

Development of ENEPO Gas Canister-powered Generator

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ABSTRACT

A generator was developed that uses a gas canister for fuel in order to make it easy to handle and store, as well as to use for people who are not accustomed to generators. Development was aimed at opening up new market opportunities focused on residential usage.

In outward appearance, the generator was given a tall, slim form in order to enhance its maneuverability and to make it more flexibly storable by minimizing its footprint. The handle was also optimized for enhanced transport, and the generator design was made functional and easy for residential user.

The generator was given a dual gas canister specification to assure continuous operation time of one hour or more, and this structure was also configured to prevent backflow of fuel between the gas canisters. A mechanism to prevent the gas canisters from being installed incorrectly, a system to stop the engine when the generator is excessively leaned, and an external breather structure to prevent the emission of white smoke when starting the generator after it has been lying on its side were also adopted.

As techniques for enhancing marketability that take handling quality into account, a wheel and handle were included as standard equipment to make the generator easier to carry. The traditional choke system was also eliminated and an engine switch interlinked with the fuel valve was adopted to simplify the starting procedure.

1. Introduction

The generator market in Japan is largely a market for industrial use generators, and the home use market is still relatively undeveloped. Factors in this situation include the difficulties of storing and handling the fuel, namely gasoline.

There has been an increase in fully electrified residences, however, and lifestyles are growing more thoroughly dependent on electrical products. In this context, people can be expected to use electricity in a variety of different situations as part of residential use, and the heightening awareness of disaster preparedness is likely to be accompanied by a growing need for backup power sources.

There is also thought to be a potential market for power sources to support camping, gardening, and other “second life” leisure activities by members of the baby boom generation who have been retiring in recent years.

The aim of this development was to provide customers

with easy-to-handle generators fueled by gas canisters that are readily available and storable. The purpose in doing so was to stimulate the latent needs among general consumers who had never used a generator before, and to create a new personal market for this product.

2. Development Concept

2.1. Concept

The concept of this development was to aim for placement as a gas-canister generator for residential users, with the slogan, “One for Every Household.” Under ordinary conditions, it could easily be used for family leisure, special activities and events, hobbies, and so on. Moreover, when the need arose, it could also serve as a household portable generator for backup power supply. The specific requirements for these purposes were as follows:

- (1) The generator should be easy to use and simple to operate, even for people who are unaccustomed to such equipment.

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- (2) The generator should be easily portable and quickly usable for family leisure and hobby activities.
- (3) The generator should be in a format that allows easy storage in small spaces, in consideration of housing conditions in the Tokyo area.
- (4) The generator should allow worry-free use.
- (5) The generator should be a product that provides the pleasure of ownership.

This generator was named by combining the words “Energy,” “Portable,” and “Epoch” to form ENEPO, embodying the meaning of “portable energy that inaugurates a new era for generators.” Figure 1 shows an external view of the ENEPO.

2.2. Target Users

Given the product concept of “One for Every Household,” the target user was broadened from the two-generation family living in a detached house in the suburbs of Japan to also include the nuclear family living in an apartment in the Tokyo metropolitan area. This target was envisioned as also including the older generation that has no particular familiarity with generators. The use of the product was also envisioned as providing a power source for barbecues, auto camping, cherry blossom viewing, and other such family activities, as well as for do-it-yourself work, gardening, fishing, and other such individual pastimes.

2.3. Conceptual Approach to the Exterior Design

The ENEPO styling was based on the key words “Smart Slim Design” (Fig. 2). The image was derived from a slim longitudinal form suggesting ease of storage even in the cramped dwelling spaces of metropolitan Tokyo. The image was also designed to convey, rather than a working machine, something smart and slender like a household appliance or item of furniture with inherent cleanliness (although the generator must not be used in the home). The aspect of portability was envisioned with the widely popular caster bag in mind, in order to suggest a smartly transportable style.



Fig. 1 External view of ENEPO

Smart Slim Design

Slim form;
Longitudinally slim for
convenient storage.

Smart movement;
Transportation with the
image of a caster bag.



Smart external appearance;
Designed with reference to
household appliances and
items of furniture that
convey a sense of
cleanliness.

