# INSTRUCTION MANUAL
# ELECTRONIC GOVERNOR FOR SINGLE UNIT OPERATION

| | Mitsubishi Part No. | Model Designation |
|---|---|---|
| Actuator | 04410-32100 | SG-4017-BR |
| Controller | 04410-33100 | XS-400B-03 |
| Manual # | NN80004Da-E | |

## Basic Controller Functions

### 1. Operation amplifier functions

The controller is essentially a network of analog circuits, of which an operation amplifier is a component. In order to facilitate the understanding of the way the controller's input signal is processed, the amplifier actions will be briefly described by referring to the following three illustrations, Fig. 1, Fig. 2 and Fig. 3:

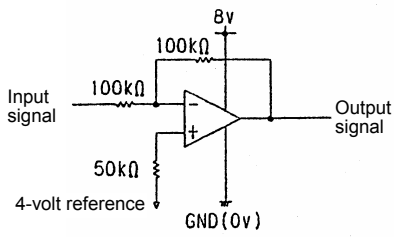



Fig. 1

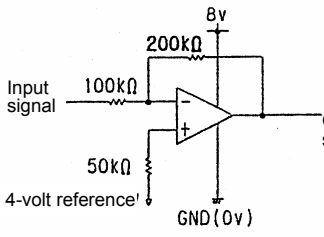



Fig. 2

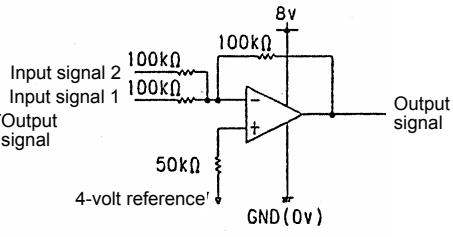



Fig. 3

The circuit diagram of Fig. 1 represents one of the standard uses of this amplifier. The amplifier here is referred to as an inverting type because of its signal voltage inverting action.

Referring to Fig. 1, assume that DC 3-volt signal applies to its input side. This input signal results in a DC 5-volt signal emerging from its output side simply because the DC 4-volt reference voltage kept impressed to its "+" side. Here's how: the 3-volt input signal is compared with 4-volt reference and the difference (3 - 4 =) -1 volt is then inverted to become +1 volt. This inverted voltage adds to reference voltage (4 + 1) to produce the DC 5-volt output signal.

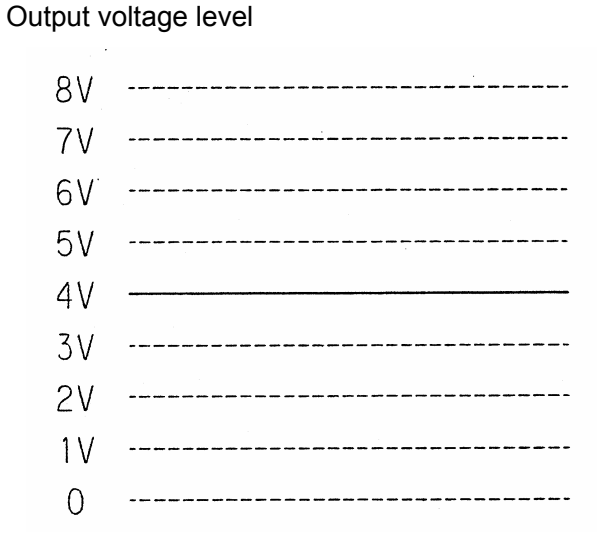
The amplifier of Fig. 2 is similar to that of Fig 1 in all but one respect: its fixed resistor is 200 kΩ, not 100 kΩ This means that the degree of amplification of this amplifier is doubled. With the same DC 3 volts applying to its input, a DC 6-volt output signal will emerge. In this case, the difference of -1 volt (= 3 - 4) will be inverted and doubled to become +2 volts, which adds to the reference voltage to result in the DC 6-volt output signal.

The input-output relationship of an inverting amplifier may be summarized as follows:

Let V1 stand for input voltage, V2 for output voltage, 4 V for reference voltage, and α for the degree of amplification. The relationship can be expressed by this equation:

$V2 = \alpha (4 - V1) + 4$

This equation tells us that the output voltage is always positive and may be lower or higher than 4 volts.




The amplifier of Fig. 3 too is similar to that of Fig. 1 in all but one respect: it has two inputs instead of one. Assume that 1 volt applies to Input 1 and 5 volts to Input 2. In this case, the explanation given above for Fig. 1 holds for each of these two input voltages. The 1-volt input signal results in -3 volts (after comparison with the reference voltage) and likewise the 5-volt input signal results in +1 volt. The sum of these two (-3 + 1 = -2), as inverted, adds straight to 4 volts (reference), there being no amplification (meaning that a = 1). Consequently, the output signal is DC 6 volts.

