DESCRIPTION • INSTALLATION • MAINTENANCE

INSTRUCTIONS

Heavy-Duty

STEEL MILL MAGNETIC CONTROLLERS

Class 9500

MILL AUXILIARY SERVICE
CONSTANT VOLTAGE D-C

WESTINGHOUSE ELECTRIC CORPORATION
BUFFALO PLANT • MOTOR AND CONTROL DIVISION • BUFFALO 5, N. Y.

EFFECTIVE JULY, 1951

NEW INFORMATION

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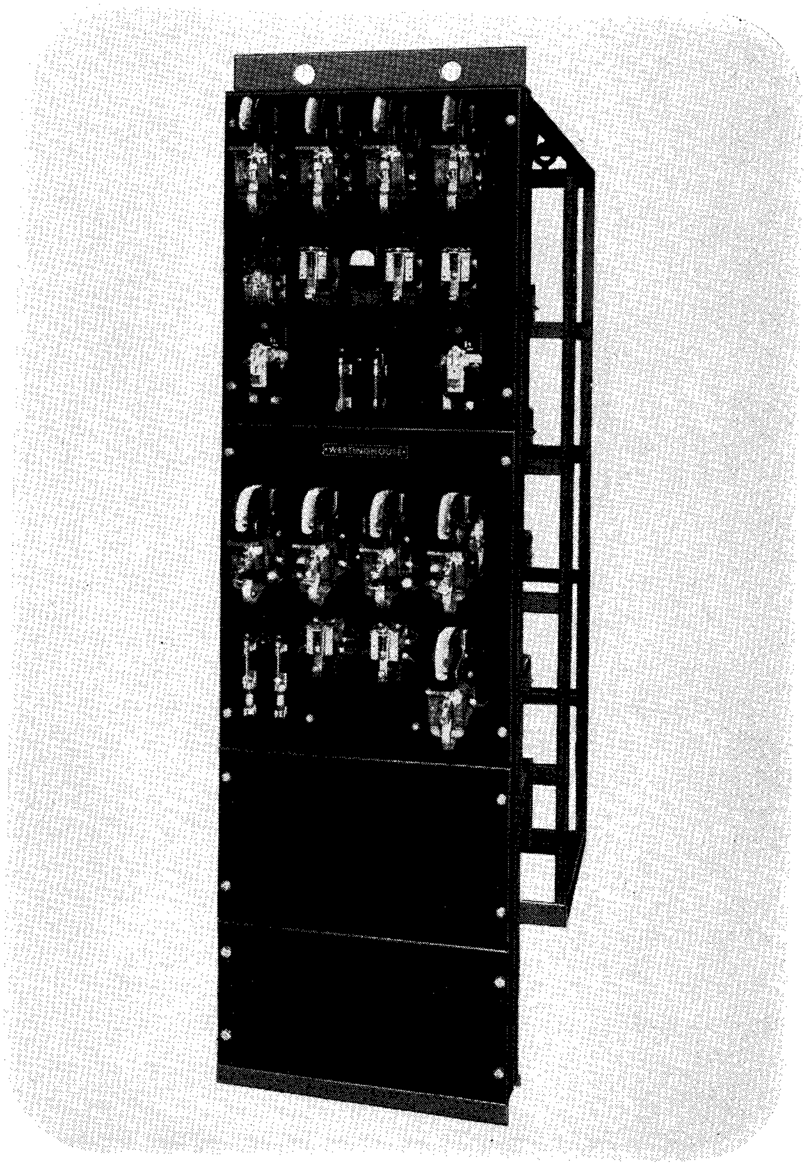


Special Class 9500 Controller Mounted on Self-Supporting, Factory-Assembled Frame with Starting Resistors Mounted and Wired (Class A Construction with 90-inch High Panel)

CLASS 9500 is the general designation given to constant-voltage, direct-current, magnetic controllers for use in mill auxiliary service in steel mill and other heavy mill applications.

The specific classes in this general classification are:

Class 9505—Non-Reversing Controller

Class 9510—Non-Reversing, Dynamic Braking Controller

Class 9515—Reversing, Plugging Controller

Class 9530—Reversing, Dynamic Braking Controller

Class 9535—Reversing, Plugging, Dynamic Braking Controller

These controllers are used for such applications as pushers, tables, screw-downs, sideguard adjustment, etc. They conform to NEMA standards for d-c magnetic control for steel mill auxiliaries.

GENERAL DESCRIPTION

A complete motor controller includes a control panel, armature circuit resistors, a pushbutton or master switch and where required, limit switches and a field rheostat. The equipment included on the control panel is listed under "Class 9500 Component Devices and Functions" below.

All contactors and relays are assembled as complete units to assure correct alignment of parts.

The arrangement of apparatus is such that controllers of the same rating or various ratings may be installed in groups and line-up to present a symmetrical and pleasing appearance.

Overload protection is provided by two thermal-magnetic relays which provide inverse time limit protection to normal loads, and instantaneous trip on abnormal loads of approximately 400 percent. Trip reset button may be set for "Automatic Reset" or "Manual Reset". Low-voltage protection is provided by a relay which prevents motor from restarting automatically upon the return of voltage.

Acceleration is controlled by definite time limit relays. These relays operate on the decay of flux in the coil when it is short circuited or when the coil circuit is opened. A wide range of adjustment permits setting the period of acceleration at the exact value which best fits the operating schedule and high contact pressure assures proper operation under the most adverse conditions of dirt and vibration.

Separate knife switches are provided for the motor armature circuit and the control circuits so that the control may be tested without energizing the motor. Locking clips on the main switch provide an extra safety feature.

CLASS 9500 COMPONENT DEVICES AND FUNCTIONS

The devices listed in Paragraph A are required for *all* Standard Class 9500 Controllers.

Each specific Class in this general classification requires additional devices to complete the controller. These devices for constant speed compound motors ∅ are listed in Paragraphs B to F, plus the necessary resistors and interlocks.

∅ Class 9505 and 9515 may also be used with series motors.
* Specific cases may require more or less accelerating points.

Paragraph A. All Class 9500 Controllers require the following:

Quantity	*Function and Device*	*Device Marking*
1	Negative Line Contactor	1M
2*	Accelerating Contactor	1A, 2A*
2	Overload Relays	1OL, 2OL
2*	Definite Time Accelerating Relays	1TR, 2TR*
1	Master Relay	MR
1	Motor Line Knife Switch with Locking Clip and 90-degree Stop	
1	Control Knife Switch (Fused)	

Note: In addition to the above, ammeters and/or shunts may be furnished for any controller as optional additions.

Class 9500 controllers have been designed with a 50 mv shunt rated at 125 to 150 percent of the motor full load current and a 100 mv ammeter with a full scale of 250 to 300 percent of full load. The selection of these values permits the reading of starting peaks and other momentary surges. This also allows recording type ammeters or other meters having 100 mv movements to be used.

Paragraph B. Class 9505 (Non-Reversing) Controllers require the following device in addition to those listed in Paragraph A:

Quantity	*Function and Device*	*Device Marking*
1	Positive Line Contactor	2M

Paragraph C. Class 9510 (Non-Reversing, Dynamic Braking) Controllers require the following devices in addition to those listed in Paragraph A:

Quantity	*Function and Device*	*Device Marking*
1	Positive Line Contactor	2M
1	Dynamic Braking Contactor	DB

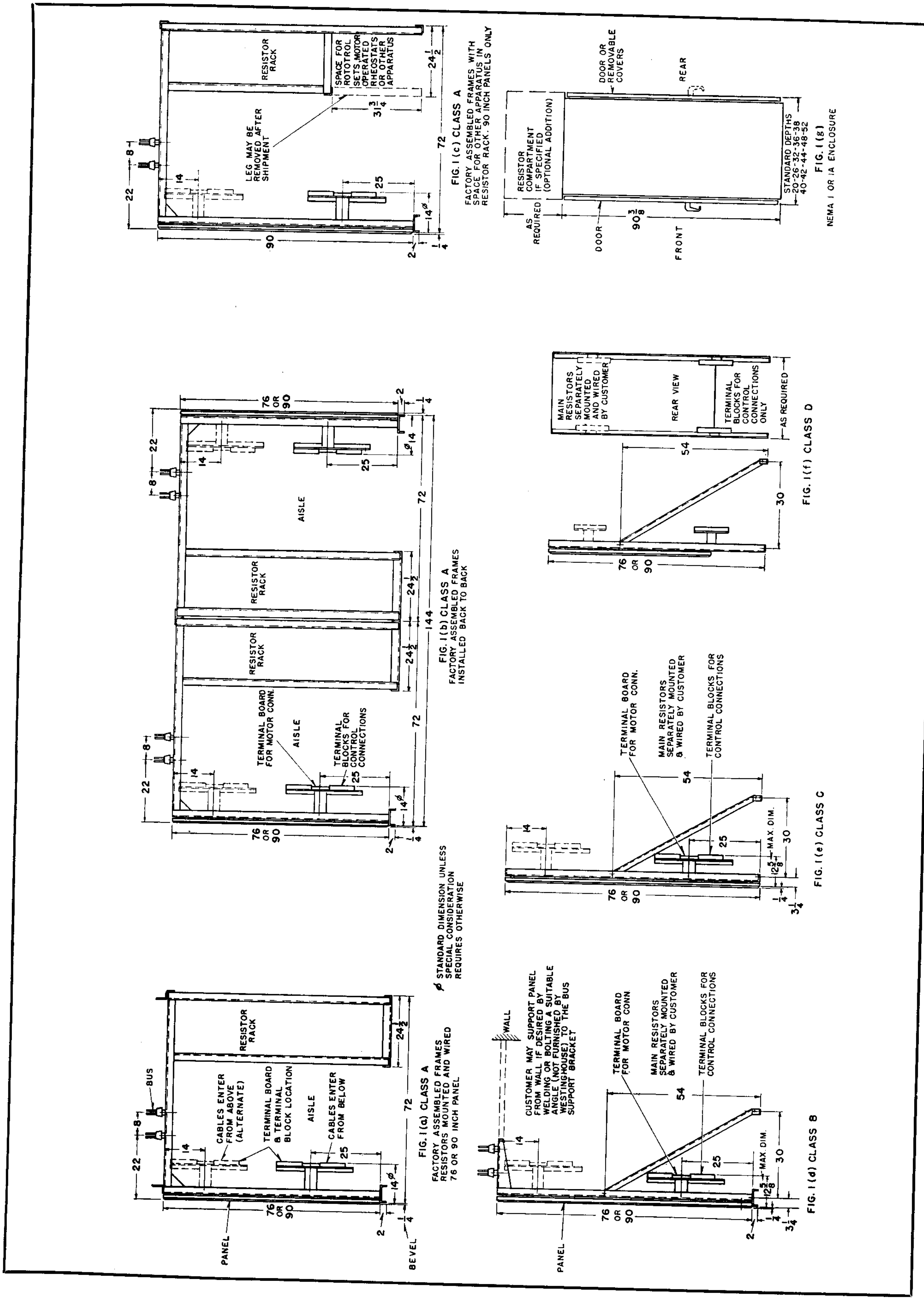


FIG. 1. Frame and Enclosure Construction Details

Paragraph D. Class 9515 (Reversing, Plugging) Controllers require the following devices in addition to those listed in Paragraph A:

Quantity	*Function and Device*	*Device Marking*
4	Armature Reversing Contactors	1F, 2F (Forward) 1R, 2R (Reverse)
1	Plugging Contactor	P
2	Plugging Relays	PF, PR

Paragraph E. Class 9530 (Reversing, Dynamic Braking) Controllers require the following devices in addition to those listed in Paragraph A:

Quantity	*Function and Device*	*Device Marking*
4	Armature Reversing Contactors	1F, 2F (Forward) 1R, 2R (Reverse)
1	Dynamic Braking Contactor	DB
1	Dynamic Braking Relay	DBR

Paragraph F. Class 9535 (Reversing, Plugging, Dynamic Braking) Controllers require the following devices in addition to those listed in Paragraph A:

Quantity	*Function and Device*	*Device Marking*
4	Armature Reversing Contactors	1F, 2F (Forward) 1R, 2R (Reverse)
1	Plugging Contactor	P
1	Dynamic Braking Contactor	DB
2	Plugging Relays	PF, PR
1	Timing Relay	3TR

Paragraph G. Armature shunt may be added to Class 9500 Controllers by the addition of the following devices:

Quantity	*Function and Device*	*Device Marking*
1	Armature Shunt Contactor	AS
1	Armature Shunt Relay	ASR
1	Armature Shunt Resistor†	

Paragraph H.

Field Relays. In most cases, a dual coil relay with adjustable pick-up and drop-out is used for field relay applications. When the field current exceeds the rating of the contacts of this relay, it is necessary either to use an auxiliary relay (or contactor) with the dual coil relay or, where possible, to substitute a single device having a higher rating.

† Part of Dynamic Braking Resistor on Class 9510, 9530 or 9535.

