Chapter 8

DIESEL ENGINE CONTROLS AND GOVERNING

Learning Objectives

As a result of this chapter, you will be able to:

1. Describe the functional relationship between the engine control governor and the fuel injection system.
2. Explain how the engine control governor senses changes in the generator load or demand and compensates by regulating the fuel delivery to the diesel engine.
3. Describe the primary components of the governing systems used on EDG units.
4. Explain how the terms isochronous and droop apply to EDG units.
5. Explain the use of other (digital) governor systems.

Purpose of Governor

The governor's purpose is to control the fuel to the engine cylinders so as to control the speed of the unit, holding the speed constant for all conditions of load imposed on the generator being driven by the engine.

In order to maintain the frequency of the generator output, the engine speed must be held constant.

Purpose of Governor (continued)

The relationship between the generator output frequency and the engine speed is expressed by the formula:

$$F = N * P / 120$$

Where F is frequency, N the engine speed in RPM, and P is the number of poles on the generator.

A 900 rpm engine requires an 8 pole generator to produce 60 Hz power.

(For 60 Hz operation, $N = 7200/P$ or $P = 7200/N$)

Basic Governor Elements

Every engine governing system must contain certain basic elements, whether the simple mechanical type or an electrical/electronic type. They include:

- A speed sensing element
- A speed setting (reference) element
- An error sensing/correcting element
- A power element sufficient to manage engine fuel controls
- A compensation/resetting/stabilizing element
- A means of determining the method of operation…droop or isochronous mode (operating in parallel or alone)

Droop - Isochronous Relationship

- Droop is defined as the percent change in speed as a unit goes from no-load to rated load condition. It can be expressed as:

  Droop (%) = Speed Change ∗ 100 / Rated Speed

  Speed Change = no-load speed – full-load speed

- Isochronous means iso (same) chronous (time). Each engine revolution takes the same time… speed is constant.

- Unit must be in Droop mode when paralleled to the offsite power system. Unit is most desirably in Isochronous when carrying loads on emergency bus during the emergency situation.