Fig. 2 Conceptual image of exterior design

3. Longitudinal Design

3.1. Advantages of Longitudinal Design

3.1.1. Enhance ease of operation

In order to enable more effective ease-of-use of the longitudinal slim design, the controls were placed higher up. This was done to minimize the sequence of operations that requires users to bend over at the waist. The generator was also configured with a total height (a) (as shown in Figs. 3 and 5) that would not require users to bend as much at the waist or knees when picking up the generator by the upper grip.

The gas canister loading mechanism (b) was located at the top of the generator to allow a closer view and encourage positive loading of the canisters.

The engine switch (c) was then placed below that, and the Stop switch position was placed at the top to make it more conspicuous (as shown in Figs. 4 and 5).

Considering the length the grip would be pulled, the position of the recoil grip was set at the appropriate height (d), where users could start the generator with a sense of security, bending the waist as little as possible (Fig. 5).

The layout has the AC socket location (e) low down on the right side of the generator. As this position makes it less likely that users walking by might trip on plugged-in AC cords, this configuration was determined with usability in mind. The 250-mm above-ground height of (e) (above the ground) is about the usual height of AC sockets in ordinary houses, and the height that home users will be most accustomed to (as shown in Figs. 5 and 6).

3.1.2. Increase freedom of placement

The functionality for “One for Every Household,” especially for users in dwellings in the Tokyo metropolitan area, includes storage of the generator when not in use (the generator must not be used in the home). This matter of the storage location can also be an important motivation for

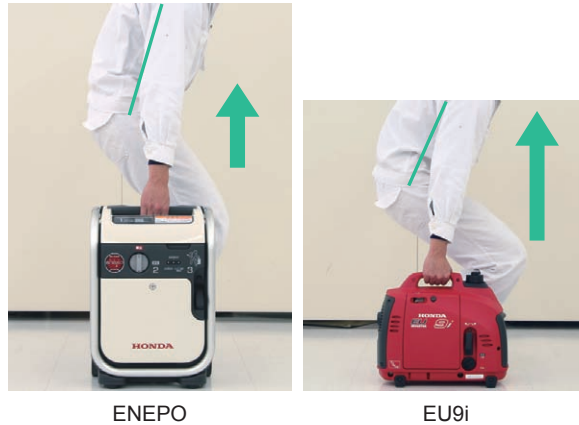


Fig. 3 Comparison of postures when lifting

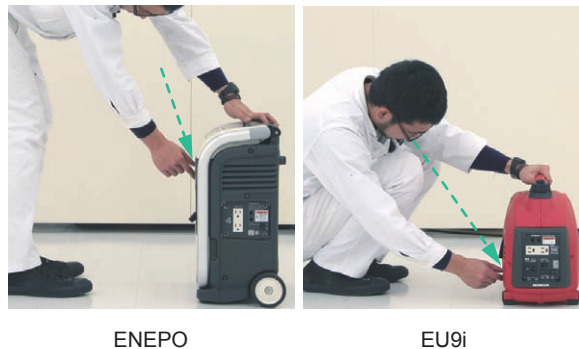


Fig. 4 Comparison of postures when using controls

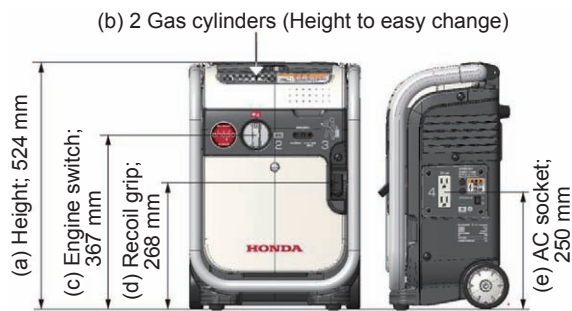


Fig. 5 Height of ENEPO controls



Fig. 6 Height of EU9i controls

purchase. The envisioned storage locations consist mainly of store rooms, storage shelves, and other such places, with a storage size about 450 mm in width at the narrowest, about 270 mm in depth, and varying heights. These locations were taken into consideration in deciding the generator footprint. The longitudinal design of the generator also contributed greatly to reduction of its footprint, yielding superior storage performance (Fig. 7).

