INSTRUCTIONS
for the

Linde
TRADE MARK

BASIC ELECTRONIC GOVERNOR

FOR 115-VOLT, 50- TO 60-CYCLE SERVICE

This Booklet Contains General Information on All LINDE EG-100 Series 115 Volt Electronic Governors. Any Exceptions, Special Instructions and Additional Information (Including Parts Pictures and Circuit Diagrams) Which Pertain to Your Particular Governor Will be Found in the Appendix Supplied with This Booklet.

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Be sure this information reaches the operator. You can get extra copies through any Linde office.
I. Introduction

The LINDE Electronic Governor is a precision device for controlling fractional horsepower (less than 1 hp) shunt-wound, direct-current motors. The governor monitors the motor speed, maintaining it constant at any selected value despite variations in load or in motor temperature. While designed primarily for controlling the special shunt motor used in certain LINDE equipments, it can be used with other suitable d.c. shunt-wound motors within its power capacity. Before any motor is used which was not specifically supplied to work with the governor, its suitability should be verified by the LINDE Development Laboratory.

The LINDE Electronic Governors discussed herein are for use with a 115-volt, 50- to 60-cycle* power supply only. (Direct current cannot be used.) When used with supplies of other a.c. voltages, a suitable step-up or step-down transformer must be used to furnish 115 volts to the governor. Governors designed for use with a 230-volt a.c. supply are discussed in Form 9256, "Instructions for the LINDE Electronic Governor for 230-Volt, 60-Cycle Service."

This booklet describes the Basic Electronic Governor. However, the information also applies, with minor exceptions, to all LINDE 115-volt electronic governors. ANY EXCEPTIONS, SPECIAL INSTRUCTIONS AND ADDITIONAL INFORMATION (INCLUDING PARTS PICTURES AND CIRCUIT DIAGRAMS) WHICH PERTAIN TO YOUR PARTICULAR GOVERNOR WILL BE FOUND IN THE APPENDIX SUPPLIED WITH THIS BOOKLET.

A. Design Features

1. Speed Range

The governor provides control over a motor speed range of better than a 100:1 ratio. (This is the ratio of maximum to minimum available motor speed. The actual usable speed range depends upon the application.) A simple control knob allows the operator to preset the speed before starting the motor, and to vary the speed quickly and accurately at any time during operation.

2. Regulation

The speed/load regulation is very good. Normal changes in load or in motor temperature have negligible effect on the speed.

3. Accuracy

An electrical meter is sometimes provided to give accurate indication of speed. The meter readings are reliable, and the governor maintains its calibration for thousands of hours of operation, since the calibration of the meter is substantially linear.

4. Reversible Operation

A reversing switch permits rotating the motor in both directions. The speed is substantially the same for either direction.

5. Simplicity - Easy Maintenance

The governor circuit is a simple one. It is composed of standard commercial parts, which have been installed on the chassis in locations which permit them to be easily and quickly replaced. A generous safety factor was used in the selection of components, to further reduce stoppages. Where external connections are used, the required terminals have been brought to a single terminal strip, so that these connections can be made easily, using a screwdriver.

6. Flexibility

The operating controls such as the motor switch, the speed adjusting means and the speed indicating meter (where one is used) are connected to terminal strips. If desired, these items can be removed from the governor and mounted in another more convenient location or they can be combined with other controls.

* The discussion applies equally to governors built for use with a 25 cycle power supply. The basic circuit will not change, although the ratings of certain components will be altered to accommodate the new power line frequency.
II. Installation

When purchased as an integral part of standard apparatus, the governor will in most cases be supplied already installed. To avoid damage during shipment, the thyatron tube is packed separately. This tube must be inserted in its socket inside the governor, before connecting the unit to any power source. Rotate the tube 1/4 turn clockwise to lock it in its socket. Be sure that the tube clip is securely fastened to the metal cap on the top of the tube. (Tube locations are shown in the parts pictures in the Appendix.)

When purchased separately for use in non-standard or customer-built equipment, the governor can be mounted in a variety of ways to suit the convenience of the operator. A suitable mounting bracket can be fabricated, or the governor cabinet can be made self-supporting by drilling proper holes and attaching it directly to the apparatus or other support with standard hardware.

The governor should be installed in a position which provides sufficient clearance at its front to permit easy removal of the chassis for servicing. The front panel and chassis are removable as a unit. Withdrawing the four panel mounting screws permits the unit to be pulled forward out of the cabinet. The required clearance for this should be available, and the power cable which supplies the governor should have sufficient extra length to permit complete withdrawal of the unit. Do not install the governor in a position where it will be subjected to excessive heat or moisture. A space of at least one inch should be provided between the back of the cabinet and any vertical wall surface, to assure adequate ventilation.

The diagram in the Appendix shows the required connections of the motor, power line, the ground and the operating controls such as the motor switch SW102, the speed adjusting potentiometer SP101, and the speed indicating means. The operating controls are connected to the governor by means of a terminal strip. Therefore, any or all of the control components can be removed from the governor and remounted in another location by simply disconnecting them from the terminal strip. Any reasonable length of cable can be used to connect these remotely operating controls and the governor. These connections are the same regardless of whether the operating controls are mounted in the governor or remotely.

The governor requires a 115-volt, 50- to 60-cycle a.c. power supply having good regulation. When operated directly from a factory power line, the line voltage fluctuations should not exceed ±5 volts; if fluctuations in excess of this value are encountered, the unit should be transferred to a steadier source, such as a lighting circuit. The governor will not work properly with line voltages below 105 volts.

IMPORTANT: Never attempt to operate the governor without first connecting the motor and controls to the proper terminals on the terminal strip. If this precaution is not observed, either or both the selenium rectifier SR101 and the condensers C104 and C105 may be damaged.

III. Operation

The section below describes the theory of operation of the governor. It is both useful and interesting particularly to a man with an electrical background. However, it is not necessary to understand this explanation in order to use or to service the governor.

The LINDE Governor is composed of four basic circuits. Each of these will be described individually below. To clarify the explanations which follow, a schematic diagram of the basic governor is shown in Figure 1. This diagram has been laid out with emphasis on electrical relationships. It is not intended to show the actual physical layout of parts or wiring.

A. Thyatron Filament and Time Delay Circuit

1. Filament Circuit

(a) Function: To supply heating current to the thyatron tube.
(b) Principal electrical component: Filament transformer TR101.