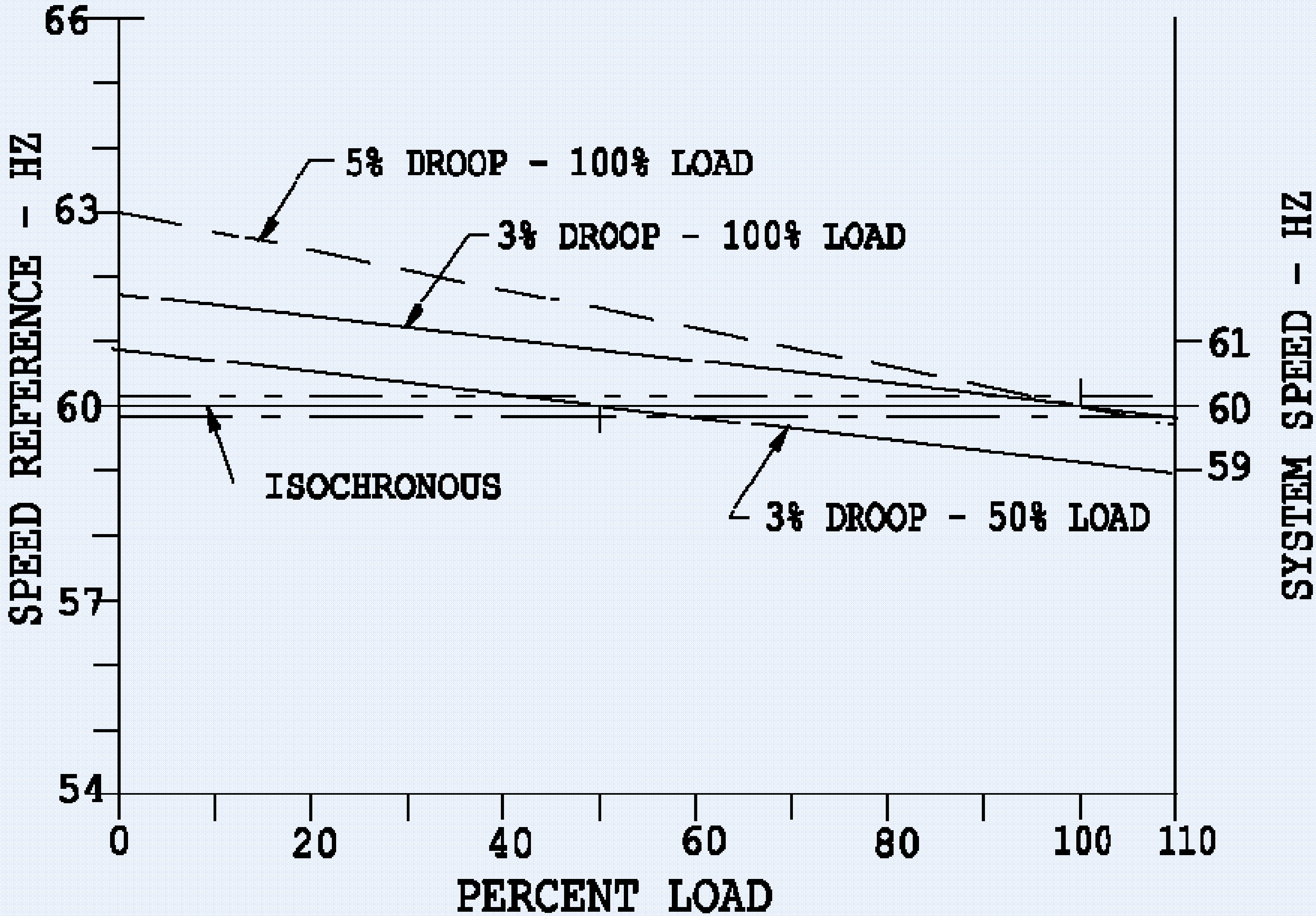


Figure 8-1 Droop-Isochronous Relationship

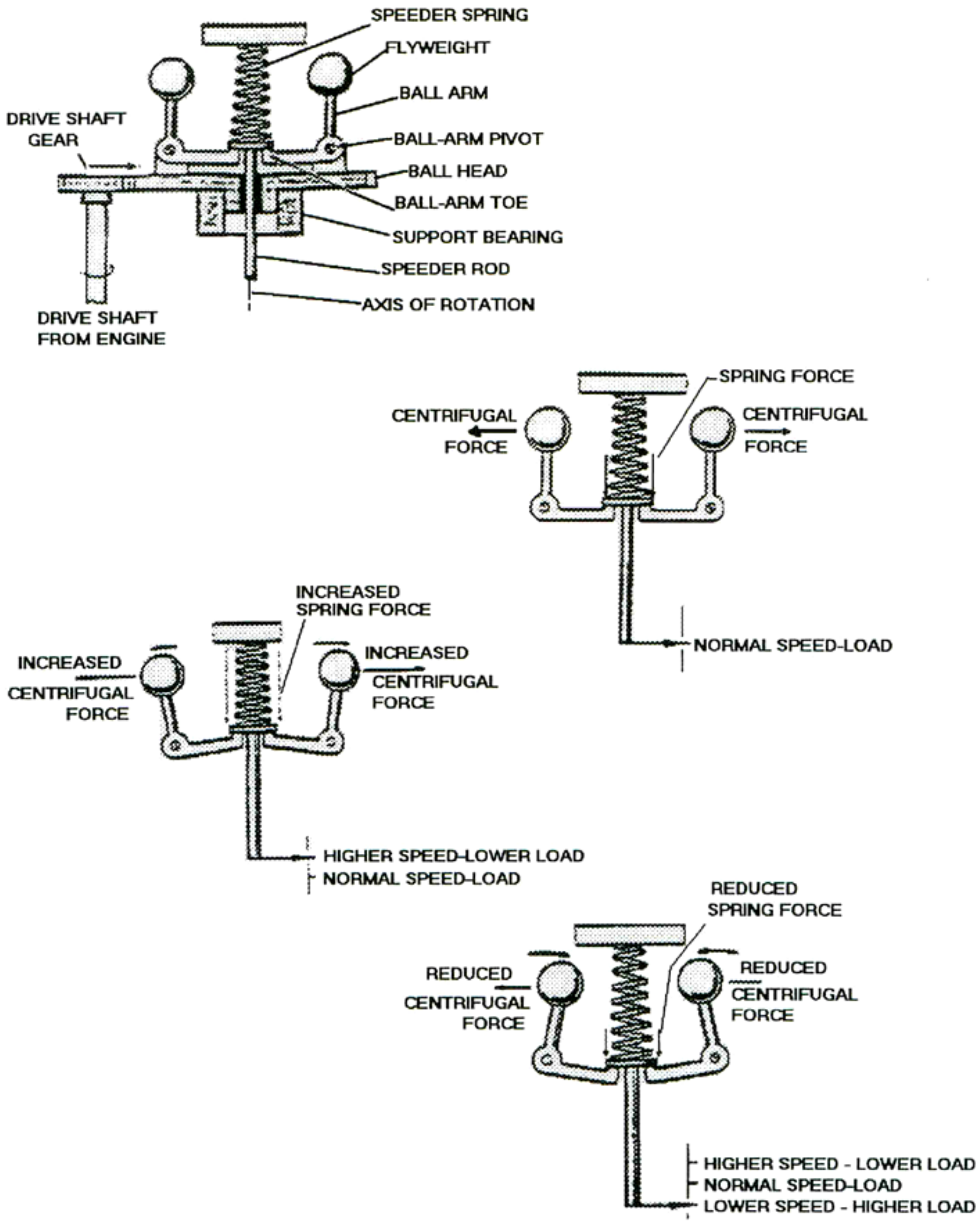


FIGURE 1 - BASIC MECHANICAL GOVERNOR

Figure 8-2

Basic Mechanical Governor

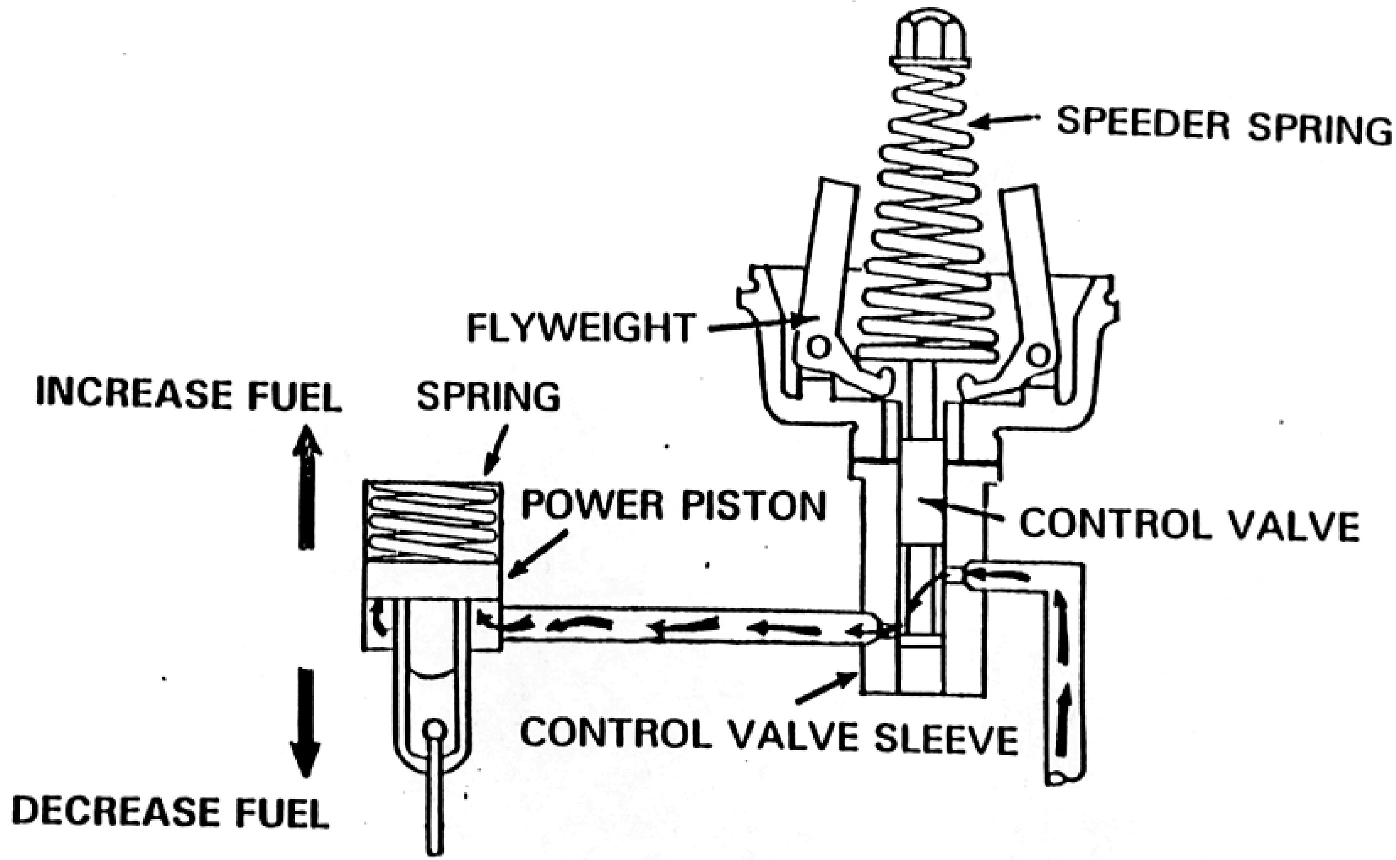


Figure 8-3 Basic Governor with Hydraulic Power Piston

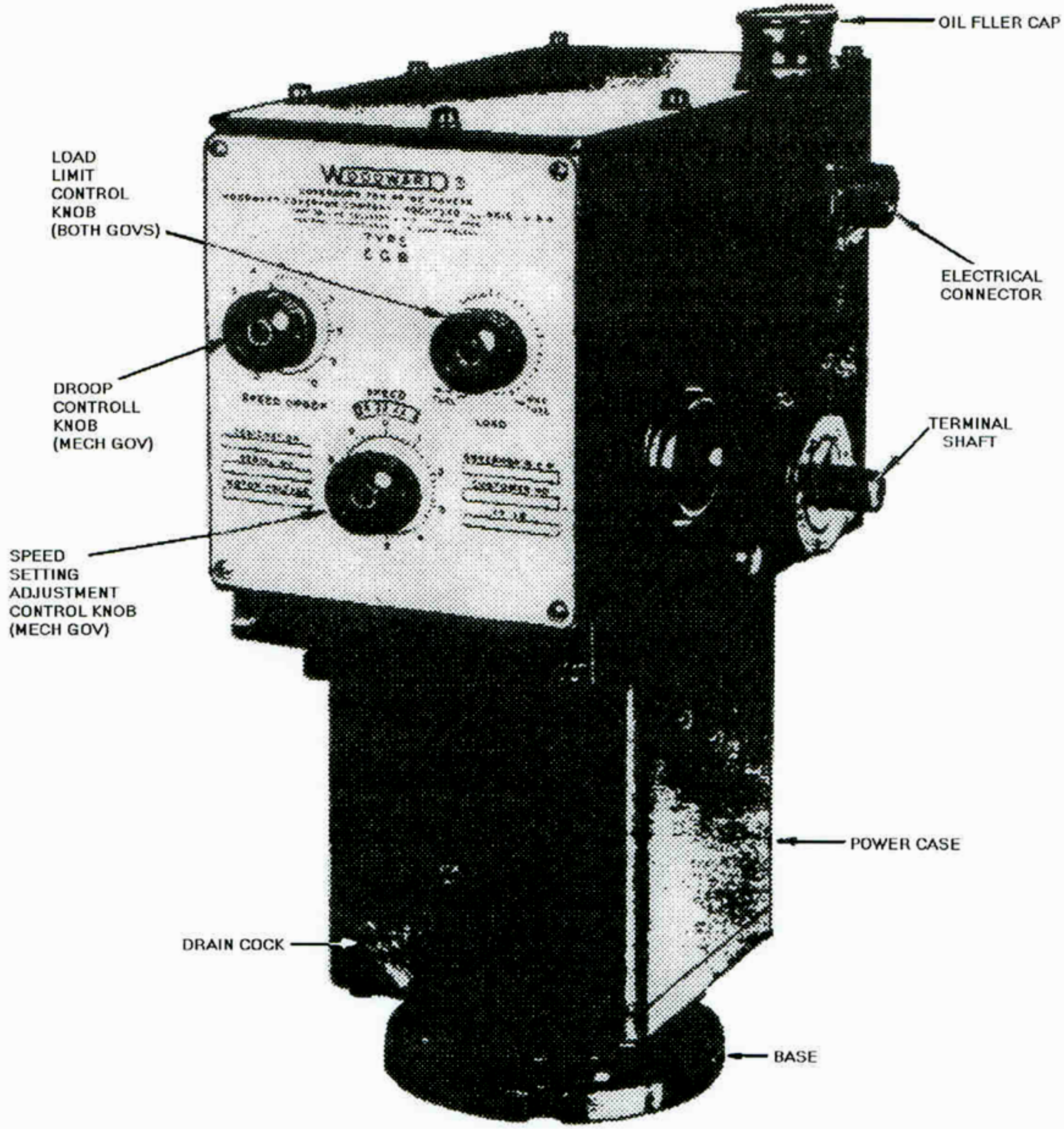


Figure 8-4

Electric Governor Hydraulic Actuator

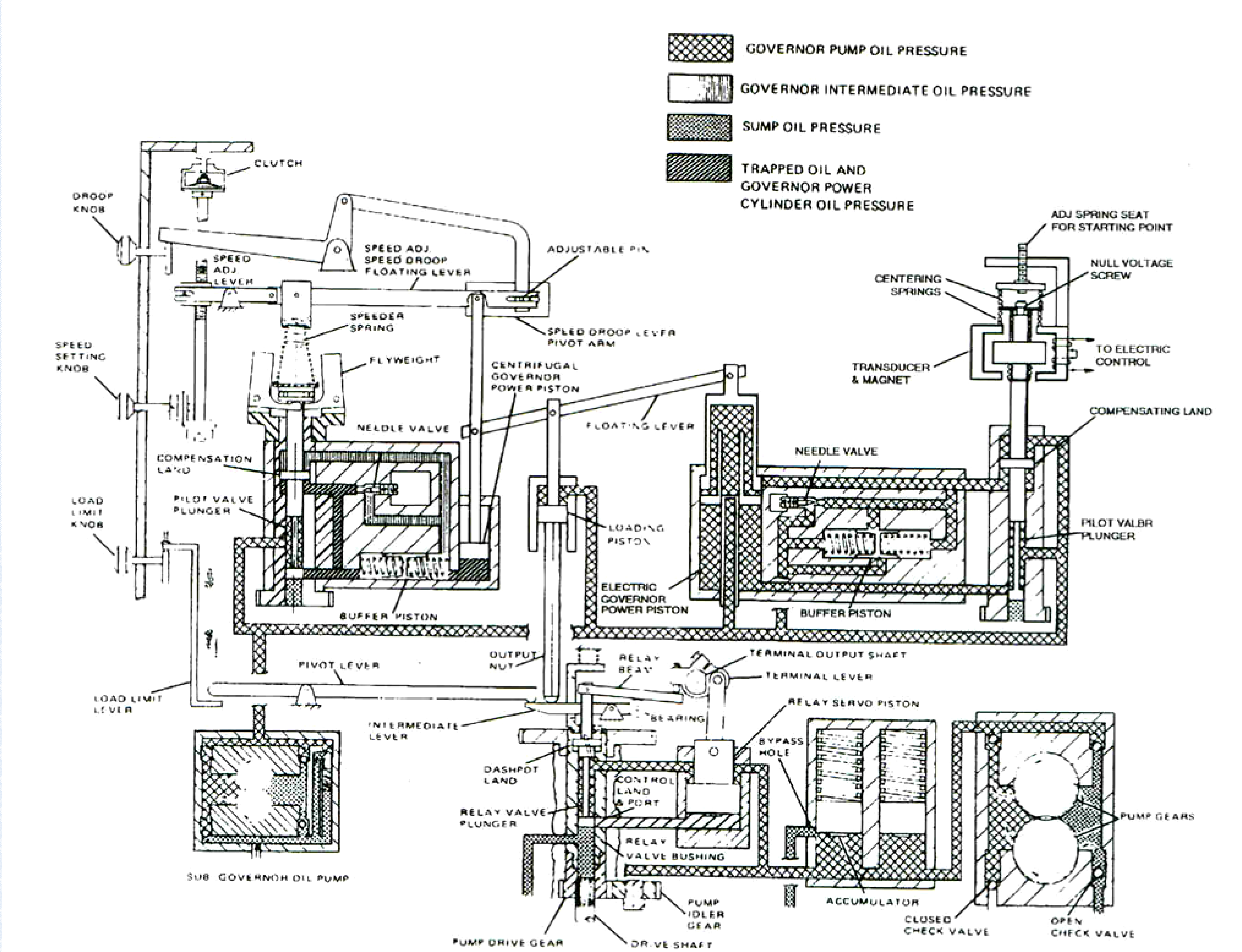