**2. PID control (proportional, integral and differential control)**

The controller performs three types (PID) of control action. Each type will be explained.

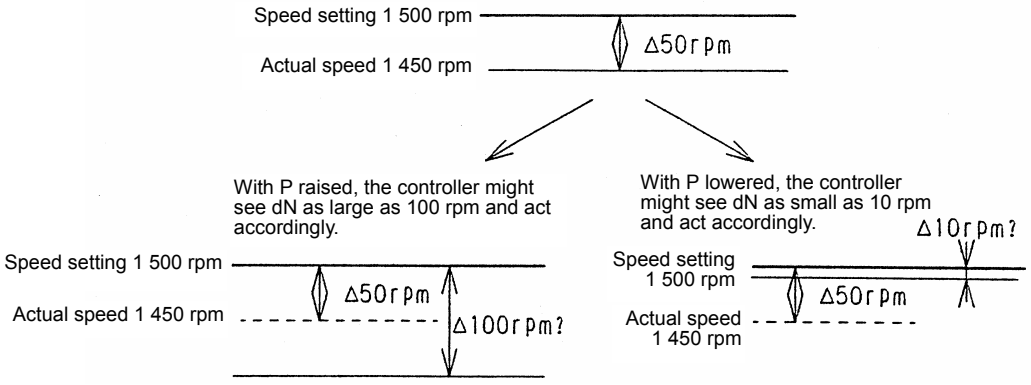
(1) P (proportional control) action

Let N stand for the speed setting (such as, say, 1 500 rpm); No for the speed (such as 1 450 rpm) at which the engine happens to be running; and dN for the difference (which is 50 rpm in this hypothetical case). Proportional action means that type of control which is proportional to this difference.

The proportionality is not constant; it varies according to sensitivity setting. Raise the sensitivity and the controller might will recognize the dN (of 50 rpm in the above case) as a larger speed difference, say, 100 rpm. The reverse of this is equally true: with lower sensitivity, it will see the 50-rpm dN as, say, a 10-rpm difference for example.

In operation, the controller operates to reduce dN as fast as it can. How fast? It depends on sensitivity setting. Remember, inordinately high sensitivity is likely to cause the engine to "hunt."

The following diagram illustrates the effect of sensitivity setting:



(2) I (integral control) action

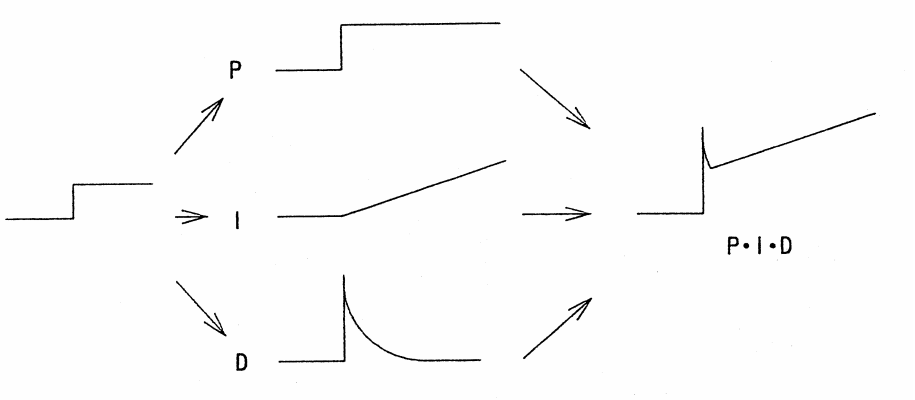
Proportional control action, described above, cannot steady the engine at the exact set level (speed setting level) and is likely to steady the engine slightly above or below the targeted level.
I (integral control) action provides such a control output as to minimize this difference or offset. This corrective output comes out with some time constant, however.
Were it not for this I control action, the electronic governor would be unable to hold the engine speed closely with ±0.5% accuracy.

(3) D (differential control) action

The two control actions, P and I, would be adequate to control engine speed but such is not the case because the engine considered here is not a constant-load prime mover. Its load has to be changed from time to time and more or less widely. P and I control actions alone, as combined, can respond to such a load change only to a moderately degree. Response can be improved by raising the sensitivity of P control action, but this would cause the speed to go up and down or "hunt."
What is needed here is obvious: a type of control by which instantaneous load changes can be promptly coped with. This need is met by D (differential) control action. D-control-action output is in pulse form, so that, as compared with P action, this control action is far less likely to cause the engine to "hunt."