In general, the requirements for field relays are listed below. In many cases, however, motor design or the application may make it advisable to omit some of these relays when they normally would be furnished or to add additional relays.

FL—Field Loss. Required on all shunt motors.

FP—Field Protective (or Field Economizer). Required on all motors whose shunt field is not continuously rated when the motor is at standstill with full field. Usually required only on shunt motors.

FA—Field Acceleration. Required on all adjustable speed motors of over two to one speed range if the field setting can be rapidly changed from "Slow" to "Fast".

FDE—Field Deceleration. Required on all adjustable speed motors of over two to one speed range if the field setting can be rapidly changed from "Fast" to "Slow".

Paragraph I.

Control Relays—CR, 1CR, 2CR, etc. In addition to the relays which are required for the various classes of controllers as listed in Paragraphs A to H above, relays of various kinds are required for dual or triple control of one motor, duplex operation of two motors, or for any of the many other special applications.

CONSTRUCTION

The devices for any given controller, as itemized in the preceding paragraphs, are mounted on ebony asbestos (standard) or slate (special) panels which are supported by angle iron framework or mounted in an enclosure.

The arrangement of the apparatus is such that the controllers may be installed in groups and line-up to present a symmetrical and pleasing appearance.

The types and classes of construction (see Fig. 1) are as follows:

Class A. Self-supporting, factory-assembled frames, with full height panels either 76 or 90 inches high; interconnecting main, excitation and control buses; main and control circuit terminal boards; and all resistors mounted and wired.

Standard frame arrangement, Class A construction, is shown in Fig. 1(a) and also in the frontispiece, page 4. The frame may be mounted with the resistor rack against a wall as the resistors are mounted and wired so that they can be removed from the "aisle" side of the resistor rack.

If desired, two frames may be mounted "back to back" as shown in Fig. 1 (b).

The frame as shown in Fig. 1 (a), for 90-inch high panels only, may be modified slightly as shown in Fig. 1 (c). This construction may be used to provide space for Rototrols, motor-operated rheostats or other equipment *providing* that there is sufficient space to mount the necessary frames of resistors. A removable "leg" (shown dotted) is provided for shipping purposes and may be removed if necessary or desirable.

Class B. L—frame construction, Fig. 1 (d), includes all features of Class A construction except line, starting and/or dynamic braking resistors are shipped separately for mounting and wiring by the purchaser. Panels must be supported by wall or floor braces. Floor brace is provided.

Class C. "Picture-Frame" construction, Fig. 1 (e), is similar to Class B, *except* main bus is omitted in addition to resistors being supplied separately, unmounted and unwired. Floor brace is provided.

Class D. "Upright" construction, Fig. 1 (f), with angle iron uprights only, and panel height not necessarily the full height of the uprights. With this construction, resistors are all supplied separately (except small control resistors); no main or excitation or control bus is supplied, and only control circuit terminal blocks are provided. Floor brace is provided.

Enclosures. All classes of construction are available in NEMA type I (General Purpose) or NEMA I-A (Semi-dust tight) enclosures, Fig. 1 (g). If main resistors are to be mounted and wired, they will be located in a separate ventilated section with removable covers on top of the controller enclosure.

The enclosure height exclusive of the resistor section is 90⅜ inches. Doors are furnished in the front and either doors or removable covers in the rear.

Enclosures may consist of a single controller mounted in an individual cabinet or several controllers mounted in a common enclosure usually having an individual door for each controller.

RATINGS

Controllers are rated in accordance with NEMA steel mill standards and should be used with a d-c motor of the voltage and horsepower rating stamped on the controller nameplate.

NEMA resistor classifications are listed in Table No. 1 below. The operating time of the starting resistors should not exceed the values given in this table for the Class of resistor as indicated on the resistor diagram.

Table No. 1 NEMA RESISTOR CLASSIFICATIONS

PERCENT FULL LOAD CURRENT ON FIRST POINT	* STARTING TORQUE % OF FULL LOAD			RESISTOR CLASS NUMBERS						
	Series Motors	Compound Motors	Shunt Motors	5 Sec. on Out of 80 Sec.	10 Sec. on Out of 80 Sec.	15 Sec. on Out of 90 Sec.	15 Sec. on Out of 60 Sec.	15 Sec. on Out of 45 Sec.	15 Sec. on Out of 30 Sec.	Cont.
25	8	12	25	111	131	141	151	161	171	91
50	30	40	50	112	132	142	152	162	172	92
70	50	60	70	113	133	143	153	163	173	93
100	100	100	100	114	134	144	154	164	174	94
150	170	160	150	115	135	145	155	165	175	95
200	250	230	200	116	136	146	156	166	176	96

* Based on Westinghouse Motors.

DESCRIPTION OF CIRCUITS

CLASS 9505 NON-REVERSING CONTROLLER

A Class 9505 elementary diagram is shown in Fig. 2. If the master switch is in the "Off" or "Stop" position and the main and control knife switches are closed, relay MR will pick up. Relay 1TR is also picked-up.

When the master switch is moved to any of the "Start" positions, the MR contact keeps the MR coil energized and provides a low-voltage protection circuit. If one of the overload relay contacts (or the contact of another protective device) in the MR coil circuit is open, MR will be de-energized and the controller will not operate until the abnormal condition is remedied, the open contact closed and the master switch is reset by being returned to the "Off" or "Stop" position.

With the master switch on point 1, contactors 1M and 2M pick-up and the armature and the starting resistors are connected in series across the line. The starting resistor limits the current through the armature and the voltage drop across R1-R2 section of the starting resistor picks-up relay 2TR. An interlock of 2M de-energizes acceleration relay 1TR.

If the master switch is moved to point 2, the first accelerating contactor 1A will also be energized after sufficient time has elapsed since 1TR was de-energized to allow this relay to drop out. Contactor 1A shorts out a portion of the starting resistor and also shorts out the coil of relay 2TR thus de-energizing it.

If the master switch is moved to point 3, the second accelerating contactor 2A will also be energized after sufficient time has elapsed to allow 2TR to drop out. Contactor 2A shorts out the rest of the starting resistor and full voltage is applied to the armature.

Fig. 3 shows the speed-torque characteristics of a compound wound motor with a Class 9505 controller. Portions of curves to the left of the speed axis indicates overhauling loads.

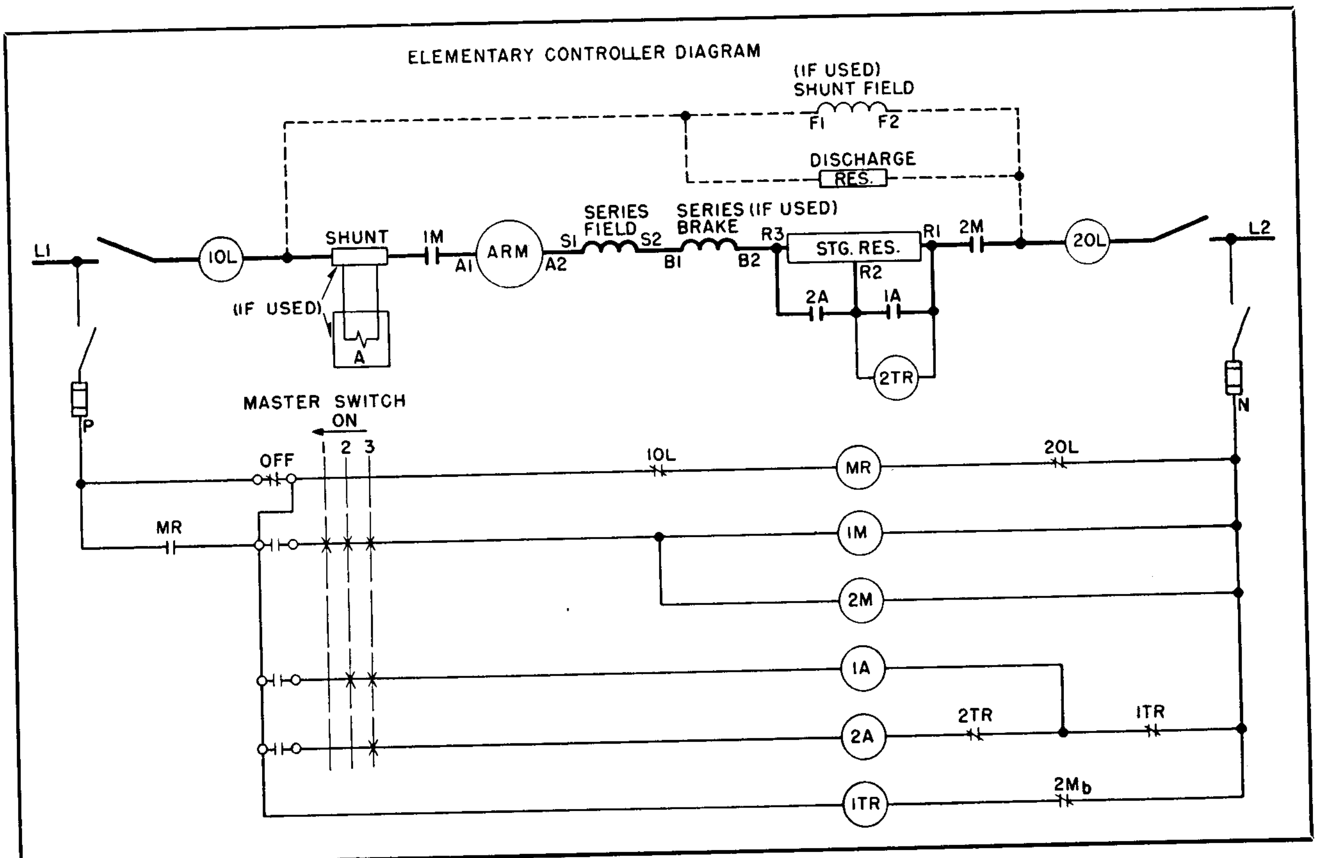
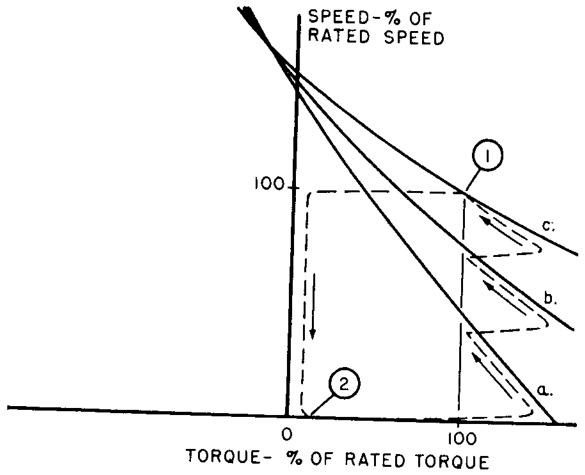


FIG. 2. Class 9505 Non-Reversing Controller



- - - - -→ - TYPICAL TRANSIENT CHARACTERISTIC

ACCELERATE TO FULL SPEED (1)

DECELERATE TO STOP (2)

CURVE	CONTACTS x= CLOSED			
	1M	2M	1A	2A
a.	x	x		
b.	x	x	x	
c.	x	x	x	x

FIG. 3. Speed-Torque Characteristics of Compound Motor with Class 9505 Controller