Figure 8-5A EGB-10C Actuator Schematic

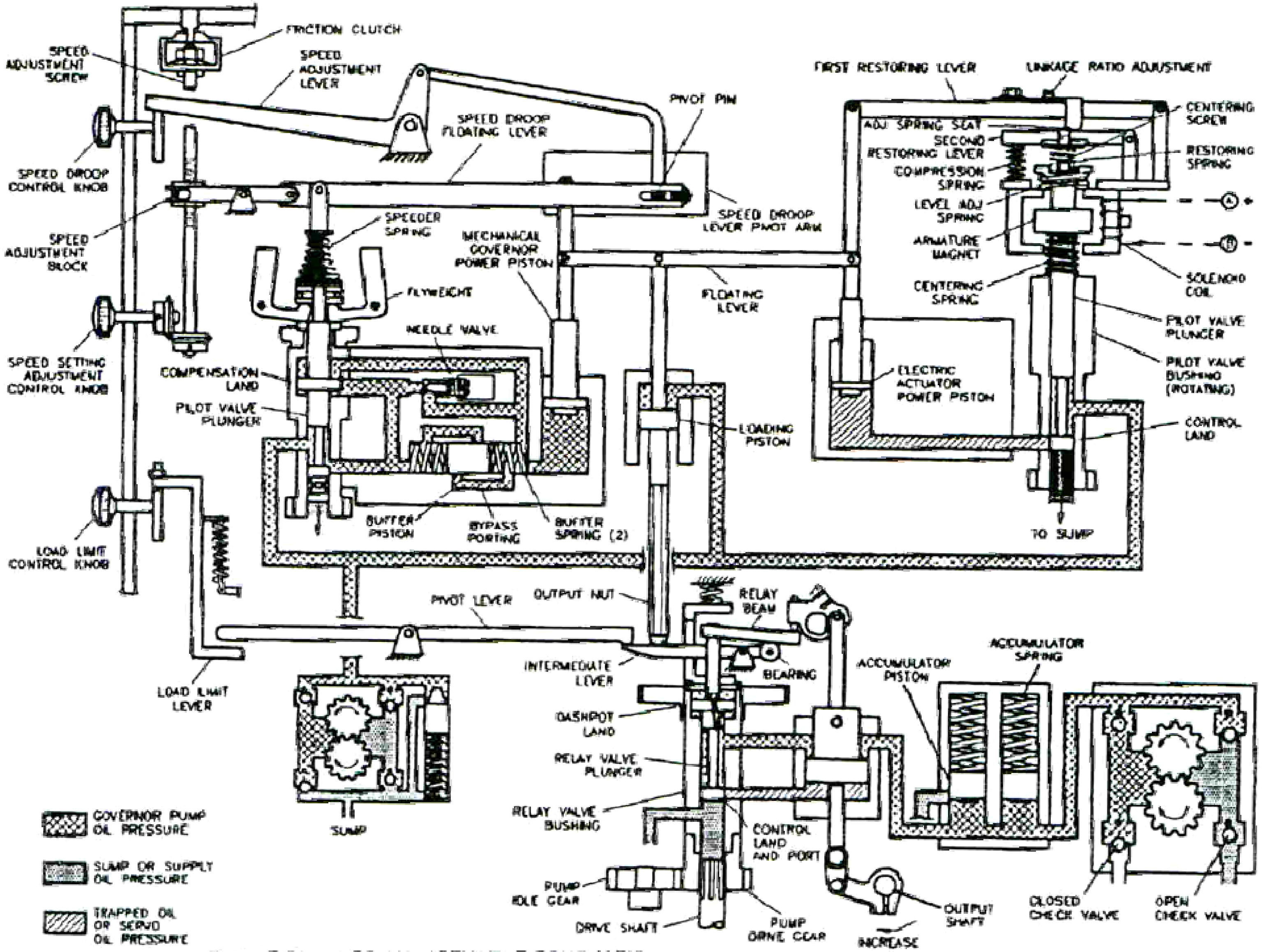
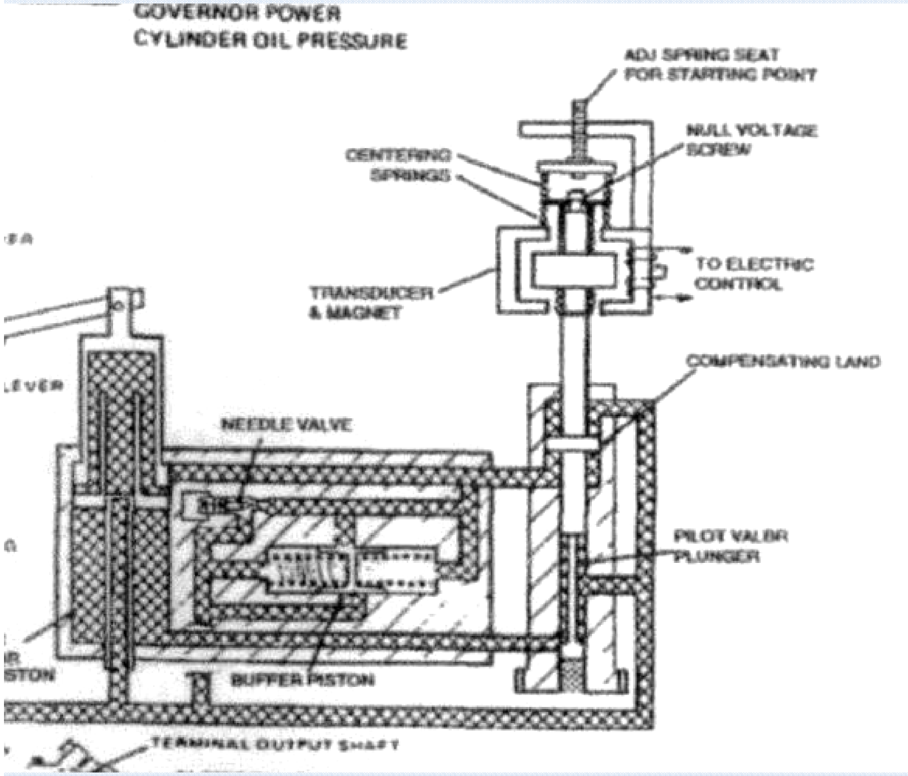
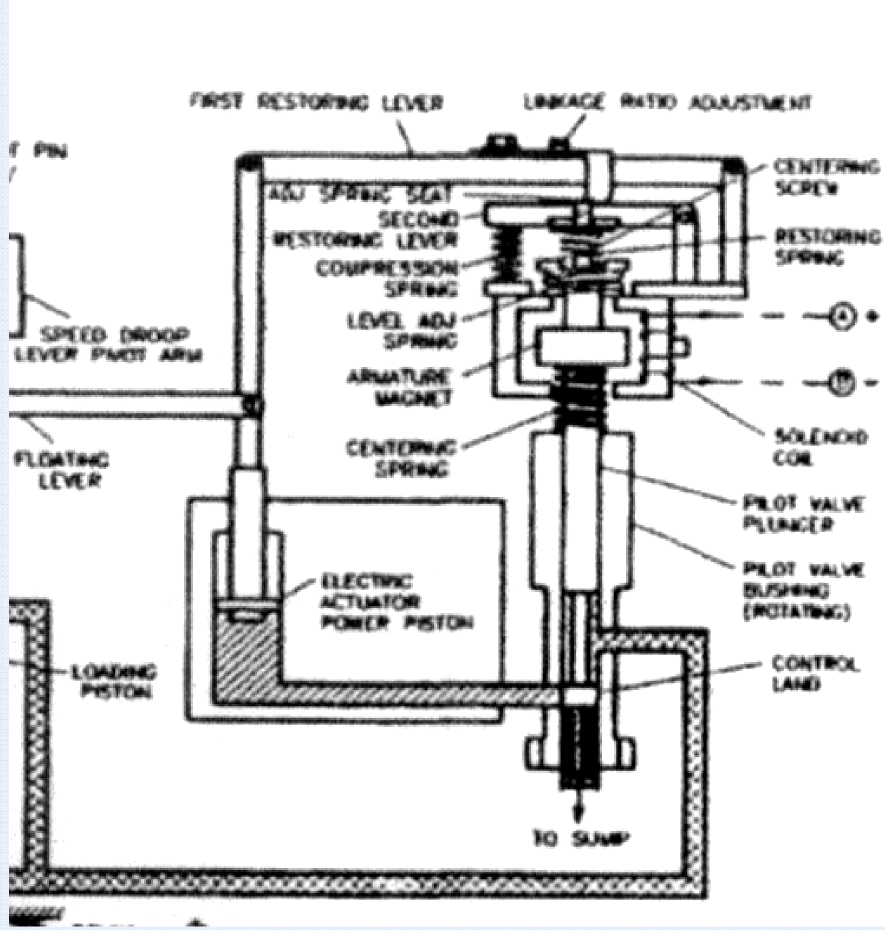


FIGURE 5A EGB-13P ACTUATOR SCHEMATIC

Figure 8-5B EGB-13P Actuator Schematic



EGB-10C



EGB-13P

Figure 8-5 A-B Major Differences Between EGB-10C and EGB-13P Actuators

Control Packages

Controls are mounted in the control panels and/or switchgear and connected into the electrical system as shown in Figures.