(c) Operation:
For proper operation, the filament of the thyatron tube TT101 must be heated to the proper temperature. To do this, the filament terminals must be connected to a 2-1/2-volt source supplying 9 amperes. When this current flows through the tube filament it becomes hot, just as the metal ribbon in an electric toaster becomes heated by the passage of current.

The proper filament current is supplied by transformer TR101. The transformer primary is connected across the 115-volt a.c. supply line. The thyatron filament terminals are connected to the transformer secondary winding, which furnishes approximately 2-1/2-volts a.c.

2. Time Delay Circuit

(a) Function: To protect the thyatron tube from damage due to premature conduction of current.
(b) Principal Electrical Component: Time Delay Relay TD101.

(c) Operation:
The thyatron filament reaches operating temperature approximately 30 seconds after the filament current is turned on. If current is permitted to flow in the motor armature circuit during this warm up period, the thyatron will be damaged. Time delay relay TD101 has been incorporated in the governor to prevent this.

The relay tube contains a pair of contacts and a heating coil. One of the contacts is mounted on a fixed metal arm; the other contact is mounted on a flexible bi-metal strip. The heating coil is mounted close to this bi-metal strip. When the governor master switch SW101 is turned on, current is supplied to transformer TR101. The thyatron filament and the relay heating coil are both connected to the secondary of TR101; heating current is thus supplied to the filament and coil simultaneously. The heat generated in the relay coil causes the bi-metal strip (and its contact) to bend toward the fixed arm (and its contact). After approximately 30 seconds (during which time the thyatron filament heats up to operating temperature) the two contacts touch, completing the circuit in which their terminals are connected. This "unlocks" the thyatron, placing the governor in operating condition.

Transformer TR101 and time delay relay TD101 are used only for filament heating and protection as explained above. They are independent of the other governor circuits, and play no direct part in the "governing" action.

B. Drive-Motor Field Rectifier Circuit
(SEE FIGURE 2)

1. Function
To supply rectified current to the field of the Drive Motor.

2. Principal Electrical Components
Voltage Adjusting Resistor R106
Selenium Rectifier SR101
Filter Condensers C104 and C105

3. Operation
The properties of selenium rectifier SR101 are such that current can flow through it in only one direction (this direction is indicated by the arrow which is part of the symbol). Whenever the voltage on the upper leg of the rectifier becomes positive with respect to that of the lower leg, current will flow down through the rectifier. When the polarity is reversed, however, no current can flow up through the rectifier. Since the rectifier is connected to the a.c. sup-
ply line, it will conduct during half of each a.c. cycle -- the half during which the upper leg is positive. The current which flows through the rectifier circuit is therefore pulsating direct current. Condensers C104 and C105 filter out the pulsations, so that a substantially steady d.c. voltage is made available between points A and B. Direct current for energizing the drive-motor field is taken from these points. Variable resistor R106 provides an adjustment for controlling the d.c. voltage output. This is adjusted at the factory to 110 volts d.c.

C. Drive-Motor Armature Power Circuit (SEE FIGURE 3)

1. Function
To supply controlled, rectified current to the drive-motor armature.

2. Principal Electrical Components
Thyratron Control Tube TT101 (C3J)
Armature Reversing Switch SW102
Feedback Resistor R102 (Function explained on page 9)

3. Operation
To keep a motor running at constant speed, its output torque must be kept continually equal to the retarding torque of the load. If the load increases, the motor's torque must also be increased, otherwise it will slow down. Conversely, a decrease in load requires corresponding decrease in motor torque to maintain constant speed.

To increase or decrease the motor output torque, we must increase or decrease the power supplied to the motor. This could be done by placing a rheostat in series with the motor armature, and adjusting this rheostat to increase or decrease the armature current as needed. This is a very inaccurate, inefficient method, however. Power is wasted in the rheostat, and it is impossible to adjust the current quickly and accurately enough to compensate for rapid load fluctuations.

Control of armature current can be effected very precisely and efficiently by using a thyratron tube in series with the motor armature. The thyratron uses a negligible amount of power in its grid circuit to control its relatively large output to the load circuit. Precise, instantaneous control of power supplied to the motor armature is effected merely by making slight alterations in a voltage which is applied to the thyratron control grid.

The Thyratron TT101 is a gas-filled triode (three-electrode) tube. The standard symbol for this tube, and the designations of the electrodes, are shown in Figure 3. In practice, the tube is connected in series with a load as shown, across an alternating current supply (Va). In the case of the LINDE Governor, the load is the drive-motor armature, and the supply is the 115-volt a.c. power line. The filament terminals X-X are connected to the heater-current supply.

The thyratron will conduct current in only one direction. When the plate voltage is positive with respect to the (center-tap connection) filament voltage, current will flow from plate to filament and around the external circuit in the direction shown by the arrows. When the plate is negative with respect to the filament, however, no current will flow. This is an inherent property of the thyratron. It thus "rectifies" the current in the circuit, just as the selenium rectifier SR does. The current which flows in the load circuit is therefore direct current, as is
required for operating the shunt-type drive-motor. When the tube is conducting current, the voltage drop across the tube is approximately 10 volts. The remainder of the supply voltage appears across the load. Due to this low voltage drop across the tube, very little power is consumed by the tube; this results in high operating efficiency.

SW102 is a reversing switch. It reverses the direction of current flow through the motor armature, thus reversing the direction of rotation. Placing SW102 in its center position shuts the motor off by opening the load circuit.

D. Thyatron Grid Control Circuit

1. Function
To supply control voltage to the grid of thyatron tube TT101, thus controlling the current passed by the tube.

2. Principal Electrical Components
A.C. Bias Transformer TR102
Phase-Shifting Condenser C101
Phase-Shifting Resistor R101
D.C. Bias Battery (4-1/2-volts)
Voltage Regulator Tube VR101
Voltage Regulator Ballast Resistor R105
Reference Voltage Potentiometer SP101
Feedback Filter Resistor R103
Feedback Resistor R102
Feedback Filter Condenser C103
Grid Protecting Resistor R104
Grid By-Pass Condenser C102

3. Operation
The grid of the thyatron can control the flow of current from plate to filament. This control is achieved by connecting a voltage source (Vg) between the grid and the filament center-tap, so as to make the grid negative with respect to the filament, as shown in Figure 3. How this negative voltage affects the plate-to-filament current flow will be seen as the explanation proceeds. It is important to remember that the plate-filament-load circuit and the grid-filament circuit in Figure 3 are two separate circuits. They have only a single point in common -- the center-tap connection on the filament. All load current flow is confined to the plate-filament-load circuit. There is no appreciable current flow around the grid-filament circuit; the grid exercises control merely by introducing its negative potential between the plate and filament, within the tube.