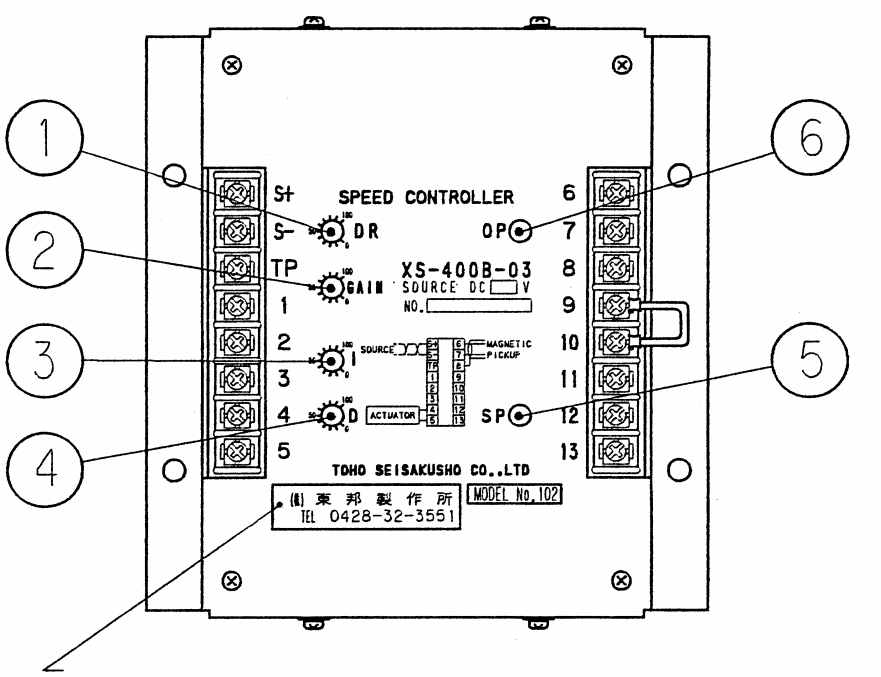
(4) PID composite control signal

As the speed of the engine deviates from the speed setting, the difference will show up in the input signal applying to the controller. How its P, I and D actions will respond to this difference signal is schematically illustrated here:



## Controller Adjustments

### 3. Controls and their functions




As you peel off the phone nameplate, two trimmers will show up. Normally these trimmers do not require readjustment. Their functions are as follows:
**Actuator gain trimmer (on the left):** This trimmer is for use in setting the sensitivity of controller and actuator. Turning it clockwise increases the sensitivity. Be careful not to overturn this trimmer or the actuator will start oscillating violently.
**Overshoot suppressing trimmer (on the right):** This trimmer is for mitigate the tendency of the engine to overshoot at starting. Remember, overturning this trimmer will deprive the controller of its control capability on the high load side, that is, the speed will fall as the engine picks up load.

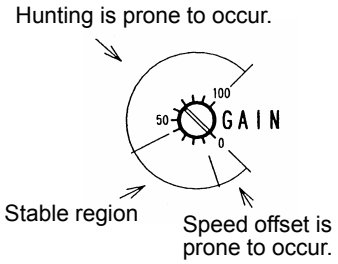
### 3.1 Trimmer functions

① DR trimmer (droop adjusting trimmer)

Adjust this trimmer when you want to widen or narrow the droop (otherwise referred to as steady-state speed regulation).
Here is how to set this trimmer: change load in this sequence: 0%→100%→0%→100% and then decrease the load. From speeds noted at 0% load and 100% load, determine the existing droop.
Obtain the desired droop by turning the trimmer clockwise (to widen the droop) or counterclockwise (to narrow the droop).

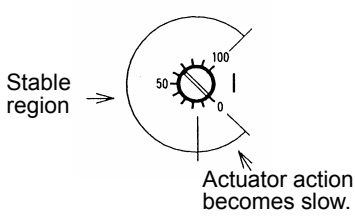
② GAIN trimmer (amplified-difference-signal output adjusting trimmer)

The degree of amplification for the speed offset signal (representing the difference between actual engine speed and set speed) is to be set by means of this trimmer. Turning it clockwise increases the degree of amplification, and vice versa.



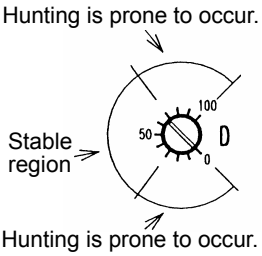
③ I trimmer (integral-action adjusting trimmer)

The speed with which the controller responds to speed difference occurring between set speed and actual engine speed is set by means of this trimmer. Turning it clockwise quickens the response.




④ D trimmer (differential-action adjusting trimmer)

When an offset occurs between actual engine speed and set speed, the control passes an anticipatory judgment on the offset. Turning this trimmer clockwise increases the duration of anticipatory judgment.




⑤ SP trimmer (speed setting trimmer)

Unlike the other trimmers, this trimmer is of multi-rotation type and can be turned 18 rotations. Turning it clockwise raises the set speed for the engine.

