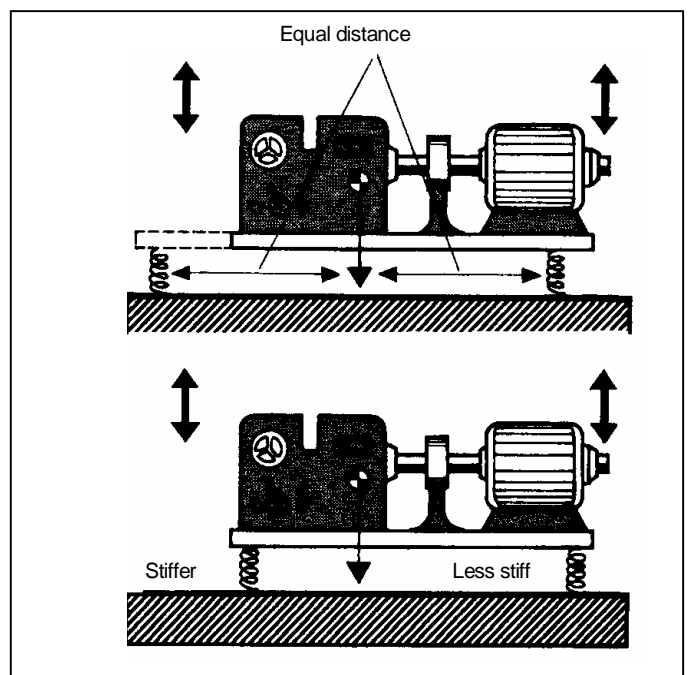
RUBBER HARDNESS –SHORE or IRHD

Rubber hardness is measured by comparing the difference of depth of indentation between the small initial force and the much larger final force applied by a standard size and shape impacting gauge.

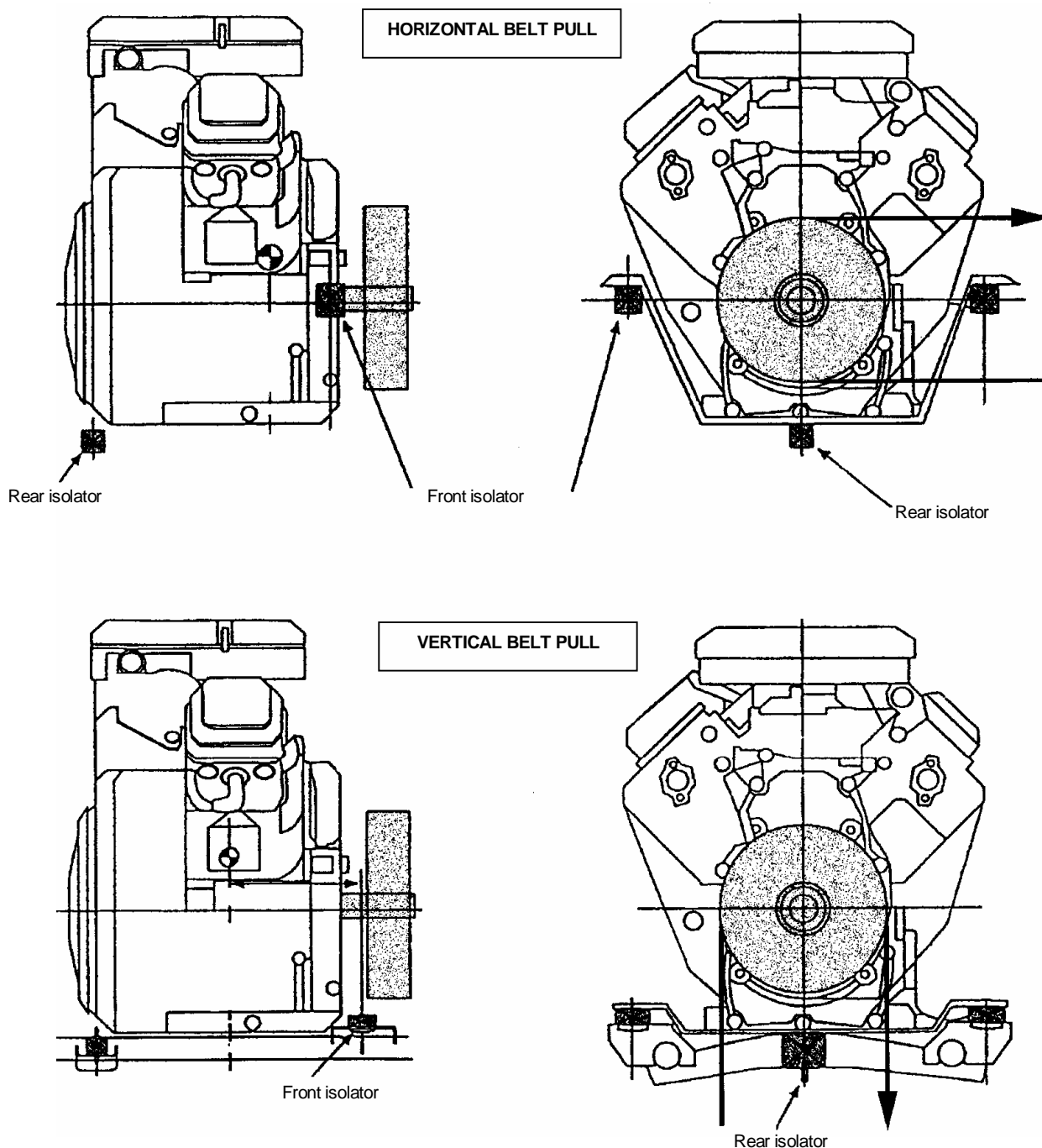
Shore A rubber hardness and ISO's IRHD use a similar hardness scale from 0 to 100 (soft to hard).

Shore D rubber hardness scale, ranging from 0 to 100 uses a needle point impacting gauge and is used for harder rubbers.

For example: standard car tyre hardness shore A - 65 and shore D - 20.



MOUNTING ARRANGEMENTS WHEN THE BELT POWER TAKE-OFF IS ACROSS THE MOUNTING SYSTEM



Install the engine so that there is no resonance when the engine speed is within the working speed range. Raise the engine speed slowly and be sure that the resonance does not increase abnormally at a given engine speed.

General methods for resonance prevention.

- Rigid mount: increase the rigidity of the engine bed and frame to bring the resonance point higher than the working engine speed range.
- Rubber mount: lower the hardness of the rubber in the vibration direction to bring the resonance point lower than the working engine speed range. Increasing the hardness will bring the resonance point higher.
- When an engine accessory or part of the machine is resonating, increase the rigidity of the resonating part to bring the resonance point higher than the working engine speed range.

NOISE

An important point in making the evaluation of the OEM product and meeting with the users satisfaction is the low noise level of the equipment. The extent of noise is influenced by the design of the OEM product and is closely related to vibration and resonance vibration.

Sound is a wave motion, which occurs when a sound source sets the nearest particles of air into motion. The movement gradually spreads to air particles further away from the source. Sound propagates in air with a speed of approximately 340 m/s. In liquids and solids the propagation velocity is greater: 1500 m/s in water and 5000 m/s in steel.

RESONANCE

When the vibration of the air caused by vibration of a vibrator (frequency and sound) coincides with the natural frequency of the space, the air vibration produces a constant wave and the sound as a result becomes larger. This condition is called resonance. The natural frequency of the space is determined by its shape and is called a resonant frequency.

Sound in many cases contains many tones at different frequencies and intensities. The disturbance generated by a sound is not only dependent on its level. The frequency also affects disturbance as higher frequencies annoy more than lower frequencies. At the same sound level, pure tones disturb more than a complex sound composed of many tones.

SOUND PRESSURE LEVEL: L_{pA}

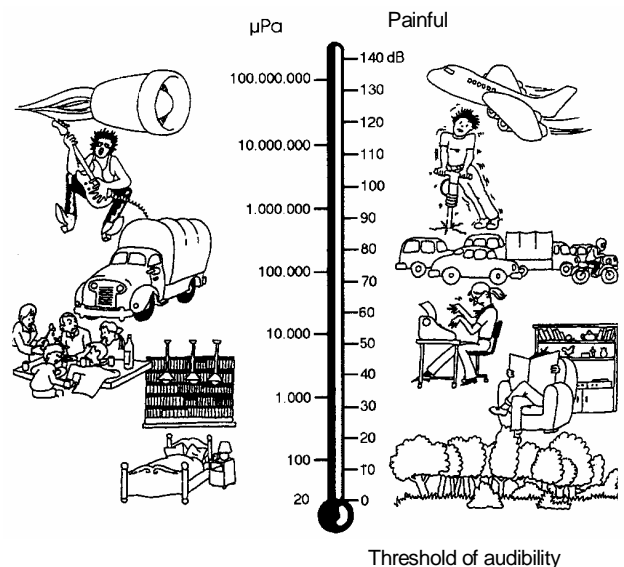
The sound is exercising a pressure. This pressure can be measured but is very small. 1 Pa is equal to 1 N/m² and this is 100,000 times smaller than atmospheric pressure.

Variations in acoustic pressure are therefore very large going from 20 (threshold of audibility) to 100,000,000 uPA (Painful).

This scale is not very practical to use and to overcome this, a relative, logarithmical scale has been introduced: decibels (dB).

This permits to compress sound pressure from 20 to 100,000,000 uPa in a scale of 134 dB.

A sound level change of 1dB can just be detected by the human ear. If a sound level is increased by 10 dB anywhere within the range of hearing, the ear perceives it as a doubling in noise.



METHODS OF MEASURING SOUNDS

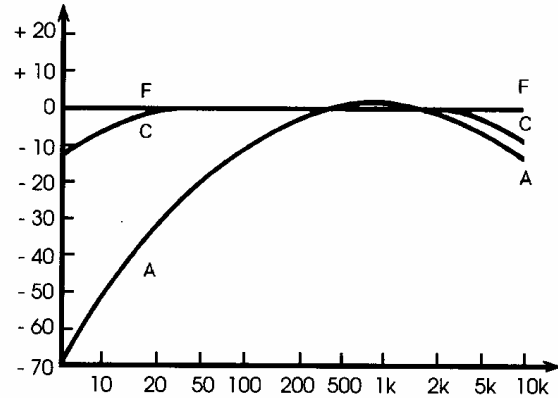
The sensitivity of the human hearing sense varies by the frequency. For this reason, a sound level meter has switches for selecting frequency compensation characteristics patterns (A, B, C, F) so that sensitivity to sounds may be varied freely.

A characteristics

In A characteristics, measured sounds are compensated in such a way that the result is the closest to the human hearing sense.

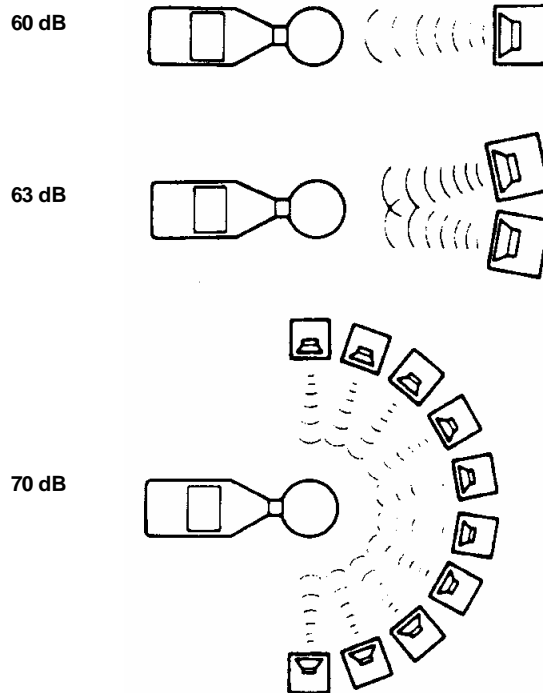
This type of characteristics are used commonly for measuring noises associated with automobiles and machines.

Measured values are indicated by dB (A).



RELATIONSHIP TO THE NUMBER OF SOUND SOURCES

1. When the number of sound sources doubles, the level increases by 3 dB.
When there are two identical sound sources (60 dB each), the resultant level is 63 dB and not 120 dB.
2. When the number of sound sources is increased ten times, the level is 70 dB rather than 60 dB.
By a normal human ear, the combined sound is felt as it is twice as large the original sound.



SOUND POWER LEVEL: L_{WA}

According to EC regulations, sound level of machines for outdoor use is expressed as sound power level L_{WA} in dB(A).

$$L_{WA} = L_{P_{Am}} + 10 \log_{10} \frac{S}{S_0} + K$$

L_{WA} = sound power level of the source tested in dB(A)

$L_{P_{Am}}$ = the surface sound pressure level, expressed in dB(A) : logarithmic average of a minimum of 6 measurements.

$$S = 2 \pi r^2$$

R = the radius of the measuring hemisphere

Where	$r = 4 \text{ m}$	$10 \log_{10} \frac{S}{S_0}$	$= 20 \text{ dB(A)}$
	$r = 7 \text{ m}$	-	$= 25 \text{ dB(A)}$
	$r = 10 \text{ m}$	-	$= 28 \text{ dB(A)}$
	$r = 16 \text{ m}$	-	$= 32 \text{ dB(A)}$

S_0 = standard surface

K = correction term for the test area expressed in dB(A).

CORRECTION FACTORS

- **Extraneous noise**

The correction K in dB which shall be added to the average sound pressure level in dB(A).

Difference (in dB) between the sound pressure level calculated when the sound is operating and the sound pressure level due to extraneous noise alone	Correction K in dB
Less than 6	No valid measurement
6	1
7	1
8	1
9	0.5
10	0.5
more than 10	no correction

- **Others**

Another correction factor K indicates the acoustic properties of the test area.

If the ground surface of the test area is rigid and made of concrete or non-porous asphalt and if there are no reflecting objects on the measuring site, there is no need to determine any environmental constant.

LOCATION AND NUMBER OF MEASURING POINTS

In the hemispherical measuring surface, there shall be in principle 12 measuring points (a minimum of 6 points) with the following coordinates:

$$x = (x/r) r$$

$$y = (y/r) r$$

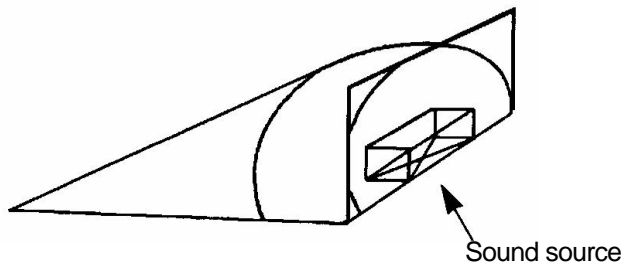
$$z = (z/r) r$$

The values x/r , y/r , z/r and z are given in the table below :

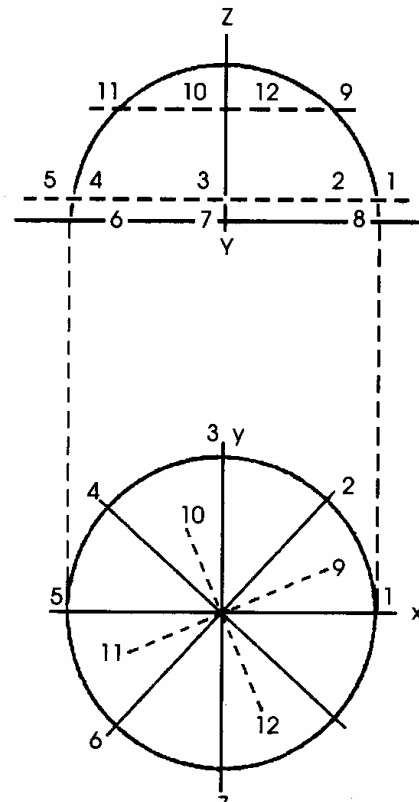
coordinate	x/r	y/r	z/r	z
1	1	0	-	1.5 m
2	0.7	0.7	-	1.5 m
3	0	1	-	1.5 m
4	-0.7	0.7	-	1.5 m
5	-1	0	-	1.5 m
6	-0.7	-0.7	-	1.5 m
7	0	-1	-	1.5 m
8	0.7	-0.7	-	1.5 m
9	0.65	0.27	0.71	-
10	-0.27	0.65	0.71	-
11	-0.65	-0.27	0.71	-
12	0.27	-0.65	0.71	-

The radius depends on the dimensions of the sound source.
For example: generator

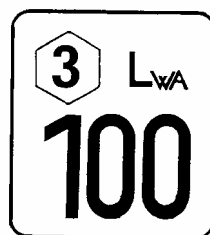
Radius	Dimension of generator
4 m	0 – 1.5 m
10 m	1.5 – 4 m
16 m	> 4 m



Hemispherical measuring surface



Model for sound power level mark according to EC-regulation



NOISE DAMPING PRINCIPLES

Basically, mufflers are divided into two types according to two physical principles: reflection and absorption. However, standard mufflers mostly comprise a combination of reflection and absorption.

Reflection mufflers

Consist of chambers of varying length which are connected together by pipes. The differences in cross-sections of the pipes and the chambers, the diversion of the exhaust gasses and the resonators formed by the connecting pipes with the chambers produce muffling which is particularly effective at low frequencies.

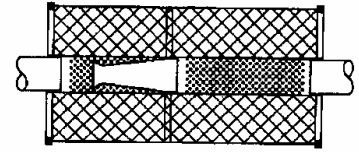
The more chambers used, the more efficient is the muffler. Reflection mufflers cause a higher exhaust gas backpressure, have a greater power loss and are heavier.

Absorption mufflers

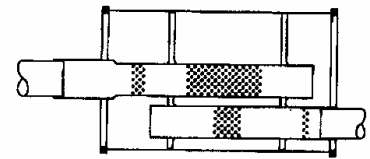
Are constructed as one chamber, through which a perforated pipe is passed. The chamber is filled with sound-deadening material. The sound enters the absorption material through the perforated pipe and is converted into heat by friction. The absorption material usually consists of long-fiber mineral wool (basalt or rock wool) with a bulk density of 120 – 150 g/l. The level of muffling depends on the bulk density, the sound absorption grade of the material and length and coating thickness of the chamber.