If the grid were connected directly to the filament (that is, if the grid-to-filament voltage were made zero), the tube would act as an ordinary rectifier. It would conduct current during the entire time that the plate voltage remained positive. Since we are applying alternating current from the 115-volt supply line, this means that the tube would conduct during the entire positive half-cycle of the a.c. wave. During the negative half-cycle, when the plate is negative with respect to the filament, no current would flow. This is shown graphically in Figure 4. The shaded portions represent the relative amount of power which is consumed in the circuit; all but a negligible amount is consumed in the load itself. Our load in this case is the drive-motor armature, therefore, the shaded portions will indicate the relative amount of power being supplied to the armature. Since the motor output torque depends upon the amount of power supplied to the motor, these shaded portions will represent the relative output torque also.

If the grid voltage is made slightly negative with respect to the filament, the tube will no longer conduct during the entire positive half-cycle. Conduction will not begin until the plate voltage reaches a certain definite value. Once this value is reached, the tube "fires," and conducts current during the remainder of the positive half-cycle. Figure 5 shows the situation graphically. The value of plate voltage at which conduction begins is precisely determined by the value of the negative voltage on the control grid.

As the grid voltage is made more negative the plate "firing" voltage becomes progressively higher; as shown by the diagrams, the tube thus "fires" progressively later in the cycle.

If the grid voltage is made sufficiently negative, the tube will not fire until the plate voltage reaches its peak. This condition is shown in Figure 6. If the

![FIG. 4 - Thyatron Current - Full Power](image)

![FIG. 5 - Thyatron Current - 3/4 Power](image)

![FIG. 6 - Thyatron Current - 1/2 Power](image)
grid voltage is made still more negative, the tube will not conduct at all, since the plate voltage never reaches the value needed to cause the tube to fire. The grid thus can cause the tube to conduct for any fraction of the positive half-cycle from 1/2 on up to 1. Comparison of Figures 4, 5, and 6 shows that by varying the voltage on the grid, we can vary the power input to the motor from half-power (Figure 6) to full power (Figure 4). The total variation of grid voltage required is less than 2 volts. To permit variation of power from zero to full power, it is necessary to add a small a.c. voltage to the negative grid voltage. This a.c. voltage must lag 90 degrees out of phase with the a.c. plate voltage, to be effective. Transformer TR102 supplies an a.c. voltage at its secondary winding of approximately 8 volts. This voltage, however, is in phase with the plate voltage, since the primary of TR102 is connected to the same supply line as the plate circuit. Resistor R101 and condenser C101 are connected as a phase-shifting network whose output to the grid circuit lags 90 degrees out of phase with the plate voltage, as is required for proper tube operation. This permits the grid to exercise control of tube current during the entire positive half-cycle, so that motor power can be varied at will from zero to maximum. The output of the phase-shift circuit is connected in series with the grid circuit, so that the phase-shifted voltage is added to the other voltages in the grid circuit.

To provide operator-control of the motor, an adjustable d.c. voltage is connected in series with the grid circuit. A d.c. voltage of 105 volts exists across potentiometer SP101 and resistor R103 in series. As shown in Figure 7, SP101 and R103 are in series with the thyratron grid circuit. When the movable arm of SP101 is at the upper end of SP101, therefore, 105 volts d.c. is connected in series with the grid circuit. As the movable arm is moved toward the lower end of SP101, progressively less of this voltage appears in series with the grid circuit. As will be explained, the setting of potentiometer SP101 establishes the operating speed of the motor.

The 105-volt supply voltage across SP101 and R103 is furnished by the voltage-regulating tube VR101 and its ballast resistor R105. This tube is a gas-filled diode (two-element) tube which has the ability to maintain a constant voltage of 105-volts d.c. across its terminals in spite of variations in line voltage or load. It does this by automatically and instantaneously increasing or decreasing the current which it draws through resistor R105. For example, suppose that the line voltage across the tube and resistor were 110-volts d.c.; the voltage across the tube would be 105-volts, and the voltage across the resistor would be 5 volts. If the line voltage were to suddenly increase to 120 volts, the tube would instantaneously draw more current through R105 so that the voltage drop across R105 would immediately increase to 15 volts. Thus the voltage drop across the tube would remain unchanged at 105 volts. This assures that the "reference" voltage supplied to SP101 and R103 remains constant at 105 volts regardless of fluctuations in the power line voltage.

A bias battery is also connected in series with the grid circuit. The battery provides a constant minimum d.c. bias of minus 4-1/2-volts on the control grid.

The grid-to-filament voltage is the sum of the various voltages in the grid circuit. (For the purposes of this analysis the a.c. phase-shifted voltage supplied by R101 and C101 can be ignored.) The grid voltage, therefore, can be any value from minus 4-1/2-volts to plus 100-volts (approximate values), depending upon the setting SP101.

The governor grid circuit is connected as Figure 7 shows, with one important difference; the lower end of the grid circuit, instead of being connected directly to the filament as indicated in Figure 7, is connected below the load (the motor armature in this case) as shown in Figure 8. Examination of Figure 8 shows that the motor armature is now in series with the grid circuit, as well as with the plate circuit. This means that any voltage which appears across the armature terminals will be added to (or subtracted from, depending upon the polarity) the other voltages in the grid-to-filament circuit.

To illustrate the effect of the armature voltage on the control grid, assume that the "reference voltage" has been adjusted to 50-volts by means of SP101. At the instant that the governor operating switch is turned on, the motor armature is, of course, not rotating. In this condition, its resistance to the passage of current is small. The voltage drop across it will also be small. The grid-to-filament voltage
leaves a remainder of plus 4 volts. The total grid to-filament voltage then is 4 volts minus 4-1/2 volts, or minus 1/2-volt. This grid voltage permits the thyratron to conduct during a major portion of the positive half-cycle of plate voltage, as shown graphically in Figure 5. The shaded portions of Figure 5 show that about 3/4 full power is then being supplied to the armature. If the motor happens to be lightly loaded, this much power may be more than is needed. The armature would naturally tend to speed up again. But this will increase the counter-e.m.f. As just explained, this would result in a more negative grid voltage, and hence would decrease the power being supplied to the armature, thus slowing it down. A condition of balance is quickly reached where:

(a) The armature revolves steadily at a certain speed.