⑥ OP light (red LED light, which turns on to signify the start of operation)

As the controller becomes energized upon turning ON of power supply, the magnetic pickup produces signal applying to the LED. When the frequency of this signal is 10 Hz or higher, the LED will light up. When this LED is off, it signifies that the controller is not operative.

### 3.2 Controller adjustment

3.2.1 Tool and instrument needed

Ⅰ. Flat-tip screwdriver (with 5-mm wide and 0.6-mm thick tip)

Ⅱ. DC voltmeter (or circuit tester)

3.2.2 Setting locations

(1) Initial-setting positions of respective trimmers

Before placing the controller in operation, check to be sure that the trimmers are set as follows:

| Trimmer | DR | GAIN | I | D | SP |
|---|---|---|---|---|---|
| Set position | 0% | 20% | 60% | 50% | About 660 rpm; 182-tooth ring gear |

Note 1: For each trimmer, one graduation (of the scale) signifies 10%. In this chart, trimmer positions are indicated in terms of 10% graduations.

Note 2: DR trimmer set at 0% position is for isochronous control.

(2) Check the wiring connections by referring to the wiring diagram.

Pay particular attention to those connections related to power supply.

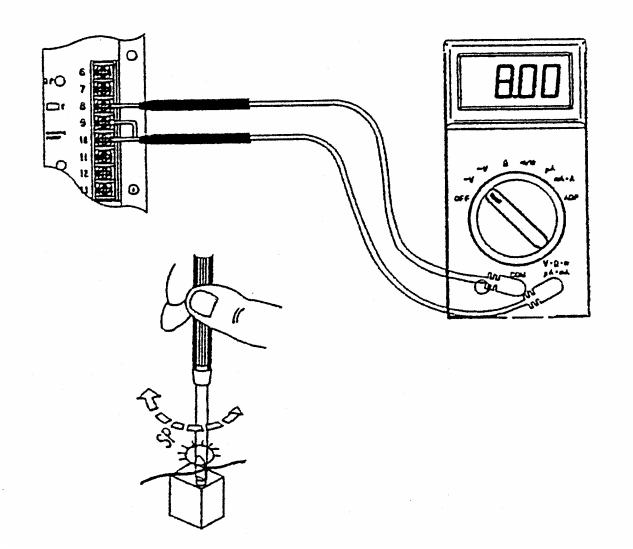
- After completing the wiring work and before turning on the power switch for the first time, re-check the connections to be absolutely sure there is no miswiring. Bear in mind that connecting the power-line wires the other way round to the S+ and S- terminals will damage the controller beyond repair.

(3) Before starting up the engine, check to be sure that the means of initiating an emergency shutting down of the engine are all in good order.

- Make sure that the overspeed relay is in sound condition, effective to shut down the engine any time. Have workers posted at key locations so that the emergency shut-down button can be operated and power supply can be turned off to bring the actuator to its full-close position to cut off fuel supply, all at instant notice.

(4) Check the DC power supply voltage before starting up the engine.

Turn on DC power supply to the controller, and read the voltage across terminals 8 and 10 by using a DC voltmeter or a circuit tester. This voltage should be at least 8 volts; if not, the controller should be suspected of malcondition.

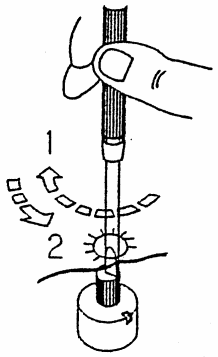


(5) Starting up the engine

Except when the engine runs up beyond its rated speed level, turn the SP trimmer slowly clockwise to the position for rated speed (or rated generator output frequency).

- Should the engine start hunting wildly or refuse to start up, take the steps prescribed in the troubleshooting procedure.

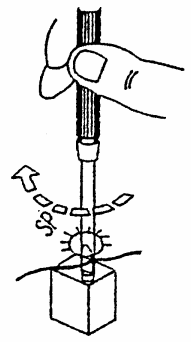
(6) Controller limit adjustment (coarse adjustment) procedure




①GAIN trimmer

Slowly turn the trimmer clockwise and, as soon as the engine begins to hunt, turn it back slowly until the engine stops hunting. From this position, turn it counterclockwise 5 to 10% and set it there. If the engine will not start hunting when this trimmer is turned all the way clockwise, operate the actuator lever by hand to induce engine hunting. Be sure to set this trimmer within the 20 ~ 40% range.

- When operating the actuator lever by hand, be careful not to get your hand pinched.
- If the droop (by DR trimmer) has been set as desired, turning the GAIN trimmer counterclockwise will widen the droop, and vice versa.



② SP trimmer

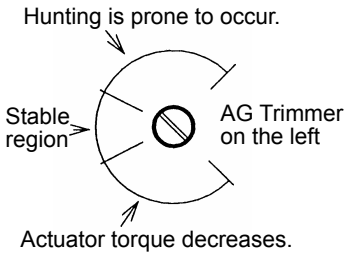
The set speed will change as you reposition GAIN and DR trimmers for adjustment. In such a case, be sure to restore the set speed (rated speed) by adjusting SP trimmer once again.