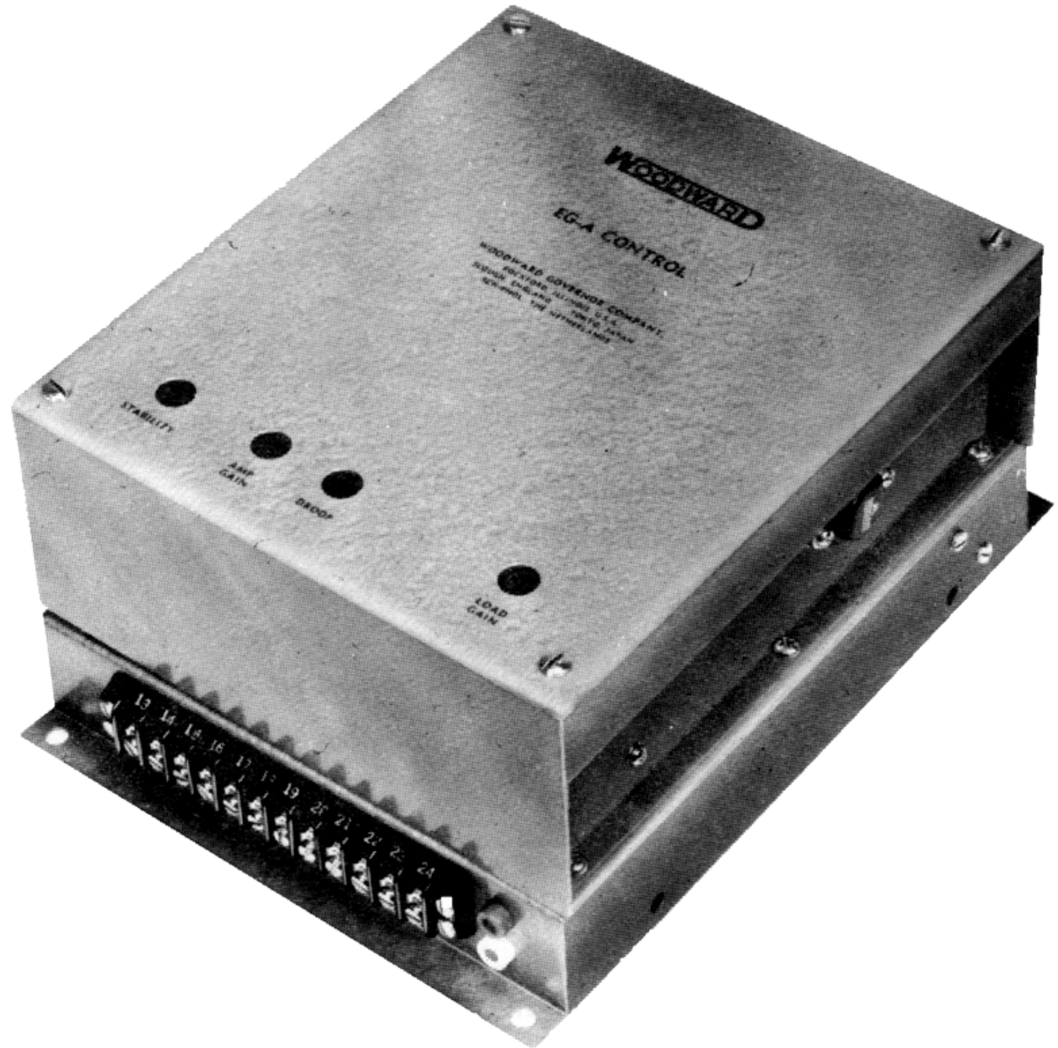


Figure 8-6

EGA Control Box

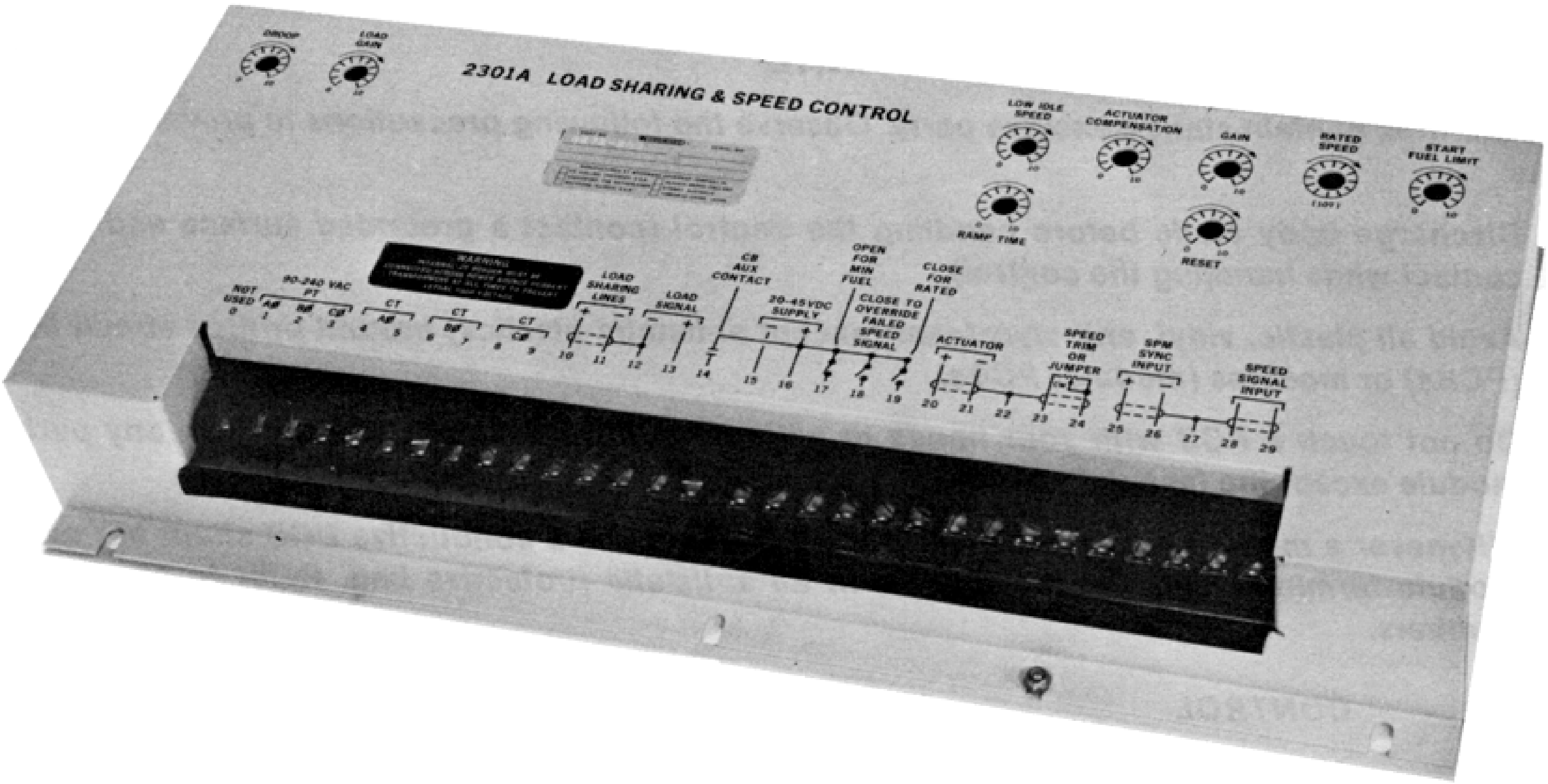


Figure 8-7 2301A Control Box

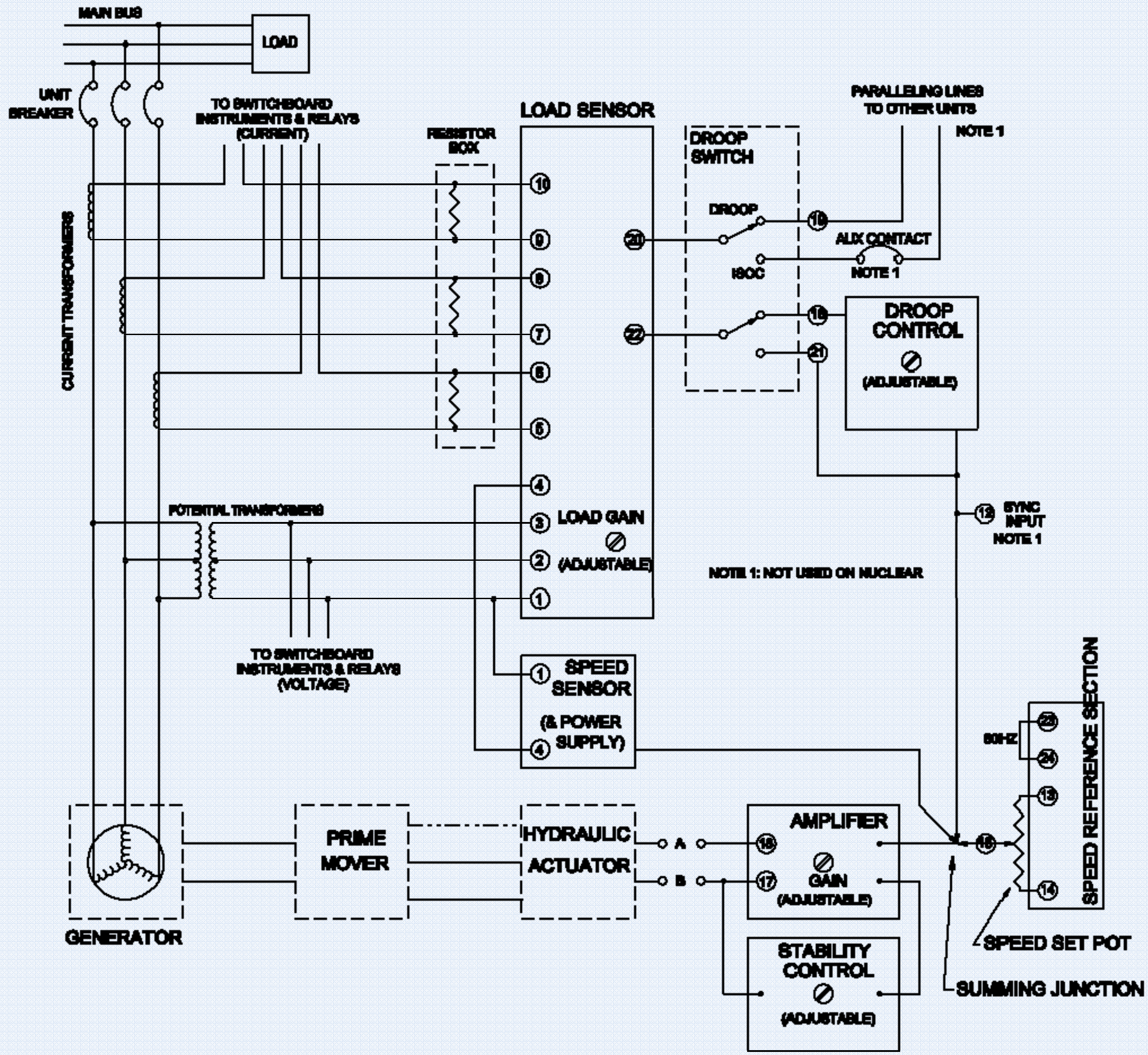


Figure 8-8 EGA Control Block Diagram

EGA Advantages and Disadvantages

Advantages of EGA

- Powered from Generator Voltages - Self Sufficient

Disadvantages of EGA

- No governing until Generator is at voltage
  - for power supply and
  - for Speed Sensing
- Will not operate at reduced speed (see above)
- Part of compensation is hydraulics within actuator, subject to oil temperature and condition.
- Most failures result in EDG operation with backup governor as actuator (at higher speed).