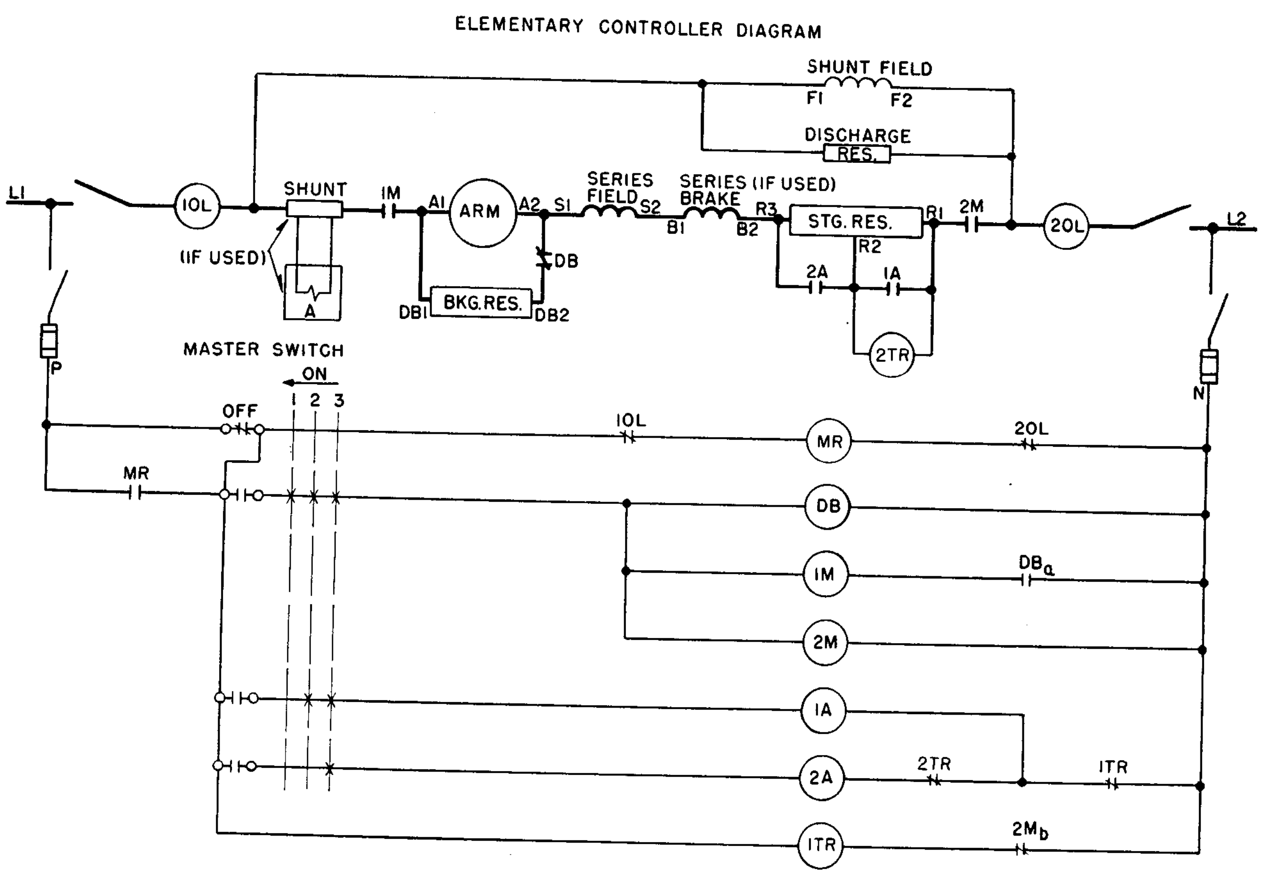
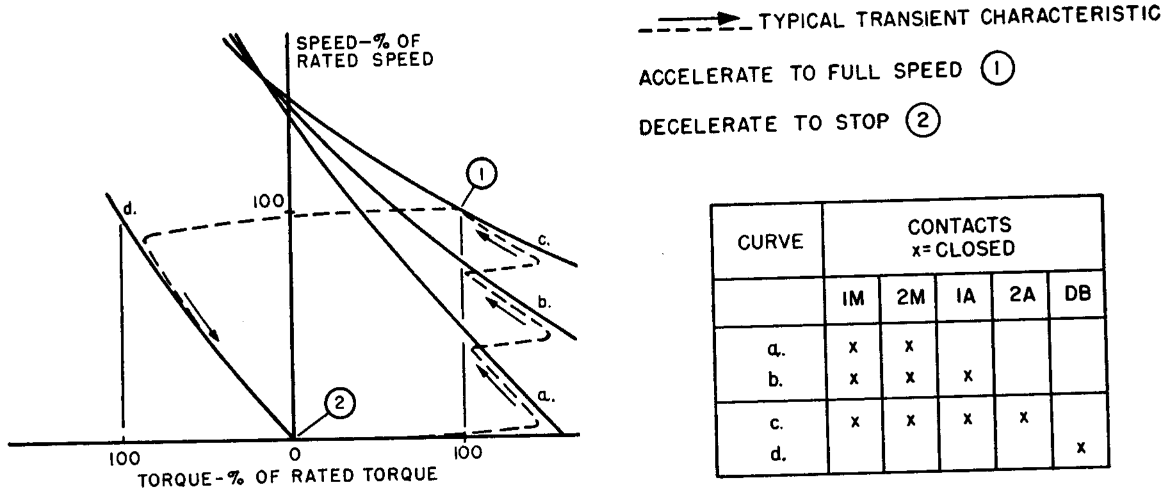


FIG. 4. Class 9510 Non-Reversing, Dynamic Braking Controller



CURVE	CONTACTS x=CLOSED				
	1M	2M	1A	2A	DB
a.	x	x			
b.	x	x	x		
c.	x	x	x	x	
d.					x

FIG. 5. Speed-Torque Characteristics of Compound Motor with Class 9510 Controller

CLASS 9510 NON-REVERSING, DYNAMIC BRAKING CONTROLLER

A Class 9510 circuit is shown in Fig. 4. This circuit is similar to a Class 9505 circuit except that the dynamic braking resistor and contactor DB have been added. Interlock DBa permits contactor DB to open the dynamic braking resistor circuit before contactors 1M and 2M close the armature circuit. If the motor is running and the master switch is returned to the "Off" or "Stop" position, the contact of DB closes and connects the dynamic braking resistor across the armature at the same time the line contactors open and disconnect the motor from the line. The motor now acts as a generator and the resistor as its load, which quickly stops the motor.

Fig. 5 shows the speed-torque characteristics of a compound wound motor with a Class 9510 controller. The braking characteristic to the left of the speed axis indicates that the direction of the torque is opposite the direction of rotation.

CLASS 9515 REVERSING, PLUGGING CONTROLLER

A Class 9515 circuit is shown in Fig. 6. When the master switch is moved to a "Forward" position, contactors 1M, 1F, and 2F connect the armature to the power circuit. When the master switch is moved to a "Reverse" position, contactors 1M, 1R, and 2R connect the armature to the power circuit; the armature polarity is now reversed with respect to the polarities of the shunt field and series field; and the direction of rotation is reversed.

Contactor 1F and 2R are mechanically interlocked so that it is impossible to close both simultaneously. Likewise contactors 2F and 1R are mechanically interlocked.

The functions of contactors 1M, 1A, 2A and relays 1OL, 2OL, MR, 1TR, 2TR are the same as their functions in the Class 9505 circuit.

The coil of relay 1TR is de-energized by the closing of contactor P rather than by the opening of interlock 2Mb.

A d-c motor is plugged by reversing the polarity of the voltage applied to the armature of the motor while in motion. In this manner, power from the

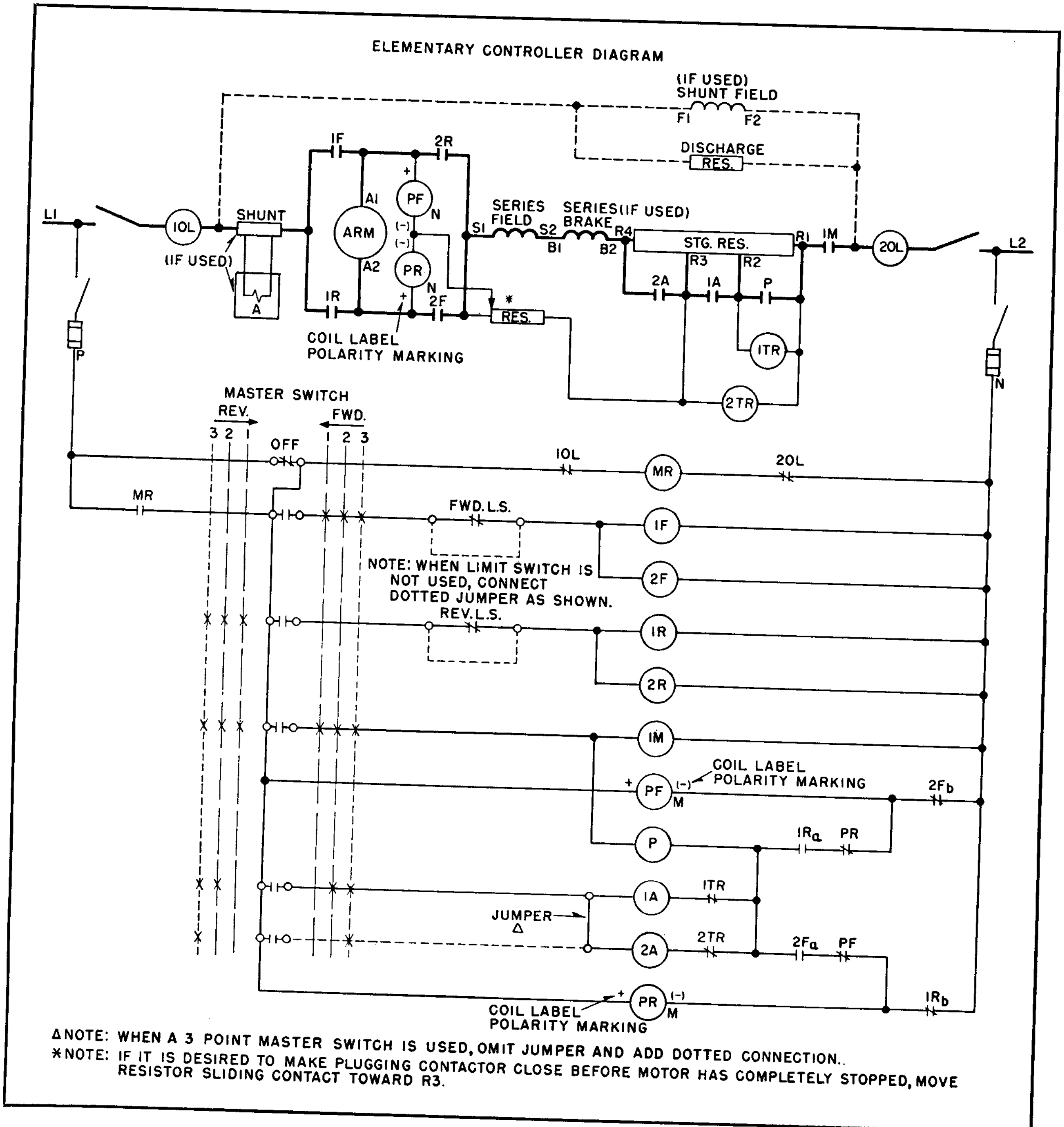


FIG. 6. Class 9515 Reversing, Plugging Controller

line can be utilized to decelerate and stop the motor. It will then accelerate in the reverse direction in the normal manner. This operation makes it possible to reverse the direction of rotation in a minimum of time. All steps of the starting resistor as well as an additional step known as the plugging resistor are inserted into the armature circuit to limit the armature current when the motor is plugged.

The plugging is controlled by two relays "Plug Forward" (PF) and "Plug Reverse" (PR). Each relay has a main coil to pick up the relay and a neutralizing coil. After the main coil is de-energized, residual magnetism is sufficient to prevent the relay armature from dropping out until the neutralizing coil is energized with the correct polarity to oppose the residual magnetism.

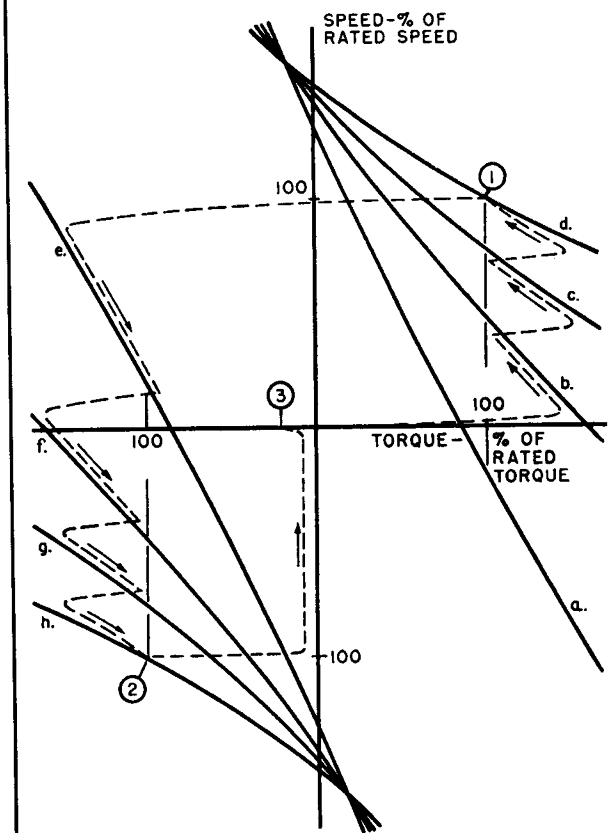
At standstill both relays are energized and if the master switch is operated to the "Forward" position, PF main coil will be de-energized and since its neutralizing coil is in parallel with the armature and the armature IR drop is of the correct polarity to neutralize the residual magnetism, PF will drop out which will allow the plugging contactor P to close and short out the plugging section of the starting resistor.

The controller then accelerates in the forward direction; the starting resistance being shunted out in steps as described previously for the Class 9505 controller.

If while operating in the forward direction, the master switch handle is moved to the "Reverse" position, the forward contactors 1F and 2F will open and the reverse contactors 1R and 2R will close. Relay PF main coil will be energized which will cause its contact to open and drop out contactor P. Contactors 1A and 2A will also open. The combined starting and plugging resistance will limit the armature current to a safe value even though the motor counter emf and the line voltage are now in series.