3.1.3. Enhanced mobility

When pulling the generator along like a caster bag, a sense of comfortable movement can be achieved by optimizing the generator's load toward the operator as well as the distance between the user and the wheels.

In the case of the ENEPO, the user grip point (A) was therefore set at 750 mm. Next, the center of gravity when the generator is tipped over was displaced from the vertical toward the user and the tipping angle for pulling was set at 26° (B), and the clearance (C) between the generator and the user when walking was established. The required length of the handle (D) when extended from the generator was then determined (Fig. 8).

The configuration takes ideal advantage of the generator's longitudinal design by placing the hinge point (E) of the handle on the diagonal line across the side face of the generator. This method of folding the handle maximizes the

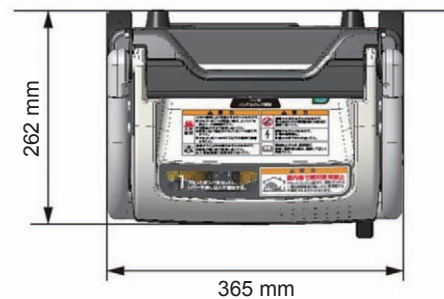


Fig. 7 ENEPO footprint

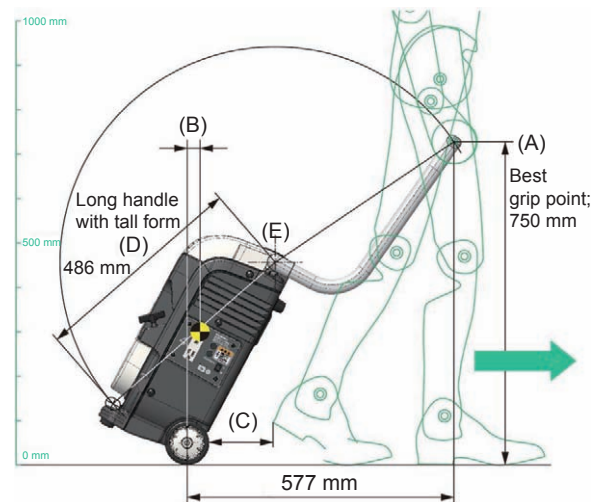


Fig. 8 Side view (generator being pulled)

distance of extension when the handle is extended to point (A) and does so with simplicity and durability.

3.1.4. Functional, clean-looking exterior design

The longitudinal design is offered with a functional layout that locates the controls high up for ease of use, has a small footprint for ease of storage, and is well suited to the use of a folding handle. This layout was then given a simple, clean-looking exterior design in order to further refine the generator's functional beauty. The purpose, which was also the development concept, was to give the product a market appeal in its external appearance that would match the tastes of home users in the Tokyo metropolitan area.

The following techniques were used:

- (1) The folding handle was formed from extruded silver-colored aluminum parts. When stored, the handle is recessed into the generator body to provide a unified appearance.
- (2) The exterior cover was given two-tone coloring that combines whites and blacks. Complex louver shapes and the controls were made all black to enhance the generator's simplicity and longitudinal slimness, and this realized a clean-looking external appearance with market appeal.

As a result, the generator design was more like a household appliance than a working machine for outdoor use, achieving differentiation from conventional products (Fig. 9).

3.2. Design of Control Indicators

3.2.1. Numerical indicators in line with operating procedures

Envisioning first-time generator users and blackouts or other such occasions when power is needed quickly, a system of indicators was devised to ensure error-free operation with a sense of security. The numbers from 1 to 4 were marked on the front surface of the generator with a height of 17 mm to indicate the order of operations from loading the gas canisters to starting the engine and plugging in to the power socket. This indicates what needs to be done first to start operating the generator. The words in the explanations accompanying those numbers were also made



Fig. 9 ENEPO coloring

large and easy to read with a height of 4.5 - 7.5 mm. Further consideration was given to ease of sensory comprehension by adding large illustrations (Fig. 10).