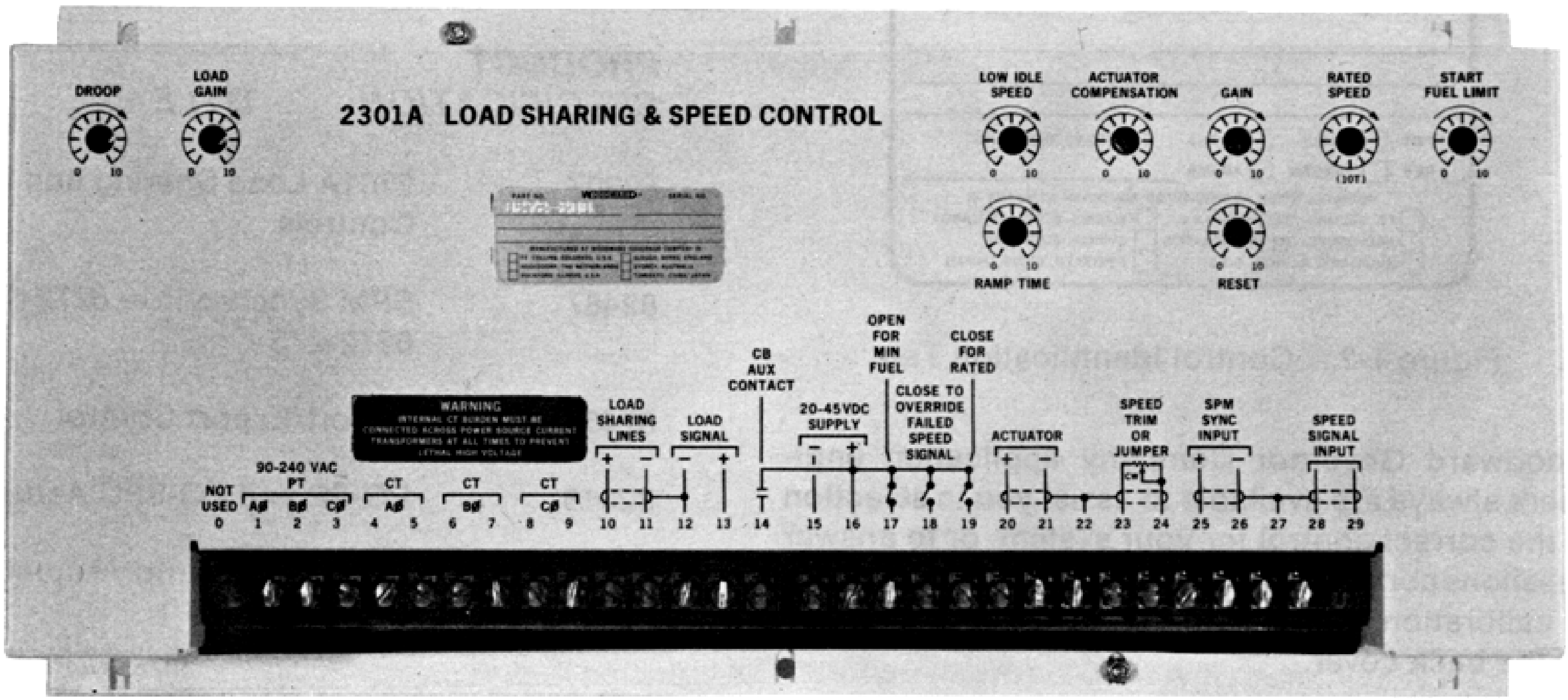


Figure 8-9 2301A Control View

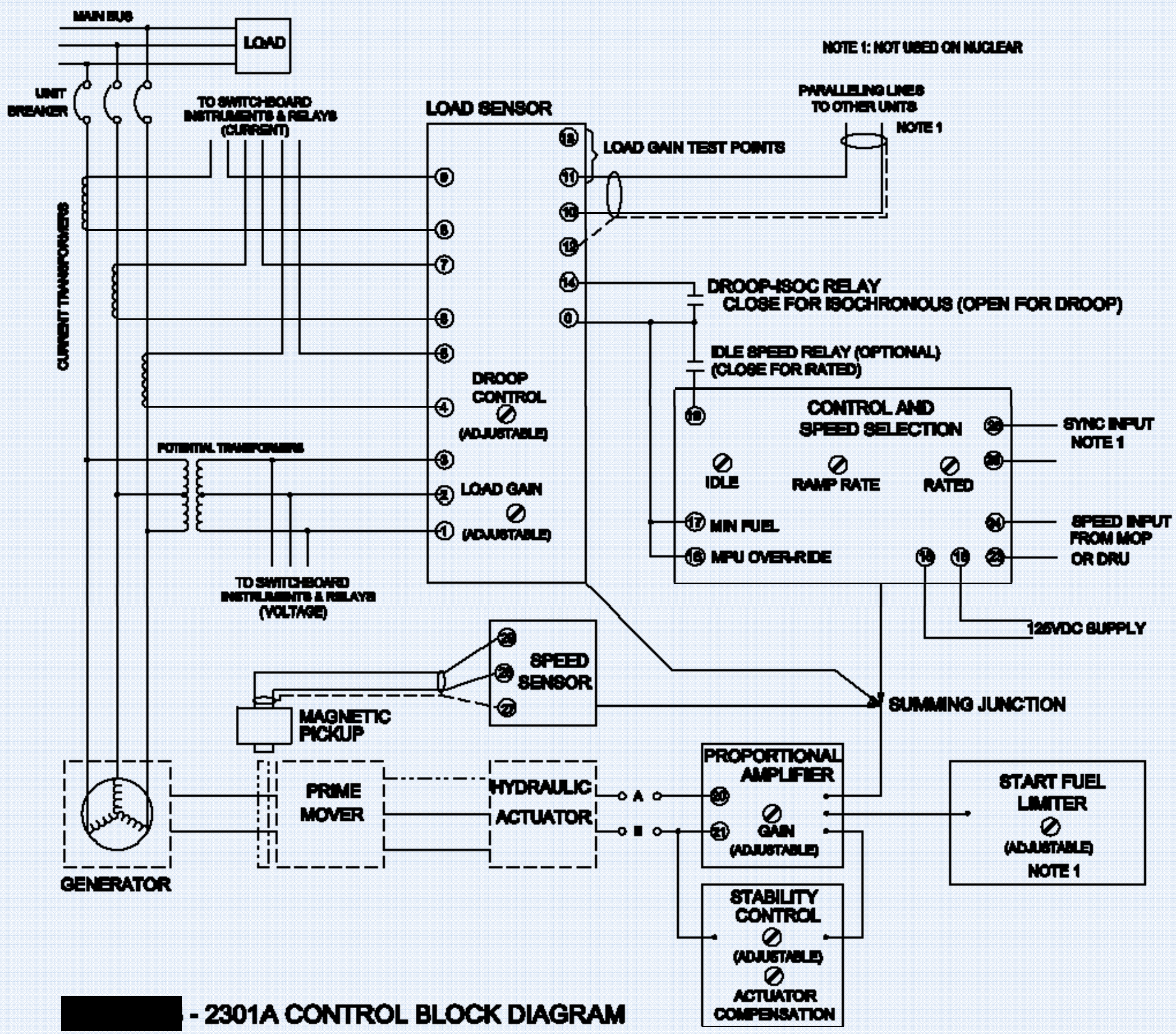


Figure 8-10 2301A Control Block Diagram

2301A Advantages

- Control under all conditions (not dependent on generator voltages).
- In conjunction with DRU, can respond to emergency signal while engine shutdown or at idle.
- All compensation is electronic - tuned for best performance.
- Can control at idle or rated speed equally well

2301A Disadvantages

- Requires external power (125 VDC) to operate
- Requires Magnetic Pickup (MPU) for speed input
  - Requires gear wheel on engine/generator
  - (MPUs are very reliable)
- Most failures result in EDG operation with backup governor as actuator (at higher speed)