The current through the neutralizing coil of PR is in such a direction to aid the residual magnetism until the armature speed is reduced almost to zero at which point the motor cemf is equal to the armature IR drop. Beyond that point the current through the neutralizing coil will reverse and oppose the residual magnetism. PR will drop out thus allowing P to reclose and short out the plugging section of the starting resistor again. The motor will then accelerate as before but in the reverse direction.

The potentiometer connected to the common point of the two neutralizing coils of PF and PR serves as a means of adjusting the motor speed at which the PF or PR relay will drop out. Moving the slider toward the starting resistor will in effect increase the armature IR drop and thus cause PF



TYPICAL TRANSIENT CHARACTERISTIC

ACCELERATE TO FULL SPEED FORWARD (1)

DECELERATE AND ACCELERATE TO FULL SPEED REVERSE (2)

DECELERATE TO STOP (3)

CURVE	CONTACTS x = CLOSED							
	1M	1F	2F	1R	2R	P	1A	2A
a.	x	x	x					
b.	x	x	x			x		
c.	x	x	x			x	x	
d.	x	x	x			x	x	x
e.	x			x	x			
f.	x			x	x	x		
g.	x			x	x	x	x	
h.	x			x	x	x	x	x

FIG. 7. Speed-Torque Characteristics of Compound Motor with Class 9515 Controller

or PR to drop out before the motor reaches zero speed.

Fig. 7 shows the speed-torque characteristics of a compound motor with a Class 9515 controller. Curves below the torque axis are for reverse rotation.

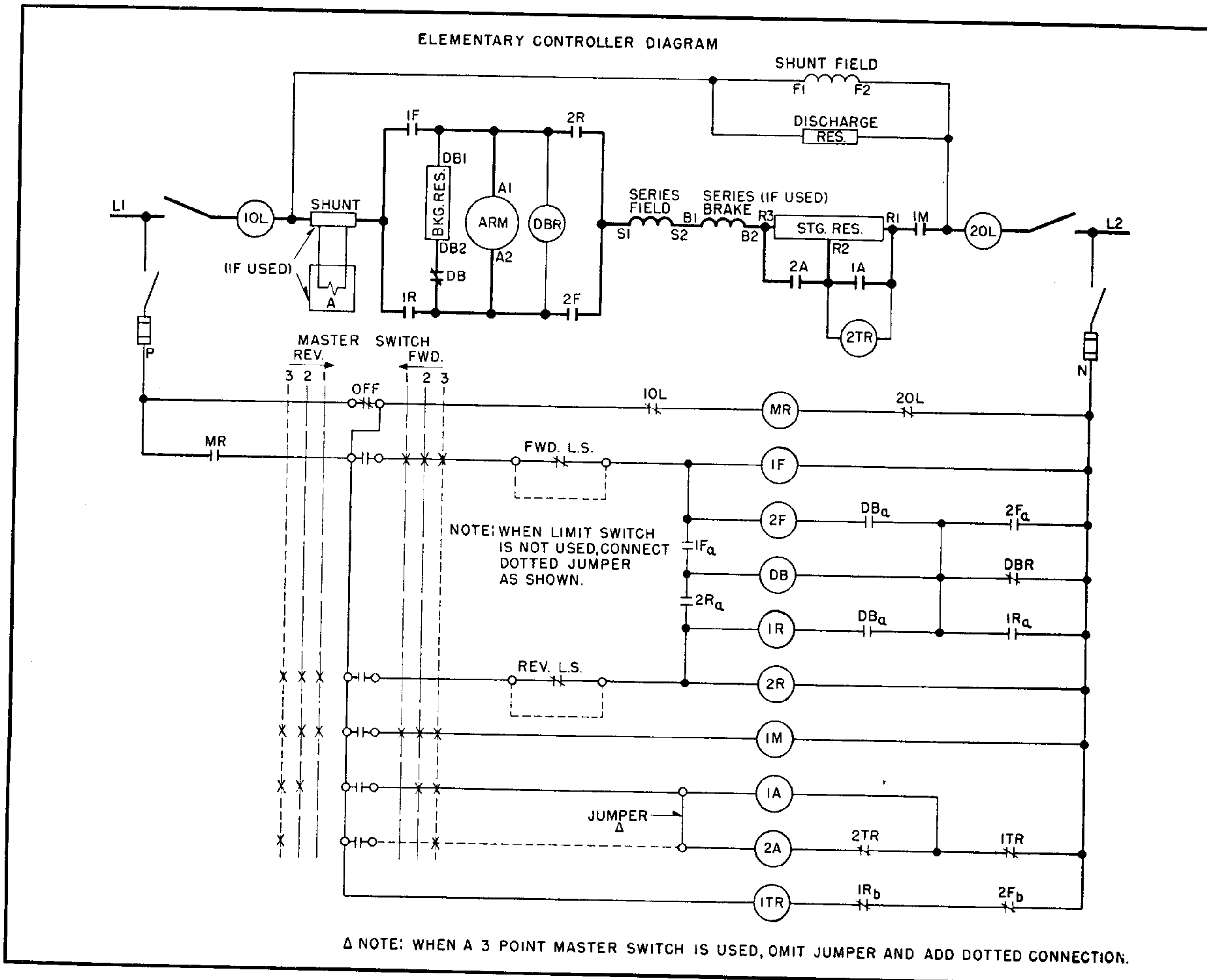
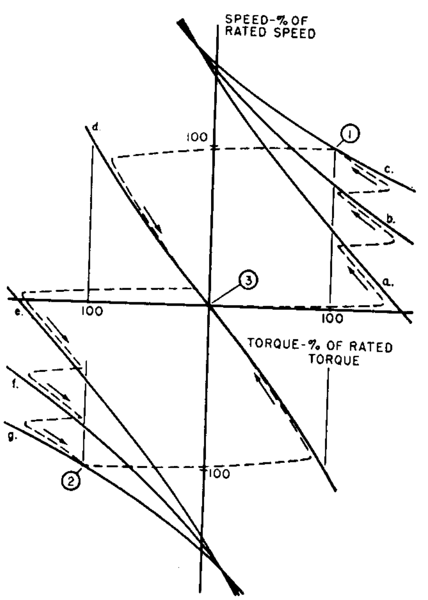


FIG. 8. Class 9530 Reversing, Dynamic Braking Controller



——→ TYPICAL TRANSIENT CHARACTERISTIC

ACCELERATE TO FULL SPEED FORWARD (1)

DECELERATE AND ACCELERATE TO FULL SPEED REVERSE (2)

DECELERATE TO STOP (3)

CURVE	CONTACTS x = CLOSED							
	1M	1F	2F	1R	2R	1A	2A	DB
a.	x	x	x					
b.	x	x	x			x		
c.	x	x	x			x	x	
d.								x
e.	x			x	x			
f.	x			x	x	x		
g.	x			x	x	x	x	

FIG. 9. Speed-Torque Characteristics of Compound Motor with Class 9530 Controller

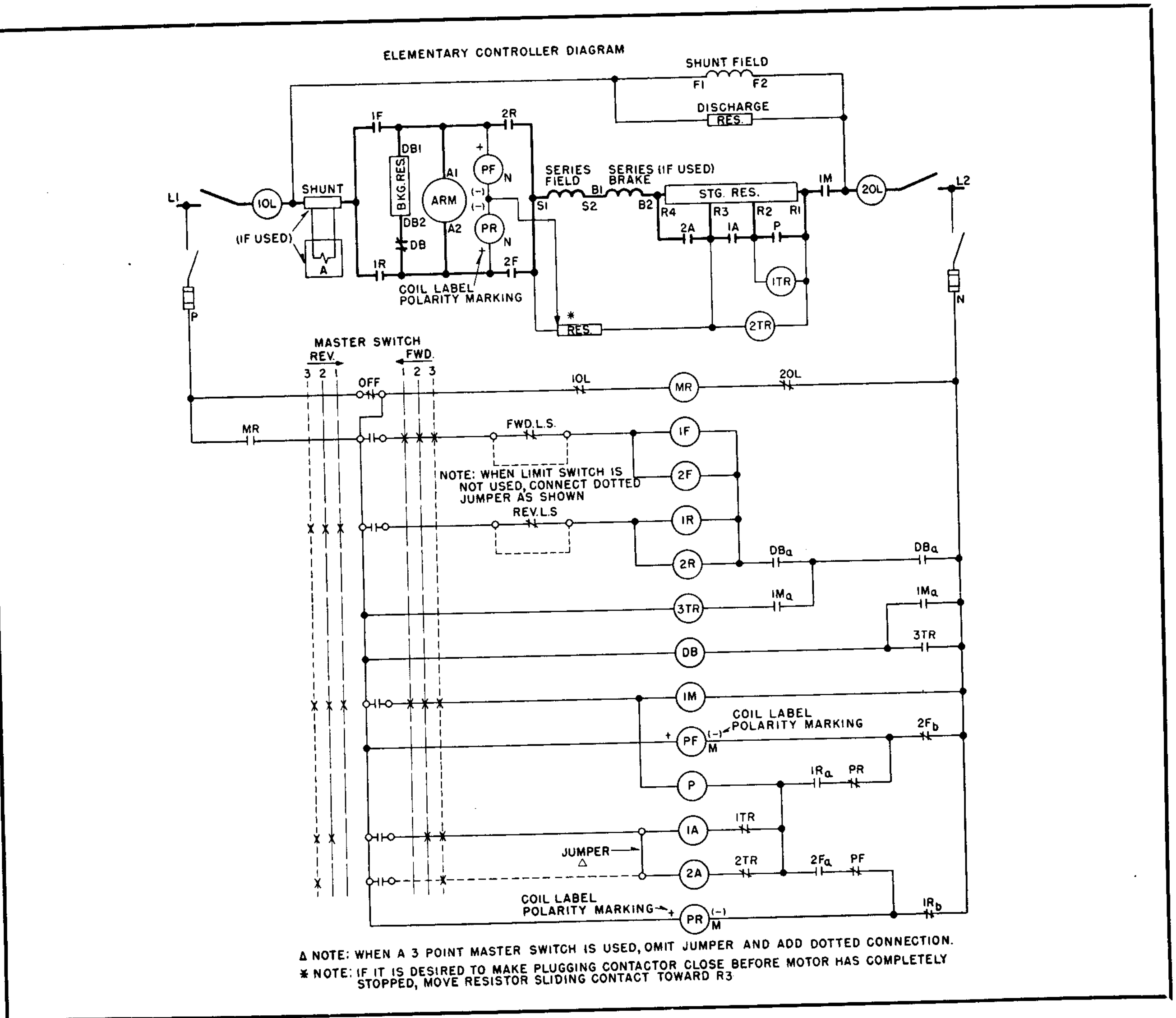


FIG. 10. Class 9535 Reversing, Dynamic Braking, Plugging Controller

CLASS 9530 REVERSING, DYNAMIC BRAKING CONTROLLER

A Class 9530 circuit is shown in Fig. 8. With the exception of contactor DB and dynamic braking relay DBR, the functions of all devices are the same as the functions of the corresponding devices in the Class 9515 circuit.

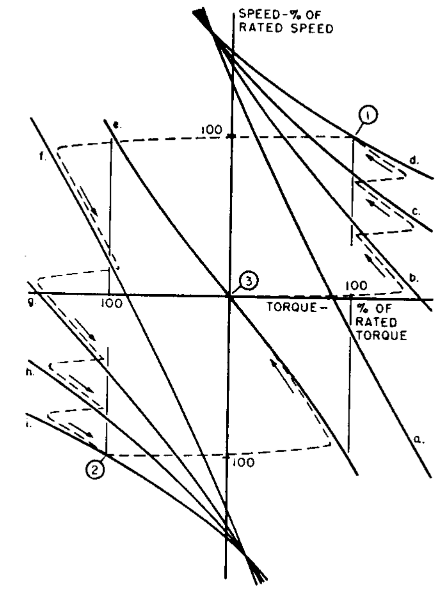
Contactor DB connects the dynamic braking resistor across the armature during stopping periods. When the motor is started, interlocks DBa permit contactor DB to open the dynamic braking circuit before the other contactors close the armature circuit.

When the armature is rotating at full speed in one direction and the master switch is moved rapidly to the opposite position, relay DBR ensures that the armature will nearly stop by dynamic braking before the contactors close the armature circuit for the opposite direction of rotation. DBR is a relay which has a very low drop-out voltage.

Fig. 9 shows the speed-torque characteristics of a compound wound motor with a Class 9530 controller.