3.2.2. Designing warning marks for gas canister use

ENEPO and other engine generators are like motorcycles and automobiles in that they emit carbon monoxide. Therefore, it is an iron-bound rule that they be operated outdoors, as carbon monoxide poisoning will typically occur during indoor operations. Gas cooking stoves, however, which are the most widely used products employing gas canisters for home use, are products for indoor use. In order to make certain that home users who are accustomed to handling these products do not operate the ENEPO indoors in the same way they do gas canister stoves, a warning mark (a) strictly prohibiting indoor operation and a general warning mark (b) about engine generators are displayed on the generator. The warning mark (a), in particular, includes the statement, "The exhaust contains a higher concentration of carbon monoxide than is found with gas canister stoves, so there is a risk of carbon monoxide poisoning from use even for a short time." In order to make users recognize these warnings before operating the generator, a design was adopted that prominently displays the (a) and (b) warnings together with illustrations at the most visible position close



Fig. 10 Numbers indicating operating procedure sequence

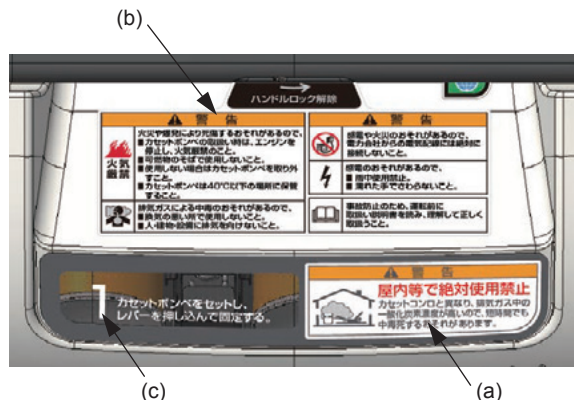


Fig. 11 Warning marks

to the number 1 marking the first operating procedure (c) as described above. This ensures that the warnings will easily be in view (Fig. 11).

4. Technology Employed in ENEPO

4.1. The ENEPO Gas Canister System

The gas canister connector on the generator differs from the Pianta compact domestic-use cultivator⁽¹⁾, which was Honda's first such gas-powered product, in that the generator is capable of loading two gas canisters. This enables the generator to provide 1.1 hours of continuous operation at the rated load of 900 VA (Fig. 12).

Figure 13 shows a structural drawing of the gas canister adaptor that is the fuel connector for the two gas canisters.

This gas canister adaptor has the following three functions:

- (1) Manual cock to open and close the path for fuel removed from the gas canisters in liquid phase
- (2) Fuel cut valve that is operated by fuel pressure
- (3) Backflow prevention valve that prevents fuel from charging the gas canisters

The following selects the backflow prevention valve (3) out of these three functions and describes the history of its development, its function, and its structure.

4.1.1. History of backflow prevention valve development

The gas canisters are non-refillable, and their refueling is forbidden under the High Pressure Gas Safety Act. However, the pressure inside the gas canisters will change



Fig. 12 Comparison of gas canister connectors

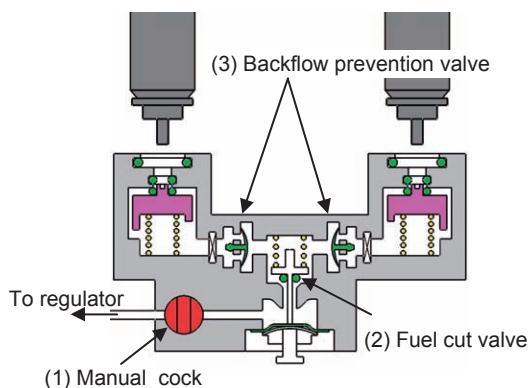


Fig. 13 Structural drawing of gas canisters and adaptor

with the ratio of components in the gas canisters (ratio of isobutane to normal butane) and the temperature of the canisters themselves. Consequently, the two canisters will not necessarily be under identical pressure. When the gas canisters are connected in parallel with the adaptor between them, therefore, the fuel that flows together into the gas canister adaptor will flow from the canister with the higher pressure to the canister with the lower pressure. This can result in phenomena similar to refueling and overcharging. For the ENEPO, therefore, a structure was devised and adopted to prevent fuel flowing from one gas canister to the other when two canisters are loaded.