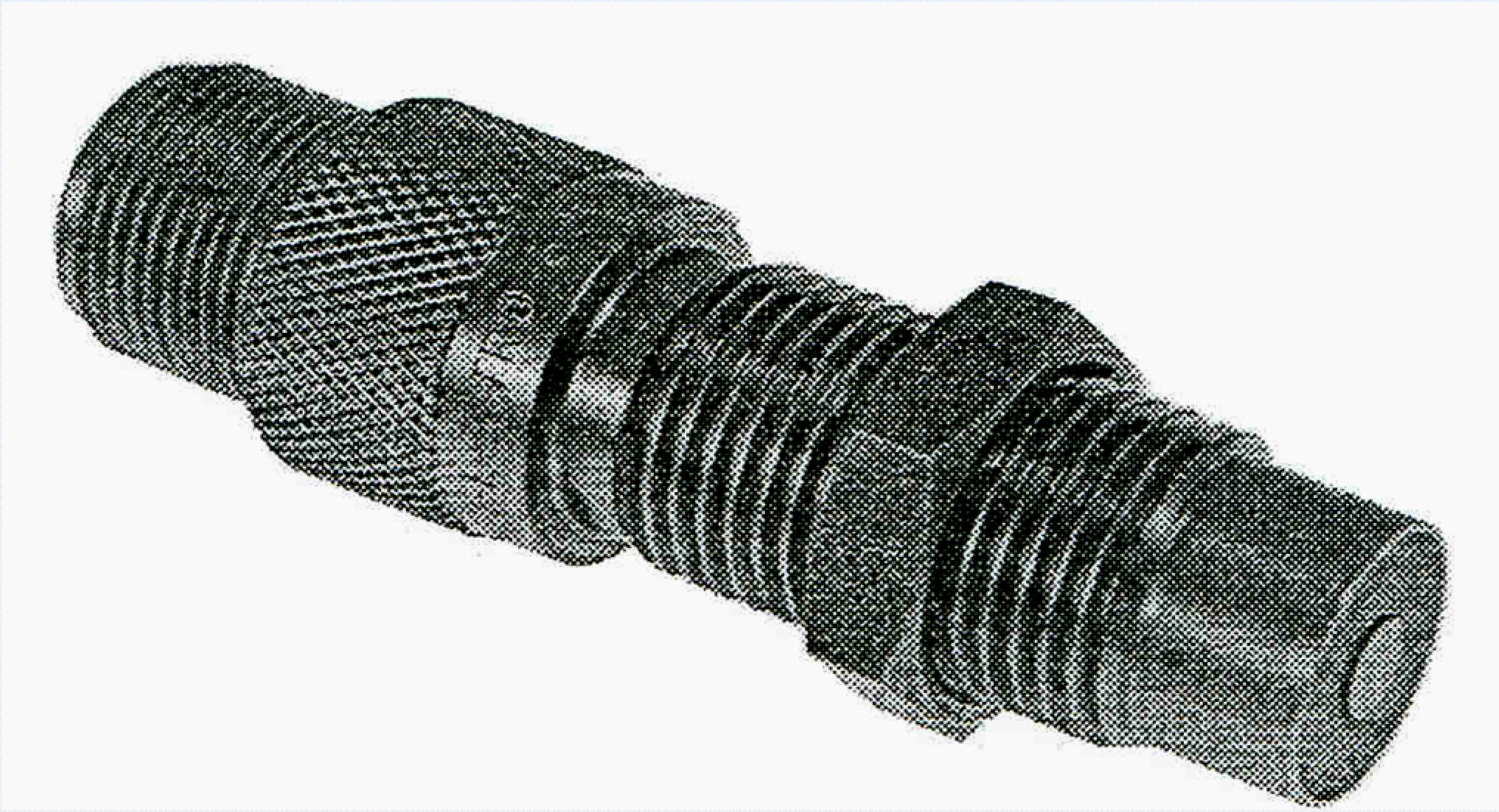


Figure 8-11 Typical Magnetic Pickup

Speed Input Devices

- Any of the speed input devices discussed can be used on either the EGA or the 2301A systems equally well.
- The use of the DRU with the 2301A results in much more flexibility in operational capabilities of the EDG.