(7) Checking the engine operation under load

Slowly load the engine up to its rated level (in some cases, up to 110 % rated load) and check to be sure that this load increase will not cause the engine to hunt and that the engine is capable of carrying the full load satisfactorily.

- An engine presenting no problem in picking up full load when it's cold might begin to lack power output as the actuator becomes hot.
- In case the engine lacks power output, proceed as follows:
  If the engine is unable to carry rated load, remove the phone nameplate on the controller panel to expose the trimmers, and slowly turn the L trimmer on the right counterclockwise. After making sure that the engine carries the load as expected, set this trimmer at a position about 1/4 graduation to the left. Check, too, that the engine will not lack power output when it is hot. After so checking, shut down the engine and re-start it to see it overshoots. Should the engine stalls on acceleration or lacks power output, it means that the actuator needs "torque up."

(8) Governor performance adjustment (fine adjustment) procedure



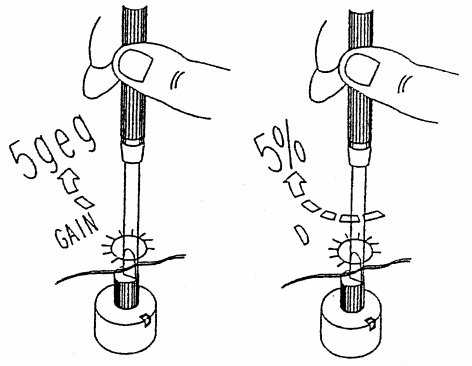

Pick up 25% load or thereabout and then unload it, taking measurements by using a frequency meter or electromagnetic oscilloscope, and adjust (as described below) if the measurements indicate problems in respect of such as speed regulation. If no problems are encountered, go to the next 25% load by repeating the above cycle of loading and unloading, in order to be sure at each time that the governor responds satisfactorily.

- Should hunting (or jiggling) occur at loading or unloading, remove the phone nameplate on the controller panel, turn the AG trimmer (on the left, under the nameplate) counterclockwise about 15 degrees.

A. Improving the instantaneous speed regulation:

Ⅰ. Turn GAIN trimmer about 5 degrees clockwise, and perform the cycle of loading and unloading: repeat this process (until the prescribed speed regulation is reached).

- Adjusting close to the threshold of hunting should be avoided, because external disturbance can cause the engine to hunt if the GAIN trimmer is so adjusted.




Ⅱ. If GAIN trimmer adjustment produces no improving effect, turn the D trimmer progressively clockwise, about half a graduation at a time, while repeating the cycle of loading and unloading. Continue this process (until the prescribed speed regulation is reached).

B. Improving the stabilizing time:

Ⅰ. Turn the I trimmer progressively clockwise, one graduation at a time, while repeating the cycle of loading and unloading. Continue this process (until the prescribed stabilizing time is reached).

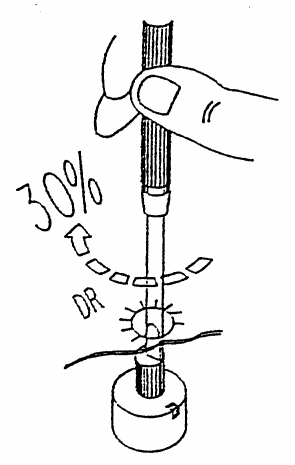
- Overturning the I trimmer in an attempt to shorten the stabilizing time is likely to cause the engine to overshoot at engine start-up.

(9) Adjustment required for and procedure of running the engine with droop

Ⅰ. Start up the engine, and hold it in no-load condition.

Ⅱ. Slowly turn DR trimmer clockwise. Normally, the engine will pick up speed.

While turning SP trimmer to hold the engine at the targeted speed (highest no-load speed, which is equal to rated speed as modified by the droop), set DR trimmer at its 30% position (3 graduations).
If, in this process, the actuator happens to be loaded heavily, the engine might slow down somewhat as you turn DR trimmer clockwise.