4.1.2. Function and structure of the backflow prevention valve

Figure 14 shows a conceptual image of the backflow prevention valve mechanism in operation. For example, when the internal pressure of gas canister A is greater than that of gas canister B, then the backflow prevention valve on the A side opens and the backflow prevention valve on the B side closes, preventing the backflow of fuel to gas canister B. As a result, charging of gas canister B does not occur.

4.1.3. Gas canister loading system

The gas canister loading system on the ENEPO was structured to yield the force necessary to fix the gas canister against a spring by moving a control lever that has a linking mechanism. This allowed the use of a single control lever to hold two gas canisters securely in place (as shown in Figs. 15 and 16).

The ENEPO is like the Pianta in that it takes fuel from the gas canister in liquid phase. Since the gas canisters need to be fixed in place with the notch down, users will be required to insert the gas canisters with the notch down⁽¹⁾.

Consequently, in the developed configuration, when the notch on the flange of a gas canister is not facing down, the

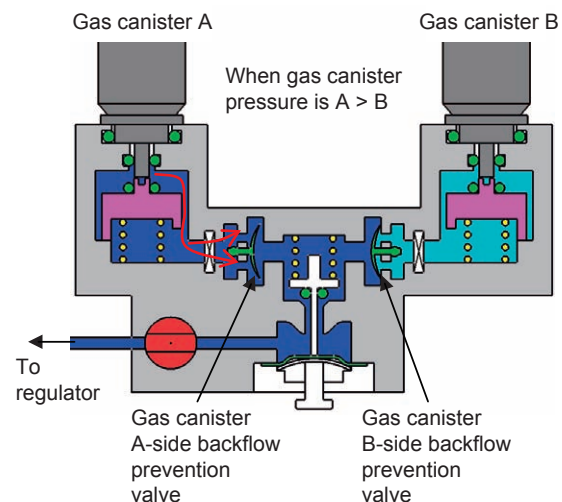


Fig. 14 Conceptual image of operation of backflow prevention valve

sensor arm that is usually held up by the force of the return spring will be depressed by the flange. If the user starts to move the control lever with the canister in that state, the sensor arm and the top cover will come into contact, and the mechanism is designed to lock up the control lever when that happens (Fig. 17).

The specifications also call for the parts to be configured so that the gas canisters are fixed in place tilted at an angle of 25°. This forces the fuel in the gas canisters to be consumed to the fullest extent (Fig. 15).

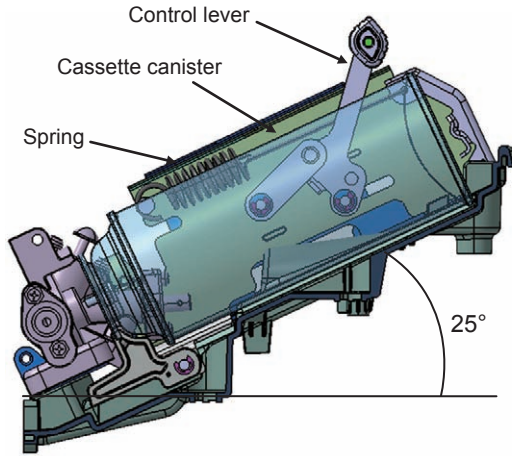


Fig. 15 Before setting

The gas canister loading system yields the force against a spring by moving a control lever.