Damping takes place across a very broad band, but only begins at higher frequencies. The shape of the perforations and the fact that the pipe passes through the wool ensures that the material is not blown out by the pulsation of the exhaust gas. Sometimes the mineral wool is protected by a layer of stainless-steel wool around the perforated pipe.

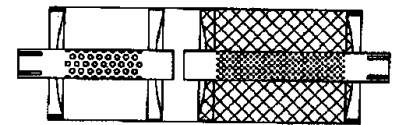
Absorption mufflers are principally used as rear mufflers.



Absorption muffler



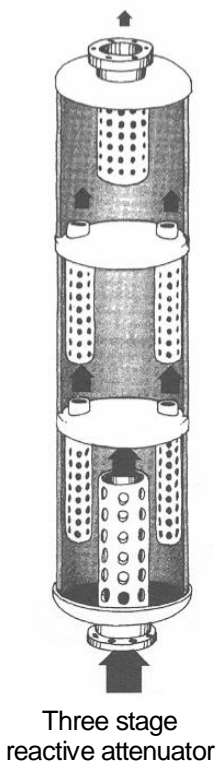
Reflection muffler



Combined muffler

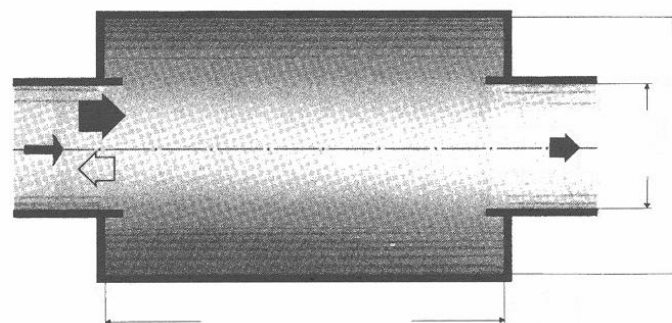
REACTIVE ATTENUATORS ARE EFFICIENT IN A NARROW FREQUENCY RANGE

A reactive attenuator is an effective method for reducing low frequency noise over a limited frequency range, and is relatively compact.



By coupling a number of attenuators of different sizes together, most conveniently within the same external casing, it is possible to cover an extended range of frequencies.

Perforated tubes are often used within the attenuator to improve gas flow and provide some absorption.



These diameters determine the level of attenuation

The chamber's length determines the frequencies attenuated

EXHAUST SYSTEM

Engines are equipped originally with the most appropriately designed exhaust muffler. In some applications however, changes to the exhaust pipes and muffler are necessary to cope with limited build-in space or noise restrictions.

If the standard exhaust system of an engine is modified, exhaust gas flow resistance (backpressure) usually increases and engine performance is reduced.

The choice of the correct exhaust pipe length, diameter and number of bends is important and should always be checked by a backpressure measurement.

Exhaust pipes

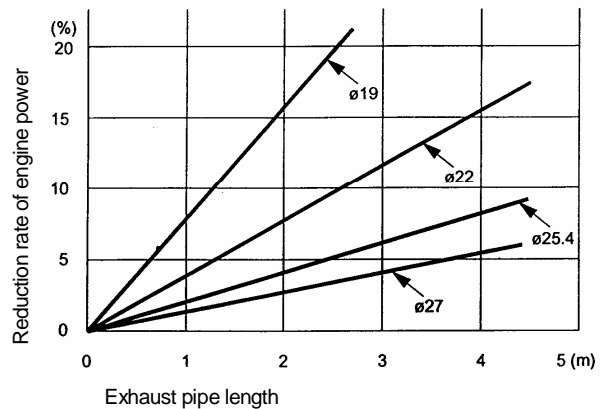
The exhaust pipe inner diameter must be the same size or bigger as the exhaust port diameter.

The exhaust backpressure will increase if the diameter of the exhaust pipe is less than specified.

On a multi-cylinder engine, there can be exhaust interference resulting in engine knocking and power drop if the exhaust pipes of different cylinders are connected together.

Exhaust pipe length should be kept as short as possible to reduce exhaust backpressure.

The figure shows the relation between increasing exhaust pipe length and the reduction rate of engine power. Reference diameter is 25.4 mm.

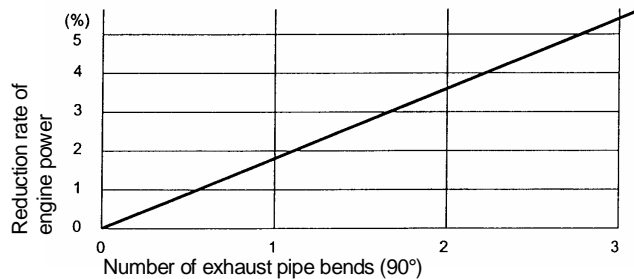


Exhaust pipe flange / gasket

The exhaust pipe flange and gasket should have the correct diameter so that there is no obstruction for the exhaust gas flow and that there is enough effective gasket and flange sealing area.

Exhaust pipe bends

Reduction rate of engine power output in relation to the number of exhaust pipe bends (90°).



Muffler volume

The muffler volume is a compromise between the available mounting space, the weight, the maximum backpressure and the desired noise damping level.

The multiplication factor 5 to 7 is commonly used to calculate the muffler volume starting from the engine displacement.

Deflector / spark arrester

A deflector and spark arrester are available as standard option.

A deflector is used to redirect the exhaust gas flow.

The function of a spark arrester is to stop flames occurring at afterburn in the muffler.

Both parts are also commonly used to lower exhaust noise level.

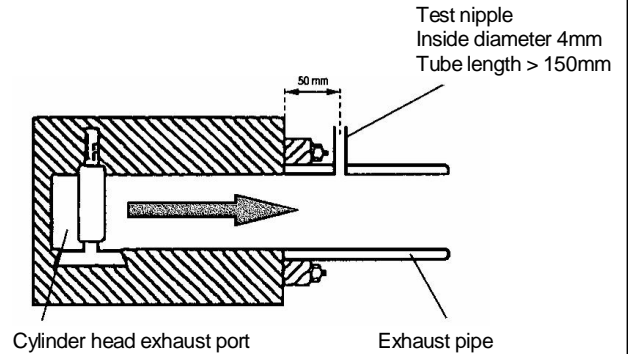


EXHAUST BACKPRESSURE MEASUREMENT

Test condition

- Full load condition
- Oil temperature 80 – 100°C
- Measurement time 20 s.
- Tools: manometer with scale: mmAq or mmHg

!! In case the muffler is equipped with spark arrester, measurement must be done with spark arrester included !!



Observe following instructions for correct measurement:

- backpressure measurement test nipple location must be close to cylinder head exhaust port (see figure).
- on a multi-cylinder engine, backpressure measurement must be done on each individual cylinder exhaust port.
- On a multi-cylinder engine, close the remaining test nipples not used for measurement. An open test nipple may interfere with the backpressure measurement.
- Backpressure is oscillating a lot, use a manometer with integrated filter or dampener and record the average pressure reading.
- Keep the measurement short in order not to damage the pressure element in the electronic manometer.
- If backpressure is oscillating too much and results in difficult recording with electronic manometer, use a tube with watercolumn.

VALVE TIMING – EXHAUST BACKPRESSURE

A high-performance spark ignition engine with great valve overlap takes full advantage of the pulse effects in the intake and exhaust manifold.

The idling and partially open throttle operation suffers since the reduced induction manifold pressure and gas flow causes back-flow of the exhaust.

Furthermore, full load fuel economy is poor since some unburned mixture will pass straight through the cylinder when both valves are open at Top Dead Center.

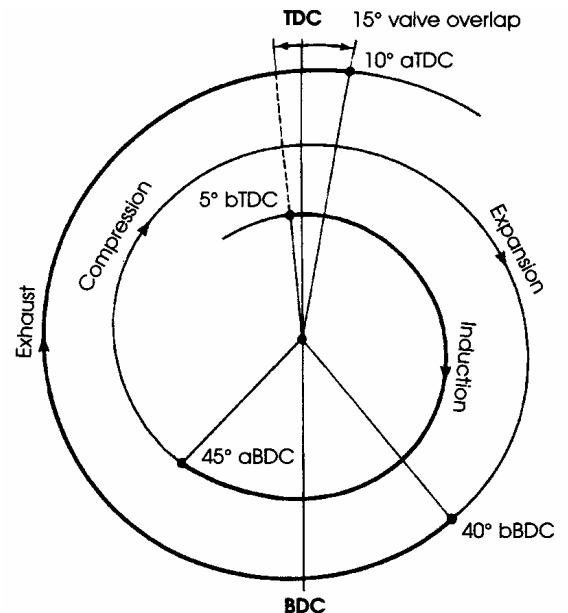
The level of exhaust residuals trapped in the cylinder has a significant effect on the cycle-by-cycle variations in combustion and the emissions of Nox.

As with exhaust gas recirculation, high levels of exhaust residuals lead to lower emissions of Nox and greater cycle-by-cycle variations in combustion.

The level of residuals increases with:

- Decreasing absolute inlet manifold pressure
- Reduced compression ratio
- Increased valve overlap
- Decreasing speed
- Increasing exhaust backpressure

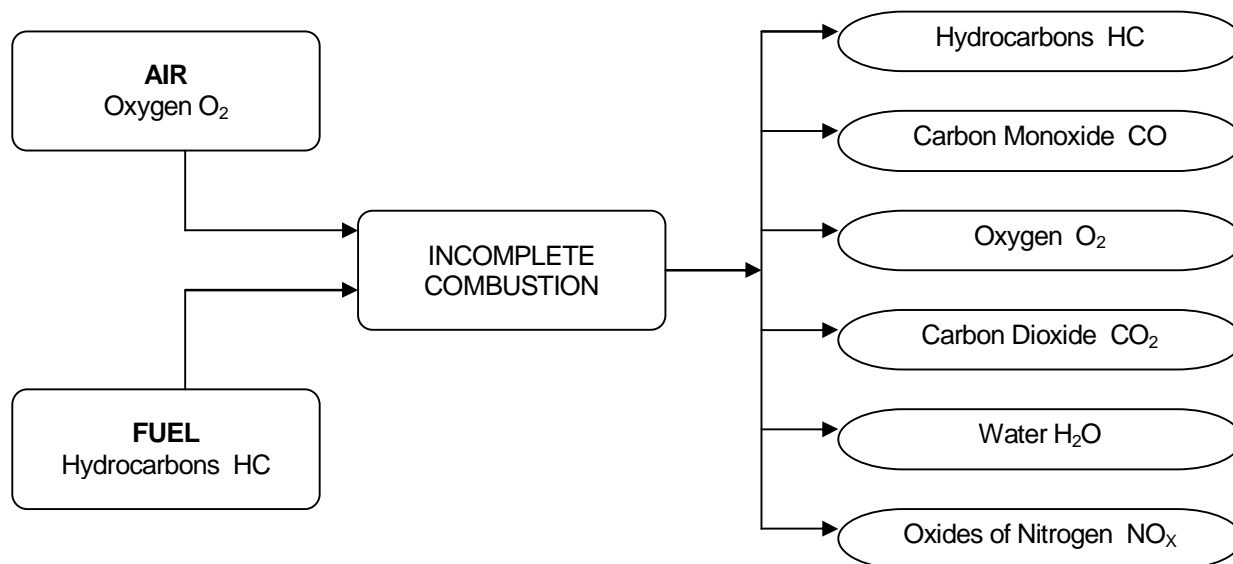
In engines with valve overlap (e.g. GX610/620), correct exhaust back pressure is important for good engine operation.



PRODUCTS OF COMBUSTION

An ideal combustion engine would burn its fuel completely. The combustion by-products (exhaust gas) of this theoretical ideal engine would be carbon dioxide (CO_2) and water vapour (H_2O).

In a real internal combustion engine, when the flame front set off by the spark hits the relatively cool cylinder walls, some of the fuel is quenched and incomplete combustion results. Also, if the carburetor is improperly adjusted, the air-fuel ratios are incorrect for complete combustion.



The basic relationship between the four components of combustion: HC-hydrocarbons, CO-carbonmonoxide, O₂-oxygen and CO₂-carbon dioxide can vary by engine; depending upon age, condition, engine temperature, mal-adjusted carburation and ignition timing.

Hydrocarbons (HC)

are unburnt or partly burnt fuel. High levels of hydrocarbons (measured in parts per million – ppm) in the exhaust gas are often related to problems in the ignition system, fouled plugs, bad ignition wires, improper timing, vacuum leaks or incorrect air/fuel ratios. They all cause improper combustion and high HC readings. Operating an engine with very lean air/fuel mixtures can give a drastic rise in the HC emission caused by delayed combustion and misfires.

Carbon Monoxide (CO)

is formed when there is not enough oxygen present during combustion. High levels of carbon monoxide (measured as a percentage of the exhaust gas - %) can be caused by a too rich fuel mixture, low idle speed, incorrect float level, blocked airfilter or incorrectly adjusted carburetor.

Carbon Dioxide (CO₂)

measured as a percentage of the exhaust gas - %, is an important diagnostic clue to the efficiency of the combustion process. The higher the percentage of CO₂ in the exhaust gas, the more efficient the engine is running. A reading of 13 % to 15 % is considered ideal, with CO and HC in the 3% range and oxygen in the near 0% range.

Oxygen (O₂)

measured as a percentage of the exhaust gas - %, indicates the accuracy of the carburetor setting. If the oxygen content is measured as the pilot screw is adjusted, a jump in the reading of at least 0.5 % shows the crossover point from rich to lean. O₂ measurement is also useful in detecting vacuum leaks and ignition problems causing a misfire. A not correctly inserted sample probe or leaking exhaust system will give high O₂ readings too.

Oxides of Nitrogen (NO_x)

Nitrogen (N) makes up approximately 78% of the air we breathe, oxygen is approximately the other 20 %. An internal combustion engine uses the oxygen to operate and exhausts the nitrogen.

However, oxides of nitrogen (NO_x) are formed when the combustion temperature exceeds 1800°C. Although NO_x compounds do not directly effect the combustion process, when they combine with unburnt fuel (HC) in certain atmospheric conditions, they are the basis of SMOG.

To measure the NO_x emission, the engine must be charged, only than the high combustion temperatures can be reached.

AIR / FUEL RATIO

The air/fuel ratio (symbol: λ = Greek letter lambda) indicates the actual air/fuel ratio as a proportion of the stoichiometric value; in other words, it expresses the amount of air supplied as compared to the amount of air required in theory.

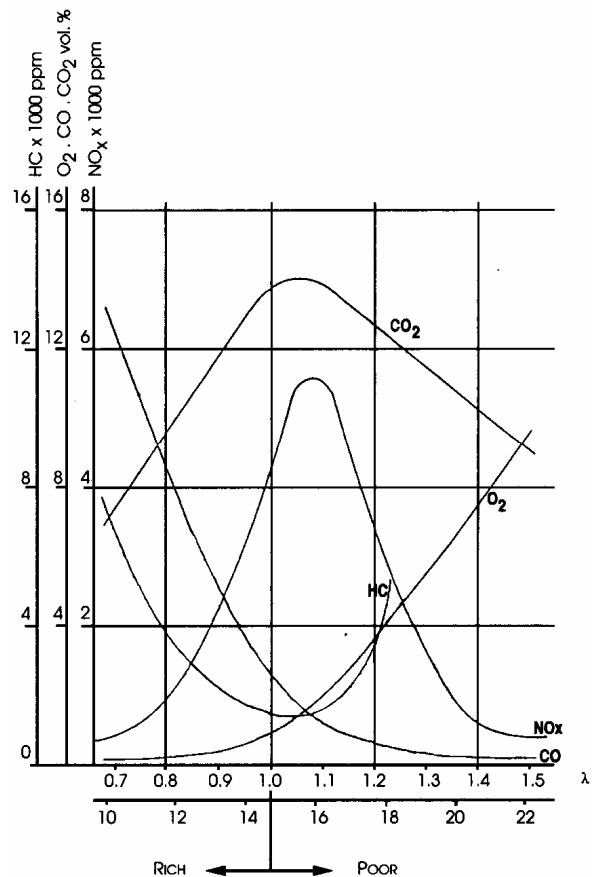
$$\text{Air /fuel ratio } \lambda = \frac{\text{air supplied to engine}}{\text{theoretical requirement in air}}$$

The air/fuel ratio at which the fuel burns most efficiently is called "Stoichiometric" point.

14.7 to 1 air/fuel ratio (Lambda λ = 1)

This is also the point at which HC and CO emissions are lowest and CO₂ is at the highest.

Note: The graph is for an engine at full load.



5 ENGINE DESIGN – EMISSION

The concentration of the pollutants: hydrocarbons (HC), carbon monoxide (CO) and oxides of nitrogen (NO_x) expelled by the engine; are dependent to a great extent on the excess-air factor lambda (λ) which is the air/fuel ratio at which the engine is being operated.

In the rich mixture range the HC and CO emissions and specific fuel consumption increase, while they are at a minimum in the lean mixture range.

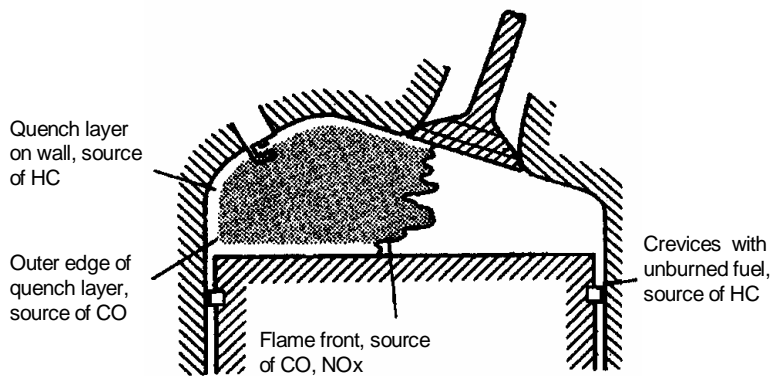
Oxides of nitrogen, on the other hand, are at a maximum with a slightly lean mixture ($\lambda = 1.05$).