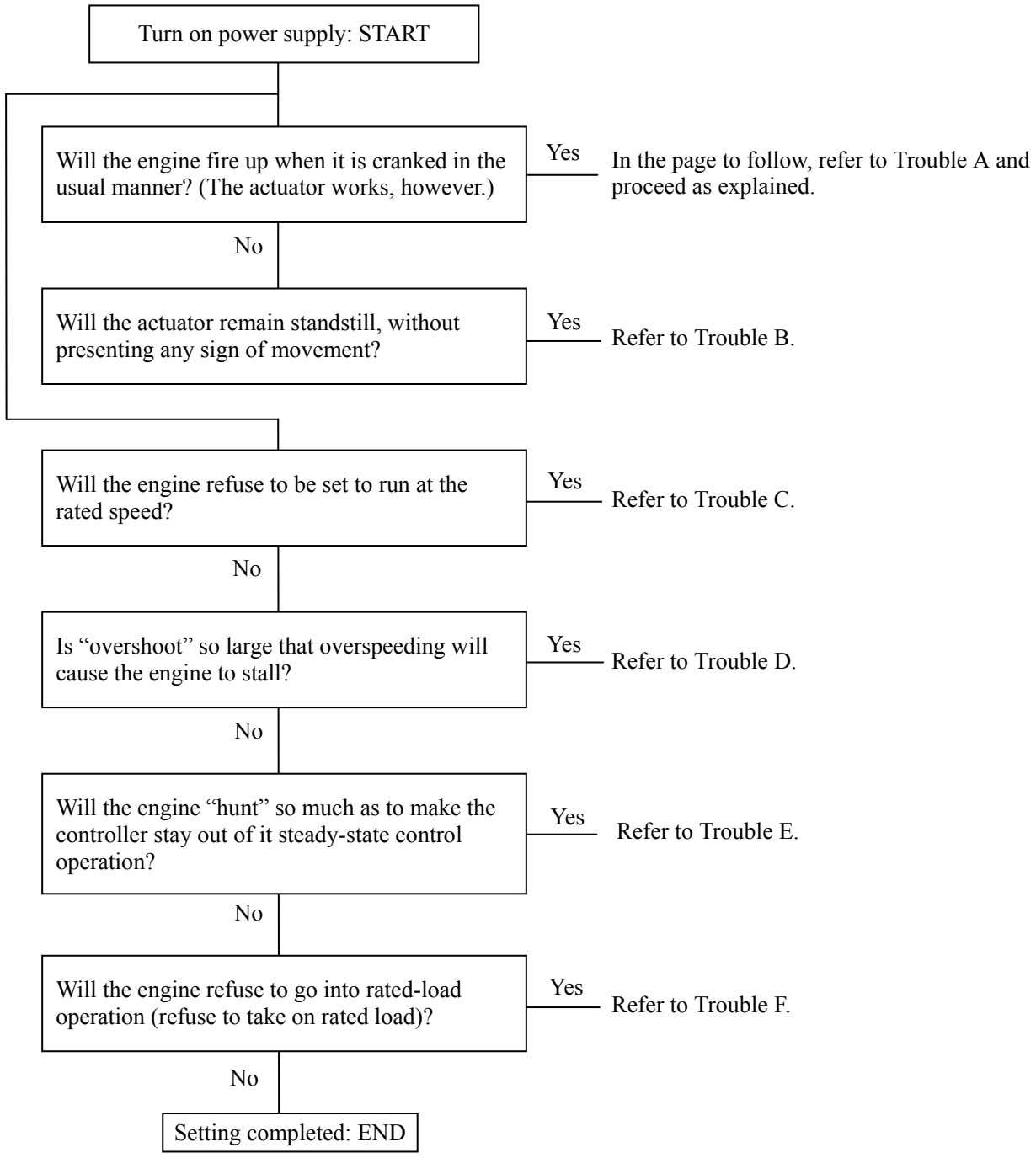



Ⅲ. Pick up engine load slowly up to full load (100% load) and check to be sure that the engine will run at rated speed. If the droop happens to be not enough, turn DR trimmer further clockwise in no-load condition and repeat steps Ⅰ ~ Ⅲ in order to obtain the desired droop.

- The present controller controls the droop by means of the signal representing the actuator's current consumption. For this reason, its control action is influenced by the actuator's hysteresis.
  If the lever on engine side starts feeling heavier, the actuator's current (mentioned above) will increase so that the actuator will exert additional torque. This will introduce some error in its control action.
  If you need a droop not involving hysteresis, select the other product having a built-in potentiometer in its actuator or, alternatively, use the converter (XD-423) for kW droop.
- Turning GAIN trimmer affects the droop. (Turning this trimmer counterclockwise will make the droop sharper, i.e., larger and, conversely, turning it clockwise will make the droop less sharp, i.e., smaller.)