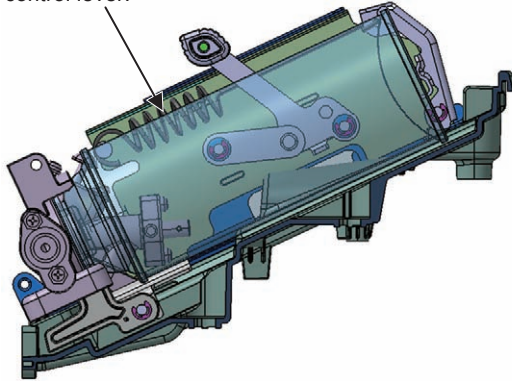


Fig. 16 After setting

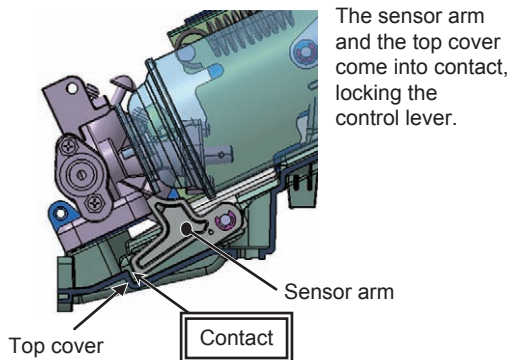


Fig. 17 Incorrect setting

4.2. Engine Stop System

When operation of the engine is continued while tilted over at too sharp an angle, the lubricating oil flows into the combustion chamber or passes through the breather and the air cleaner to infiltrate the combustion chamber. This causes the oil to ignite inside the combustion chamber, and white smoke is generated as a result. A system was therefore devised to detect tilting in the generator's operating attitude and automatically stop the engine.

The detection and control of the generator's angle is handled using an acceleration sensor in an inverter unit and an electronic controller to process its output. The system detects the tilt of the generator from the direction of acceleration relative to the earth's axis. The system is thus designed to allow stopping of the generator engine and power generation at the desired amount of tilt and after the desired amount of time by configuring a freely selectable threshold angle value that will stop the generator when tilted to the extent that it cannot remain standing on its own.

The quantity G_{xyz} , which is the combination of accelerations on the X, Y, and Z axes of the acceleration sensor, comes to 1 g, as shown by the equation below:

$$G_{xyz} = \sqrt{G_x^2 + G_y^2 + G_z^2} = 1g \quad (1)$$

By determining the angle of the Z axis, the angles in all directions can be detected.

$$\theta_z = \sin^{-1} \frac{G_z}{G_{xyz}} \quad (2)$$

The actual tilt angle is $\Delta\theta = 90^\circ - \theta_z$.

The direction of the Z axis, however, is subject to the influence of acceleration from engine vibration and other such factors, and this influence is observed in actual angle detection. It was determined from test results that, as a result, use of this quantity in detection becomes complicated.

Rather than using the Z axis component in the acceleration sensor, therefore, the quantities G_{xyz} and G_{xy} , which are the combined accelerations on the X and Y axes, are used instead to calculate the $\Delta\theta$ that is the tilt of the generator. G_{xy} is calculated as follows:

$$G_{xy} = \sqrt{G_x^2 + G_y^2} \quad (3)$$

G_x : Acceleration in the X-axis direction

G_y : Acceleration in the Y-axis direction

G_{xy} : Combined acceleration from the X and Y axes

G_{xyz} and G_{xy} can be used to calculate the $\Delta\theta$ in Fig. 18.

$$\Delta\theta = \sin^{-1} \frac{G_{xy}}{G_{xyz}} \quad (4)$$

It is apparent from the fact that the $\Delta\theta$ angle can be calculated using just the X axis and Y axis that the angle in all directions can be detected using the X axis and Y axis. However, the quantity G_{xy} cannot distinguish the state in which the generator has top and bottom reversed (is upside down). It was decided, therefore, to use the Z axis to distinguish this state for detection purposes. In this development project, the judgment angle has been configured as $\Delta\theta = 53^\circ$, in order to ensure reliable detection for the excessively leaned state without compromising usability.

Figure 19 shows the total detection range of this generator, including angle detection by the above combined XY-axis acceleration for 360° around the generator and top-bottom reversal detection from the Z axis. This system allows for detection within this entire range.

4.3. External Breather Structure

The ENEPO is constructed to allow the generator to be placed on its side, for convenience when transporting it by car. When the generator is started after having been held on its side, however, oil that has pooled within the breather channel may enter the engine combustion chamber and cause white smoke to be produced. For this reason, the check valve has been located in the external breather tank, as shown in Fig. 20, in a structure that prevents oil from pooling inside the breather channel when the generator is placed on its side, and even in the unlikely event that it falls over forward or backward (as shown in Figs. 21 and 22).