CLASS 9535 REVERSING, DYNAMIC BRAKING, PLUGGING CONTROLLER

A Class 9535 circuit is shown in Fig. 10. This circuit is a combination of the Class 9515 circuit and the Class 9530 circuit with relay DBR omitted. Relay 3TR, a time delay relay, keeps the dynamic braking circuit open when the master switch is moved rapidly through the "Off" position. If the master switch is moved to the stop



CURVE	CONTACTS x=CLOSED								
	IM	IF	2F	IR	2R	P	IA	2A	DB
a.	x	x	x						
b.	x	x	x			x			
c.	x	x	x			x	x		
d.	x	x	x			x	x	x	
e.									x
f.	x			x	x				
g.	x			x	x	x			
h.	x			x	x	x	x		
i.	x			x	x	x	x	x	

FIG. 11. Speed-Torque Characteristics of Compound Motor with Class 9535 Controller

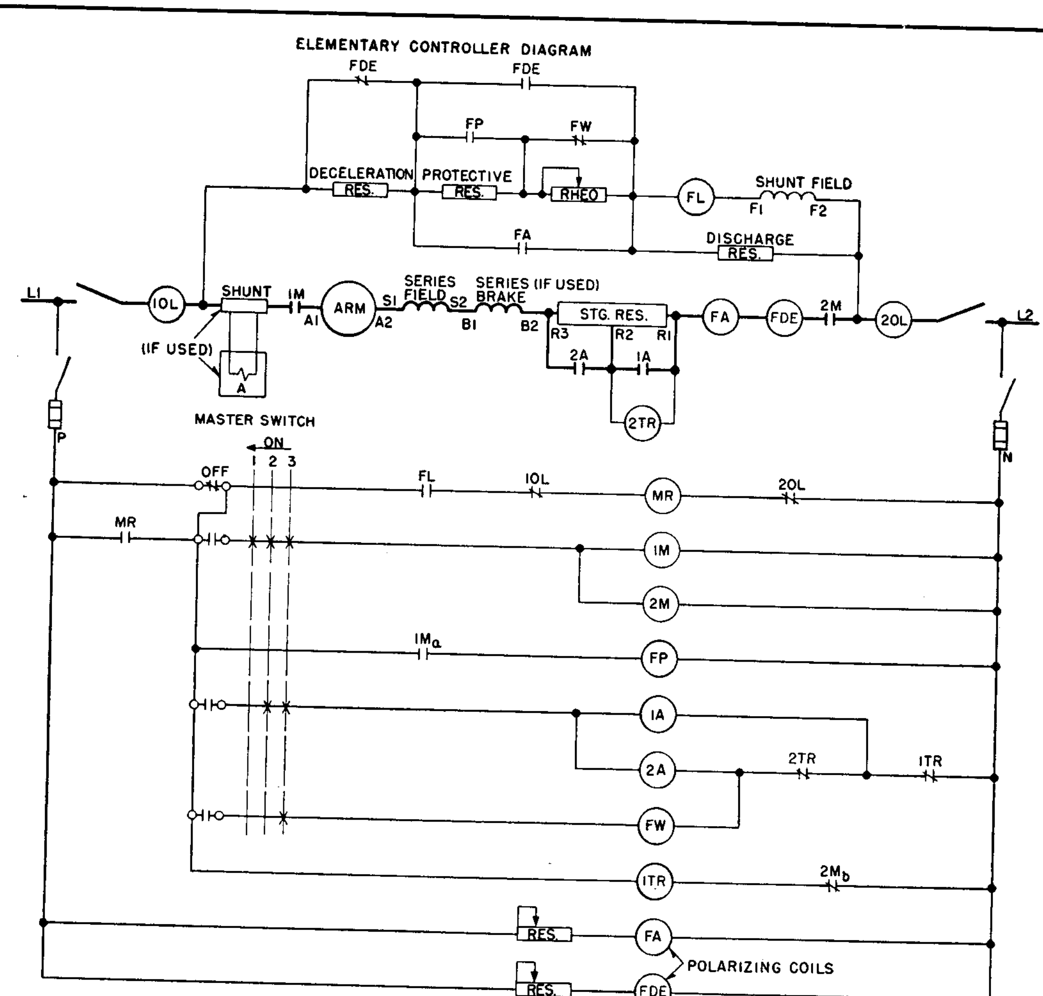


FIG. 12. Class 9505 Non-Reversing, Adjustable Speed Controller

position, DB will drop out and apply dynamic braking after 3TR drops out.

Fig. 11 shows the speed-torque characteristics of a compound wound motor with a Class 9535 controller.

CONTROLLERS FOR SERIES MOTORS

A Class 9505 or a Class 9515 controller may be used with a series wound motor. These circuits are the same as those of Figs. 2 and 6 respectively, except that the shunt fields and discharge resistors are omitted. The speed-torque characters are similar to those of Figs. 3 and 7 except that the slope of the curves is steeper. At no load, most series wound motors will exceed their maximum permissible speed.

CONTROLLERS FOR ADJUSTABLE SPEED SHUNT MOTORS

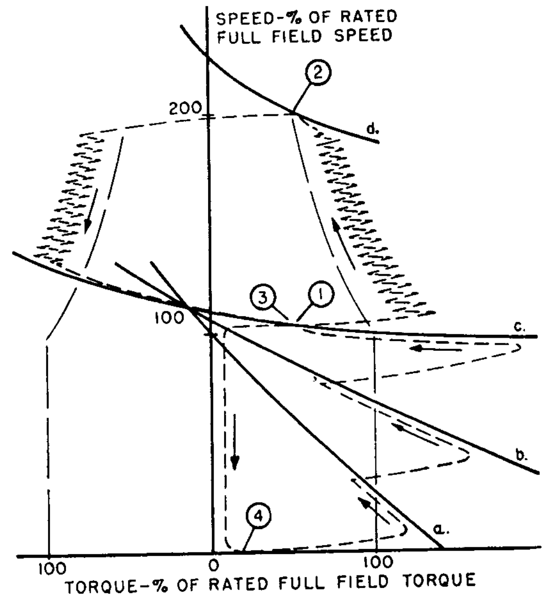
Class 9500 controllers are also built for use with adjustable speed, shunt wound motors. Fig. 12 shows a typical circuit for a Class 9505 controller for such a motor. This circuit is similar to the circuit of Fig. 2 with the addition of the shunt field rheostat, resistors, and relays FA, FDE, FL and FP.

Field relays are usually relays having two operating coils and their pick-up and drop-out are adjustable over a wide range. Each coil may either be a strap wound coil capable of carrying the armature current of the motor or a wire coil suitable for the control voltage or the motor field current. One wire coil is also used which has two separate voltage windings.

Field Protective Relay (FP) inserts a resistance in series with the shunt field to reduce its heating when the motor is at standstill. This increased heating at standstill is due to the absence of ventilation from the internal fan on the motor armature.

Field Loss Relay (FL) prevents operation of the controller when the field current falls below a certain value, by opening the MR coil circuit. Loss of field on a shunt machine might result in the motor reaching a dangerously high speed.

Field Accelerating Relay (FA) is a field fluttering relay whose purpose is to keep the armature current from exceeding certain limits while the motor is accelerating due to field weakening. It accomplishes this by shorting out the field rheostat when the armature current gets too high, which strengthens the shunt field and limits the acceleration rate. The armature current starts to fall and



TYPICAL TRANSIENT CHARACTERISTIC

ACCELERATE TO FULL FIELD SPEED AT HALF LOAD (1)

ACCELERATE TO WEAK FIELD SPEED AT FULL LOAD (2)

DECELERATE TO FULL FIELD SPEED AT HALF LOAD (3)

DECELERATE TO STOP (4)

CURVE	CONTACTS x = CLOSED				
	FW	1M	2M	1A	2A
a	x	x	x		
b	x	x	x	x	
c	x	x	x	x	x
d		x	x	x	x

FIG. 13. Speed-Torque Characteristics of Adjustable Speed Shunt Motor with Class 9505 Controller

FA contact opens which then weakens the field and the motor accelerates again. The cycle is repeated until the motor speed reaches the new rheostat setting. A polarizing coil is employed which aids the main series coil on acceleration and therefore opposes it on the reverse current of deceleration. Thus, FA is allowed to pick-up only on acceleration.

Field Decelerating Relay (FDE) is a field fluttering relay similar to FA except that it operates to limit armature current while the motor is decelerating due to increased field strength. This is accomplished by FDE relay contact opening to insert resistance in the field circuit which weakens the field and limits the deceleration rate. The armature

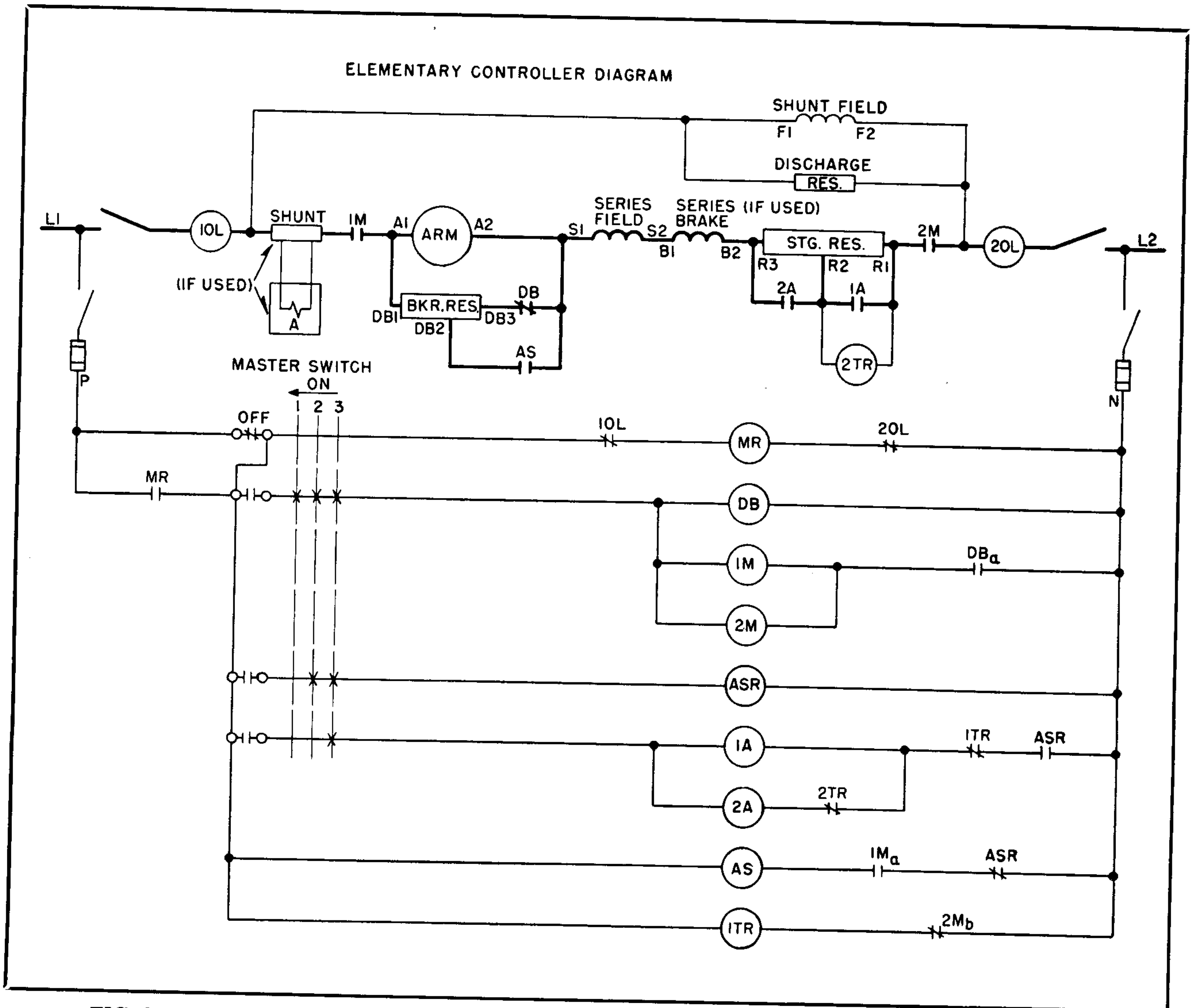


FIG. 14. Class 9510 Non-Reversing, Dynamic Braking Controller with Armature Shunt Slow Down

current starts to fall and FDE contact recloses, which again strengthens the field and the motor again decelerates. The cycle is repeated until the motor speed reaches the new rheostat setting. A polarizing coil prevents FDE from picking up on accelerating currents.

The circuit shown is a typical circuit but there are quite a few modifications and features which may be added to suit individual applications. Relay FW is included in this circuit to illustrate one such variety. This relay is picked up only on the third or highest speed point of the master switch. When FW picks up, its contact opens and inserts the field rheostat in the field circuit.

Fig. 13 shows the speed-torque characteristics of a variable speed shunt motor with a Class 9505 controller.