Lean mixture adjustment causes NO_x to rise and has a derogatory effect on engine operation.

With the engines in series production today, it is not possible to make the air/fuel mixture leaner than $\lambda = 1.1 \dots 1.2$ while still maintaining reliable ignition and good combustion; this can be remarked from the increase in fuel consumption.

As a consequence, the goal of new engine development is to extend lean-running capability into the excess-air factor ranges around $\lambda = 1.4$ through further engine improvements, thus reducing fuel consumption and NO_x emission.

SOURCE OF EMISSIONS IN SPARK IGNITION ENGINE



Crankcase ventilation (blow-by)

The concentration of hydrocarbons in the crankcase can be many times that found in the engine's exhaust gases. Control systems conduct these gases to a suitable point in the engine's intake manifold from where they are drawn into the combustion chamber for burning. Originally, these gases were allowed to escape untreated directly into the atmosphere. Today, crankcase emission control systems are a standard legal requirement.

5 Increasing the compression ratio is decisive for the thermal efficiency of the engine and exhaust emissions.

A limitation is that the combustion temperature is higher, so:

- Ø More NO_x emission
- Ø Risk of self-ignition (knock) requires higher octane fuel which is difficult with unleaded fuel.

Shape of the combustion chamber influences HC emission.

- Ø Good turbulence gives rapid combustion and good efficiency, reduces HC emission, lower fuel consumption and the use of lower octane fuel is possible
- Ø Spark plug position (central) gives good flame travel.

The valve timing is decisive for the exchange of burned gas and fresh mixture.

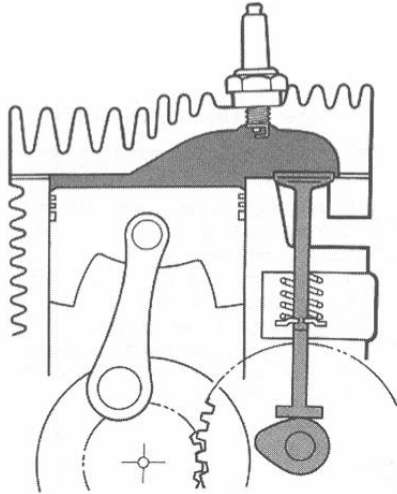
- Ø Valve overlap (opening and timing) influences emission (HC- NO_x) and efficiency (power-torque).
- Ø Valve timing can only be optimized for one engine speed and load.
- Ø Exhaust backpressure is important.

Intake passage design.

- Ø Swirl gives good mixing and good fresh mixture charging.

Ignition and spark plug

- Ø Large electrode gap, open spark gap and thin electrodes give good mixture ignition.
- Ø A high energy ignition gives good flame travel.
- Ø Ignition advance has to be adapted to lean mixture (low combustion speed).
- Ø NO_x emission can be reduced by retarding the ignition (lower temperature and less time for O_2 to react) but this has an adverse effect on power output and fuel consumption.



SV ENGINE LAYOUT

In the side valve engine, the valves are located to the side of the combustion chamber

In the side valve cylinder head design, the clearance between part of the cylinder head and piston at the end of the compression stroke is very small. This forms an area of “squish”, from which gas is ejected into the main chamber. The turbulence that this jet generates ensures rapid combustion.

If a too large squish area is used, the combustion becomes too rapid and noisy. This design also reduces the susceptibility to knock, since the gas furthest from the spark plug is in the squish area.

The end gas in the squish area is less prone to knock since it will be cooler because of the proximity of the cylinder head and piston. Excessive turbulence also causes excessive heat transfer to the combustion chamber walls and should be avoided for this reason also.

The main considerations in combustion chamber design are:

- The distance travelled by the flame front should be minimised.

By minimizing the distance between the spark plug and the end gas, combustion will be as rapid as possible. This has two effects. Firstly, it produces high engine speeds and thus higher power output. Secondly, the rapid combustion reduces the time in which the chain reactions that lead to knock can occur. This implies that, for geometrically similar engines, those with the smallest diameter cylinders will be able to use the highest compression ratios.

- The exhaust valve(s) and spark plug(s) should be close together.

The exhaust valve is very hot (possibly incandescent) so it should be as far from the end gas as possible to avoid inducing knock and pre-ignition.

- There should be sufficient turbulence.

There should be sufficient turbulence to promote rapid combustion. However, too much turbulence leads to excessive heat transfer from the chamber contents and also too rapid combustion, which is noisy. The turbulence can be generated by squish areas or shrouded inlet valves.

- The end gas should be in a cool part of the combustion chamber.

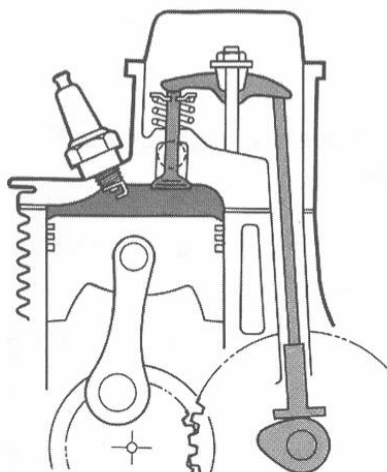
The small clearance between the cylinder head and piston in the squish area forms a cool region. Since the inlet valve is cooled during the induction stroke, this too can be positioned in the end gas region.

The poor combustion chamber shape of the side valve engine contributes to a poor surface-to-volume ratio and a reduction in efficiency .

The maximum compression ratio with this design is limited to 6 – 6.5 : 1, which makes it suitable for low octane fuel use.

Currently most engines have a compression ratio of about 9 : 1, for which a side valve geometry would be unsuitable. Overhead valve (OHV) engines have a better combustion chamber for these higher compression ratios. If the camshaft is mounted in the crankcase, the valves are operated by push rods and rocker arms.

A more direct alternative is to mount the camshaft in the cylinder head (OHC – overhead camshaft). The camshaft can be positioned directly over the valves, or to one side with valves operated by rocker arms.

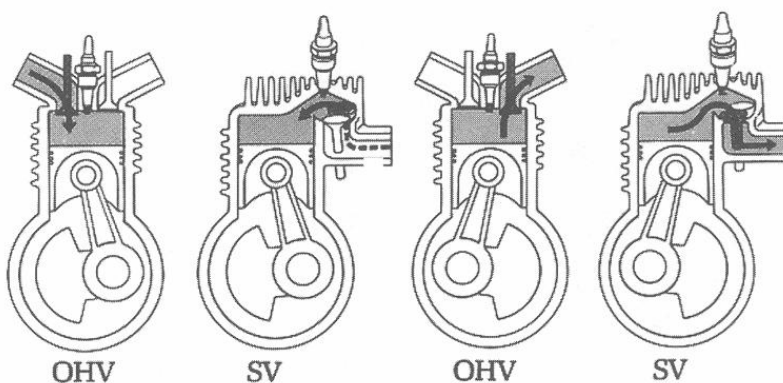


OHV ENGINE LAYOUT

With the overhead valve design, the valves are located above the combustion chamber.

INTAKE AND EXHAUST EFFICIENCY

The overhead valve layout enables smoother intake plus quicker and more complete exhaust. This increased efficiency improves fuel economy and reduces carbon deposit.

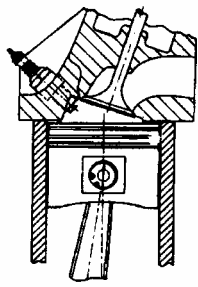


In general, the maximum power output of an engine is proportional to the piston area, while the maximum torque output is proportional to the swept volume.

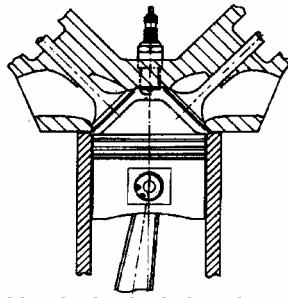
In over-square engines the cylinder diameter is larger than the piston stroke, this permits larger valves for a given swept volume. This improves the induction and exhaust processes, particularly at high engine speeds. In addition, the short stroke reduces the maximum piston speed at a given engine speed, permitting higher engine speeds.

The disadvantage with over-square engines is that the combustion chamber has a poor surface-to-volume ratio, leading to increased heat transfer.

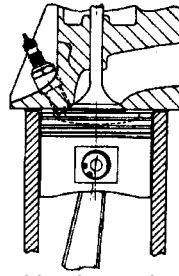
Under-square engines have combustion chambers with a better surface-to-volume ratio, leading to better fuel economy.



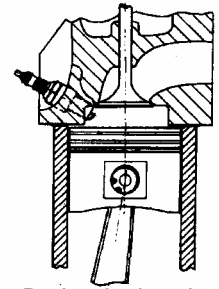
Wedge chamber



Hemispherical chamber



Bowl in piston chamber



Bath-tub chamber

WEDGE COMBUSTION CHAMBER

This is a simple chamber that produces good results. The valve drive train is easy to install, but the inlet and exhaust manifold have to be on the same side of the cylinder head.

HEMISPHERICAL CHAMBER

This chamber has been popular for a long time in high-performance engines since it permits the use of larger valves. The arrangement is inevitably expensive. With the inlet and exhaust valves at opposite sides of the cylinder, it allows crossflow from inlet to exhaust. Crossflow occurs at the end of the exhaust stroke and the beginning of the induction stroke when both valves are open; it is beneficial since it reduces the exhaust gas residuals.

PENTROOF CHAMBER

More recently, pentroof chambers with four valves per cylinder have become popular; these have a shape similar to that of a house roof. The use of four valves give an even greater valve area than does the use of two valves in a hemispherical head.

BOWL IN PISTON CHAMBER

A cheap alternative, which has good performance is the bowl in piston combustion chamber. The combustion chamber is located in the piston head.

BATH-TUB CHAMBER

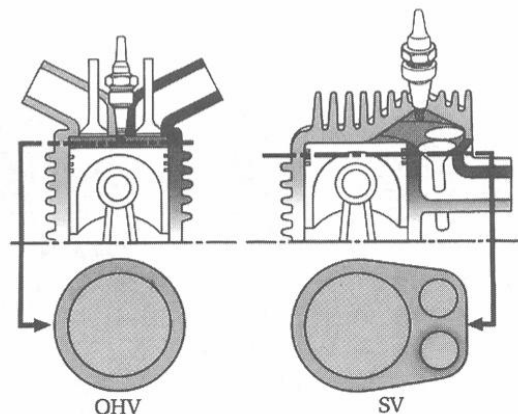
This very compact combustion chamber gives good economical performance; it can also be used in a crossflow engine.

All these combustion chambers have:

- Short maximum flame travel
- Spark plug is close to the exhaust valve
- A squish area to generate turbulence
- Well-cooled end gas

CYLINDER THERMAL BALANCE

In the side valve engine, heat is concentrated around the exhaust port. The overhead valve layout, however, gives excellent thermal balance, so there is less distortion and oil consumption.



FACTORS INFLUENCING EMISSION VALUES

		CO	NO _x	HC	Specific fuel consumption	Power
Air/fuel ratio	lean	<	>	<	<	<
	rich	>	<	>	>	>
Ignition timing	advanced	<	>	<	<	>
	retarded	>	<	>	>	<
Compression ratio	high	<	>	<	<	>
	low	>	<	>	>	<
Oil consumption	low	<	=	<	=	=
Atmospheric pressure	high	<	>	<	<	>
	low	>	>	>	>	<
Temperature	high	>	<	>	<	<
	low	<	>	<	>	>

!!! IMPORTANT NOTE !!!

Emission certification for engines is done considering the standard aircleaner system and exhaust system. Any modification to these systems changes intake pressure or exhaust backpressure and affects the exhaust emission values of the engine. Any alteration to the standard aircleaner system or exhaust system has to be tested and approved by Honda.

CARB /EPA EMISSION REGULATION

The California Air Resources Board (abbreviated as CARB) and the Environmental Protection Agency (EPA) have established emission regulations for general purpose engines in order to reduce harmful atmospheric pollution by nitrogen oxides (Nox), hydrocarbons (HC) and carbon monoxide (CO).

CARB

- Ø Applicable to small off-road spark-ignited engines below 19kW (25HP)
- Ø Tier 1
 - Implementation date January 1, 1995
 - Enforcement date August 1, 1995
- Ø Tier 2
 - Final regulation effective March 23, 1999
 - Implementation for non-handheld engines in 2002; 2006 for vertical shaft engines
 - In-use standards: durability period that an engine needs to comply with the emission regulation
 - Production line and in-use testing introduced
- Ø Classification and emission limit values

Engine class	CO (g/kWh)	HC + Nox (g/kWh)
0 –65 cc	536	72
> 65 cc to < 225 cc	467	16.1
> = 225 cc	467	12

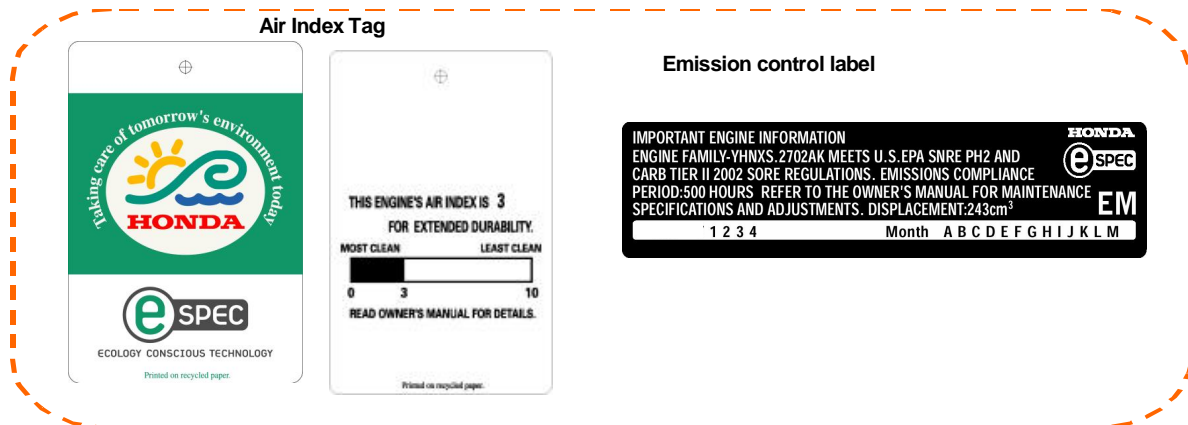
EPA

- Ø Applicable to small off-road spark-ignited engines below 19kW (25HP)
- Ø Phase 1
 - Effective date August 2, 1995
 - Implementation date "1997 model year"
 - Similar to CARB Tier 1
 - CO standard 387 g/HP-hr
 - Engines certified to CARB Tier1 meet EPA Phase 1
- Ø Phase 2
 - Final regulation effective June 1999
 - Implementation 2001-2007 – depending on engine class
 - In-use standards: durability period that an engine needs to comply with the emission regulation
 - Production line and in-use testing introduced
- Ø Classification and emission limit values

Engine class	CO (g/KWh)	HC + Nox (g/KWh)
< 20 cc HandHeld	805	50
20 to < 50 cc HandHeld	805	50
> = 50 cc HandHeld	603	72
0 to < 66 cc	610	50
66 to < 100 cc	610	40
100 to < 225 cc	610	16.1
> = 225 cc	610	18

EMISSION LABELING

The "Air Index Tag" is attached on the high tension cord of the engine.
 The "Emission control label" is on the fan cover of the engine.
 Only the Honda factory is authorized to install this label at the time of production.



EU (European Community) Emission regulation**BASIC CONCEPT OF 2002/88/EC**

- ∅ The regulation is based on Industry demand (1998) to conform with existing US EPA emission regulations
- ∅ A two stage approach will be applied: Stage 1 in 2004 and Stage 2 foreseen for 2008
- ∅ On Stage 2, the Emission Durability Period will be introduced: the initial emission of the new engine, as well as the emission of the engine at the end of the EDP must be lower than the Stage 2 emission limits.
The engine manufacturer selects for the EDP the number of hours that is most closely to the expected useful engine life, in accordance to below table.

Class	SH1	SH2	SH3	SN1	SN2	SN3	SN4
No. hours	50	125	300	50, 125, 300	125, 250, 500	125, 250, 500	250, 500, 1000

- ∅ Classification and emission limit values (g/kWh)

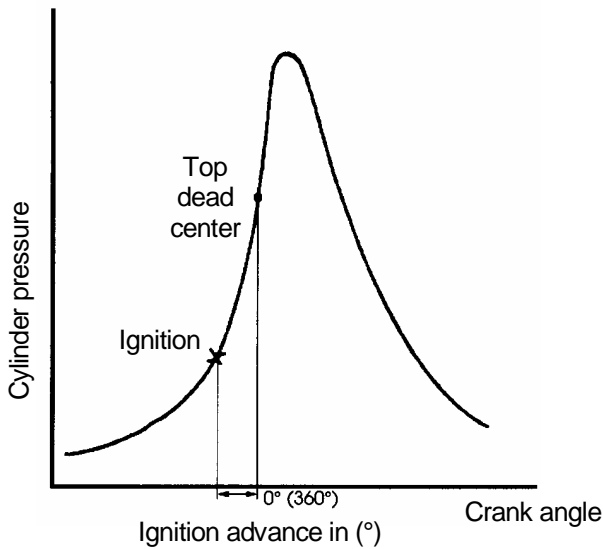
Class	CO		HC		NOx		HC + NOx	
	I	II	I	II	I	II	I	II
< 20 cc HandHeld	805	805	295		5.36	10		50
20 to < 50 cc HandHeld	805	805	241		5.36	10		50
> = 50 cc HandHeld	603	603	161		5.36	10		72
< 66 cc	519	610				10	50	50
66 to < 100 cc	519	610				10	40	40
100 to < 225 cc	519	610				10	16.1	16.1
> = 225 cc	519	610				10	13.4	12.1

- **Stage I** emission limit values apply for initial engine emission only.
- **Stage II** emission limit values apply at the end of the emission durability period (EDP).