4.4. Carrying Handle Locking Mechanism

A structure was devised to keep the locking pin on the handle constantly pushed out by the force of the return

spring. Thus, when the handle arrives at a specified position, the handle locking pin slides into a hole in the handle and automatically locks it in place.

Turning the handle knob in the handle unlocking direction simultaneously draws the left and right handle locking pins inward, unlocking the handle (Fig. 23).

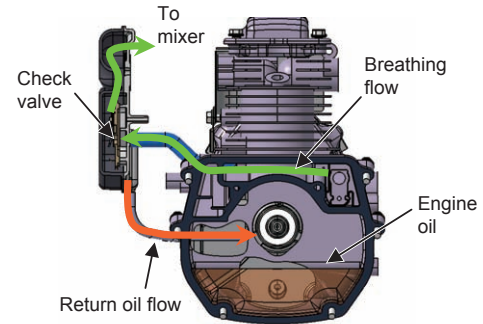


Fig. 20 External breather structure

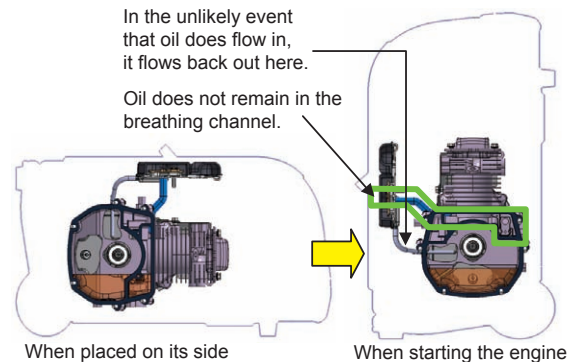


Fig. 21 When generator is placed on its side

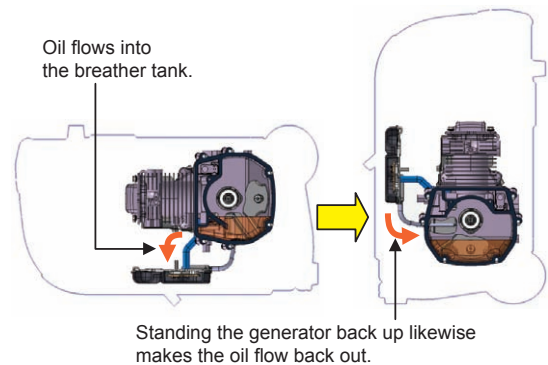


Fig. 22 When generator falls over forward

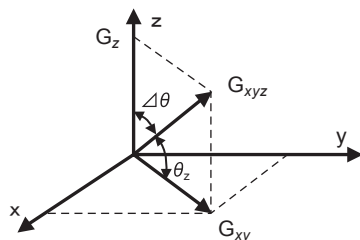


Fig. 18 Relationship of $\Delta\theta$ and coordinate axes

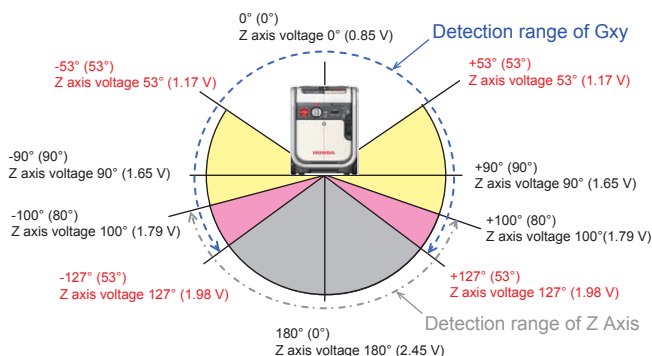


Fig. 19 Generator tilt-angle detection range

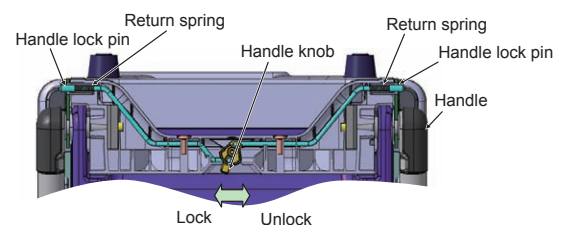


Fig. 23 Handle lock (unlock)

This structure allows automatic locking of the handle and simultaneous unlocking for both sides with a single knob.