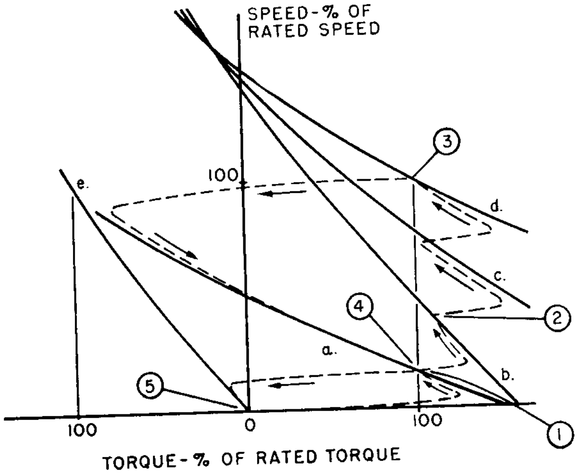
CONTROLLERS FOR CONSTANT SPEED SHUNT MOTORS

The circuit for a Class 9505 controller for a constant speed, shunt wound motor is similar to that of Fig. 12 except that relays FA, FDE and FW are not required, nor are the field rheostat or the decelerating resistance.

ARMATURE SHUNT

Fig. 14 shows armature shunting added to Class 9510 controller.

Resistors in series with the armature reduce the motor speed in direct proportion to the voltage drop across the resistor. This drop is numerically equal to the product of the resistance and the armature current; therefore, on light loads (either



TYPICAL TRANSIENT CHARACTERISTIC

ACCELERATE TO SLOW SPEED (1)

ACCELERATE TO INTERMEDIATE SPEED (2)

ACCELERATE TO FULL SPEED (3)

DECELERATE TO SLOW SPEED (4)

DECELERATE TO STOP (5)

CURVE	CONTACTS x = CLOSED					
	AS	1M	2M	1A	2A	DB
a.	x	x	x			
b.		x	x			
c.		x	x	x		
d.		x	x	x	x	
e.						x

FIG. 15. Speed-Torque Characteristics of Compound Motor with Class 9510 Controller with Armature Shunt

motoring or overhauling), the resistance will have little or no effect on the speed.

However, if a second resistance is connected in shunt (or parallel) with the armature, sufficient current can be drawn by this "armature shunt" resistor to secure sufficient voltage drop to obtain the lower speed desired.

In practice, the series resistor is usually the starting resistor and the armature shunt resistor a part of the dynamic braking resistor.

The armature shunt contactor AS, which connects part of the dynamic braking resistor across the motor armature, is picked up by the armature shunt relay ASR.

The armature shunt relay may be any type of auxiliary relay but the type usually employed has provision for two coils, either of which will pick-up the relay.

The armature shunt contactor pick-up may be initiated by the master switch or by limit switches or a combination of both.

The dual coil relay is used in conjunction with the forward and reverse slow-down limit switches so as to pick-up the armature shunt contactor slightly in advance of the "Stop" position in either direction thus slowing down the drive so that a smooth, accurate and quick stop can be made when the "Stop" position is reached. The two coils permit arranging the forward and reverse slow-down circuits independently so that slow down is accomplished only when *approaching* the "Stop" position.

Fig. 15 shows the speed-torque characteristics of a compound wound motor controlled by a Class 9510 controller with an armature shunt. Note that with the armature shunt connected, the armature speed is low even with an overhauling load.

SERIES BRAKE

Any Class 9500 controller may have a series brake connected in series with the motor series field provided the motor load is never less than 10 percent of full load. A series brake so used would set when the motor load dropped to less than ten percent, then release as the motor load picked up and motor speed dropped due to the setting of the brake. The brake would continue to set and release.

SHUNT BRAKE

Any Class 9500 controller may have a shunt brake. The coil of the shunt brake is energized from the control bus by the normally open contact of a brake relay (BR).

MASTER SWITCHES

A master switch is a manually-operated switch by which the operator causes the controller to

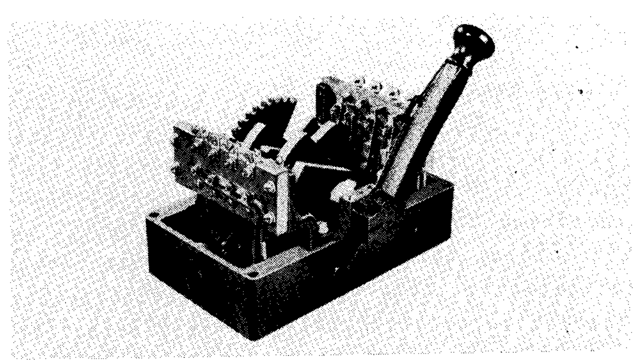


FIG. 16. Type SM Mill Master Switch

start, stop, reverse or otherwise change the operation of the motor being controlled.

A master switch may be a Mill Type Master Switch such as shown in Fig. 16 or it may be a control switch or pushbuttons mounted on a desk or operator's station. Pushbutton operation usually requires the use of control relays to secure the desired operation.

LIMIT SWITCHES

Limit switches are devices for electrically controlling or limiting the movement of mechanical apparatus. They may be used to limit the travel of a machine, to stop it at a given point; to provide slow-down ahead of the designated stopping point; to alter the motion of a machine during phases of its cycle or to provide interlocking between two or more drives to name some of the common uses.

The three common types of limit switches used with constant voltage controllers are the lever type, the rotating cam, and the traveling nut.

Lever Type Limit Switch. The lever type consists of a set of contacts operated by a lever. (See Fig. 17). The limit switch is placed so that the mechanism to be controlled will strike the lever when it reaches the desired position and thus effect whatever change in the motion or interlocking is desired at that point. This type of limit switch is frequently used where the moving mechanism travels with linear motion such as a transfer car on a track.

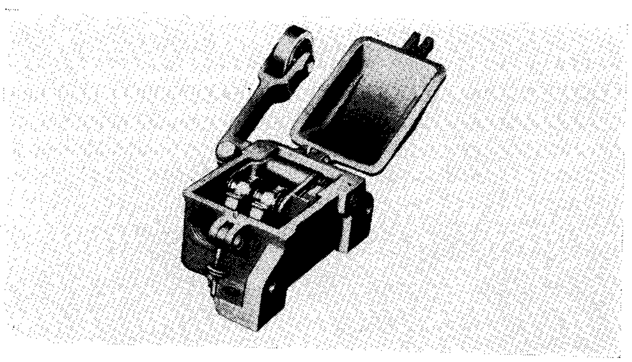


FIG. 17. Type HS Lever Type Limit Switch

Cam Type Limit Switch. The cam type limit switch (see Fig. 18) consists of a number of contacts each operated by separate adjustable cams mounted on a common shaft. The shaft is connected to the mechanism to be controlled either directly or through gears so that the complete travel of the mechanism is somewhat less than 360 degrees rotation of the limit switch shaft (usually around 300 degrees). There are also some applications such as a crank driven mechanism on which the limit switch shaft rotates 360 degrees for one operation.

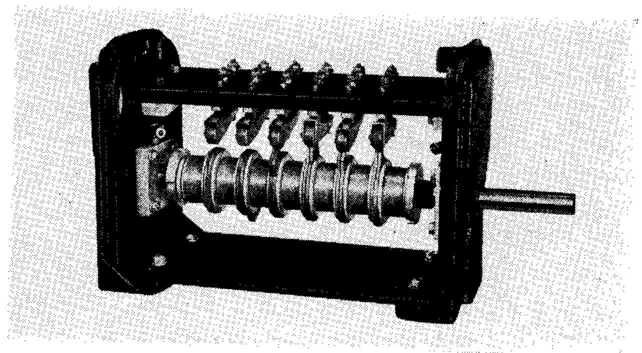


FIG. 18. Type A Cam Limit Switch

Each cam has two adjustments. The cam length may be adjusted to provide any degree of contact operation within the limits of the particular cam as described below. The cam may also be rotated on the shaft so that the contact operation period occurs in the correct part of the cycle.

The cams consist of two identical halves each from 10 to 180 degrees in periphial length in standard sizes. The contacts are spring closed and either half of the cam will open the contact. Thus a 10-degree cam, for example, can be adjusted so that the contact will be open anywhere from 10 to 20 degrees depending upon the amount the cam halves overlap, if any.

Traveling Nut Limit Switch. The traveling nut limit switch consists of a threaded shaft, a nut in this shaft which is prevented from turning, and a number of switch units which are operated by the nut as it travels along the screw. The shaft is geared to the moving part, and after the proper set-up is made, the nut is the exact measure of the position of the moving part.

The position of the switch units along the threaded shaft may be adjusted so as to provide indication to the control that the mechanism is in the corresponding position.

Adjustment of Limit Switches in the Field. From the above description it will be obvious that the correct operation of a drive using limit switches depends upon the switch being mounted in the correct position and having the correct relationship with the mechanism.

Cam limit switches, for example, can be delivered from the factory with the correct cams in place but in almost every case the individual cams will have to be adjusted so that the contacts open and close exactly as required.

Refer to the instruction leaflet for instructions for each individual type of limit switch.

INSTALLATION AND OPERATION

Foundations for controllers should be solid enough to prevent vibration, and so located to afford accessibility, protection and ventilation for the control.

Controller locations should be largely determined by the degree of protection afforded the control by its enclosure, if any, and by local conditions relative to exposure, cleanliness, presence of gas fumes etc. The degree of protection provided against destructive and injurious elements will to a large extent determine the life and dependability of the controller. Special attention should be given to the problem of ventilation where the controller is required to dissipate considerable energy in the form of heat. The location should also be as near the motor and other associated equipment as possible, and preferably in sight of the operator's location.

Accessibility requirements for connecting and servicing controllers will vary for different designs and should be definitely determined before the foundations are located. For floor-mounted types, all sides should be accessible where possible, and in most cases they must be accessible from the front and also the back. Outlines for the controllers should be carefully checked to determine minimum space requirements.

Foundations for floor-mounted controllers should be level and should include means for securing the controller in place. The means of securing controllers are mainly imbedded, through, or expansion bolts, or by lag screws as may be best suited for the controller and its foundation.

Foundations should include conduits or other suitable means for connecting the controller to associated generators, motors, brakes, limit switches, master switches and other auxiliary devices. To properly determine conduit requirements the outline should be checked for available and suggested locations for conduits. The number and size of conduits will depend on cable groupings as indicated on the wiring diagram, and the cable sizes.

When steel conduits are used they should be grounded. If alternating current circuits are on the same panel, they should be arranged so that all wires of a single phase or of a polyphase circuit are located in the same conduit.

The controller when installed should be properly set in position, leveled, and then bolted to the foundation. Where floor-mounted controllers are provided with channel bases, they should be grouted to the floor if feasible.

To grout the base, close each end of the channel with a mixture of fairly dry mortar and back it up with boards or bricks. Then pour a mixture of grout into the large holes on top of the channel base until the channel has been completely filled. Mix the grout from one part sand, one part cement, and sufficient water to make it flow smoothly.

Power and control connections should be completed for the equipment in accord with the circuits shown on the diagrams. Connections between d-c instruments mounted remote from the controller and their shunts need no special consideration except that the total lead resistance should not exceed one ohm. A one ohm variable resistor is provided to adjust the total lead resistance to one ohm—the value for which the instruments are calibrated.

During erection the equipment should be protected against dust, building dirt and falling objects if installation is being made in a new building still under construction.

Adjust relay 1TR so that during the starting period the second peak of armature current is equal to the first. Adjust relay 2TR so that the third current peak is equal to the second.

To check the connections, open the armature knife switch, close the control knife switch, operate the master switch, see if the circuit devices operate in the order described under "Description of Circuits," Part Two of this book. Keep in mind that under these conditions any relay which has a coil connected to the armature circuit (2TR, FA, FDE) will not operate. Open the control knife switch.

To operate the controller, close the armature knife switch before the control knife switch. This order of closing switches will prevent any possibility of picking up the armature circuit contactors and then closing the armature knife switch on a short circuit.

MAINTENANCE

Equipment well cared for will provide satisfactory and dependable operation with a minimum of trouble. It cannot, therefore, be too strongly emphasized that good maintenance will prove to be a profitable and highly important factor in satisfactory controller operation.

All possible safety precautions should be taken before working on electrical apparatus, and only skilled personnel should service the electrical equipment.

Minimum controller maintenance will be required if the equipment is located in the most favorable of all possible locations as outlined in the installation and erection instructions, Part Three of this book. A plan should also be worked out and put into practice whereby the controller equipment is provided with a periodic and systematic inspection. This type of preventative maintenance will often avoid expensive replacement of complete apparatus under breakdown conditions.

Suggestions for the maintenance of each type of relay contactor, and switch are given in the corresponding instruction leaflets.

Preventative maintenance by means of periodic inspection and servicing should include the items covered in the following paragraphs.

CLEANING

Thoroughly clean all dust from the apparatus, preferably by blowing it out with compressed air. In the absence of an air supply, clean the equipment by brush or by any other acceptable method. It should be noted that oily rags or waste should not be used as they will leave an oil film on the equipment which will collect dust particles.

LUBRICATION

Except for special equipment, controllers require no lubrication. This is especially true of contactors and relays. In the few cases where lubrication is desirable such as on built-in rotating machines, bearings for large master switches, etc., it should be used sparingly and great care should be used in applying it. The use of oil on contactors and relays will cause dirt to collect in the bearings and moving parts, and may cause operating difficulties because of increased friction. A-C magnet faces may have a thin film of light oil to prevent rusting.