EU Emission label with mention
of engine approval number

IGNITION TIMING



As there is a time lag between the spark plug sparking, the mixture igniting and the mixture exploding in the combustion chamber - commonly expressed as flame travel speed - the spark plug must be timed to spark before the piston reaches the Top Dead Center (TDC).

This is the ignition timing (advance) and is usually expressed in (°) of crankshaft rotation before TDC.

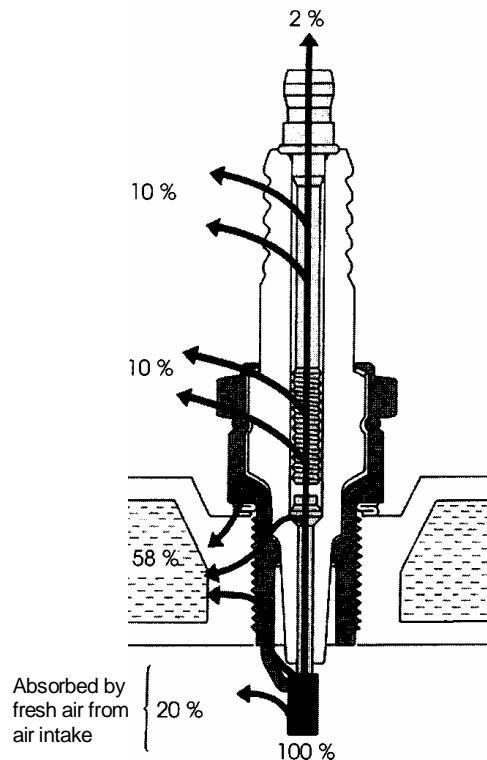
SPARK PLUG HEAT RANGE

The heat range of a spark plug is its ability to dissipate heat from the combustion chamber to the cylinder head. The heat range (dissipation capability) of a spark plug mainly depends on the length of the insulator nose. The combustion heat is transferred from the insulator nose through the center electrode to the plug housing and from there it goes to the cylinder head. A hot plug has a long insulator nose, which exposes more surface area to combustion gases than a cold plug with a short insulator nose. For optimum operating conditions, the spark plug temperature range should be kept between 400°C and 900°C. If a spark plug operates above 900°C at high-speed, pre-ignition appears. On the other hand, if a spark plug operates below 400°C at low speed, carbon fouling may result.

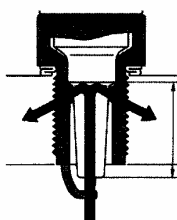
A cold plug is generally used in a high-speed and/or heavy-duty application.

A hot plug is chosen for low speed applications with moderate to low load, where there is the possibility of spark plug carbon fouling.

SPARK PLUG HEAT DISSIPATION

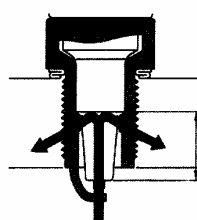


HOT PLUG



Long insulator nose

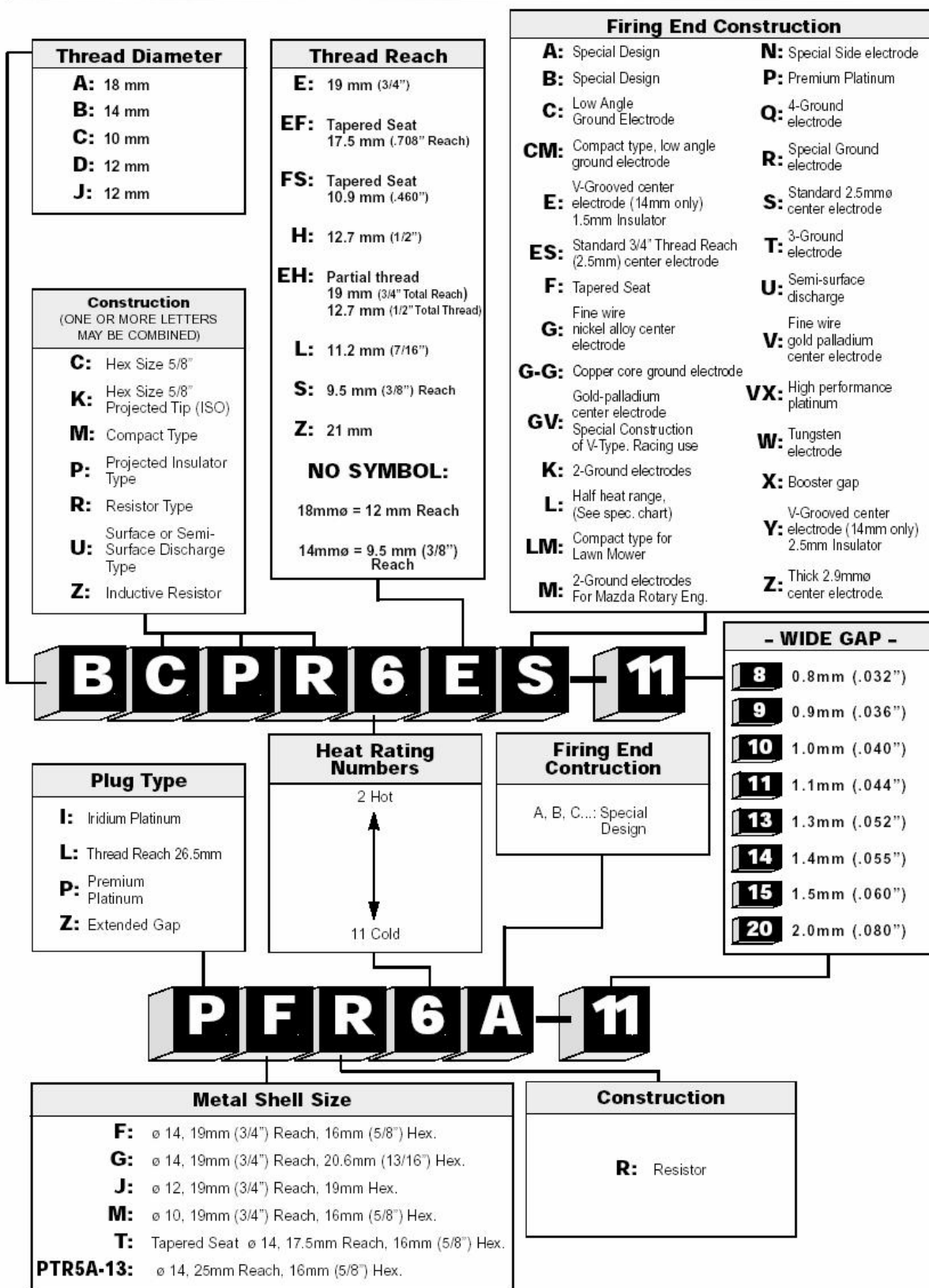
COLD PLUG



Short insulator nose

SYMBOLS USED ON NGK SPARK PLUGS

DESIGN SYMBOLS: SPARK PLUGS



FUNCTION OF OIL

Ø REDUCES FRICTION

Ø DISTRIBUTES FORCE

As the load on ball bearings, roller bearings, chains, etc. is on a point or across a surface, a large force is applied to the contact point. Oil enlarges the area to which the force is applied and distributes force to prevent concentration at one point.

Ø COOLING

Oil cools the friction surfaces by carrying away heat generated on, or delivered to the surface.

Ø PREVENTS CORROSION

Oil film covers metal surfaces to prevent contact with the air.

Ø SEALING

Piston rings seal the high pressure of combustion. Oil assists ring sealing.

Ø CLEANING

Carbon and sludge accumulates and is distributed throughout the oil, thus preventing solidification.

Ø TRANSMISSION AND ABSORPTION OF POWER

Oil in an hydraulic torque converter functions as a medium to transmit power smoothly (e.g. hydrostatic transmission).

Oil in a shock absorber functions to absorb energy.

OIL VISCOSITY

Viscosity is an essential feature of oil.

- High viscosity : oil film is strong (effectiveness as a lubricant is good)
fluidity is poor (resistance is large and power loss is excessive)

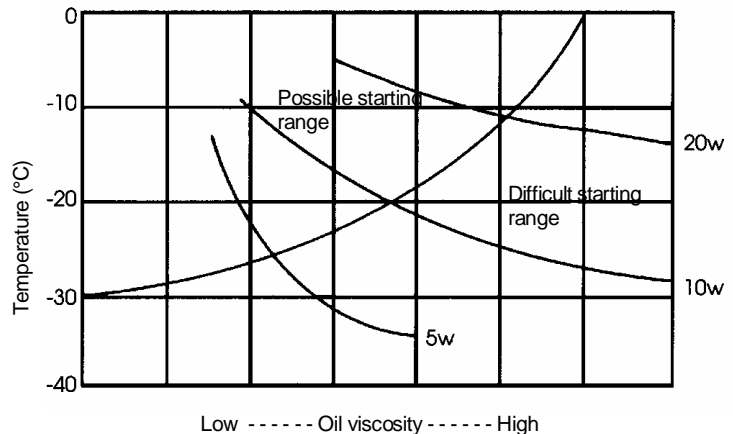
- Low viscosity : oil film is weak (effectiveness as a lubricant is poor)
fluidity is good (resistance and power loss are small)

- Relationship of viscosity and temperature.

When temperature decreases, the viscosity increases and power loss increases.
An appropriate oil should be selected according to the ambient temperature.

Force or electric power required to start the engine in cold conditions is affected by the viscosity of the engine oil.

The viscosity grade of oil most suited to the ambient operating temperature must be used.



SAE VISCOSITY GRADE

Oils are classified in accordance with SAE (American Society of Automotive Engineers) standards. The relationship with ambient temperature is shown in the table below.

(A higher number corresponds to a higher viscosity)

SAE	Ambient temperature °C
SAE 30	48.9°C ~ 0°C
SAE 20	33.3°C ~ 0°C
SAE 20W	26.7°C ~ -12.2°C
SAE 10W	15.6°C ~ -23.3°C
SAE 5W	-12.2°C ~ -34.5°C
SAE 10W-30	48.9°C ~ -23.3°C
SAE 10W-40	58.9°C ~ -23.3°C

Select the correct type of engine oil, conform with the engine temperature operating conditions.

- Electric starter type: -15°C ~ 40°C
- Recoil starter type: -15°C ~ 40°C
- Kerosene fuel type: +15°C ~ 40°C

- Ø Use an oil with smaller number (lower viscosity) in winter and one with larger number (higher viscosity) in summer.
- Ø Multi-grade oil has all-round stability under seasonal and temperature changes. SAE10W-30, for example, is applicable for all seasons. It has a viscosity equivalent to SAE10W at a low temperature and provides a lubrication effectiveness corresponding to SAE30 during operation.

SERVICE CATEGORY

When selecting the correct engine oil for an engine application, refer to:

SAE : viscosity grade

API : service category (American Petroleum Institute)

CCMC : service category (Comité des Constructeurs du Marché Commun)

GASOLINE FUELED ENGINES

Always use **SF**, **SG**, **SH** or **SJ** class oils in general purpose gasoline engines.

DIESEL FUELED ENGINES

Always use **CC** or **CD** class oils in general purpose diesel engines.

OIL CONSUMPTION

A small quantity of the engine oil comes into the combustion chamber through the piston rings or the closed crankcase ventilation system and is burned.

The engine oil consumption is expressed in cm^3/h .

An oil consumption of $5\text{cm}^3/\text{h}$ indicates that 5 cubic centimeters of oil are consumed during 1 hour of operation.

In a new engine, oil consumption is generally higher and the oil becomes contaminated sooner due to the effects of running-in.

The first 20 hours of operation are generally considered as the running-in period. Special attention should be paid to oil maintenance during this period.

INCLINATION

The oil level should be kept between the upper and lower marks.

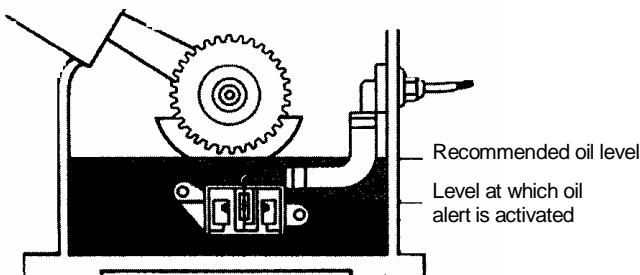
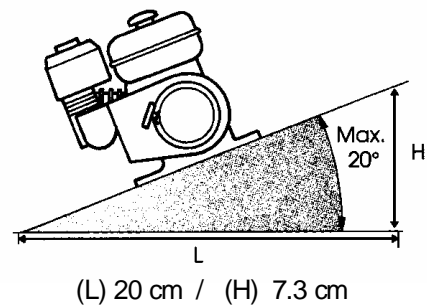
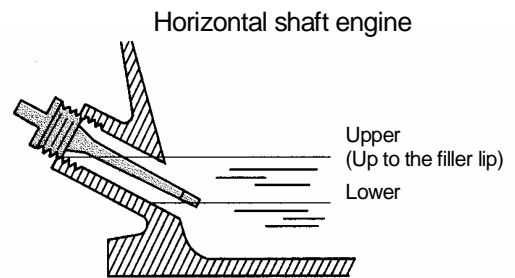
If oil level is above the specified upper level, oil temperature may rise excessively or excessive crankcase breather oil discharge may occur.

If the oil level is below the specified level, engine damage may occur or the engine will be shut down by the oil alert system.

The engine must be mounted and operated horizontally. Maximum permissible inclination is 20° in any direction.

Operation at steeper angles can cause the following troubles:

- fuel overflow from the fuel tank cap
- fuel overflow from the carburetor
- obstructed fuel supply to the carburetor
- increased oil consumption
- engine seizure because of inadequate lubrication
- incorrect operation of oil alert system
- incorrect operation of breather system



The maximum permissible operating angle of 20° in any direction assures correct operation and lubrication of the engine even if the oil level drops to the lower oil level.

Steeper operating angles are permitted, if checked by an application test and approved by Honda.

STANDARD AMBIENT OPERATING TEMPERATURES

Honda general purpose engines are designed to operate within the following ambient temperature range :

Engine type	Ambient temperature range
GX100 / GX120 / GX160 / GX200 / GX240 / GX270 / GX340 / GX390 GXV270 / GXV340 / GXV390 GC135 / GC160	- 15 °C ~ + 40 °C
GCV135 / GCV160 GXV 160 GX22 / GX25 / GX31	- 5 °C ~ + 40 °C
GCV520 / GCV530 / GXV520 / GXV530 GX610 / GX620 / GX670 / GXV610 / GXV620 / GXV670 GX360 / GX640 GD110 / GD1250	-25 °C ~ + 40 °C
GD 321 / GD 411 (recoil start)	- 10 °C ~ + 40 °C
GD 321 / GD411 (electric start)	- 15 °C ~ + 40 °C

HIGH TEMPERATURE USE (+40 °C)

Honda engines normally can not be used in an operational environment with the ambient temperature higher than 40 °C.

If such conditions are unavoidable, the engine type whether fully open or fully enclosed, type of equipment, usage, load condition and other factors must be carefully investigated on site or in the same temperature conditions.

- If the temperature of the engine intake air rises, the air density becomes lower (same condition as for high altitudes, air becomes thinner) and the power output will drop.
- The speed drop at rated load continuous operation should be within 3%.

COLD CLIMATE USE (to -15 °C)

For use in cold climate areas, even at temperatures around -10 °C, considerable temperature variations could be encountered due to wind and usage environment. Confirmation testing should therefore be conducted at the operating site. The following checks should also be made as a precaution.

- Set the idle speed at a slightly higher level.
- Engine oil should be the grade most suited for the ambient temperature.
- Use a battery of a larger capacity and keep fully charged.
- Coat the governor arm and spring and the remote control system with low temperature grade grease.
- Drain accumulated water from the fuel tank, strainer and float chamber.
- Filter type air cleaners will develop loss of power, speed deficiency and engine stall due to clogging caused by freezing.
- The cooling air intake opening of the recoil starter housing may require blocking with tape or a cover, depending on ambient temperature condition.

FRIGID CLIMATE USE (below -15 °C)

For use in temperature below -15 °C, matching of the engine and application is necessary; consult Honda for instructions.

If the engine is used at extremely cold temperatures below the normal operating temperature range, resistance due to the increased engine oil viscosity will cause hard starting. Oil leakage may occur by hardening of the oil seal lip due to exceeding the limit of cold resistance range. Blow by of the oil seal lip may occur due to a rise in the crankcase pressure resulting from the breather pipe freezing.

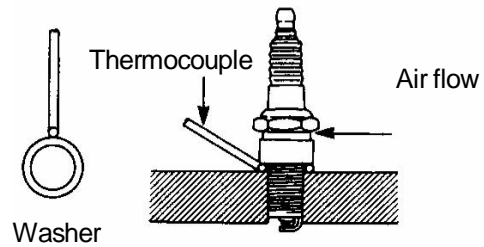
Cracks may develop in plastic and rubber parts.

TEMPERATURE MEASURING METHOD

- Use "Type K" thermocouples and a handy type temperature gauge with 6 channel input selection capability.
- Engine speed during temperature measurement should be within the recommended operating range and temperatures should be measured under the assumed load condition most commonly used by customers.
- Measurements are made after warm-up running.
- The actual operational test should be for at least one hour, with measurements taken at 10 minutes intervals, under continuous load and continued until temperature rise stabilizes.

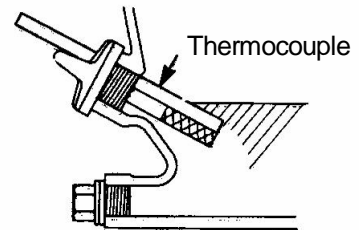
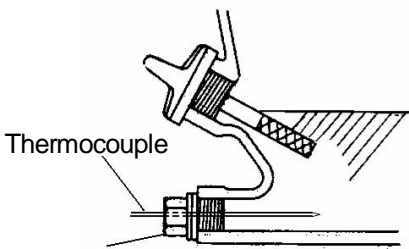
SPARK PLUG SEAT TEMPERATURE

The spark plug seat temperature is measured using a thermocouple brazed to a copper gasket of the same size as the spark plug gasket. The spark plug gasket should be removed before installing the thermocouple ring. The brazed section of the thermocouple (where ring is brazed to thermocouple) must be positioned downwind of the cooling air.