## Troubleshooting

### 4. Troubleshooting procedure flowchart



## How to shoot respective types of trouble

| Trouble | Possible cause | How to check | Remedy |
|---|---|---|---|
| A. Cranking will not fire up the engine for start-up. (Each time the engine is cranked, the actuator lever moves to the position of maximum fuel feed to the engine.) | Fuel is not coming to the engine. | Try to control the engine manually. | Inspect the fuel system. Make sure the safety devices are in sound condition. |
| B. The actuator will not move at all. | Connections to terminals S+ and S- are the other way around, or terminal securing screws are loose. | Inspect the terminals S+ and S-. | Correct the connections as necessary. Replace the controller by a new one. |
| | Power supply voltage is off the specification. | Undo connections at S+ and S-, and read voltage by using a DC voltmeter. | Correct the voltage at source side. Replace the existing power supply line wires by larger size wires. |
| | Open in the harness. | Disconnect terminal 4 from 5 in the controller and read ohmic resistance. A reading of 3Ω or so means good continuity; if infinity (∞) is read, it means there is an open circuit. | Replace the harness. |
| | The linkage is seized. | Try to move the linkage by hand to see if it moves smoothly. | Eliminate bindings, if any, and smoothen the linkage. |
| | No signal is coming to the controller from the magnetic pickup. | Be sure that OP light is on, and read the voltage across terminals 6 ~ 7 just when the engine is cranked for start-up. | The reading should be at least one volt, AC. If not, re-set or replace the pickup. |
| | The actuator is out of working order. | Replace the actuator by another known to be good and sound. | Replace the actuator. |
| | | Detach the actuator's receptacle, and read ohmic resistance between the actuator's terminal pins and the body. On each pin, the reading will be ∞ if the actuator is in sound condition. | If the reading indicates short circuit or some resistance, replace the actuator. |
| | | Read ohmic resistance between actuator pins A and B. If the reading is ∞, it means that the coil is open-circuited. | Replace the actuator. |

| Trouble | Possible cause | How to check | Remedy |
|---|---|---|---|
| B. The actuator will not move at all. | The controller is out of working order. (The battery is run down.) | Assuming that everything checked thus far is satisfactory, read voltage between terminals 8 ~ 10. If this reading is about 8 volts (DC), nothing is wrong with the controller; if not, the controller is in trouble. Second, short terminals 8 ~ 12 with a jumper, and check to see if the actuator works properly. At the same time, read voltage between terminals S+ and S- ; if this voltage is lower than 16 V (DC), it means that the battery is in run-down or discharged state | Replace the controller. Replace the battery. Size of wires between battery and controller and between controller and actuator:<br>Up to 10 m, 1.25 $mm^2$<br>Up to 20 m, 3.5 $mm^2$<br>Up to 30 m, 5.5 $mm^2$ |
| C. Inability to set the rated speed. | Trimmer or circuit board in faulty condition. | Check to be sure that the actuator in current open state has some margin. | Turn SP trimmer clockwise. This should result in a rise of engine speed; if not, it means that the trimmer or board is in faulty condition. |
| D. Large overshoot. Engine stalling due to overspeeding likely to occur. | I trimmer has been turned clockwise too much. | Turn back the trimmer counterclockwise (40%) and recheck. | Re-set by considering the stabilizing time. If I trimmer has to be turned clockwise, be sure, before turning it, to turn GAIN trimmer clockwise just a little. |
| | SP trimmer is set too far. | Turn SP trimmer l8 rotations counter-clockwise, and recheck. | If engine overspeeding still occurs, the controller must be replaced. If, on the hand, the speed is now lower, slowly turn SP trimmer clockwise to set. |
| E. The engine keeps hunting, and the controller is unable to perform steady-state control. | GAIN setting is too large. | See if the actuator lever hunts with a frequency of 2 ~ 3 Hz. | Slowly turn GAIN trimmer counterclockwise to stop hunting. If this does not stop the hunting, go to D trimmer to remedy as stated below: |
| | D setting is too large. | See if the actuator lever hunts with a frequency of 4 ~ 5 Hz. | Slowly turn D trimmer counterclockwise to stop the hunting. |