4.5. Structure Enabling Simple Engine Starting

The ENEPO features an engine starting procedure comprising the simple actions of (1) loading the gas canisters, (2) operating the engine switch, and (3) pulling the recoil starter.

4.5.1. Chokeless structure

A shutoff valve that automatically closes the gas flow when the engine is stopped is required to use gas fuel. The shutoff valve features a variety of electric-type (such as the solenoid valve) or mechanical-type (such as the vacuum cock) mechanisms.

Power products unequipped with a battery generally employ the shutoff valve with a vacuum cock. However, even if intake manifold vacuum were to be used for the vacuum cock, sufficient vacuum might not be obtained due to the throttle opening at the engine start and limitation in recoil pulling speed. To avoid this, a choke system such as used in a gasoline fuel generator has been installed, and operated at the engine start. This being the case, the ENEPO is designed to use the crankcase pressure to open and close

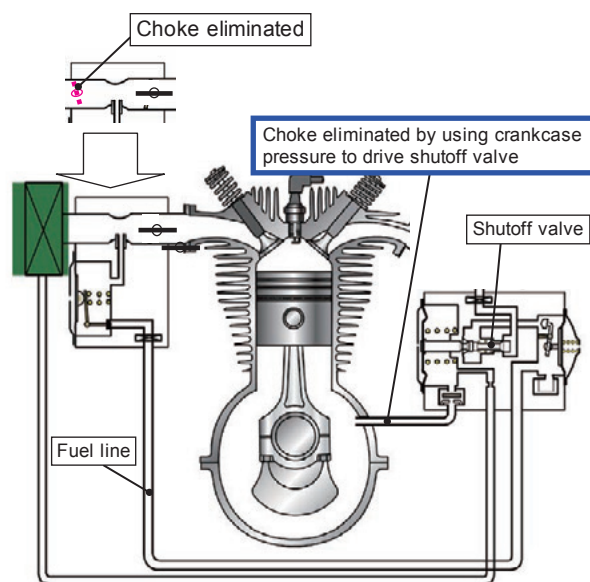


Fig. 24 Shutoff valve drive system

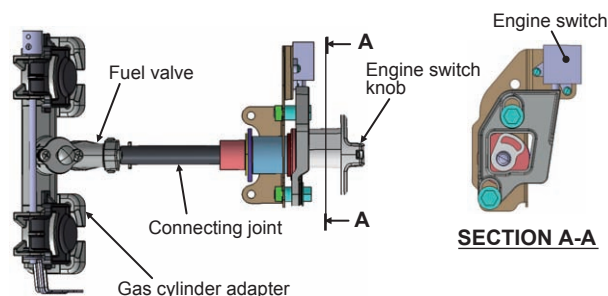


Fig. 25 Engine switch interlinked with fuel valve

the shutoff valve, eliminating the need for a choke.

Figure 24 shows the shutoff valve drive system.

4.5.2. Engine switch interlinked with fuel valve

Since the engine switch and fuel valve are linked by a connecting joint, turning a single knob simultaneously operates the engine switch and the fuel valve.

This reduced the number of steps in starting the engine, simplifying the operation of the generator (Fig. 25).

5. Conclusions

This development project resulted in commercialization of an easy-to-handle generator. At the same time, applying a slim, functional design lowered the barrier for users who have no previous experience with generators, raising expectations that this generator could open up a new market.

Future goals include studying the potential for the product not only in Japan but in international markets as well, and to develop the generator as a worldwide product.

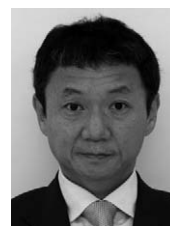
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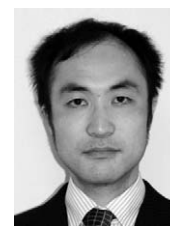
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