OIL TEMPERATURE

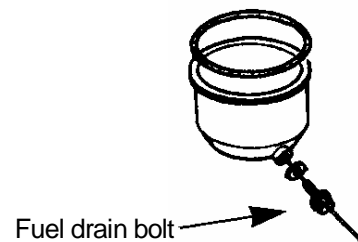
The engine oil temperature is measured by bonding a thermocouple to the oil dipstick. Be sure that the oil level is correct; an incorrect oil level will influence the measurements.



On some engines (e.g. V-twins) it is more preferable to measure the oil temperature at the oil drain plug. Generally, the oil temperature measured at the oil drain plug is more accurate.

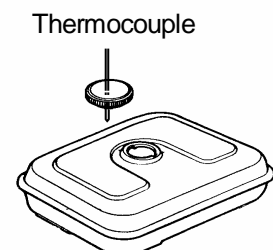
CARBURETOR FLOAT CHAMBER TEMPERATURE

Gasoline temperature in the carburetor float chamber is measured through the drain bolt. Drill a hole in the drain bolt, insert a thermocouple and bond it. Be sure that the thermocouple does not contact the float.



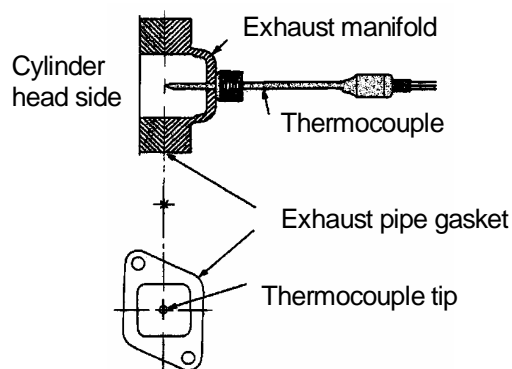
FUEL TANK TEMPERATURE

Gasoline temperature in the fuel tank is measured by inserting a thermocouple through the filler cap. Position the thermocouple probe 10 mm from the tank bottom.



EXHAUST GAS TEMPERATURE

Drill a hole in the exhaust pipe as near to the cylinder head as possible. Insert the thermocouple probe so it extends to the exhaust port/exhaust pipe gasket area. Ensure the probe does not contact the inner surface of the manifold/port as this will alter the measurement result.



MAXIMUM ENGINE OPERATING TEMPERATURES

Following maximum component temperatures (converted to 40 °C ambient air temperature) should be respected.

Engine operating maximum ambient temperature is 40 °C.

GX / GXV ENGINES	Maximum temperature (converted)
Spark plug seat temperature	270 °C
Engine oil temperature	140 °C
Gasoline inside fuel tank temperature	60 °C
Gasoline inside carburetor float chamber temperature	60 °C
Air temperature	40 °C
GC / GCV ENGINES	
Spark plug seat temperature	250 °C
Engine oil temperature	140 °C
Gasoline inside fuel tank temperature	60 °C
Gasoline inside carburetor float chamber temperature	60 °C
Fuel pump body temperature	60 °C
Air temperature	40 °C
GX22 / GX25 / GX31	
Spark plug seat temperature	270 °C
Engine oil temperature	140 °C
Gasoline inside fuel tank temperature	55 °C
Fuel tank surface temperature	70 °C
Air temperature	40 °C
PROPANE ENGINE	
Spark plug seat temperature	250 °C
Engine oil temperature	140 °C
WATER COOLED ENGINE GX360 / GX640	
Cooling water temperature (at engine discharge)	105 °C
Inlet port temperature	60 °C
Timing belt compartment (in belt case)	100 °C
Water hose surface under continuous load	110 °C
Water hose surface after stopping	130 °C
Head gasket area (at exhaust side)	150 °C

GD 320 / 321 / 410 / 411	Maximum temperature (converted)
Engine oil temperature	120 °C
Fuel inside fuel tank temperature	60 °C
Exhaust gas temperature	Within recommended operating range (see performance curves)
GD 1100 / 1250	
Cooling water temperature (at engine discharge) 2600 rpm type 3000 rpm type 3600 rpm type	Under 105 °C Under 100 °C Under 100 °C
Water hose surface under continuous load	110 °C
Water hose surface after stopping	130 °C
Diesel fuel temperature at injection pump inlet	70 °C
Engine oil temperature (drain bolt)	120 °C
Inlet port temperature	60 °C
Timing belt chamber temperature	100 °C
Head cover gasket temperature (exhaust port side)	150 °C
Exhaust gas temperature	Within recommended operating range (see performance curves)

TEMPERATURE CONVERSION FORMULA

The outside temperature and engine temperatures must be measured and converted to the specified 40 °C ambient air temperature.

Conversion formula: $40\text{ °C} - \boxed{\text{°C}} + \boxed{\text{°C}} < \text{Maximum temperature}$

Ambient air temperature
Measured temperature

Example: engine oil temperature 100 °C / ambient air temperature 20 °C

$$40\text{ °C} - 20\text{ °C} + 100\text{ °C} < 140\text{ °C}$$

$$120\text{ °C} < 140\text{ °C}$$

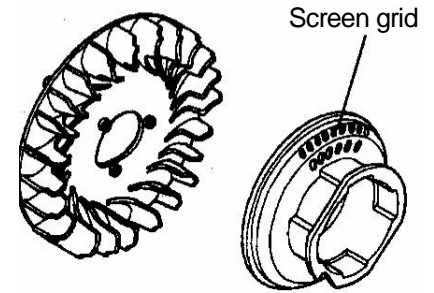
ROTATING SCREEN GRID

The engine may overheat due to a drop in cooling efficiency caused by:

- clogging of the cooling air inlet of the recoil starter housing by straw, grass clipping (lawn and grass cutting) and other debris.
- Dirt, dust and mud adhering to the cylinder cooling fins.

The rotating screen grid should be used when operating the equipment in the presence of excessive amount of straw, grass and debris. The rotating screen grid restricts the cooling-air flow; the engine operating temperature may rise and should be watched carefully.

If the screen grid is applied on an engine in semi or full enclosure, the cooling air intake duct surface should be increased in the same proportion as the screen grid opening area reduction.

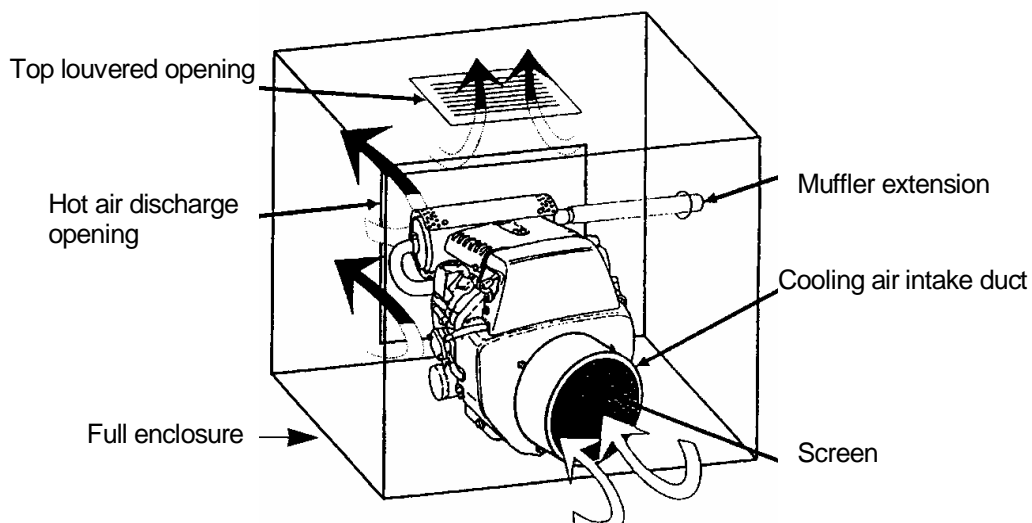
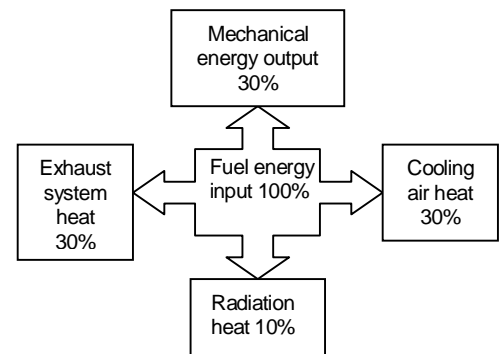


SEMI AND FULL ENCLOSURE – COOLING REQUIREMENTS

An air-cooled engine must transfer the developed heat directly to the air surrounding the engine. The amount of heat can vary considerably with the engine power output, but is proportional as illustrated in the diagram.

If the engine is mounted in an open installation, there should not be a cooling problem. If the engine is mounted in a semi or full enclosure, then it is important to provide:

- Adequate hot air discharge openings
- Adequate inward flow of cooling air
- Supply of cool intake air for aircleaner
- Adequate ventilation openings to discharge heat when engine is stopped.
- Exhaust tube extension



COOLING AIR INTAKE

The engine must be provided with a cooling duct so that fresh air can be drawn directly from outside the enclosure cover; preventing that cooling air is mixed with the hot air inside the engine enclosure.

Install the cooling air duct with the intake port in a place free from dust and dirt.

A flexible seal should be used to make a tight connection between air duct and engine.

For intake noise emission reduction, it is best that the air duct includes a right angle turn.

The air duct should have a minimum cross-sectional area, as given in the technical data, for unrestricted airflow. A rule of thumb for the duct size is to divide the engine capacity by factor 1.4 for a single cylinder engine and by 1.7 for a twin cylinder engine.

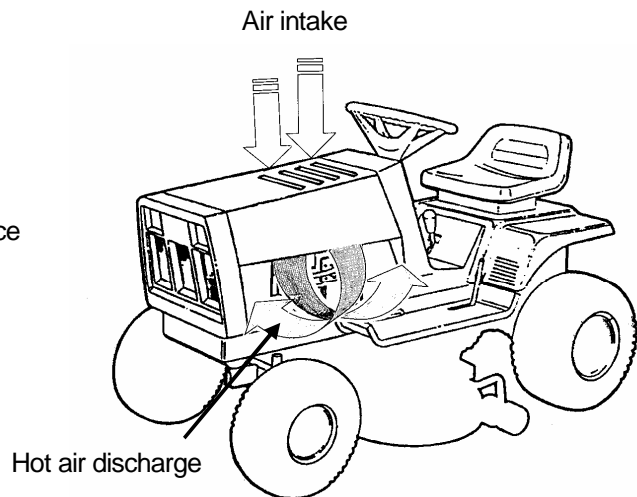
E.g: twin cylinder GCV 530 divided by 1.7 = 310 cm² air duct surface.

When the engine is operated in dusty areas, install a fixed screen at the intake port of the cooling air duct. If the screen reduces the opening area, increase the size of the area by an equal percentage.

AIRCLEANER AIR INTAKE

In order for the engine to develop the recommended power and to keep the air cleaner element maintenance interval, the intake air must be cool and clean.

If the air cleaner does not take its air from the blower housing, than a air cleaner intake duct should be provided in the enclosure.



HOT AIR DISCHARGE

Hot cooling air must be collected and discharged directly outside the enclosure. Adequate discharge ducts should be provided.

The minimum cross section of the hot air discharge opening must be larger than the cooling air duct opening.

Position the discharge port and direction so that the hot discharge air does not flow into the intake duct of the cooling system.

EXHAUST SYSTEM

The exhaust system becomes hot during operation and remains hot for a while after operation.

Separate the exhaust system from the engine compartment and position the exhaust system in the flow route of the discharged cooling air.

Be sure the exhaust gas is directly discharged outside the enclosure without being blocked or restricted by any obstacle. The exhaust gas must not flow into the cooling air duct (no re-circulation).

Provide the engine with an exhaust deflector or exhaust pipe extension if necessary.

The direction of the discharged exhaust gas and heated cooling air is important, as it can lead to hot spots on the frame or equipment and is a potential risk for fire.

RADIATION HEAT – HOT SOAK TEMPERATURE

If the engine is shut down when hot, the flow of cooling air is stopped and the temperature in the enclosure will rise suddenly.

Provide ventilation on top of the enclosure to prevent the engine compartment temperature from rising too high after the engine has been stopped.

Especially the fuel system is sensitive to temperature rise after engine stop;

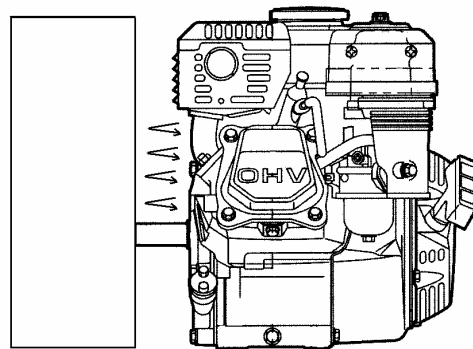
High temperature in fuel lines, carburetor or fuel tank may develop vapor lock and resulting starting problems.

The fuel temperature in the carburetor float chamber should be checked 10 – 15 min after the hot engine has been stopped; fuel temperature should stay below the Honda standard (max. 60°C).

AIRFLOW REFLECTION

When mounting the engine on an application, avoid that cooling air or exhaust gas is reflected by any shield or panel.

The reflected hot airflow will increase the temperature of several components and may lead to an overheated engine and fuel vapor lock.



To verify that an engine installation provides satisfactory cooling, it requires a careful test program under the most realistic, severe operating conditions.
Be sure that the engine meets all temperature requirements as stated in the Honda standards.

LAMP COILS

4 types of lamp coils are available; connecting these coils in series or parallel will double the output voltage or output power.

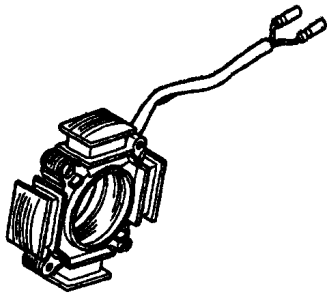
Lamp coils are used to feed appliances, not needing a regulated voltage such as light-bulbs.

Special care should be taken to the engine speed because this will influence directly the lamp coil's output voltage and power.

Lamp coil type	One coil	Two coils (series)	Two coils (parallel)
6 V / 15 W	6 V / 15 W	12 V / 15 W	6 V / 30 W
6 V / 25 W	6 V / 25 W	12 V / 25 W	6 V / 50 W
12 V / 15 W	12 V / 15 W	24 V / 15 W	12 V / 30 W
12 V / 25 W	12 V / 25 W	24 V / 25 W	12 V / 50 W

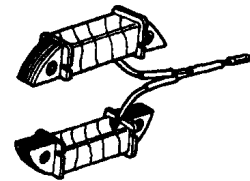
CHARGE COILS

Several types of charge coils are available, each of them have to be combined with a specific rectifier or rectifier/regulator.

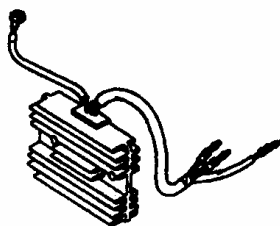


7A / 18A charge coil

1A charge coil

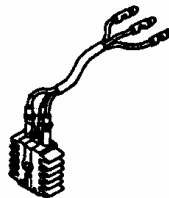


2.8A / 10A charge coil

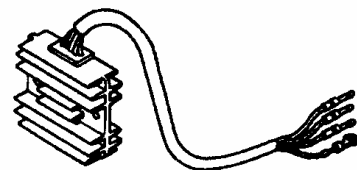


18A / 20A rectifier/regulator

3A rectifier

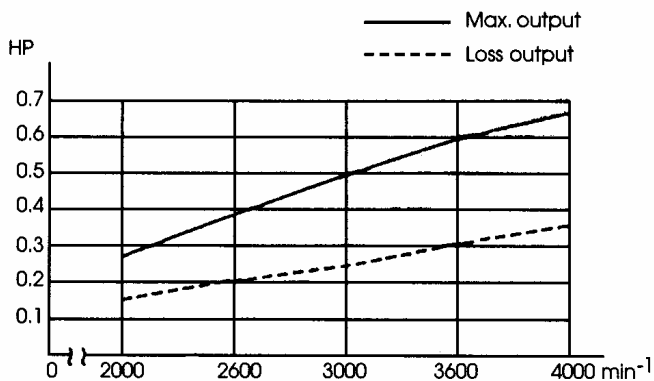


1A rectifier



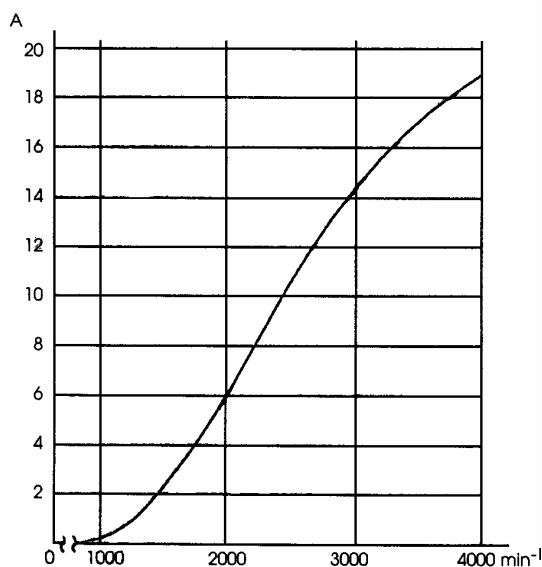
10A / 12A rectifier/regulator

CHARGE COIL POWER CONSUMPTION AND PERFORMANCE



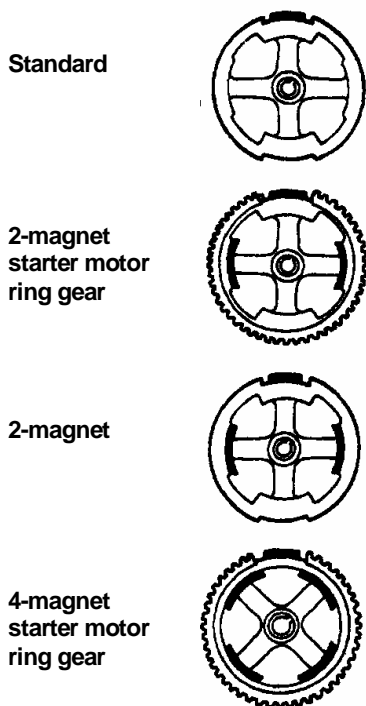
18A charging coil : engine power loss

The charge coil and lamp coil performance is directly related to the engine operating speed. When making a coil selection for a certain application, verify the engine's operating speed range in this application. Calculate the engine power loss from the charge coils and lamp coils when making an engine power selection.