MECHANICAL INSPECTION

Moving parts should be checked and operated where possible in an effort to locate loose pins, bolts, and weak springs; and to locate parts which are developing excessive friction and are becoming hard to operate. Parts subjected to the greatest wear should receive special attention, and should be replaced when the wear has become excessive.

CONTACTS

Current-carrying contacts should be inspected for wear and for signs of excessive heating. Deeply pitted and burned contacts, as well as those worn thin, should be replaced with new ones. When making replacements, it is desirable to replace contacts in pairs rather than to install a new contact to operate with one that is partly worn. In general, the condition of a contact should be judged from its shape and the condition of its contact-making surface, bearing in mind that contact surfaces need not be entirely smooth. A slightly roughed surface, if clean, is entirely satisfactory. Contact color is not necessarily an indication of condition as the color is often due to oxidation of the contact material. A dark copper contact may have an undesirable high contact resistance due to the formation of copper oxide and it would be wise to clean it, whereas, a dark silver contact still has low contact resistance and need not be cleaned.

When replacements are made, surfaces for seating the new contacts should be clean. Contacts which are burned, but not badly, may be cleaned with sand paper; and if exceedingly rough, with a fine file. The use of a file should be avoided where possible, and when it is used, care should be taken to maintain the shape of the contact. Replacements must be tightly secured, as a loose contact will soon overheat.

Arc shields, when removed for the inspection or replacement of contacts, must be fixed firmly in their proper position after the replacement or inspection is completed. Otherwise, they will not function as effectively in interrupting currents flowing through the contactor.

SPRINGS

In connection with maintenance, springs (and especially contact springs) are often overlooked. Weak springs may cause bouncing contacts and in many cases is the chief cause of frozen or welded contacts; and they are also a contributing cause of overheating resulting from low contact pressure. It is important, therefore, that springs be systematically checked for signs of deterioration. There are two methods which may be used; one is by comparison with new springs of the same design; and the second is by measuring contact pressures for comparison with the recommended values of the manufacturer.

By comparison with a new spring as to size, shape and tension, it is readily possible to determine when a spring has been so overstressed or overheated as to have lost its efficiency. This comparison cannot be expected to indicate minor deficiencies or small reductions in tension.

Where there is any doubt concerning the condition of the spring, or where there is evidence of overheating, the contact pressure should be measured as noted in the following paragraph.

To measure the contact pressure, a spring scale should be attached to the moving contact at, or near, the point where it touches the stationary contact. A thin piece of paper is then placed between the contacts and the contactor is mechanically closed. A pull is then exerted on the moving contact through the scales in a direction vertical to the contact surface, so that the line of pull projects through the center of this surface. The contact pressure is then the measure in pounds required to separate the contacts sufficiently to permit the paper to be removed from between them.

When a spring is proven inefficient, it should be immediately replaced, and spring washers should be added or taken out as required to provide the recommended contact pressure. For recommended contact pressures, refer to the instruction leaflets included for the various contactors used.

LOOSE CONNECTIONS

As loose connections are an evasive and annoying source of trouble, they should be checked —especially on those applications subject to changing temperatures and vibration. As many connections as possible should be checked, and it is especially important that connections to external leads be tightly made.

REPLACING PARTS

The replacement of defective coils requires that coil leads be disconnected. In instances of this kind, and especially where multiple coils are used, it is important that the connections to the replacement coil be the same as to the original coil. Otherwise, relative polarities may be changed and the device may become inoperative. Similarly, other replacements involving connections should be made to provide the same circuits as on the original equipment.

It should be kept constantly in mind that any change or replacement should improve the operation of the control and associated motor-driven equipment. Replacements, if carelessly made, may result in less dependable operation than existed before they were made.

DASHPOTS

When dashpots are used, they should be kept free from dirt, friction or anything that will cause sluggish action.

The proper oil level should be maintained at all times.

The oil for dashpots is a special grade that changes very little in viscosity with wide temperature changes. Only the special oil should be used. If substitute oils are used, the calibration of the relay will be changed and the relay may not operate properly.

SHUNTS

Flexible shunts of fine stranded copper must be tightly connected and must not have broken strands. Broken strands increase the current on the remaining strands and cause overheating.

MAINTENANCE CHECKS

Preventative maintenance will prove well worth while, yet there will still be occasions when contactors or relays fail to function properly. When this occurs, a check should be made for the following causes which are among the more common reasons for such failures:

A. Failure to close may be caused by:
   1. Disconnected power supply or voltage too low.
   2. Loose or broken connection to the operating coil.
   3. The operating coil may be open or short circuited.
   4. There may be mechanical friction or interference between parts which may prevent it from closing.

B. Failure to open may be caused by:
   1. Mechanical interference between parts.
   2. Contact tips may have welded together due to overheating.
   3. Residual magnetism may be holding magnet because of low kickout spring pressure.

Table No. 2. DEVICE TYPE AND SUPPLEMENTARY PUBLICATION

DEVICE AND TYPE	PUBLICATION	APPLICATION*
Contactor		
201-SM, 202-SM, 204-SM	I.L. 3413	Line, Accelerating, Reversing, Plugging and Armature Shunting Contactors.
208-SM	I.L. 3414	
M-310, M-410, M-510, M-610, M-710, M-810, M-910	▲	
241-SM, 242-SM	I.L. 3445	Dynamic Braking Contactor.
144-SM	I.L. 1919	
148-SM	I.L. 1920	
M-301, M-401, M-501, M-601, M-701	▲	
Contactor or Relay (M contactor 50 ampere frame)		
M-010, M-110, M-210	I.L. 15-800-M010/110/210-1	Master Relay (MR) and Control Relays, Field Relays (High Current Fields), Shunt Brake and Clutch Relays, Solenoid Control
M-011, M-111, M-211	I.L. 15-800-M011/111/211-1	
M-020, M-120, M-220	I.L. 15-800-M020/120/220-1	
M-021, M-121, M-221	I.L. 15-800-M021/121/221-1	
M-022, M-122, M-222	I.L. 15-800-M022/122/222-1	
M-001, M-101, M-201	I.L. 15-800-M001/101/201-1	
Electrical Interlock		
L-39	I.L. 2170	Int. for SM Contactors
L-46	I.L. 15-829-L46-1	Int. for 50 Amp. M. Contactor
L-61	▲	Int. for M-310, etc. and M-301, etc.
Relays		
AP	I.L. 15-827-1-AP	Plugging Relay (PF and PR)
AV	▲	Dual Coil Field and Adjustable Voltage and/or Current Relay (FA, FDE, FL, ASR, etc.)
AYB	R.P.D. 23-034	Multi-Contact Control Relay (CR, 1CR, etc.)
AYC	I.L. 15-827-4-AYC	Control Relay (CR, 1CR, etc.)
AYJ	I.L. 15-827-5-AYJ	Jamming Relay
AYK	▲	Multi-Contact Control Relay (CR, 1CR, etc.)
AYV	I.L. 15-827-6-AYV	Dynamic Braking Relay (DBR)
AZ	I.L. 15-827-7-AZ	Timing Relay (1TR, 2TR, etc.)
HI	I.L. 2671	Dual Coil Field and Adjustable Voltage and/or Current Relay (FA, FDE, FL, ASR, etc.)
TI-2	I.L. 3487	Overload Relay (1OL, 2OL)
Master Switches		
SM-Master Switch	I.L. 2672	
W-Control Switch	R.P.D. 37-150-CS	
W-Instrument Switch	R.P.D. 37-150-IS	
Pushbuttons		
F	P.L. 15-025	
HD	D.B. 15-010	
OT	D.B. 15-022	
Limit Switch		
A	I.L. 3253	Rotating Cam Limit Switch
TN	I.L. 1651	Traveling Nut Limit Switch
LS	I.L. 3906	Lever Type Limit Switches
HS	I.L. 1878	
PL	I.L. 2263	
438	I.L. 2621	
S-12A, S-13A, S-24, S-26	I.L. 3325	
15-080	I.L. 1650	
Field Rheostat		
LR & LK	I.L. 14-515-1	Manual
SO	▲	Motor Operated
SM	▲	
Ammeter Shunt		
G	I.L. 43-850-A	50 Millivolt
Brakes		
DI	I.L. 1422	Shunt or Series
Resistors		
Unit Frame	Application Data 14-990	
M	I.L. 1733	
Grid	I.L. 1734	

* Refer to "General Description", Part One of this book.
▲ Not available at Present.

DESCRIPTION • INSTALLATION • MAINTENANCE

INSTRUCTIONS

Heavy-Duty

STEEL MILL MAGNETIC CONTROLLERS

Class 9500

MILL AUXILIARY SERVICE
CONSTANT VOLTAGE D-C

WESTINGHOUSE ELECTRIC CORPORATION
BUFFALO PLANT • MOTOR AND CONTROL DIVISION • BUFFALO 5, N. Y.

SUPERSEDES I.B. 9500-1A

OCTOBER, 1959
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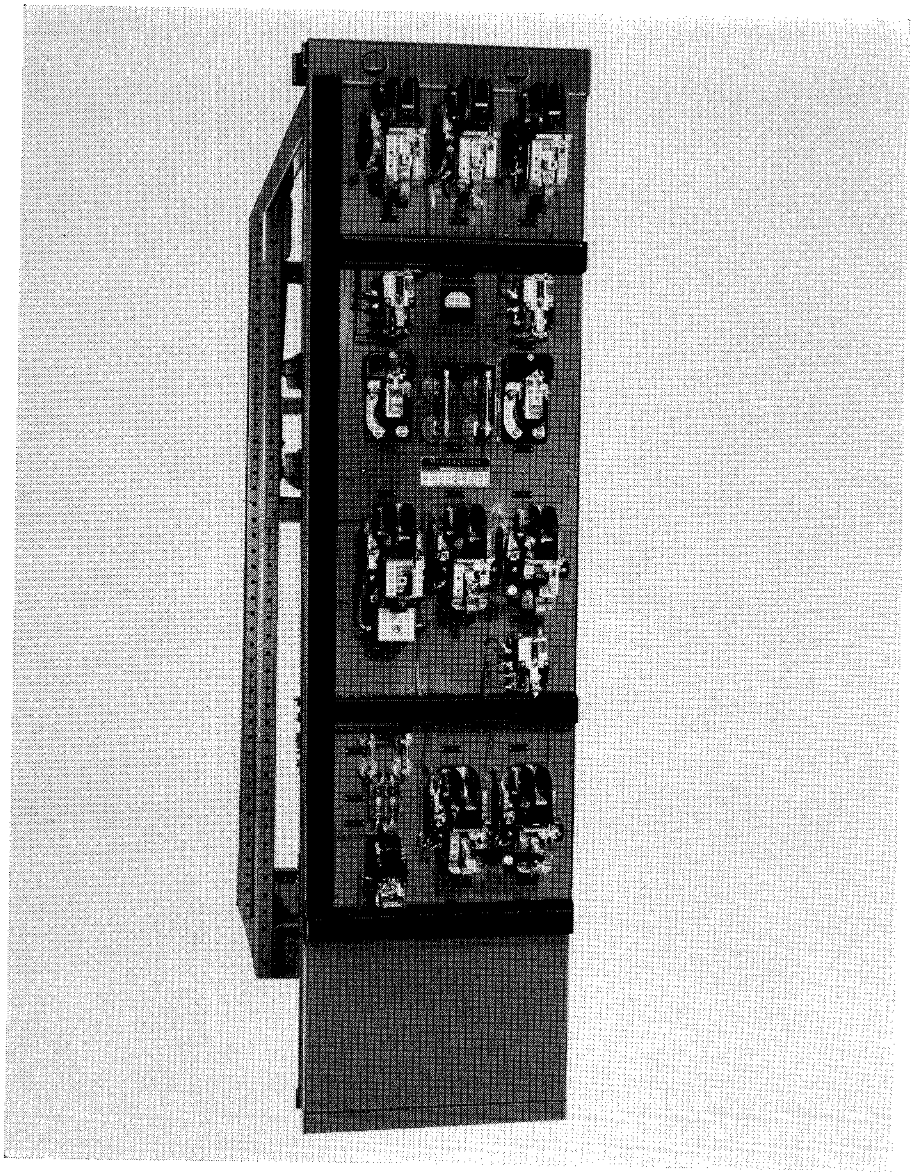


Special Class 9500 Controller Mounted on Bolted Self-Supporting, Factory-Assembled Frame with Starting Resistors Mounted and Wired (Class A Construction with 90-inch High Steel Panel)

Class 9500 is the general designation given to constant-voltage, direct-current, magnetic controllers for use in mill auxiliary service in steel mill and other heavy mill applications.

The specific classes in this general classification are:

Class 9505—Non-Reversing Controller

Class 9510—Non-Reversing, Dynamic Braking Controller

Class 9515—Reversing, Plugging Controller

Class 9530—Reversing, Dynamic Braking Controller

Class 9535—Reversing, Plugging, Dynamic Braking Controller

These controllers are used for such applications as pushers, tables, screw-downs, sideguard adjustment, etc. They conform to NEMA standards for d-c magnetic control for steel mill auxiliaries.