(b) This armature speed produces a certain steady value of counter-e.m.f.

(c) This value of counter-e.m.f. establishes a particular grid voltage.

(d) This particular grid voltage permits the thyratron to pass a particular quantity of current to the armature.

(e) This particular quantity of current provides just enough power to keep the armature running at the "certain speed" established in Step 1, thus completing the chain.

Although the above explanation seems lengthy, the condition of balance is actually reached almost instantaneously after turning on the motor.

It can be seen from the foregoing that the "reference voltage," as determined by the setting of SP101, establishes the operating speed of the motor.

Since the motor operating speed is proportional to the "reference voltage," this voltage can be used to provide visual indication of the speed of the motor, or of the apparatus which it propels. Accordingly, a voltmeter, in series with its dropping resistor, is connected across the reference voltage. When the meter dial is calibrated to the motor or apparatus in terms of revolutions-per-minute or inches-per-minute, it will serve as an accurate, dependable speed indicator. Since the "reference voltage" is on continually, even when the motor is not running, the motor operating speed can be preset by adjusting SP101 until the meter indicates the desired speed.

A slight additional analysis will show how the governor maintains the motor speed constant in spite of variations in load. If the load on the motor momentarily increases for some reason, it would tend to cause the armature to slow down. This would decrease the counter-e.m.f. and would instantly affect the voltage on the thyratron control grid, making it less negative. Instantly the tube would increase the power supplied to the armature. This power increase would balance the load increase, and the motor would continue to operate at substantially its original speed.
A decrease in load would be counteracted in an analogous manner. The circuit would operate to decrease the armature power, thus counterbalancing the decrease in load.

The thyatron control grid is extremely sensitive to the most minute changes in the motor's counter-emf. The corrective action is so instantaneous that there is no appreciable change in motor speed, though the load be varied rapidly and within wide limits.

Resistor R102 is a "feedback" resistor. It is connected so that it is in series with both the armature circuit and the "reference voltage" circuit. Connected in this way, it feeds back a small compensating voltage from the armature circuit to the "reference voltage" circuit, helping to maintain the motor speed constant under varying load conditions.

Condenser C103 filters out the individual pulsations in the voltage across R102 so that only an average value is fed back to the "reference voltage" circuit.

Resistor R104 has been inserted in the grid circuit to protect the thyatron tube from damage in the event of a flow of current in the grid circuit. It plays no direct part in the operations of the grid control circuit.

Condenser C102 by-passes transient voltages, preventing them from affecting the normal grid voltage.

The contacts of time-delay relay TD101 are in series with the "reference voltage" circuit, as shown in Figure 1. When these contacts are open, no voltage appears across SP101 and R103. This leaves only the bias battery voltage of minus 4-1/2-volts on the thyatron grid. This value of voltage being sufficient to completely prevent the thyatron from conducting no plate current can flow, regardless of whether the operating switch SW102 is on or not. After the 30 second delay period, the contacts of TD101 close, completing the circuit and thus supplying a reference voltage to the grid circuit. Normal operation can then occur.

Dynamic Braking. For some applications it is desirable to stop the motor as quickly as possible. To do this, a dynamic braking circuit is added between the motor armature and the thyatron tube as shown in Fig. 8. The components needed to make the circuit are a start-stop switch and a 5 ohm 25 watt variable resistor (ohmite #0362).

When the start-stop switch is in the R or Running position, the motor armature is connected to run at the desired speed. When the switch is in the S or Stop position, the armature is shorted through the braking resistor BR. Increasing the resistance slows the braking action, decreasing it speeds up the braking action.

![FIG. 9 - Dynamic Braking Circuit](image)

### IV. Maintenance

#### A. General Information

Many years of experience with thousands of LINDE electronic governors have shown that these units are relatively trouble free and seldom require servicing. Very large safety factors are used and most of the components have a practically unlimited life. The few wearing parts have a very long service life and they are readily available and easy to replace. The serviceman need not have a knowledge of electronics, the only requirement being that he have available a voltmeter, an ammeter and an ohmmeter and that he be familiar with the use of these instruments.

The type of test meter used in checking the governor will influence the results obtained. The voltage readings given are based on the use of voltmeters having a resistance of 1000 ohms per volt or more such as the Weston model 980 or model 697 Analyzers. These particular meters have in addition a built-in ohm-

meter which can be used for testing resistors and condensers, and a.c. scales for checking line and transformer voltages. The model 980 also has built-in ammeter scales. However, any other suitable meter with 1000 ohms-per-volt scales can be used.

It is important that the d.c. meter scales be used in measuring d.c. voltages, and a.c. scales be used in measuring a.c. voltages. If this is not done, the meter readings obtained will be valueless.

Because of the wave form of the armature current, a d.c. D'Arsonval type of ammeter, such as the Weston model 301 or model 469, should be used to measure the armature current. Other types of meters will not give correct readings.

In many cases, the symptoms alone will indicate what should be done. Below is a list of the symptoms and suggested means for correcting the trouble. If
these suggested means do not eliminate the trouble, it may be necessary to make a complete check on the governor as indicated later in these instructions. Run the checks in the order given in the instructions and do not skip any steps. If a step does not locate the trouble, go on to the next step until the cause of the trouble is found.

For complete information on motors which may be used with this governor, refer to Table 1 at the back of the book.

Wearing Parts in the Governor

Below is a list of the parts which may require replacement after a very long period of service. With the exception of the selenium rectifier, all of the wearing parts are of the plug-in type and can be easily replaced. It is very unusual to have to replace any parts other than those listed below.

1. **Bias Battery** -- This battery normally has a life in excess of one year but it is recommended that it be replaced every six months.

2. **Selenium Rectifier SR101 and Condensers C103, C104, and C105** -- These units usually have a life in excess of 10,000 hours. See instructions for test procedure.

3. **Time-Delay Relay TD101** -- This unit may fail to close properly due to a manufacturing defect. See instructions for test procedure.