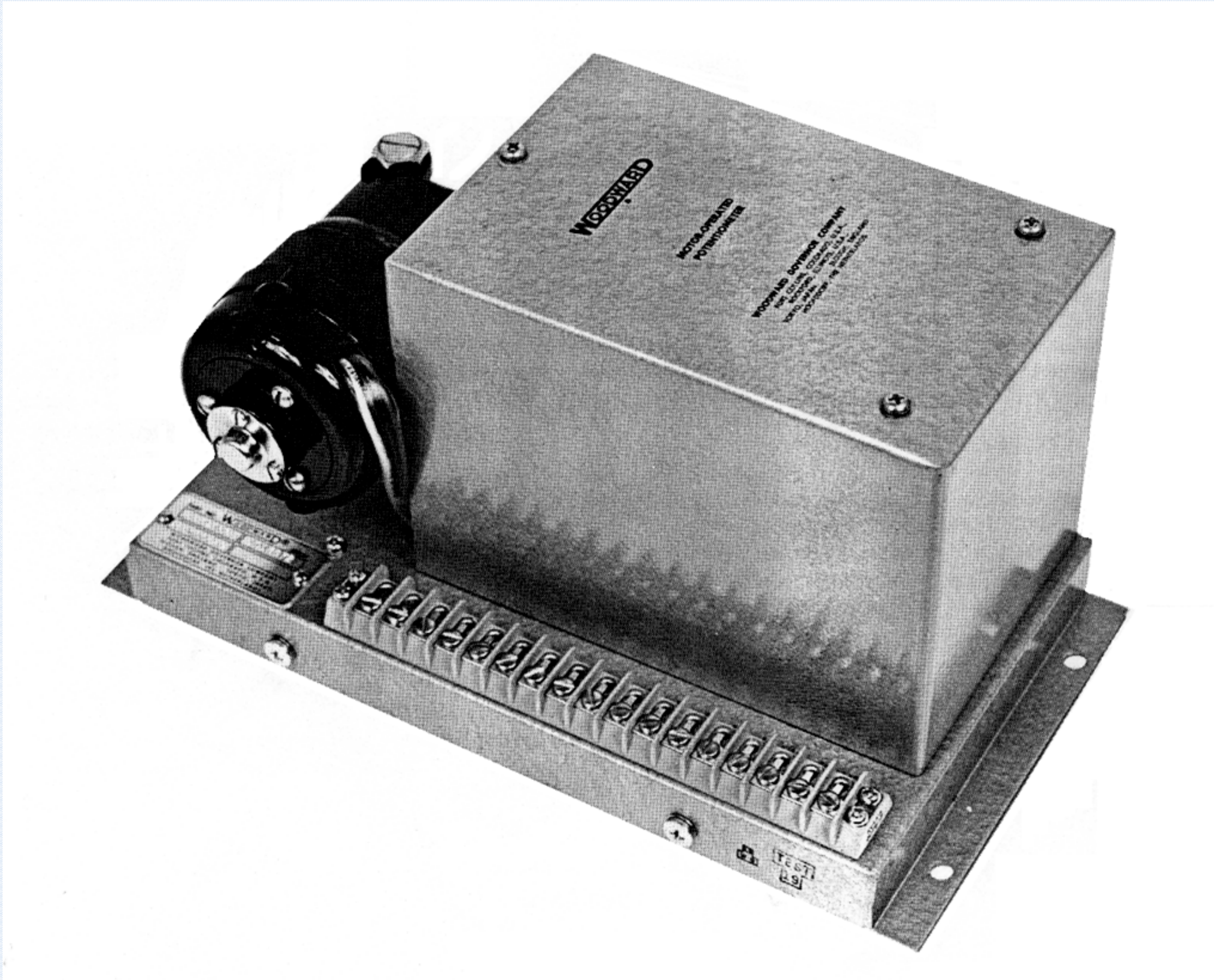


Figure 8-12 MOP for 125 VDC Motor

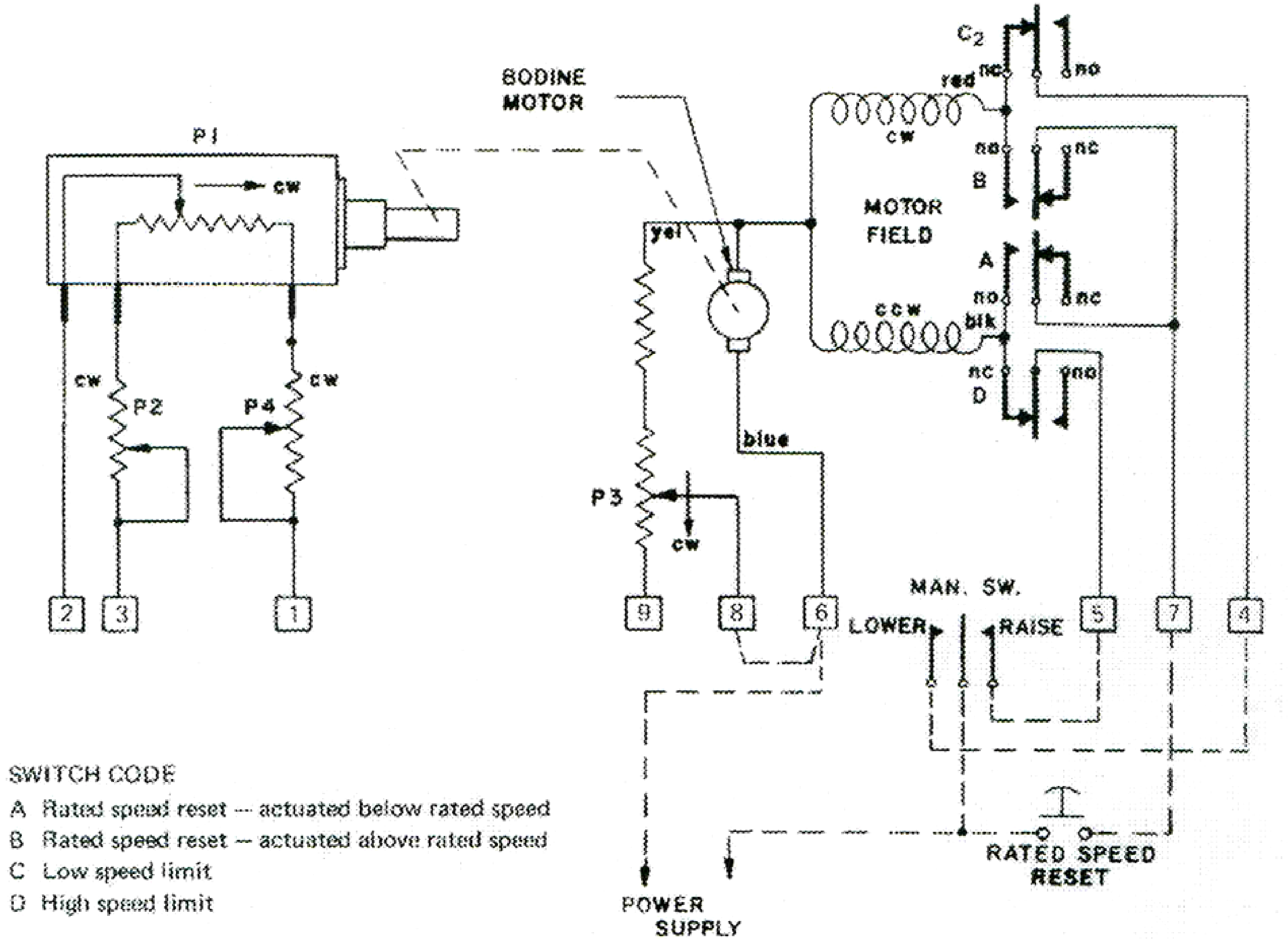


Figure 8-13 Schematic of MOP Unit

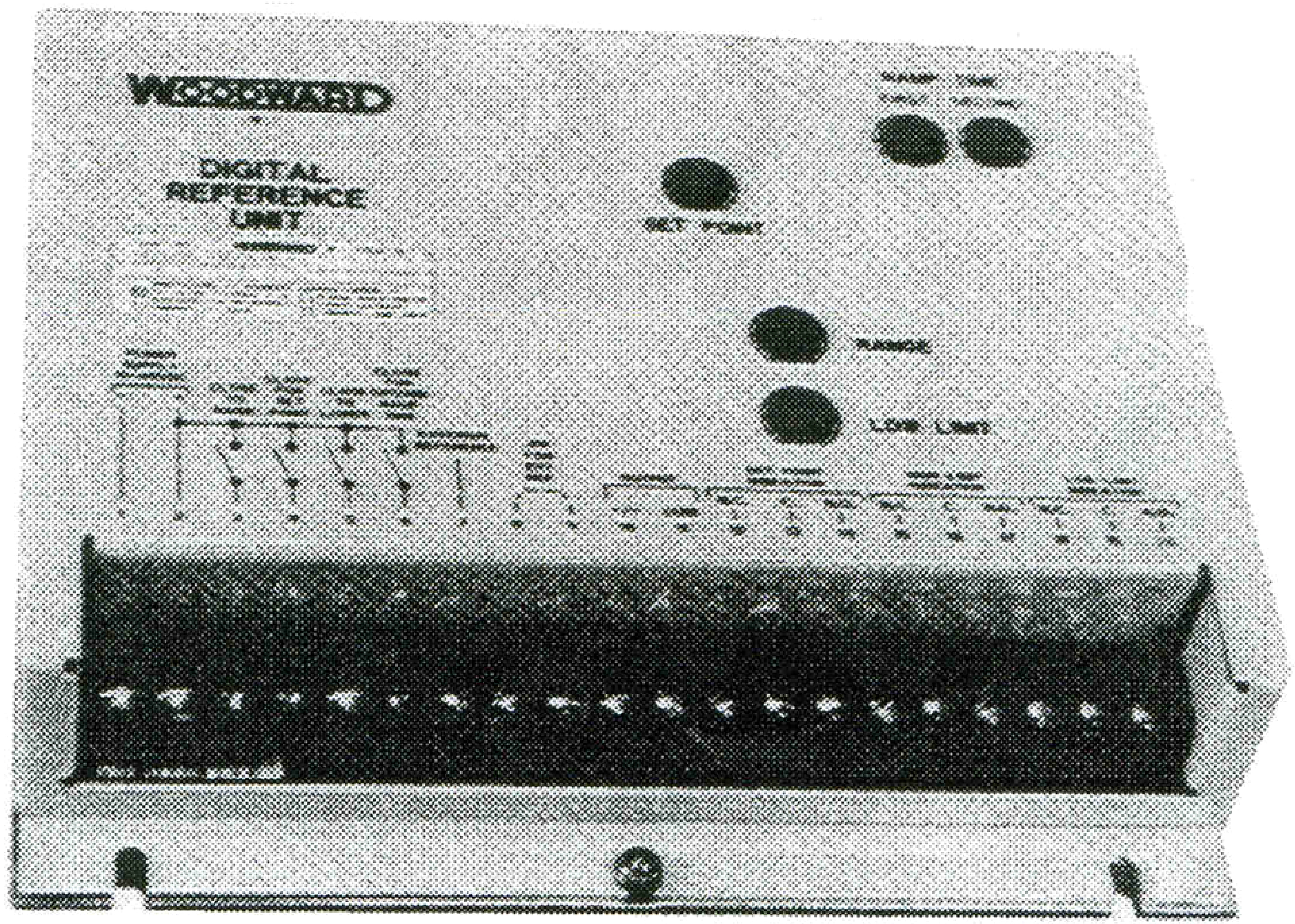


Figure 8-14 Digital Reference Unit (DRU)

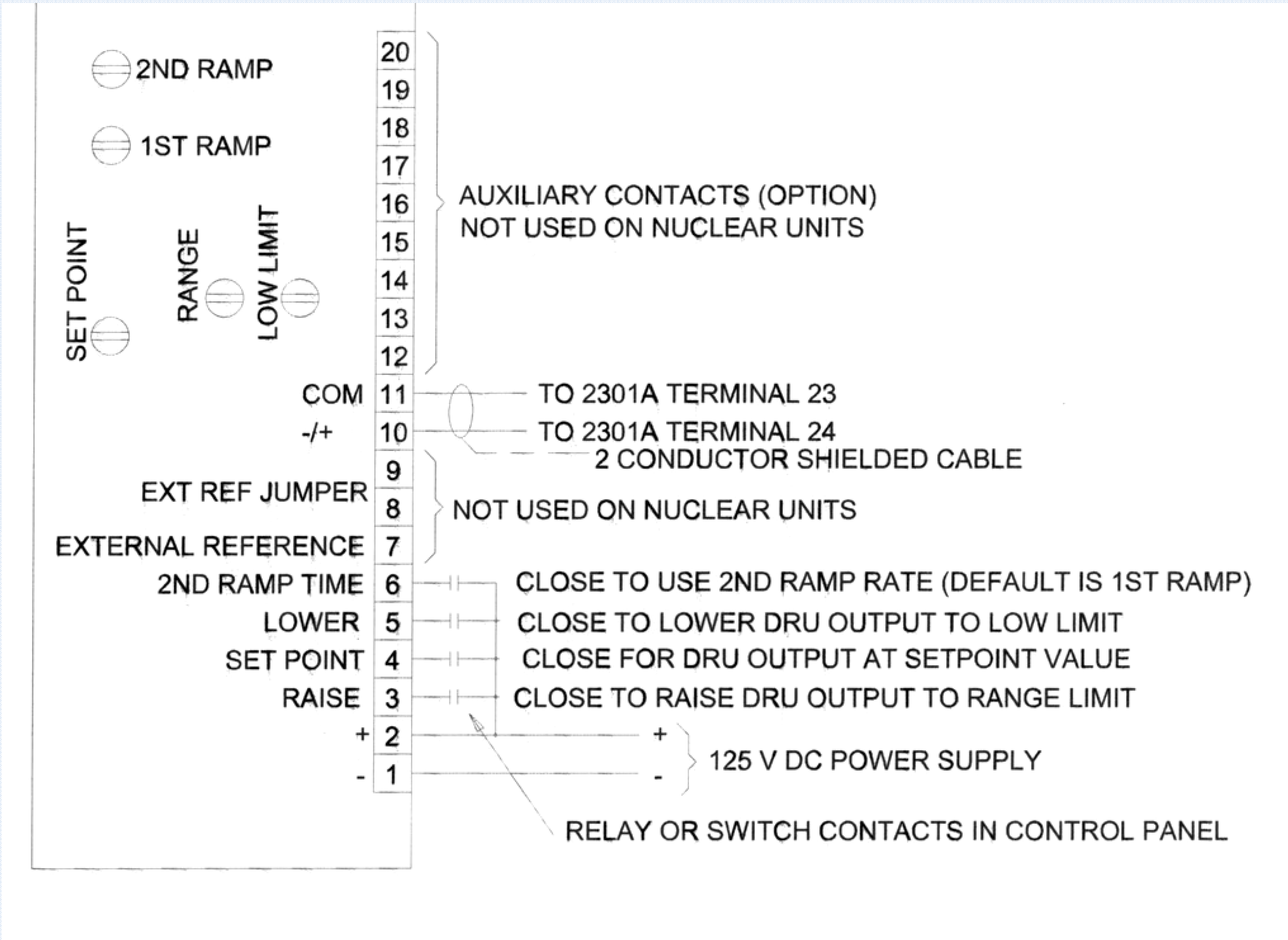


Figure 8-15 DRU Connections

The relationship between governor actuator output shaft rotational position and the engine fuel input is illustrated in Figure 8-16.

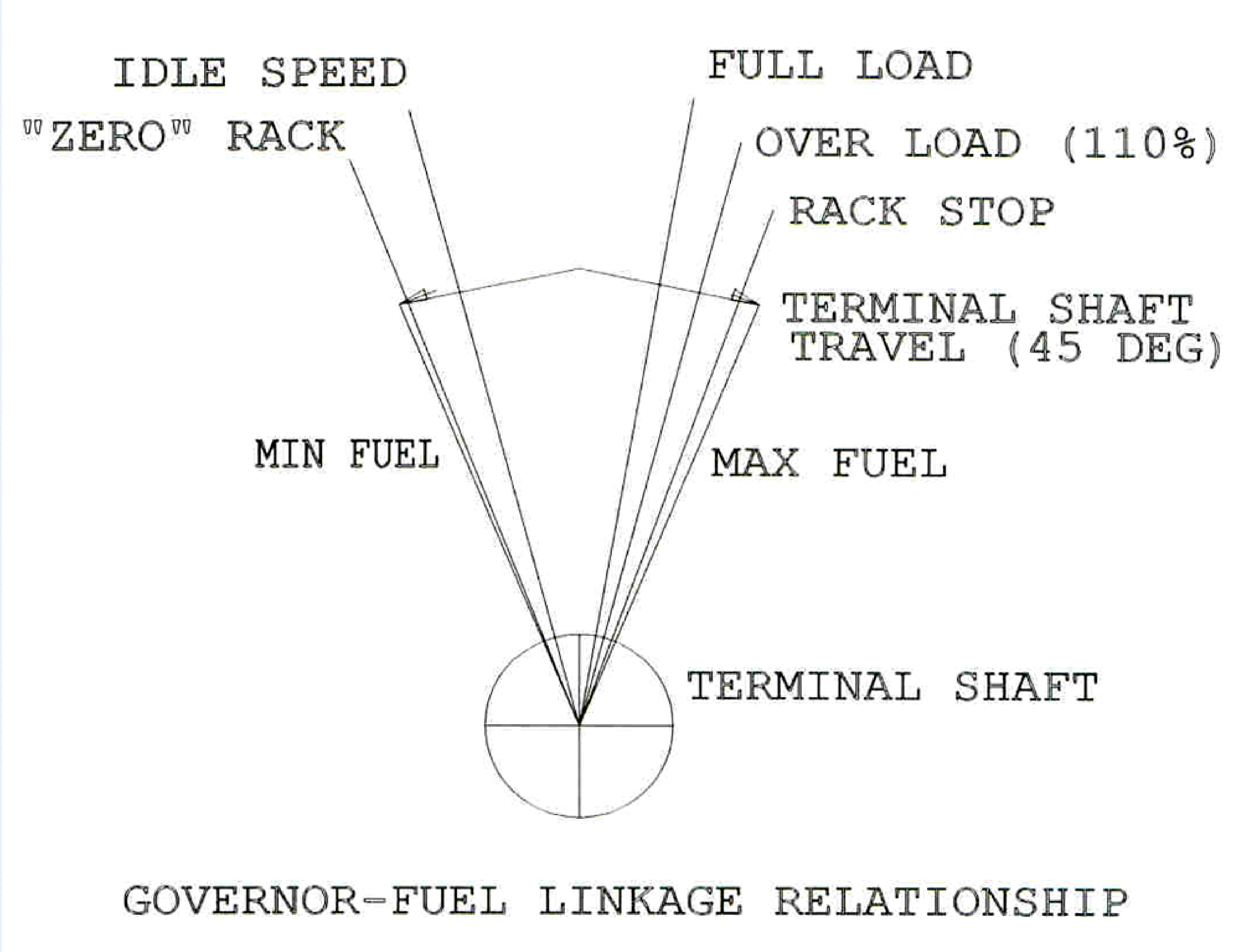


Figure 8-16 Relationship Between Governor Output and Fuel Control (Rack)

Purpose of Discussion on Governor Conversions

The purpose of this discussion is to cover the conversion of governing systems used in Nuclear Power Plant Emergency Diesel Generators (EDG's) from the currently installed Woodward EGA governing system to the Woodward 2301A governing system.