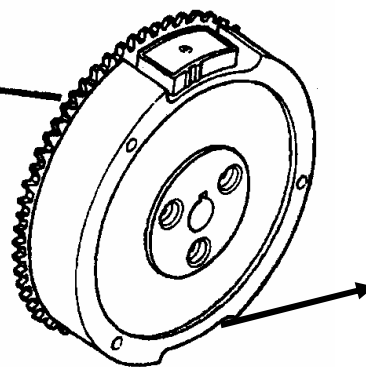


18A charging coil : performance curve

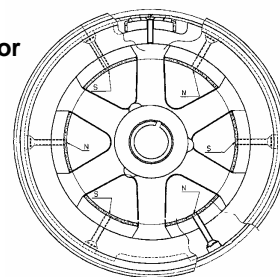
Standard flywheel types



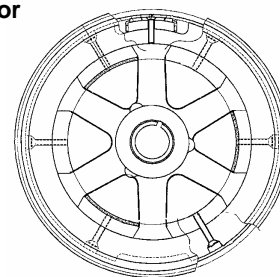
V-twin engine flywheel types



6-magnet starter motor ring gear



3-magnet starter motor ring gear

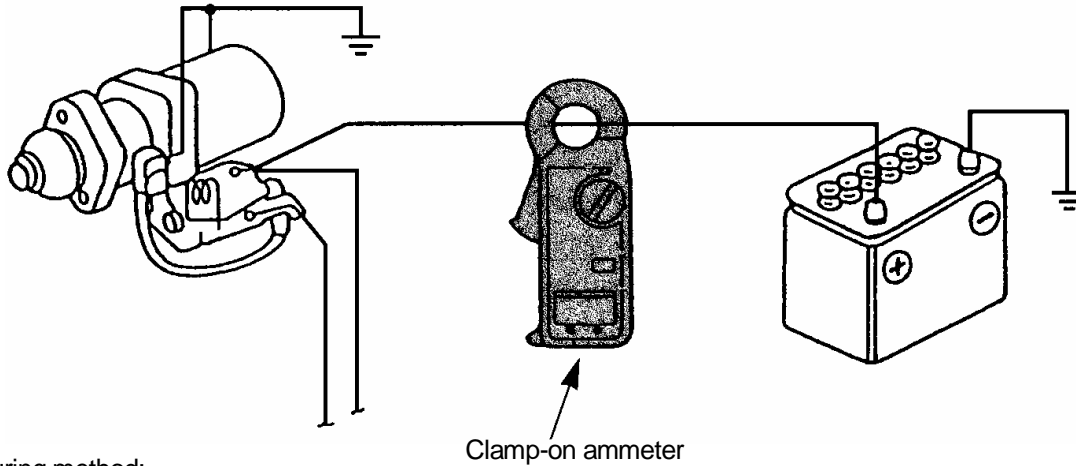


ELECTRIC STARTER MOTOR

On engines equipped with electric starter motor and directly coupled to an application (direct drive, belt drive, chain drive, etc...), the load on the starter motor should be checked.

If the starter motor current is too high, a provision should be made for unloading the engine when starting. For example : centrifugal clutch, belt tensioner.

On compressor applications, a manual or automatic pressure release valve should be provided on the compressor to lower the load on the electric starter motor or recoil starter.



Measuring method:

With the engine in cold condition, note the oil viscosity and oil temperature.

Put the ignition switch to off.

Use a clamp-on ammeter on the cable between battery and starter motor and measure:

- the starter motor peak current
- the starter motor cranking current

ELECTRIC CONDUCTOR SECTION

The electrical resistance of a wire increases in proportion to length, decreases with the increase of diameter and varies according to material of the conductor.

Consult the reference table below for conductor cross-section selection.

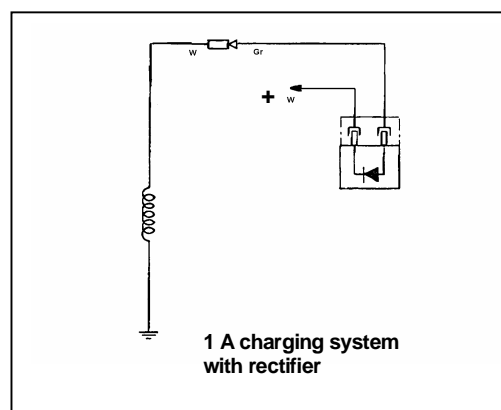
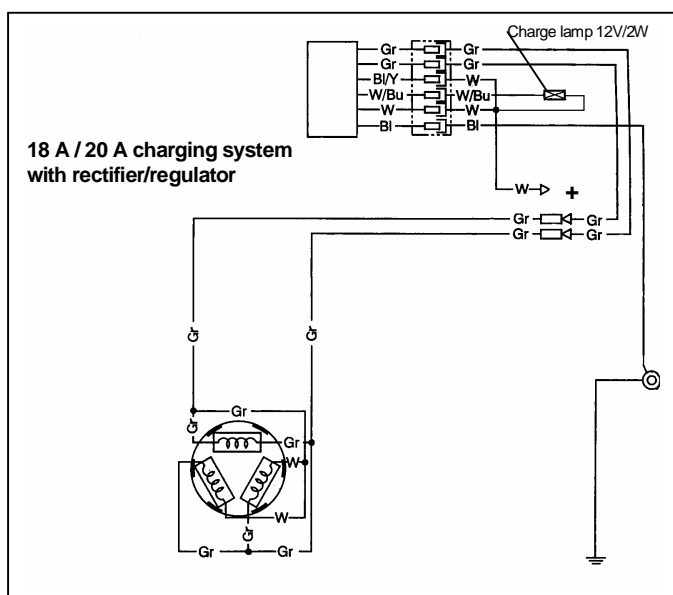
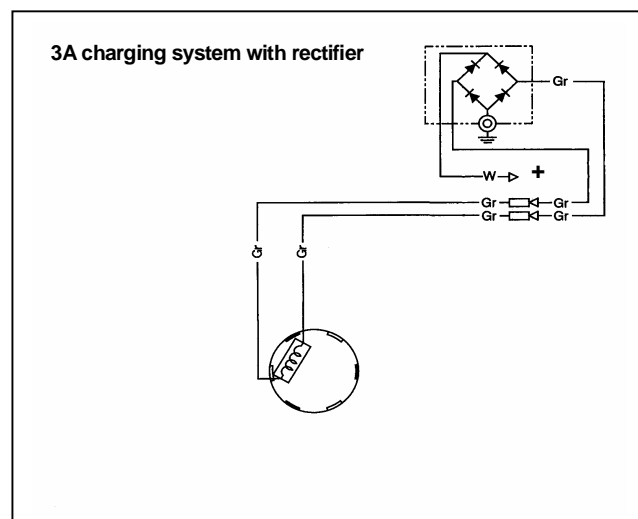
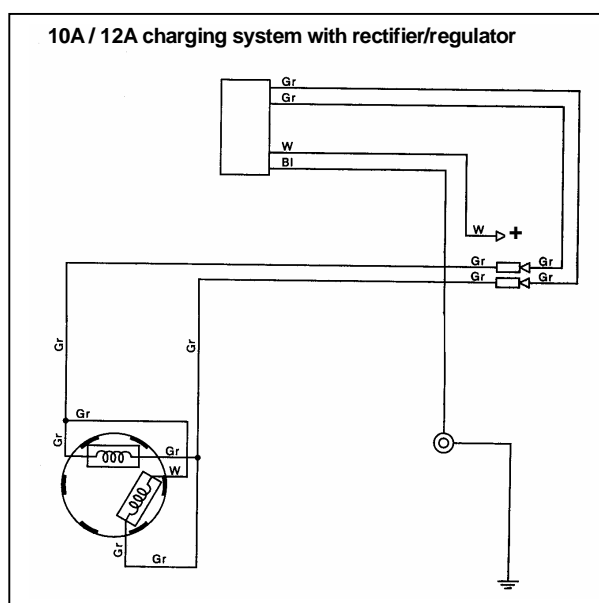
Nominal conductor cross section mm ³	Permissibile continuous current at ambient temperature (40°C)
1.25	15 A
2	25 A
2.5	32 A
4	42 A
6	54 A
10	73 A
16	98 A
25	129 A

RECOMMENDED BATTERY SIZE / FUSE

Engine type	Battery size (for operating temp. -15 to + 40°C)
GX 120 -200	12V - 18 Ah
GX 240 - 390	12V - 30 Ah
GXV 160	12V - 4 Ah
GXV 270 - 390	12V - 30 Ah
GD 321 - 411	12V - 30 Ah
GCV 520 / 530	12V - 30 Ah
GX 360 / 640 / 610 / 620 / 670	12V - 35 Ah

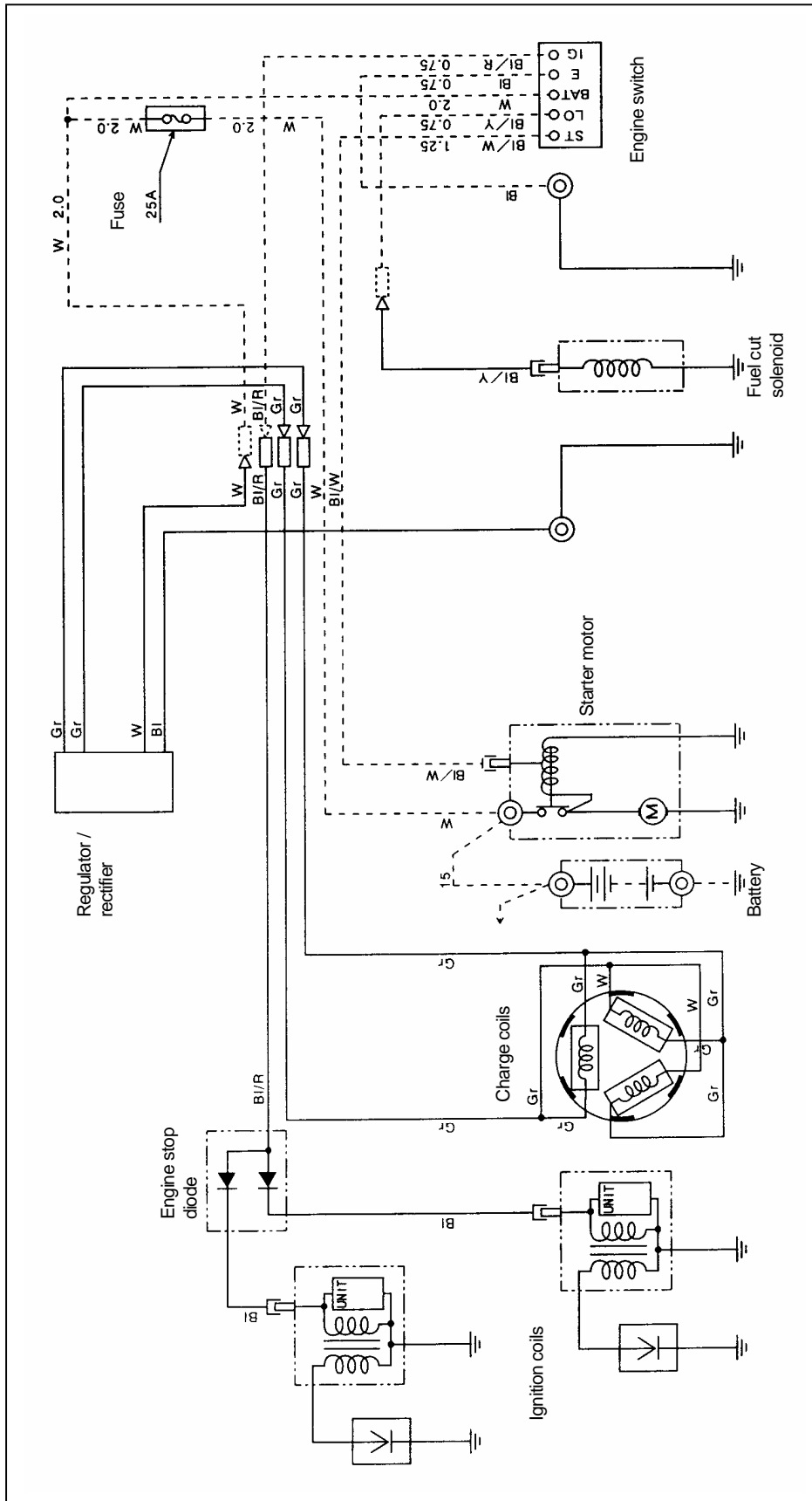
Charging system	Fuse
1 A	5 A
2.8 / 3 A	15 A
7 A	15 A
10 A	15 A
12 A	25 A
18 A	25 A
20 A	25 A

CHARGING SYSTEM: STANDARD WIRING DIAGRAMS



Colour code:
 Gr = gray
 BI = black
 W = white
 BI/Y = black-yellow
 W/Bu = white-blue

RECOMMENDED WIRING: BATTERY, ENGINE SWITCH, STARTER MOTOR



The dotted lines show the wiring between engine switch, battery, main fuse, starter motor and engine.

Wire diameters are indicated as: 0.75, 1.25, 2.0 and 15 mm².

Engine switch continuity:

OFF position – continuity between IG and E (ignition to ground)

ON position – continuity between BAT and LO (battery voltage to fuel solenoid)

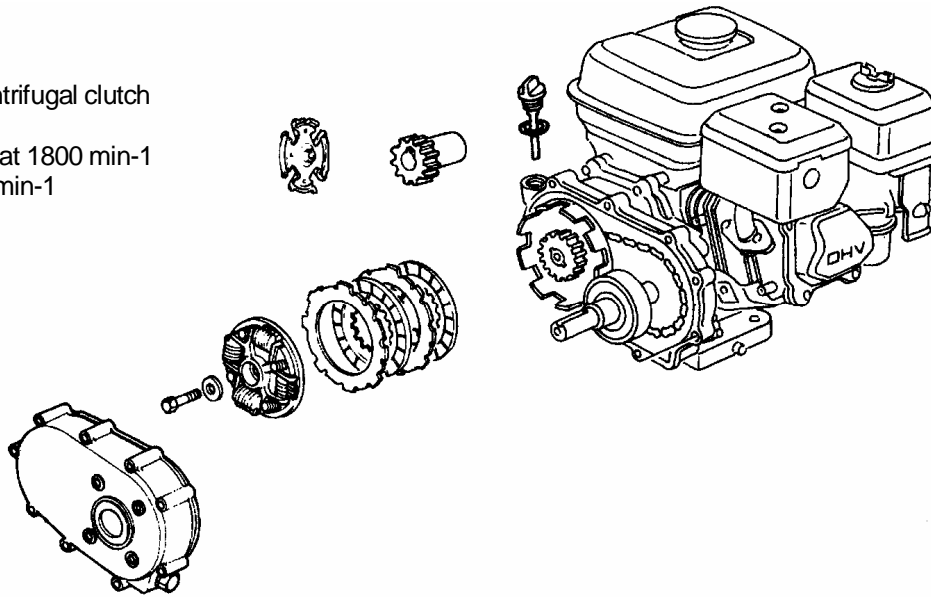
START position – continuity between BAT, LO and ST (battery voltage to starter solenoid)

STANDARD REDUCTION UNITS

R-TYPE

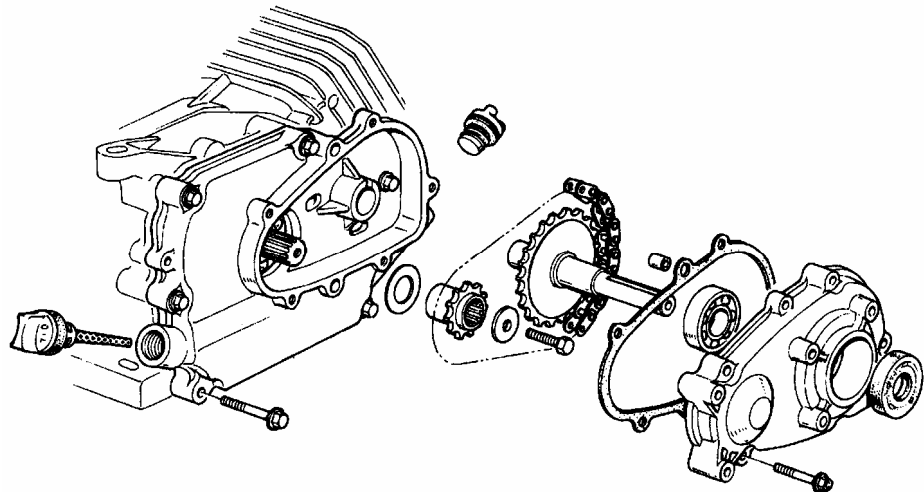
1/2 reduction with centrifugal clutch

Clutch engagement at 1800 min-1
Clutch lock at 2200 min-1



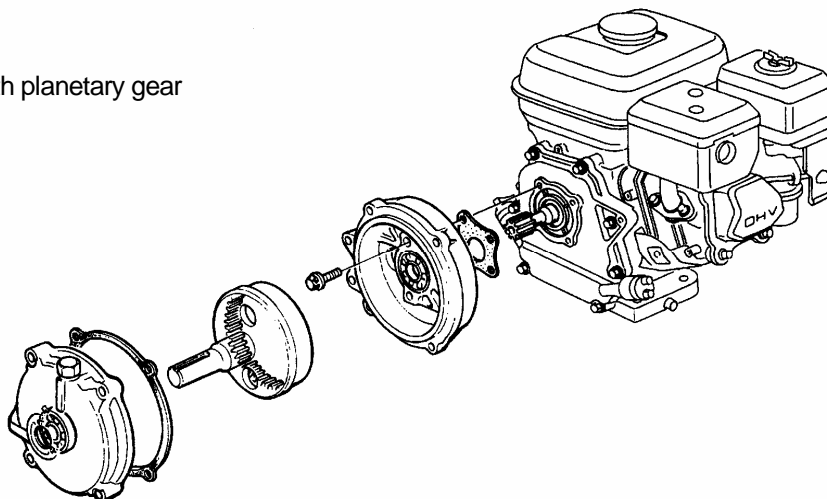
L-TYPE

1/2 reduction with chain-sprocket

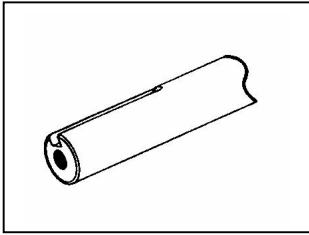


H-TYPE

1/6 reduction with planetary gear



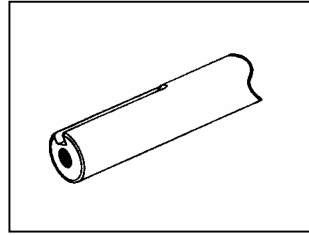
STANDARD OUTPUT SHAFTS



S: straight (mm)