4. **Voltage Regulator Tube VR101** -- These tubes usually last indefinitely unless it contains a manufacturing defect. Usually if it glows blue in operation, it is good.

5. **Thyratron Tube TT101** -- These tubes have an extremely long life (20,000 hours is unusual) and they seldom need to be replaced. The great majority of these tubes which are replaced are replaced needlessly. If a tube seems to be defective, always recheck it after the trouble has been cleared up to make certain that the tube actually is defective.

B. Trouble Symptoms and Their Corrections

Part I. Fuses Blow

1. If the fuses blow when the motor armature is not energized, the difficulty may be due to:

   (a) A short in the governor wiring.

   (b) A short in either transformer TR101 or TR102. This can be checked by disconnecting one primary lead of the transformer and noting if the fuse still blows.

2. If the fuse blows when the motor armature is energized, the difficulty may be due to:

   (a) An overloaded motor. In the event of such occurrence, examine the mechanism operated by the motor for conditions which might be causing an overload. These include tight gears, faulty bearings, misalignment, excessive roll pressure, jamming, foreign material on rails or gear trains, etc.

   The armature current of the motor is roughly proportional to the torque delivered by the motor. Armature current can, therefore, be used as an indication of motor load. When the normal current values to be expected are available, a quick check of the motor load can be made by inserting an ammeter in series with the armature. In some cases, the machine instruction booklet gives proper values of current. When normal current values have not been provided, they can be obtained by operating the equipment under average conditions and recording the current readings registered on an ammeter in series with the armature. These readings should then be inscribed on a label or plate and mounted on the apparatus in a convenient location.

   Because of the wave form of the armature current, a d.c. D’Arsonval type of ammeter, such as the Weston model 301 or model 489, should be used to measure the armature current. Other meter types will not give correct readings.

   The ammeter can be inserted in series with the armature circuit at any convenient point. A suggested location is at the terminal strip in the governor. Disconnect the wire from terminal T101-1 and connect the ammeter between the wire and the terminal. The positive side of the ammeter connects to the terminal, the negative side of the meter to the wire.

   (b) If disengaging the load does not eliminate the difficulty, the next thing to check is the field voltage. A low field voltage will cause an abnormally high armature current. The small KBD motors should have 110-volts d.c. across the field winding. All other motors should have 115 volts across the field winding.

   Test the field voltage between terminals T101-6 and T101-7 on the terminal strip. This voltage should be the voltage required by the particular head in use, as stated in the proper instruction literature. If the field voltage is not correct, it may be adjusted by means of resistor R106. Resistor R106 has a total resistance of 25 ohms. In order to function properly, R106 should never be reduced below 10 ohms. If the correct field voltage can not be obtained without making R106 less than 10 ohms, it is probable that either rectifier SR101 or condensers C104 and C105 are defective. The easiest way to check these components is by substitution. It should be noted that when either the rectifier or the con-
denser is found to be defective, it is advisable to replace both of them in order to avoid the possibility of another breakdown within a short period of time.

(c) If taking steps (a) and (b) do not indicate the reason for fuse blowing, then the motor gear head may be binding. This can be checked by removing the motor from the gear head. If this stops the fuse blowing, the gear head may be binding or it may be misaligned with the motor or it may lack lubrication. Here again, an ammeter in the armature circuit can be of considerable help in locating the trouble.

(d) If taking steps (a), (b), and (c) have not cleared the trouble, the motor itself may be defective.

With the governor turned off, note if the armature rotates freely. Excessive friction may indicate that the armature bearings are defective or that the motor was improperly assembled. If neither of these is causing the trouble, check the armature and field resistances against the values given on the motor chart. If this does not show up the trouble, it is likely that the armature has a partial short which will not show up in this test. Substitute another motor.

Part II. Motor Will Not Run
1. If the pilot light does not light, the difficulty may be due to blown fuses F101 and F102, no line voltage, or a defective switch SW101.

2. Check to make certain that the thyatron tube TT101 is properly turned in its socket and that it is warmed to touch. If the tube is cold, make sure that the socket prongs contact the tube pins. If the tube is still cold, substitute a new tube.

3. Test the field voltage between terminals T101-6 and T101-7 on the terminal strip. Refer to procedure outlined in Part I, Paragraph 2-(b).

4. Check the speed control potentiometer. Rotate SP101 from minimum to maximum settings. The speed indicator meter reading should vary smoothly from nearly zero to slightly above top scale. If the governor is not equipped with a speed indicator, a d.c. voltmeter connected between terminals T101-3 and T101-4 should vary smoothly from zero to approximately 100 volts d.c. as SP101 is rotated from minimum to maximum settings.

5. Check the bias battery. The bias battery should be tested with the master switch SW101 open. The battery should give a reading between 4.3 and 4.6 volts d.c. Any battery which gives a reading below 4.3 volts should be replaced. Although the life of this battery is in excess of one year, we recommend that it be replaced every six months as a routine service measure to eliminate the possibility of trouble.

The battery is wrapped in a fiber paper or rubber jacket to protect it from being cut by the battery mounting clip. When installing a replacement battery, transfer this jacket to the new battery. Be sure, also, that the red wire lead is connected to the positive terminal of the battery, and that the black-and-white wire lead is connected to the negative battery terminal. Any 4-1/2 volt battery can be used in an emergency, but batteries other than the specified battery may not fit the battery clips.

If, by any chance, the battery remains in the circuit far beyond its normal life, the battery cells may corrode and leak fluid. Should this occur, carefully clean all fluid from the chassis and install both a new battery and a new fiber jacket.

6. Check the resistance of the motor field and armature windings in accordance with the motor chart.

7. Check R-102 for proper value in accordance with the motor chart.

8. Check all wiring between the governor and the motor for continuity. This includes all switches, relays, pushbuttons, etc., which may be in the motor circuit but which are not actually in the governor.

Part III. Motor Speed Erratic and Speed Adjustment SP-101 Has Little Affect on Speed

1. Check the Bias Battery. Refer to Part II, Item 5 for procedure.

2. Check the Speed Potentiometer. Refer to procedure listed in Part II, Item 4.

3. Check Resistors R104, R101, R103, and R102 with an Ohmmeter. They should check within ±10 per cent.

Part IV. Motor Speed Unsteady But Can Be Controlled by the Speed Adjustment SP101

1. Check the line voltage. It should be between 110 and 125 volts 60 cycles a.c. Voltages below 105 volts a.c. may cause the speed to be unsteady because of improper operation of the voltage regulator tube.