The primary reason for the change is the obsolescence of the EGA system.

Secondarily, the 2301A system provides better control, including allowing for slow starting of the EDG unit with capability to respond to an 'emergency signal' whenever received.

FAST START PROBLEM

A ten-second fast start sequence is equivalent to 35 to 50 hours of engine operation at rated load. Fast starts ultimately reduce the life and reliability of the unit. Fast starts along with fast loading of the generator stress the engine and the generator.

The NRC authorized plants to make slow starts by Generic Letter 84-15. However, units with the EGA governing system cannot make a slow start on the electric governor. It is necessary to use the mechanical backup governor (in the actuator). In this state, the unit **cannot** respond to an emergency start signal. The unit is effectively 'inoperable' when on the mechanical governor.

The 2301A governor, applied with the DRU, can be operated at idle speed under electronic governor control and **can** go to rated speed immediately (in ≈5 seconds) upon an emergency signal.

GOVERNOR CONVERSIONS TO DATE (FME UNITS)

The following plants have made a governor conversion:

- Detroit Edison – Enrico Fermi – 4 OP units
- Beaver Valley – Duquene P&L – 2 Pielstick Units
- Snupps – Callaway, MO – 2 Pielstick Units
- Snupps – Wolf Creek, KA – 2 Pielstick Units
- PSNH – Seabrook – 2 Pielstick Units
- BG&E – Calvert Cliffs – 3 OP Units
- South Carolina – VC Summer – 2 Pielstick Units
- Duane Arnold – 1 of 2 OP units converted.

OTHER FME UNITS…

Plants Expressing Interest in Governor Conversion:

- Alabama Power-Farley: 2 OP and 3 PC units. FME is working on this project.
- Indian Point: 3 ALCO units. FME is working on this project -- conversion early 2011.
- Millstone III: 2 Pielstick Units
- PECO -- Peach Bottom & Limerick: OP units.

IN SUMMARY…

- The EGA Governing System IS obsolete. Woodward has stated they are not providing EGA controls and will not attempt repair of older units.

- Woodward has also recently indicated they will no longer supply or repair MOP's. The DRU can be easily substituted.

- The 2301A is actually a better governing system. It has better response and is more flexible in application. Coupled with the DRU, it can solve a number of problems such as reducing the number of fast starts that units are subjected to. Because of the number of 2301A units in use, it will be maintained into the foreseeable future.

Other Governing Systems – Digital Governing

Several companies have developed other governing systems, including digital governor systems. Woodward Governor Co. has introduce a number of models of digital governors, or governor system components, including the following:

- The 2301D, a digital version of the 2301A
- The 723 PLUS series of governors and components

We will discuss these as they may apply to a Nuclear Power Plant:

The digital governing systems have many features that make them particularly applicable to commercial power applications and special conditions. However, most of those features are simply not suitable for Nuclear applications, including those relating to load sharing situations, automatic power transfer, unattended and/or remotely controlled generation, etc.

Digital Governing (continued)

There are also a number of problems with applying a digital governing system. The Woodward models require a power supply voltage between 18 and 40 volts DC. Most Nuclear Plant station battery systems are at 125V_{DC} (varying from 90-140V_{DC}). To apply a digital system would require either:

1. A dedicated separate battery system for the governor power (24V_{DC} typical)
2. An inverter power supply, where DC input is converted to AC, transformed to a lower voltage, then rectified back to DC and regulated to the desired output voltage.
3. A simple voltage dropping circuit – hard to regulate when input voltage can vary from 90 to 140V_{DC} and the load is not constant.

Digital Governing (continued)

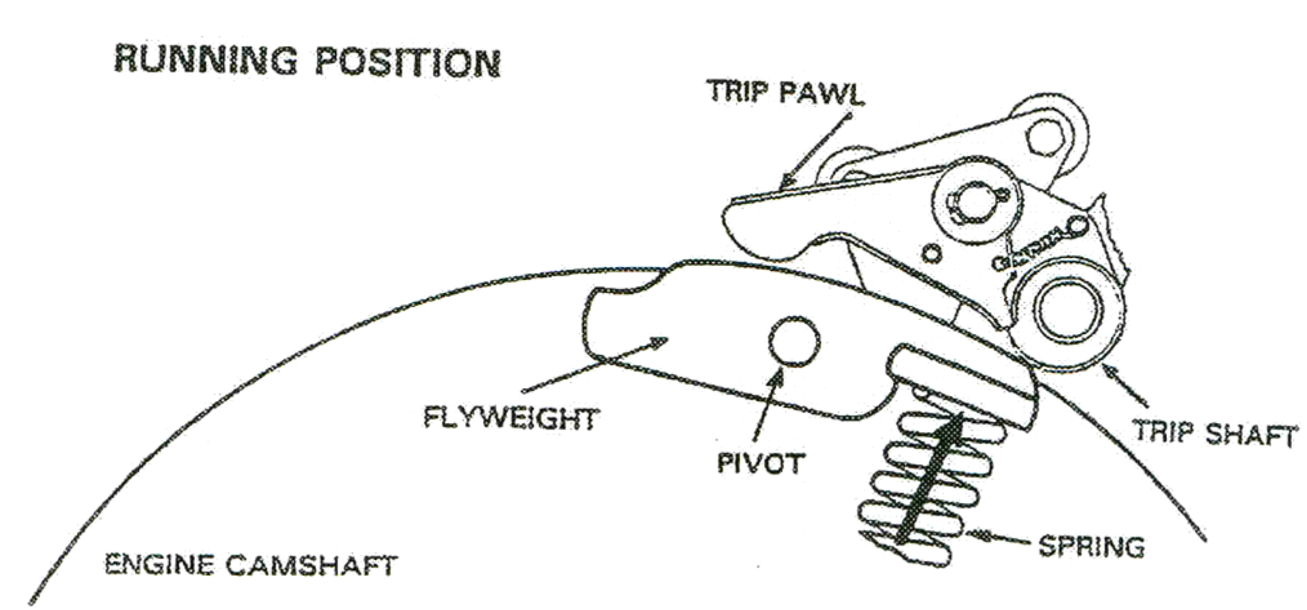
- Applying the 2301D would be equivalent to the 2301A installation and would be a candidate for replacement of the EGA systems except for the power supply problem.
- The situation with the 723 series is that for a generator application, the system requires not only the 723 module but a DSLC (Digital Synchronizer Load Control) unit. Both are powered with 18 to 40 VDC and the combination takes more space that would be available in replacing EGA components.
- Neither would result in any improvement in the frequency response or recovery because, for large motor starting loads, that is more controlled by the engine than by the speed or response of the governor system.

Digital Governing (continued)

- The governing system in a Nuclear plant is really quite simple. It provides good control of frequency when the EDG unit is supplying power to the emergency bus, and it allows the unit to be loaded on the offsite power bus for periodic surveillance testing.
- Digital governor components are also much more expensive than the analog (2301A) systems.
- As a mater of interest, if a unit had already been converted to a 2301A system, conversion to a 2301D would be much simpler as both use the same actuator on the engine (one of the more expensive components when making a governor conversion).

Engine Over-speed Protection

A mechanical over-speed trip switch (governor) is illustrated in Figure 8-17



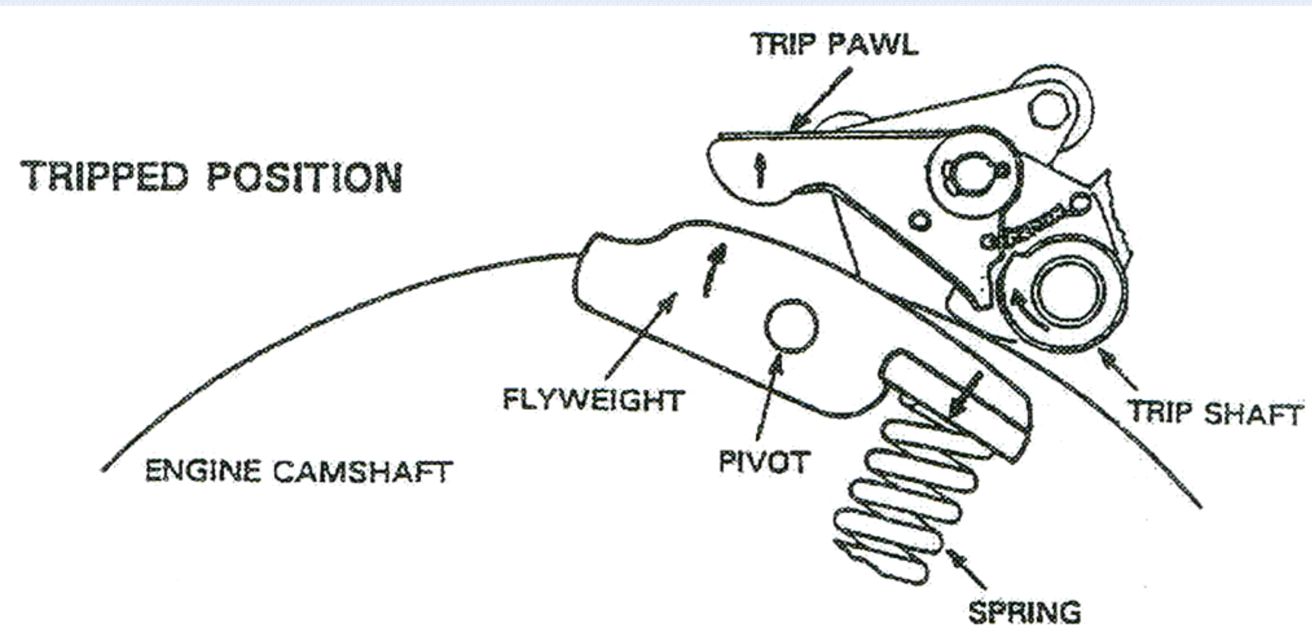


Figure 8-17

Over-Speed Trip (Governor) Mechanism

END OF CHAPTER 8