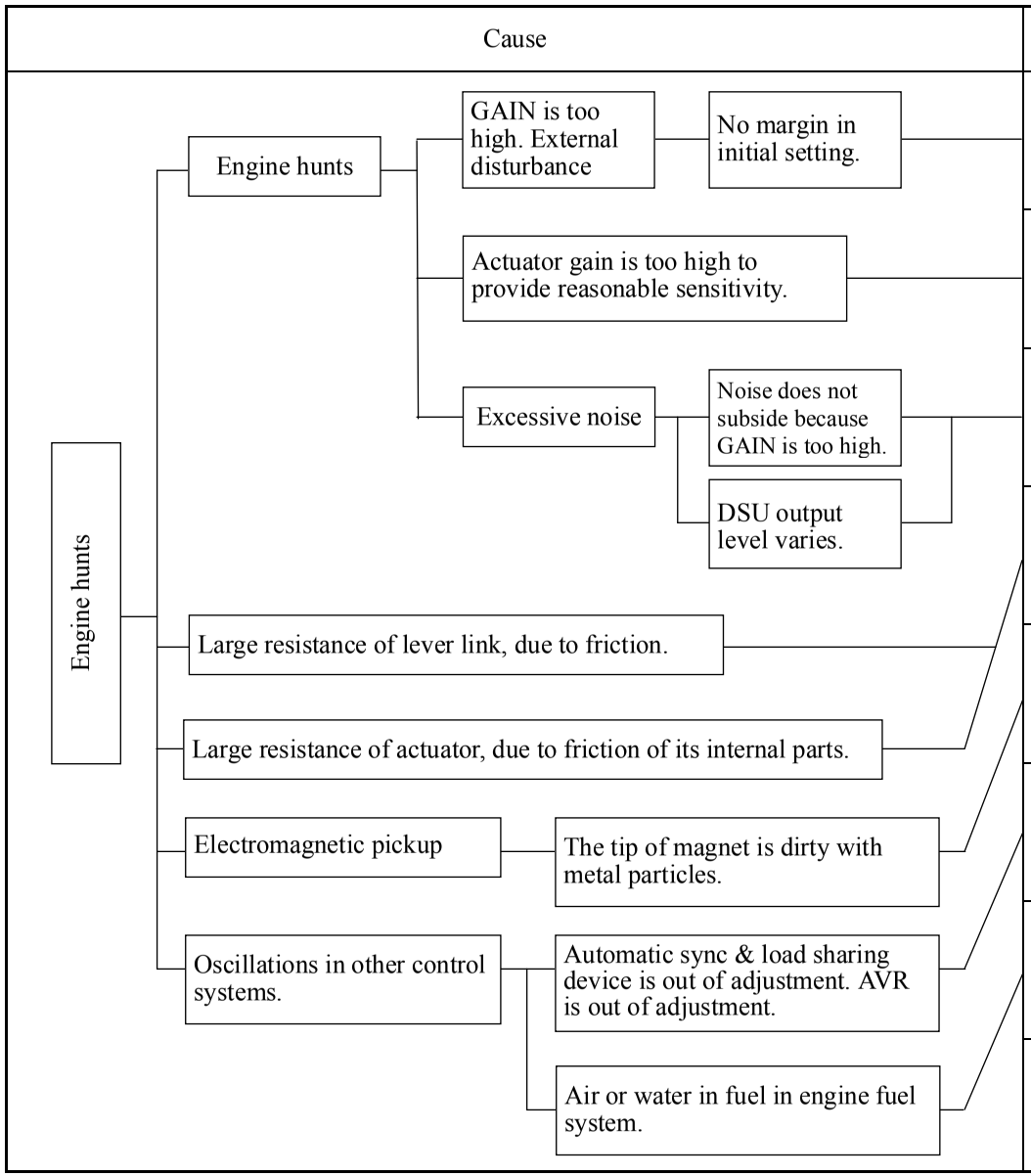
| Trouble | Possible cause | How to check | Remedy |
|---|---|---|---|
| E. The engine keeps hunting, and the controller is unable to perform steady-state control. | I trimmer has been turned clockwise too much. | See if the actuator lever oscillates with a small amplitude at a rate of about one Hz, thus changing the rack position too slowly. | Slowly turn I trimmer counterclockwise to stop the hunting. |
| F. The engine is unable to run with rated load. | Not enough fuel. | Check the open position of the actuator. | Increase fuel feed to the engine. |

## Specifications

| Item | Specification |
|---|---|
| Model designation | XS-400B-03 |
| Power supply voltage | DC 24 volts |
| Permissible voltage fluctuation | ±10% |
| Current consumption (controller alone) | 250 mmA, approx. |
| Current consumption (assembly) | 2 A (steady state), approx. |
| Input signal | 1 V (AC), min., from magnetic pickup, as input for speed control |
| Output signal | 200 Hz PWM |
| Frequency setting range (controller proper) | SP setting range: 2 000 ~ 6 000 Hz or over |
| Permissible ambient temperature range | -10° ~ 60°C |
| Accuracy of operation | ±1.0% |
| Ambient atmosphere | Atmosphere without corrosive gases |
| Weight | _____ kg, approx. |

- An actuator with output torque not exceeding 30 kgf·m can be connected to the controller.

## Cause of Engine Hunting




| Explanation | Judg-ement |
|---|---|
| High GAIN is liable to cause circuits to oscillate. | |
| Instantaneous load change is prone to induce oscillation, which causes the engine to keep on hunting (jiggling). | |
| DSU output level affected by noise<br>If GAIN is too high, hunting may not die down even when noise disappears. | |
| Sluggish or rough movement tends to give rise to slow-integral or irregular hunting. | |
| The frequency of controller's input signal becomes disturbed and this results in detection of a wrong frequency to induce engine hunting. | |
| High sensitivity causes engine hunting unless the engine is running alone. Inadequate adjustment gives rise to differences in voltage, power factor and phase and consequently to engine hunting. | |
| Engine hunting resulting from contaminated fuel is of irregular kind. | |
| | |