2. Make sure that the voltage regulator tube VR101 shows a blue glow which indicates that it is working.

(a) If it does not glow, check the voltage across T101-6 and T101-7. This should be 110 to 115 volts d.c. depending on the motor used. If this voltage is OK, then check R105. If R105 is OK, replace VR101. NOTE: This tube has an extremely long life and seldom requires replacement.

(b) Test the field voltage between terminals T101-6 and T101-7 on the terminal strip. Refer to procedure outlined in Part I, Paragraph 2-(b).

3. Check the Speed Control Potentiometer. Refer to procedure listed in Part II, Item 4.
4. Loads in excess of the motor rating may cause the motor speed to fluctuate. This can be checked by measuring the armature current.

5. Operating the motor above its rated speed may cause the speed to fluctuate. See the motor chart for the maximum recommended speeds for the various motors.

6. Where the electronic governor is used as a wire feed control, drive roll slippage may appear to be a fluctuation in the motor speed. Therefore, make sure that the drive rolls are not slipping. Similar difficulties may be experienced where the drive wheel slips in a carriage drive.

**Part V. Motor Starts But Stops After a Period of Operation or Motor Starts and Stops Intermittently**

1. This is usually caused by Time-Delay Relay TD101 opening after a period of operation or making poor contact.

   (a) The easiest test is to substitute a new tube.

   (b) Another simple test is to strike the top of TD101 sharply with a light object such as a pencil. This will cause the contacts to bounce if they are not making firm contact. The contact bounce will show up as spurs in the motor speed.

2. Check the bias battery. If it is less than 4.3 volts, replace the battery.

3. Check to make certain that the thyatron tube is properly turned in its socket and that it is warm to touch. If the tube is cold, make sure that the socket prongs contact the tube pins. If the tube is still cold, substitute another tube.

4. Check the speed adjustment SP101. Refer to procedure listed in Part II, Item 4.

**Part VI. Pilot Light Does Not Light**

1. Check the fuses. They should both be 5 ampere "Slow-Blo" fuses.

2. If the fuses are good, check the line voltage across terminals T101-9 and T101-10. This voltage should be between 110 and 125 volts for proper operation of the governor.

3. If 1 and 2 check OK, test the switch SW101.

4. Check the voltage across the pilot light terminals. This should be the same as the line voltage. If the voltage is correct and the pilot light still does not light, replace the pilot light assembly.

**Part VII. Motor Coasts Too Long**

1. Check the value of the dynamic braking resistor. If necessary, this resistor can be reduced to zero.

2. If the motor coasts too long, reduce the value of this resistor until the proper speed of braking is obtained. If necessary, this resistor can be reduced to zero.

3. If the motor does not coast long enough, increase the value of this resistor until the proper amount of coasting is obtained.

**C. Complete Governor Check**

If the above suggestions do not clear the trouble, it will be necessary to run a complete check on the governor. Follow the procedure in the order given below, complete each step and do not skip any steps. The entire procedure given below can be made in a matter of minutes and the only requisites are the recommended meters and a knowledge of how to use the meters.

If a spare governor or control is available, it is advisable to exchange units and run the complete governor check on the test bench rather than the production line.

**Part I. Mechanical Stoppages**

Before checking for electrical failure, make certain that the drive-motor and governor are not being overloaded. Loads beyond their ratings may:


2. Overheat the motor, or damage gears.

3. Cause motor speed to vary erratically, or to be out of calibration with the speed indicator.

In the event of such occurrences, examine the mechanism operated by the motor for conditions which might be causing an overload. These include tight bearings, misalignment, excessive roll pressure, jamming, foreign material on rails or gear trains, etc.

To check the motor load, refer to Sec. B, Part I, Item 2 (a) and use outlined procedure.

**Part II. Electrical Stoppages**

When the governor is not functioning properly, and you have determined that the trouble is not mechanical, proceed with the following step-by-step tests. Complete each step before going to the next. Do not skip any tests.

In describing these tests, it is assumed that the power line, controls and drive-motor are connected to the governor. The terminal strip referred to is located on the bottom side of the governor chassis. To reach this terminal strip you must remove the chassis from the cabinet, and remove the bottom plate from the chassis.

**(a) Control and Power Circuit Tests**

1. **Line voltage**

   Check the line voltage between terminals 9 and 10 on the terminal strip. This should be 110 to 125 volts a.c. (50 to 60 cycles).
(ii) Master switch

Turn on the master switch SW101. The pilot light PL101 should light immediately. If it fails to light, check fuses F101 and F102. If the fuses are good, a faulty master switch or pilot light is indicated.

(iii) Fuses

Normally 5 ampere "Slo-Blo" fuses are used in the governor.

Fuses can be tested by inspection, or by means of an ohmmeter. Do not use a buzzer. The buzzer current may exceed the fuse rating and blow it.

(iv) Drive-motor field voltage

Test the field voltage between terminals 6 and 7 on the terminal strip. This should be approximately 110 volts d.c.

Resistor R106 has been adjusted at the factory to provide the proper field voltage. It should not be necessary to readjust R106, except possibly after a long period of service or when certain parts such as rectifier SR101, condensers C104 and C105, or the drive-motor are replaced.

Resistor R106 has a total resistance of 25 ohms. To function properly, R106 should never be reduced below 10 ohms. If the correct field voltage as given on the motor chart cannot be obtained without making R106 less than 10 ohms, it is probable that one of the following conditions exists:

a.) The line voltage is below 110 volts a.c.

b.) The resistance of the motor field is below normal. This could be due to partial or complete shorts in the field winding. See Table I on page 15 for typical values.

c.) Rectifier SR101 is defective. (Refer to paragraph (d) on page 14 for testing.)

d.) Condensers C104 and C105 are defective. (Refer to paragraph (c) on page 14 for testing.)

(v) Reference voltage

Within 30 to 45 seconds after the master switch SW101 is closed, the contacts of time delay relay TD101 close. This places a d.c. voltage across potentiometer SP101. Since the speed indicator meter is connected across SP101 and resistor R103, the meter will give a reading as soon as the relay contacts close. This serves as a test to indicate the presence of reference voltage.