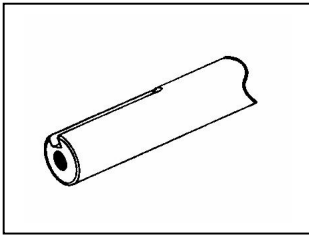
Metric standard type

Used for power transmission through pulley, centrifugal clutch and direct coupling



L: straight (mm)

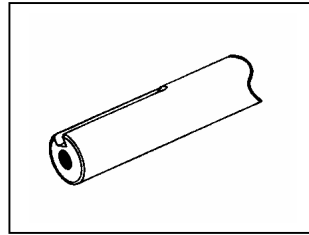
1/2 reduction type for applications with low rotational speed



Q: straight (inch)

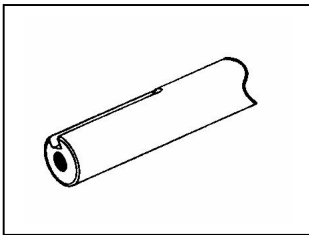
Imperial standard type

Used for power transmission through pulley, centrifugal clutch and direct coupling
Offers bigger diameter than similar S-type shaft



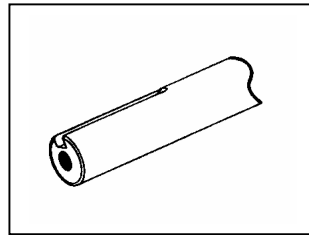
H: straight (inch)

1/6 reduction type for applications with very low rotational speed



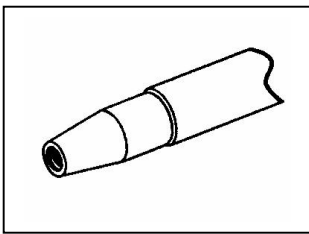
T, B : straight (inch)

Imperial standard type, big diameter, for high power output engine types (V-twin)



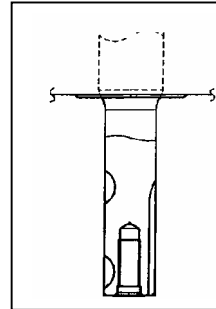
R: straight (mm)

1/2 reduction type with centrifugal clutch



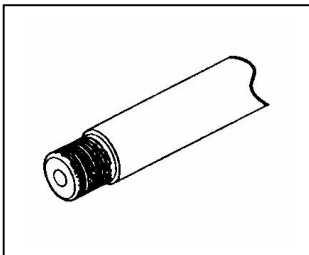
V: tapered (inch)

Conical shaft for generator coupling



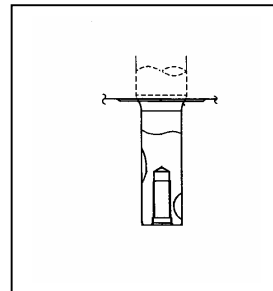
N-type long

Vertical shaft for lawnmower application
Long type for additional pulley mounting



W: straight with thread (mm)

Shaft for direct coupling of waterpump impeller



N-type short

Vertical shaft for lawnmower application

POWER TRANSMISSION SYSTEMS

The power transmissions between the engine output shaft and the application can be classified into three types:

- Direct drive - direct shaft coupling as used on generator, pump.
- Belt drive - as used on plate compactor, compressor.
- Other drive – gear drive, clutch, transmission, flexible coupling, etc.

Transmission efficiency

- Direct drive $\eta = 1.00$
- V - Belt drive $\eta = 0.95$
- Flat belt drive $\eta = 0.90$
- Flexible coupling $\eta = 0.98$

Shaft coupling

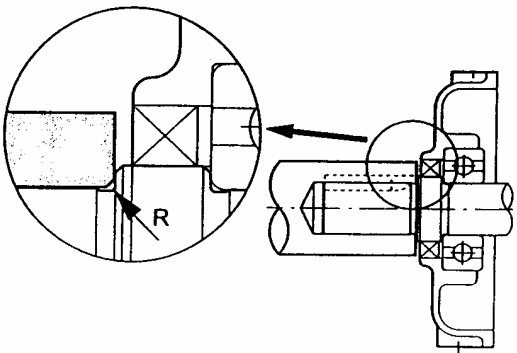
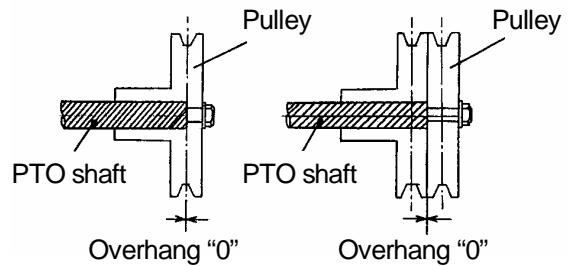
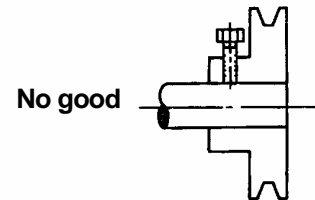
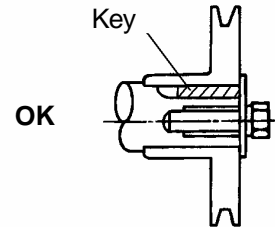
Install the attachment (pulley, clutch) on the crankshaft using a correct key.
Use the appropriate washers and retainer bolt and torque the bolt securely.

Don not install an attachment without a key.

Do not secure an attachment with a retainer bolt directly on the engine output shaft.

The attachment center should not overhang the end of the crankshaft.

Mount the attachment as close to the engine as possible.



Interference between the inner chamfer of the attachment shaft and the engine output shaft shoulder (point R) should be checked carefully.

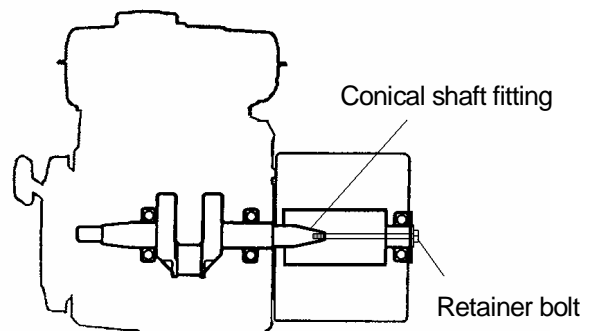
If the inner chamfer of the attachment shaft is too sharp, there is a risk of cutting through the hardened surface of the engine shaft.

Three bearing drive

This connection method builds up a unitary construction which distributes the load over the complete structure and is generally used for generators and high pressure pumps.

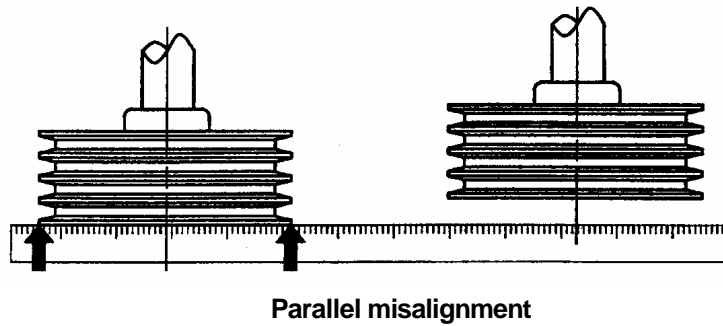
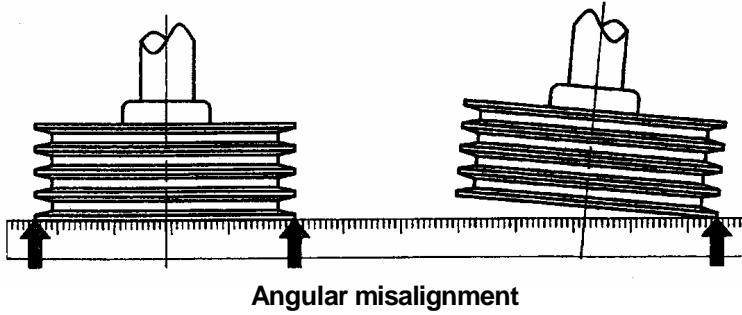
For correct alignment of the engine shaft and application shaft, the mounting surface of the application must be machined accordingly.

In case of conical shaft fitting, the connection must be secured by a retainer bolt.



BELT DRIVE SYSTEMS

Pulley alignment



Calculation of pulley ratio

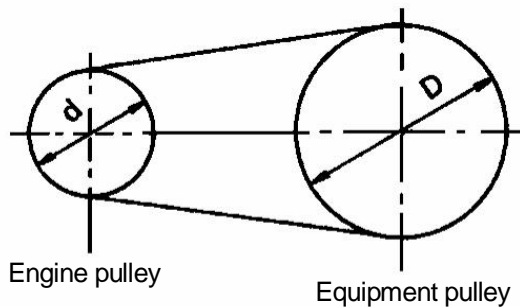
- Check the operating speed of the equipment
- Determine the recommended operating speed of the engine
- Determine the minimum diameter of the smallest pulley (see minimum pulley diameter-belt type)
- Calculate the pulley diameters with the formula :

ENGINE

EQUIPMENT

$$\text{Pulley diameter (d) x Engine speed (n)} = \text{Pulley diameter (D) x Equipment speed (N)}$$

$$D = \frac{d \times n}{N}$$

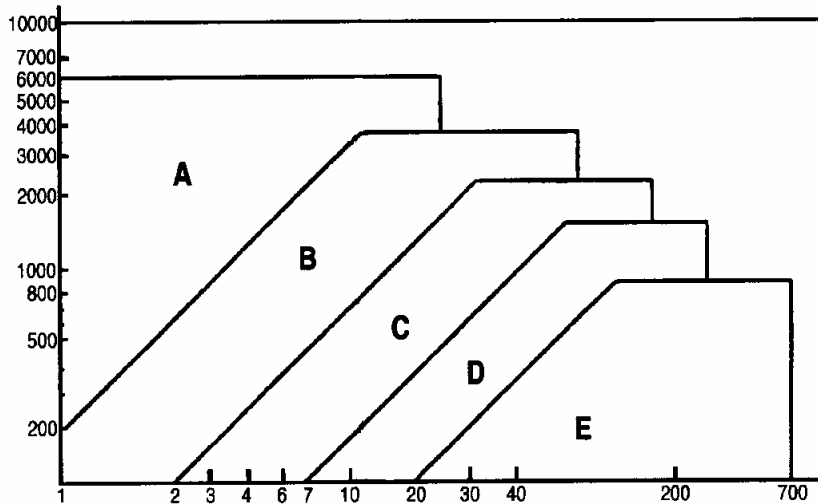


Minimum pulley diameter – belt type

Small pulley diameters increase the bending stress on the V-belt, have a limited contact area between belt and pulley and therefore reduce the transmission efficiency and durability.

Minimum diameter pulleys should be avoided as much as possible.

- For A-type belts used on engines of less than 5.0 HP, the minimum pulley outer diameter is 80 mm.
- For A-type belts used on engines of 5.0 HP or more, the minimum pulley outer diameter is 90 mm.
- For B-type belts used with all engines, the minimum pulley outer diameter is 120 mm.



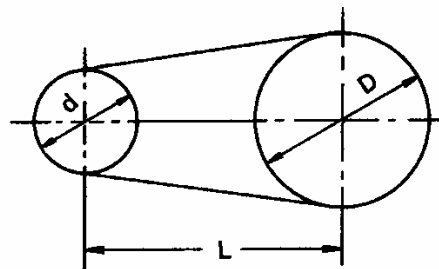
Belt type	M	A	B	C	D	E
Belt width (mm)	10	13	17	22	32	40
Minimum pulley diameter (mm)	50	80	130	200	300	450

DETERMINING LENGTH OF BELT

$$\text{Belt length} = 2L + \frac{\pi}{2} (D + d) + \frac{(D - d)^2}{4L}$$

$$\text{Belt number}^* = \frac{\text{belt length (mm)}}{25.4}$$

* round off fractions to next higher integer



CALCULATION OF BELT SPEED

$$\text{Belt speed (m/s)} = \frac{\pi \times (\text{small pulley diameter mm}) \times (\text{small pulley rpm})}{60 \times 1000}$$

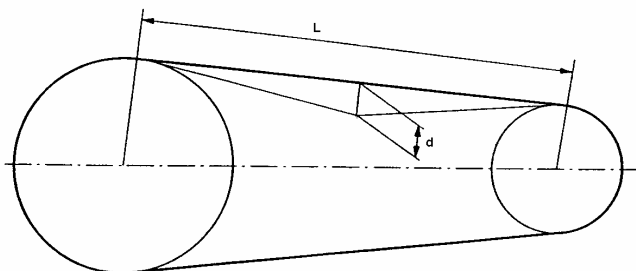
Ideally, V-belt speed should be approximately 15 m/s to 20 m/s.
 Power transmission efficiency drops when V-belt speed is over 22 m/s.
 V-belt speed should not exceed 30 m/s.

BELT TENSION SETTING

Damage may occur to the belt due to operation with excessive tension; where under insufficient tension it may slip and cause a decrease of the transmission efficiency and durability.

Apply a force (see table below) perpendicular to the belt on the center point of the span (L) .
 Adjust the deflection (d) so that:

$$d = 0.016 \times L$$



Belt type	Diameter of small pulley (mm)	Minimum setting		New belt setting	
		Force to deflection (kg)	Axial load (kg)	Force to deflection (kg)	Axial load (kg)
M	40 - 50	0.5	14	0.7	20
A	67 - 80	0.8	23	1.2	34
	81 - 90	0.9	26	1.4	39
	91 - 105	1.1	31	1.7	46
	106 -	1.2	35	1.8	53
B	118 - 135	1.4	45	2.1	68
	136 - 160	1.8	54	2.7	81
	161 -	1.9	58	2.9	86
C	180 - 205	2.8	84	4.2	126
	206 - 255	3.3	102	5.0	153
	256 -	3.9	119	5.9	178
D	300 - 330	5.7	171	8.6	256
	331 - 390	6.8	208	10.2	312
	391 -	7.4	226	11.1	340
E	450 - 550	10.4	316	15.6	347
	551 -	12.4	378	18.6	568

* Adjust the belt tension in between minimum setting and new belt setting.

POWER CORRECTION FACTORS FOR V-BELT DRIVES

The table below gives the power multiplication factors for different kinds of applications and running periods. The procedure is to multiply the actual power which has to be transmitted by the correction factor and to determine the belt size according to this corrected power.

Operating hours / day for internal combustion engines with less than 4 cylinders.

	Up to 10 hours / day	From 10 to 16 hours / day	Over 16 hours and continuous
Light duty	1.1	1.2	1.3
Medium duty	1.2	1.3	1.4
Heavy duty	1.4	1.5	1.6
Extra heavy duty	1.5	1.6	1.8

Light duty:

Blowers – centrifugal pumps – rotary compressors – fans up to 7.5kW – light duty conveyors.

Medium duty:

Belt conveyors for sand, grain, etc. – mixers – fans over 7.5kW – generators – machining tools – presses – positive displacement rotary pumps – vibrating screens.

Heavy duty:

Bucket elevators – piston compressors – piston pumps – pulverizers – wood working machines.

Extra heavy duty:

Crushers – extruders – mills.

CRANKSHAFT LOADING

The sources of PTO shaft loading can be separated into two groups:

Sources of axial (thrust) load

- Centrifugal pumps with open faced impellers
- Plate type clutches
- Fans and blowers

Sources of radial load

- Belt drive systems
- Chain drive systems
- Gear drive systems

Ball bearings on the crankshaft can withstand radial load as well as axial load.

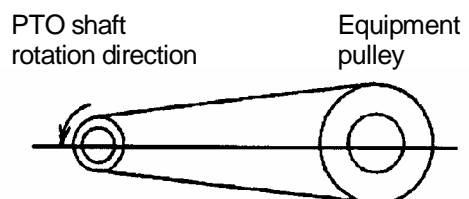
Plain bearings on the crankshaft can withstand radial load but a thrust washer should be installed on the crankshaft to support axial load.

In order to reduce crankshaft bearing load on GX engines with inclined cylinder, the belt drive should be set up in the following way. In the horizontal position, the driven shaft of the application must be located to the right side of the counterclockwise rotating engine PTO shaft.

With this set up, the load on the crankshaft bearing: static belt tension and engine combustion load, are well balanced.

Other recommendations to reduce engine bearing overload:

- multiple belts in case of high power transmission
- pulley(s) on the PTO shaft as close as possible to the bearing
- pulley diameter and distance between pulleys big enough to ensure adequate belt contact
- correct belt tension.