When no speed indicator meter is used, a d.c. voltmeter connected to terminals 2 and 5 should indicate 105 volts when the contacts of TD101 close.

(vi) Speed adjustment

As soon as the reference voltage is applied to speed-adjusting potentiometer SP101 it delivers to the grid of the thyatron a voltage proportional to the desired speed. To check whether SP101 is operating properly, refer to Sec. B, Part II, Item 4.

(vii) Time delay relay

The contacts of time delay relay TD101 should close 30 to 45 seconds after the master switch SW101 is closed. Failure to do so could be caused by one of the following:

a.) Defective relay. Substituting another relay is the quickest way to test for this.

b.) The voltage on the heating coil of the relay may be abnormally low. The voltage between pins 2 and 3 on the relay mounting socket should be between 2.35 and 2.5 volts a.c. Voltages lower than this may indicate that the line voltage is abnormally low, or the transformer TR101 is defective.

c.) A break in the primary or secondary circuits of transformer TR101.

In some cases the contacts of the relay may fuse and remain closed all of the time. This would cause reference voltage to be applied to the thyatron grid as soon as the master switch SW101 is closed. The relay should be replaced immediately to avoid damaging the thyatron.

(viii) Bias battery

Refer to Sec. B, Part II, Item 5 for checking procedure.

(ix) Voltage regulator circuit

The voltage regulator tube VR101 shows a characteristic purplish glow in normal operation. Absence of this glow indicates that the tube itself or resistor R105 may be defective. To check the tube, substitute one known to be good.

Absence of glow may also indicate that the input voltage is too low. The input voltage (measured between terminals 6 and 7 on the terminal strip) should be approximately 110 to 115 volts d.c.

Output voltage of the regulator tube, measured between terminals 5 and 9 on the terminal strip, is 105 volts d.c.

(b) Resistor Tests

When testing resistors, be sure that the governor is disconnected from the power line.

All resistors except R102, R105, and R107 are located on the underside of the chassis.

The nominal resistance values are given in the circuit diagram. With the exception of R107, the values are not critical, and may vary up to ±20% from the
nominal value, although a tolerance of ±10% is preferable. R107 determines the calibration of the speed indicator meter; it should be within ±5% tolerance. When measuring its resistance, one side of R107 must be disconnected, to avoid the shunting effect of SP101.

(c) Condenser Tests
When testing condensers, be sure that the governor is disconnected from the power line.

Condensers C101 and C102 are paper condensers which are used so conservatively that it is very unlikely that they will require replacement unless they are mechanically damaged. A fairly reliable check of C101 and C102 can be made by connecting an ohmmeter across the condenser terminals, without disconnecting the condenser from its circuit. If the condenser is good, the meter will read the resistance in parallel with the condenser. For C101 this resistance will be approximately 56,000 ohms. For C102 this resistance will be approximately 1,000,000 ohms. If the condenser in either case is shorted, the reading will be much lower than that indicated.

Condensers C103, C104, and C105 are electrolytic condensers. The three are contained in a single metal case. If one of them is damaged, all three must be replaced. The condenser plugs into a socket and therefore can be easily replaced.

These electrolytic condensers are used conservatively. They should give years of service before requiring replacement. The end of their useful life is usually indicated when it is no longer possible to obtain 110 volts d.c. across the motor field (measured between terminals 6 and 7 on the terminal strip), even when R106 is reduced to as little as 10 ohms. When the field voltage is measured, be sure that the power line is delivering at least 110 volts a.c., and that the selenium rectifier SR101 is in good condition.

Occasionally an electrolytic condenser may fail by short-circuiting. This can be detected by disconnecting the motor field from terminals 6 and 7 on the terminal strip, then connecting an ohmmeter across these terminals. When the ohmmeter needle comes to rest, it should indicate a resistance of at least 20,000 ohms. Reverse the ohmmeter leads and take a second reading. The highest reading of the two is the significant one. When the higher reading is a few hundred ohms or less, it indicates a shorted condenser.

Because of its position in the circuit, it is difficult to test C103 without first disconnecting it. However, since it is very lightly loaded, its life will usually be much greater than that of C104 or C105.

If C104 or C105 should short-circuit, this may damage SR101 or R106 by overloading them. If C104 or C105 is found to be shorted, therefore, SR101 and R106 should also be checked.

(d) Selenium Rectifier Test
Selenium rectifier SR101 is used conservatively. It should give many thousands of hours of service.

The end of the rectifier's useful life is indicated when it is no longer possible to obtain 110 volts d.c. across the motor field (measured across terminals 6 and 7 on the terminal strip) even when R106 is reduced to as little as 10 ohms. When measuring the field voltage, be sure that the power line is delivering at least 110 volts a.c. and that condensers C104 and C105 are in good condition.

(e) Transformer Test
A transformer can be tested by measuring the secondary voltage under normal load, while the proper voltage is applied to the primary winding. The primary voltage in case of the governor will be the line voltage. The circuit diagram shows the voltage of the secondary as marked by the manufacturer. As noted below, the actual voltage as measured is not exactly this value.

(i) Transformer TR101. With a line voltage of 115 volts a.c., the secondary voltage (with the thyatron tube inserted in its socket) is approximately 2.45 volts a.c. when the transformer is cold and 2.35 volts a.c. when the transformer is hot. This voltage can be measured under load by removing the time delay relay TD101 from its socket and placing the voltmeter leads on pins 2 and 3 of the socket.

(ii) Transformer TR102. With a line voltage of 115 volts a.c., the secondary voltage is 8 volts a.c. This voltage can best be measured at the terminal plate under the chassis where the transformer leads connect to C101 and R101.

(f) Thyatron Tube Test
The thyatron tube TT101 (C3J) should give more than 10,000 hours of service before requiring replacement. If all previous tests show that the circuits are in good order, and that the tube may be causing trouble, the quickest way to check the tube is to substitute one known to be good. When substituting a tube, be sure to turn the governor master switch off a few minutes to permit the time delay relay to open its contacts.

(g) Motor Tests

(i) Check the resistance of both the armature and field windings in accordance with the motor chart.

(ii) Check the length of the brushes to make certain that they have not worn to the extent that they no longer make contact with the commutator.

(iii) Make certain that the armature turns freely in its bearings.

(iv) Since the field is fully energized at all times, the motor will normally run at a fairly high temperature. This is particularly true when it is operated at low speeds, or is stopped for long periods of time without turning the master switch off.