BELT DRIVE: CALCULATION OF RADIAL LOAD

The radial load on the engine crankshaft on belt drive systems is composed of:

- the static radial load determined by the belt tension (see page 72)
- the dynamic radial load determined by the engine torque and the diameter of the engine pulley

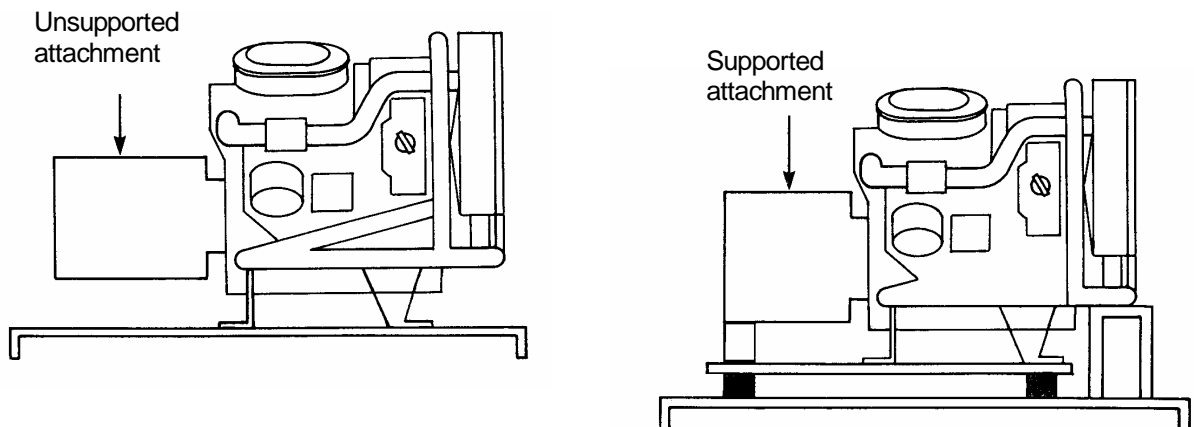
The smaller the pulley diameter on the engine's crankshaft, the higher is the radial load.

An approximate formula can be used to calculate the dynamic radial force.

$$F \text{ (radial force in N)} = \frac{M \text{ (engine torque in Nm)} \times 2}{D \text{ (pulley diameter in m)}}$$

DIRECT DRIVE SYSTEMS

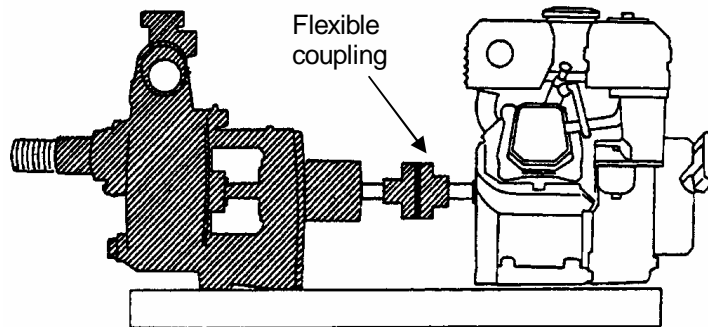
- Support the attachment at the backside
Too much weight attached to the engine crankcase / crankcase cover may damage the oil packing or oil seals.



- Align the drive and driven shaft perfectly; maximum run-out in driven shaft is below 50 µm
- Ensure that the driven shaft is balanced within 30g-cm to minimize vibration and bearing wear.
- Limit the weight of the directly coupled attachment to a minimum so that:
 - required recoil starter pulling force is within the limits
 - minimum required engine rpm can be reached to start the engine with the recoil starter
 - electric starter cranking current is within the limits
 - engine running-out time is not too long
 - there is no afterburn in exhaust system.
- Ensure that the thrust load on the engine shaft is within the limits (eg. waterpump impeller).

DIRECT DRIVE SYSTEMS

- Use a flexible coupling on the drive shaft when the attachment is very heavy, heavily pulsating or when the alignment is not precise.



- Timing of attachment power cycle to engine power cycle

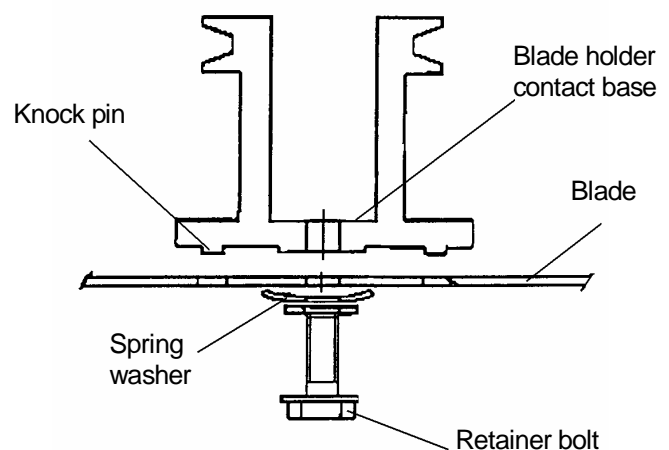
In applications where a single cylinder engine is directly coupled to a multi-cylinder, pulsating application (multi-cylinder compressor, waterpump, hydraulic pump), it is important to synchronize the power cycle of the engine (combustion stroke) with the power cycle of the application (high pressure, maximum delivery reached).

- Lawnmower blade holder coupling

The lawnmower blade holder fixing on the engine shaft is very critical with regards to user's safety and engine shaft damage protection.

Attention points:

- Correct blade holder depth and inner diameter for tight fit on crankshaft.
- Correct dimension of key and key-way for tight fit on crankshaft key-way
- Blade holder contact base flat surface for overall contact with crankshaft face
- Retainer bolt correct tightening torque
- Washer and spring washer quality for securing the retainer bolt
- Blade holder material hardness ; no material deformation on contact area crankshaft – blade holder



INERTIA

Inertia is that property of matter, which causes a resistance to any change in the motion or velocity of a body.

The present consideration of inertia relates to changes in the rotational speed of the engine, caused by the flywheel and the rotating members directly attached to the engine crankshaft. A flywheel is used on an engine to even out load pulsations or cyclic speed changes caused by combustion pressures.

Every engine has a minimum rotational inertia required for satisfactory operation. This is an important consideration for ease of starting, to prevent kickback as well as for smooth operation.

With the advent of blade brake clutch applications, it became necessary to study this item more in detail. A flywheel change alone may improve or enable an application to be satisfactory.

Applications using engines with very low inertia driven attachments may have inadequate starting performance; a small portable waterpump with a light weight plastic impeller is such an example.

Note that the required rotational inertia can be satisfied by a flywheel or other member directly coupled to the crankshaft (mower cutting blade, ...) and that this inertia is the resultant total inertia of the flywheel and all directly coupled rotating members in combination.

Inertia can also be excessive causing hard starting, delayed stopping and possible torsional problems.

The high inertia system is more difficult to set in motion causing hard starting for both rewind and electric starting systems.

Once in motion, the high inertia system is more difficult to stop resulting in higher stopping times with following possible problems:

- flooding / restart problems may develop as fuel continues to be drawn into the cylinder while the engine is rotating.
- eventual engine damage due to continual flooding
- safety concerns as rotating parts are still in motion for some period after initial shutdown

Finally, high inertia can cause torsional problems since one end of the crankshaft is coupled to a high inertia driven member which attempts to rotate at a constant speed while the crankshaft itself is driven by combustion pressure at fluctuating speed over the cycles.

Resulting torsional stresses may lead to failure of the crankshaft or the joint at which the driven member is attached to the crankshaft.

For example:

To keep the flywheel brake performance on a lawnmower engine within the limits of the EN safety regulation (3 sec. stopping time), the total inertia mass of all parts fitted to the engine PTO shaft must be within certain limits.

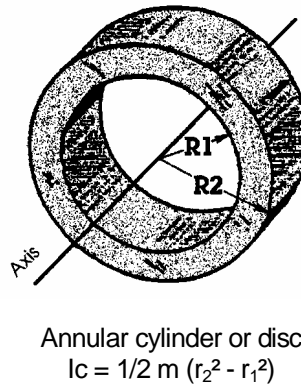
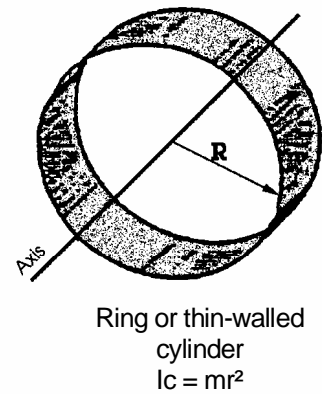
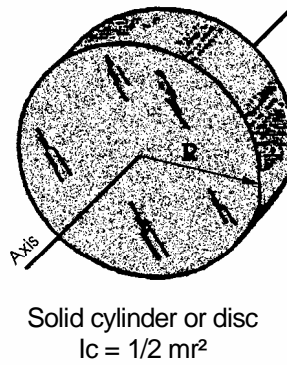
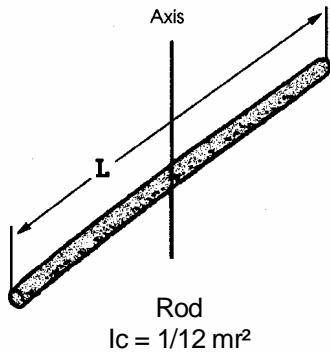
Maximum total inertia mass is 250 kg/cm² of which:

Blade is 228 kg/cm²

Blade holder and pulley 22kg/cm²

INERTIA OF ROTATING MEMBERS

Some standard formulas are available for determining the rotational inertia or $m r^2$ of less complex shapes. The “ $m r^2$ ” formula can be used to determine the approximate rotational inertia of flywheels, pulleys, gears, etc.



I_c is the rotational inertia of various rigid bodies around their geometrical centers and is the product of the total mass (**m**) of the body and the squared number of the radius (**r²**) of the body.

From the above relationship, it is apparent that the rotational inertia of a body depends upon two factors:

1. The total mass or weight of the body
2. The distribution of the mass around the axis of rotation
This is determined by the size and shape of the body.

The single cylinder engine has unique characteristics that must be considered in the power output, power transmission and vibration.

The illustration shows the typical cyclical speed variation of a single cylinder engine.

The horizontal line marked as "Crankshaft rpm" is the average engine speed, such as you would read on a typical tachometer with normal damped response.

At the time of ignition, just before TDC, the instantaneous rotational speed is at its lowest point.

As combustion occurs, the piston is very rapidly accelerated to its maximum speed during the power stroke and then the engine "coasts" and gradually loses speed until the next power stroke occurs.

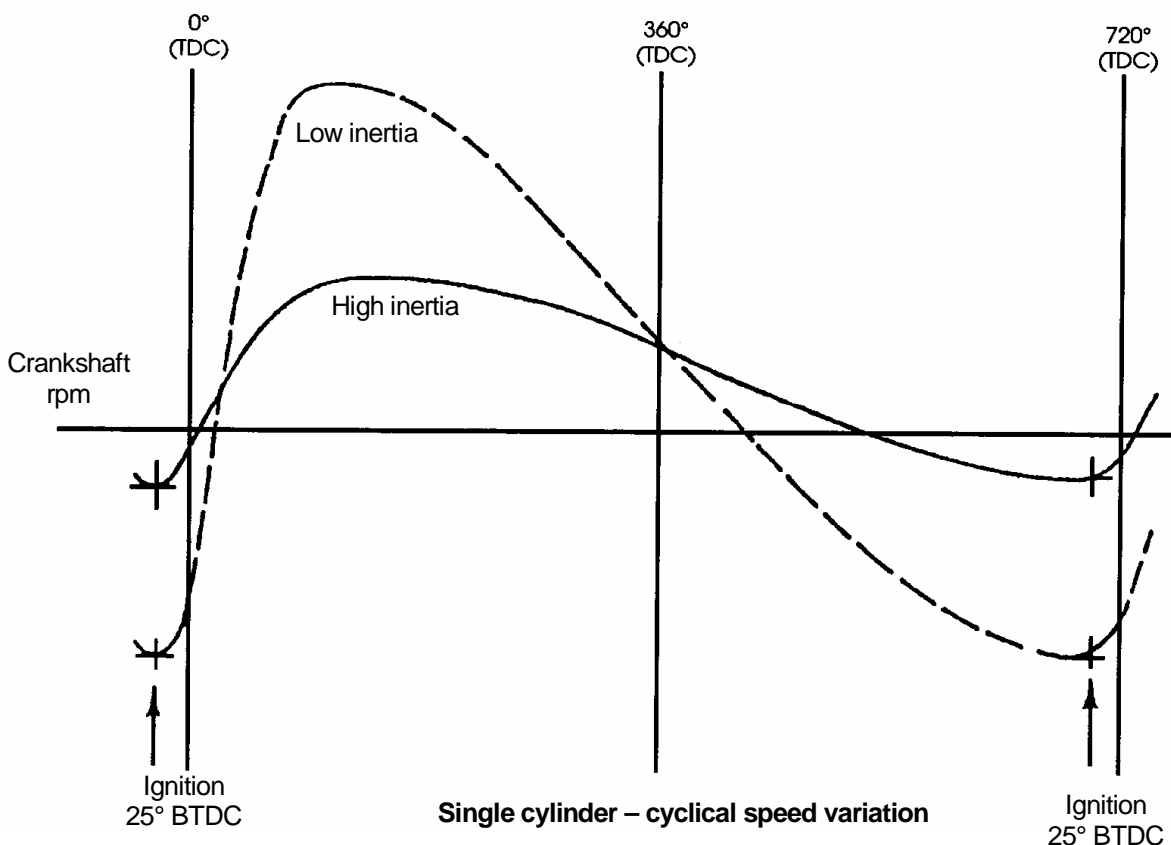
As shown on the illustration, the speed change is affected by the inertia of the system, with the lightest inertia having the highest acceleration and speed change.

During the power stroke acceleration, the instantaneous torque is very high and typically 7 or 8 times the average torque of the engine. The momentary speed change with attached rotational inertia equivalent to a rotary mower blade is 300 – 400 rpm.

With very light rotational inertia, it has been experimentally found that the torque is as high as 14 times the average torque and the momentary speed change is around 1000 – 1200 rpm.

This speed characteristic can explain why it is necessary to use proper size belts and pulleys to avoid power loss and why it is necessary to have very tight connections to the crankshaft PTO to avoid rocking, fretting or damage.

In general, the greater the inertia the more important is the connection, as the largest inertia takes most of the load on acceleration, stores most of the energy and supplies the most energy as its "coasts" to the next power stroke.



Use the following formulas to calculate the approximate maximum horsepower of the engine to drive a given application.

COMPRESSOR

$$\frac{\text{Air displacement (l/min)} \times \text{maximum pressure (bar)}}{747} = \text{Max. engine power (HP)}$$

GENERATOR

$$\frac{\text{Max. power output alternator (kVA)} \times 1.34}{\text{Alternator efficiency } 0.8} = \frac{\text{Max. continuous engine power (HP)}}{0.85} = \text{Max. engine power (HP)}$$

CENTRIFUGAL WATER PUMP

$$\frac{\text{Capacity (l/min)} \times \text{total head (m)} \times 0.38 \times 50 \text{ mm/pump outlet diameter (mm)}}{1980} =$$

$$\frac{\text{Max. continuous horsepower (HP)}}{0.85} = \text{Max. engine power (HP)}$$

HIGH PRESSURE PUMP – HYDRAULIC PUMP

$$\frac{\text{Pressure (bar)} \times \text{capacity (l/min)}}{440 \times \eta} = \text{Max. engine power (HP)}$$

$\eta = 0.6$ (water)
 $\eta = 0.7$ (oil)

ROTARY MOWERS

Guideline for walk behind lawnmower

- Cutting width: 42 cm - 2.6 HP
- 46 cm - 3.5 HP – 5 HP
- 47 cm - 4.5 HP - 5 HP
- 53 cm - 4.5 HP – 5.5 HP

Guideline for ride-on mower

- Cutting width: 76 cm - 11 HP
- 97 cm - 13 HP
- 102 cm - 13-14 HP
- 105 cm - 16 HP
- 120 cm - 20 HP

Conversion table: engine mechanical power to generator electrical power

Maximum Generator output (VA) (1)				
Engine model	Max. engine Power (W) (95%)	Max. governed engine power (W) (85%) (*80%)	alternator efficiency (2)	
			0.70	0.80
G100K2	1380	1170	820	940
G150K1	2380	2020	1410	1620
G200K1	3230	2750	1920	2200
GC135	2280	1824 *	1277	1459
GC160	2800	2240 *	1568	1792
GX100	1760	1500	1050	1200
GX120K1	2370	2000	1400	1600
GX160K1	3280	2790	1950	2230
GX200	3890	3310	2320	2650
GX240K1	4940	4200	2940	3360
GX270	5650	4800	3360	3840
GX340K1	6940	5900	4130	4720
GX390K1	7840	6660	4660	5330
GX610K1	12160	9730 *	6810	7780
GX620K1	12780	10220 *	7150	8180
GX670	15200	12160 *	8510	9730
GX360K1	7700	6550	4580	5240
GX640	13100	11100	7770	8880
GD321 / 100 dB(A)	4270	3630	2540	2900
GD411 / 100 dB(A)	5700	4800	3360	3840

(1) For generators with direct coupled 2-pole single bearing type alternators
At steady speed 50Hz / 3000 rpm and cos phi = 1
Accuracy : +/- 0.15 kVA

(2) Total alternator efficiency including all electrical and mechanical losses

Important Notes :

- 1) The listed generator output values are in accordance to the engine operating conditions for power measurements according to SAE J607a (SAE J1349 for GD321/411)
(ambient temperature 15.6 °C / atmospheric pressure 760 mm Hg)
- 2) After running-in of the engine has been completed, due to the standard tolerances in actual engine power output, a tolerance of 0 / -5% must be allowed on the listed maximum generator output values.
- 3) Generator maximum output values for continuous operation will be generally 10-15 % lower.
- 4) The listed generator output values are only applicable to generators featuring an unrestricted engine surrounding (no enclosure / no shrouds etc...)

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A large, empty rectangular box with rounded corners, intended for writing notes. The box is outlined in black and occupies most of the page area below the header and above the footer.