Under no circumstances should an OXWELD standard series-wound drive-motor be substituted for the special shunt motor required by this unit.
TABLE I - "LINDE" D.C. SHUNT MOTORS FOR USE WITH 115 VOLT ELECTRONIC GOVERNOR

<table>
<thead>
<tr>
<th>Motor</th>
<th>Part No.</th>
<th>Max. Recommended Motor Speed in RPM (Note #1)</th>
<th>Max. Possible Motor Speed in RPM (Note #2)</th>
<th>Max. Continuous Armature Current in Amp. (Note #3, 6)</th>
<th>Maximum No Load Armature Current in Amp. for Motor Alone (Note #6)</th>
<th>Max. Increase in Armature Current (in Amp.) Caused by Attaching the Gear Head (Note #0)</th>
<th>Armature Resistance through Brush (in Ohms) Cold (Note #4)</th>
<th>Feedback Resistor Setting (R102)</th>
<th>Field Voltage Hot (Note #5, 6)</th>
<th>Field Current in Amp. Hot</th>
<th>Field Resistance (in Ohms) Cold (Note #6)</th>
<th>Field Resistance (in Ohms) Hot</th>
<th>Color Code &amp; Pin Numbers New Motors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dunmore Type KBD Standard Speed</td>
<td>57V23 57V23 57V28</td>
<td>4,500 5,500 0.75 at any speed 0.4 at 4,500 RPM</td>
<td>0.1 8.0 4.78</td>
<td>1 ohm</td>
<td>110 0.260 360</td>
<td>420</td>
<td>Armature - Green Pin #1 Armature - White Pin #2 Field - Black Pin #3 Field - Red Pin #4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dunmore Type KBD High Speed</td>
<td>57V29</td>
<td>6,000 11,500 1.0 at 1,000 RPM 1.5 at 6,000 RPM 0.6 at 6,000 RPM</td>
<td>0.1 3.5 1.13</td>
<td>1 ohm adjusted to 1/2 ohm</td>
<td>110 0.260 360</td>
<td>420</td>
<td>Armature - Green Pin #1 Armature - White Pin #2 Field - Black Pin #3 Field - Red Pin #4</td>
<td></td>
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<tr>
<td>Dunmore Type W2 for EH-2 Head</td>
<td>57V31</td>
<td>4,000 5,100 1.1 at 500 RPM 2.0 at 4,000 RPM 0.65 at 4,000 RPM</td>
<td>0.175 at 4,000 RPM</td>
<td>4.5 2.59</td>
<td>1 ohm adjusted to 1/2 ohm</td>
<td>115 0.170 600</td>
<td>700</td>
<td>Armature - Green Pin #1 Armature - White Pin #2 Field - Black Pin #3 Field - Red Pin #4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dunmore Type W2 for DEH Head</td>
<td>B-300420 B-300757 B-300099</td>
<td>4,000 5,100 1.1 at 500 RPM 2.0 at 4,000 RPM 0.45 at 4,000 RPM</td>
<td>0.15</td>
<td>4.5 2.59</td>
<td>1 ohm adjusted to 1/4 ohm</td>
<td>115 0.170 600</td>
<td>700</td>
<td>Armature - Green Pin #1 Armature - White Pin #2 Field - Black Pin #3 Field - Red Pin #4</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Dunmore Type A3BD</td>
<td>D-301533</td>
<td>5,000 6,400 0.5 at 5,000 RPM 0.14 at 5,000 RPM</td>
<td>0.1 17.2</td>
<td>1 ohm</td>
<td>125 0.110 500</td>
<td>1050</td>
<td>Armature - White Armature - White with Red Tracer Field - Black Field - Red</td>
<td></td>
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</tr>
</tbody>
</table>

* Color Code Old Motors

Armature - White Field - Black
Armature - White with Field - Red
Red Tracer

NOTE:

1. The motor will run at considerably higher speeds, but the speed regulation, commutation, and brush life may be poor above the recommended maximum speed.
2. The motor will run at this speed but it is not recommended as speed load regulation is poor and damage to the motor may result from speeds in excess of the recommended value. See Note #1.
3. The maximum continuous armature current is dependent on the motor speed. The current values are given for low and high speeds. There is a straight line relationship between these speeds. The maximum armature current for intermittent operation, such as is usually found in welding, is 2.5 amp. d.c. for the W2 motors, 1.2 amp. for the KBD standard motor, and 1.7 amp. for the KBD high speed motor.
4. Resistance measured directly at the commutator bars and not through the brushes.
5. The field voltage is adjusted by means of R106. The resistance of the field changes as the motor warms up and thus effects both the field voltage and current. Therefore, the field voltage should be adjusted to the indicated field voltage after the field has been energized for 30 minutes or more.
6. All voltages and currents are direct current values measured on a D'Arsonval type meter.
INDUSTRIAL GASES
LINDE Oxygen, Nitrogen, Argon, Neon, Helium, Krypton, Xenon, Hydrogen, and mixtures
PREST-O-LITE Acetylene

CALCIUM CARBIDE
UNION CARBIDE Calcium Carbide

OXY-ACETYLENE EQUIPMENT
OXWELD Apparatus for Cutting, Joining, Treating, and Forming Metals Acetylene Generators Manifolds, Regulators and Valves Welding Rods and Supplies
PREST-O-LITE Welding and Cutting Apparatus

ELECTRIC WELDING AND CUTTING EQUIPMENT
HELIARC Welding and Cutting Equipment SIGMA Welding Equipment
UNIONARC Welding Apparatus and Supplies UNIONMELT Automatic Welding Apparatus and Supplies

SPECIAL EQUIPMENT
LINDE Jet-Piercing Equipment Stone-Shaping Equipment Plate-Edge Preparation Equipment Steel-Conditioning Machines Steel Production Equipment Sub-Zero Cold Treatment Equipment Liquid Oxygen Converters Liquid Nitrogen Refrigerators Liquefied Gas Containers Storage and Transfer Equipment For Cryogenic Fluids
OXWELD Oxy-Acetylene Cutting Machines PREST-O-LITE Cylinders, Shells, and Shapes RIBBONRAIL Welding Equipment

OXYGEN THERAPY SUPPLIES
LINDE Oxygen U.S.P. Oxygen Regulators
OXWELD Oxygen Manifolds and Valves

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