GENERAL DESCRIPTION

A complete motor controller includes a control panel, armature circuit resistors, a pushbutton or master switch and where required, limit switches and a field rheostat. The equipment included on the control panel is listed under "Class 9500 Component Devices and Functions" below.

All contactors and relays are assembled as complete units to assure correct alignment of parts.

The arrangement of apparatus is such that controllers of the same rating or various ratings may be installed in groups and line-up to present a symmetrical and pleasing appearance.

Overload protection is provided by two thermal-magnetic relays which provide inverse time limit protection to normal loads, and instantaneous trip on abnormal loads of approximately 400 percent. Trip reset button may be set for "Automatic Reset" or "Manual Reset". Low-voltage protection is provided by a relay which prevents motor from restarting automatically upon the return of voltage.

Acceleration is controlled by definite time limit relays. These relays operate on the decay of flux in the coil when it is short circuited or when the coil circuit is opened. A wide range of adjustment permits setting the period of acceleration at the exact value which best fits the operating schedule and high contact pressure assures proper operation under the most adverse conditions of dirt and vibration.

Separate knife switches are provided for the motor armature circuit and the control circuits so that the control may be tested without energizing the motor. Locking clips on the main switch provide an extra safety feature.

For detailed information on specific controllers, such as the number of accelerating contactors, contactor size etc. etc. refer to Price List 9320.

CLASS 9500 COMPONENT DEVICES AND FUNCTIONS

The devices listed in Paragraph A are required for *all* Standard Class 9500 Controllers.

Each specific Class in this general classification requires additional devices to complete the controller. These devices for constant speed compound motors ∅ are listed in Paragraphs B to F, plus the necessary resistors and interlocks.

Paragraph A. All Class 9500 Controllers require the following:

Quantity	*Function and Device*	*Device Marking*
1	Negative Line Contactor	1M
2*	Accelerating Contactor	1A, 2A*
2	Overload Relays	1OL, 2OL
2*	Definite Time Accelerating Relays	1TR, 2TR*
1	Master Relay	MR
1	Motor Line Knife Switch with Locking Clip and 90-degree Stop	
1	Control Knife Switch	
2	Control Fuses	

Note: In addition to the above, ammeters and/or shunts may be furnished for any controller as optional additions.

Class 9500 controllers have been designed with a 50 mv shunt rated at 125 to 150 percent of the motor full load current and a 100 mv ammeter with a full scale of 250 to 300 percent of full load. The selection of these values permits the reading of starting peaks and other momentary surges. This also allows recording type ammeters or other meters having 100 mv movements to be used.

Paragraph B. Class 9505 (Non-Reversing) Controllers require the following device in addition to those listed in Paragraph A:

Quantity	*Function and Device*	*Device Marking*
1	Positive Line Contactor	2M

Paragraph C. Class 9510 (Non-Reversing, Dynamic Braking) Controllers require the following devices in addition to those listed in Paragraph A:

Quantity	*Function and Device*	*Device Marking*
1	Positive Line Contactor	2M
1	Dynamic Braking Contactor	DB

Paragraph D. Class 9515 (Reversing, Plugging) Controllers require the following devices in addition to those listed in Paragraph A:

∅ Class 9505 and 9510 may also be used with series motors.
* Specific cases may require more or less accelerating contactors. (Refer to P.L. 9320).

Quantity	Function and Device	Device Marking
4	Armature Reversing Contactors	1F, 2F (Forward) 1R, 2R (Reverse)
1	Plugging Contactor	P
2	Plugging Relays	PF, PR

Paragraph E. Class 9530 (Reversing, Dynamic Braking) Controllers require the following devices in addition to those listed in Paragraph A:

Quantity	Function and Device	Device Marking
4	Armature Reversing Contactors	1F, 2F (Forward) 1R, 2R (Reverse)
1	Dynamic Braking Contactor	DB
1	Anti-Plugging Relay	AP

Paragraph F. Class 9535 (Reversing, Plugging, Dynamic Braking) Controllers require the following devices in addition to those listed in Paragraph A:

Quantity	Function and Device	Device Marking
4	Armature Reversing Contactors	1F, 2F (Forward) 1R, 2R (Reverse)
1	Plugging Contactor	P
1	Dynamic Braking Contactor	DB
2	Plugging Relays	PF, PR
1	Timing Relay	3TR

Paragraph G. Armature shunt may be added to Class 9510, 9530 or 9535 controllers without any additional devices, by employing the dynamic braking contactor DB and the dynamic braking resistor for this as well as their normal function. Where separate armature shunt contactor is required, or on class 9505 or 9515 which do not have dynamic braking; the following additional devices are required:

Quantity	Function and Device	Device Marking
1	Armature Shunt Contactor	AS
1	Armature Shunt Relay	ASR
1	Armature Shunt Resistor†	

Paragraph H.

Field Relays. In most cases, a dual coil relay with adjustable pick-up and drop-out is used for field relay applications. When the field current exceeds the rating of the contacts of this relay, it is necessary either to use an auxiliary relay (or contactor) with the dual coil relay, or, where possible, to substitute a single device having a higher rating.

In general, the requirements for field relays are listed below. In many cases, however, motor design or the application may make it advisable to omit some of these relays when they normally would be furnished or to add additional relays.

FL—Field Loss. Not required on series motors or mill type compound motors having less than 60 percent shunt field (note: Westinghouse mill type compound motors have less than 60 percent shunt field). Required on straight or stabilized shunt motors or mill type compound motors having 60 percent or more shunt field.

FP—Field Protective (or Field Economizer). Required on all motors whose shunt field is not continuously rated when the motor is at standstill with full field. Not required on Westinghouse mill type motors either shunt or compound.

FA—Field Acceleration.▲ Required on all adjustable speed motors of over two to one speed range if the field setting can be rapidly changed from "Slow" to "Fast".

FD—Field Deceleration.▲ Required on all adjustable speed motors of over two to one speed range if the field setting can be rapidly changed from "Fast" to "Slow".

Paragraph I.

Control Relays—CR, 1CR, 2CR, etc. In addition to the relays which are required for the various classes of controllers as listed in Paragraphs A to H above, relays of various kinds are required for dual or triple control of one motor, duplex operation of two motors, or for any of the many other special applications.

CONSTRUCTION

The devices for any given controller, as itemized in the preceding paragraphs, are mounted on steel (standard), ebony asbestos, or slate panels, which are mounted on a fabricated steel frame, or mounted in an enclosure.

The arrangement of the apparatus is such that the controllers may be installed in groups and line-up to present a symmetrical and pleasing appearance.

The types and classes of construction (see Fig. 1) are as follows:

Class A. Self-supporting, factory assembled frames with full height panels (90 inch high panels are standard, for other heights consult price list or

† Part of Dynamic Braking Resistor on Class 9510, 9530 or 9535.

▲ Field Acceleration & Field Decelleration Relays may be required on adjustable speed motors of two to one or less speed range if connected to high inertia load.

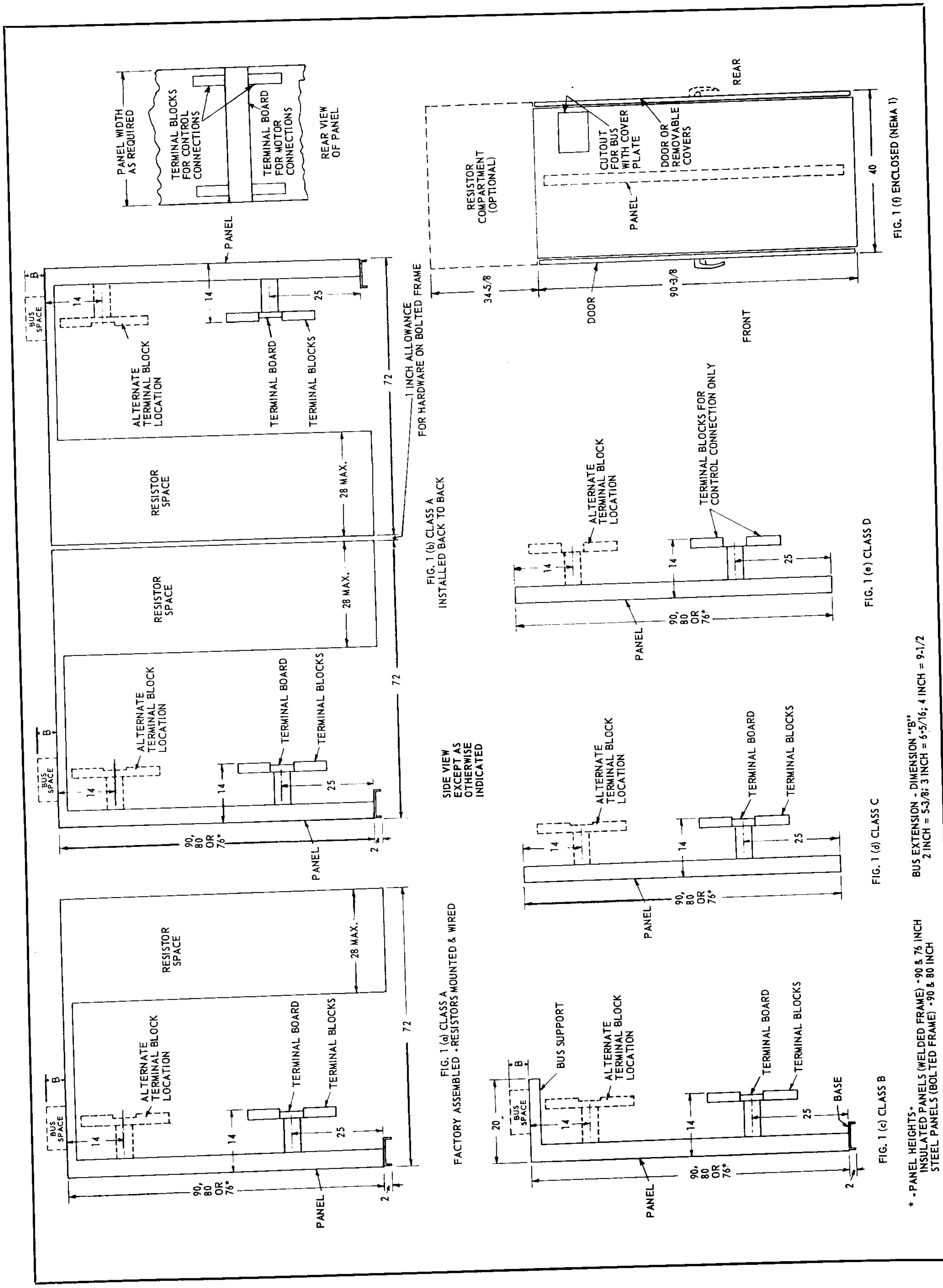


FIG. 1. Frame and Enclosure Details.
For reference only—Do not use for construction

refer the question to Headquarters); interconnecting main and control buses; main and control circuit terminal boards; and all resistors mounted and wired.

Standard frame arrangement is shown in Fig. 1(a) and also in the frontispiece, page 4. "Unit Frame" construction is used such that each controller panel, the resistors, and the supporting frame is a complete self supported unit in itself. This construction besides giving a sturdier installation, permits qreater flexibility. Controllers are bolted together and may be rearranged easily or separated and moved to new locations if mill layout is changed. The frame may be mounted with the resistor rack against the wall as the resistors are mounted and wired so that they can be removed from the "aisle" side of the resistor rack.

Controllers are usually shipped in sections consisting of several panels bolted together with a common main bus. Splice bars are provided to connect the bars to the adjoining section.

If desired, two frames may be mounted "back to back" as shown in Fig. 1 (b).

Class B. Fig. 1 (c), includes all features of Class A construction except line, starting and/or dynamic braking resistors are shipped separately for mounting and wiring by the purchaser. Panels must be supported by wall or floor braces and are usually shipped in sections with a common main bus.

Class C. Fig. 1 (d), is similar to Class B, *except* main bus is omitted in addition to resistors being supplied separately, unmounted and unwired. Panels are usually shipped individually.

Class D. Fig. 1 (e), is the least expensive class of construction but requires the most installation. The panel must be supported, armature circuit resistors mounted and wired and if there is more than one panel a bus must be provided and wired to each panel. Since no terminal board is provided for motor armature connections, the cables must be left long enough to reach directly to the contactor studs. Class D controlled panels are shipped individually.

Enclosures. All classes of construction are available in NEMA type I (General Purpose) enclosures with or without gaskets, Fig. 1 (f). If main resistors are to be mounted and wired, they will be located in a separate ventilated section with removable covers on top of the controller enclosure. All controller enclosures have the same height and depth and resistor enclosures, where used, are likewise all the same height so that enclosed controllers may also be installed in groups and present a symmetrical and pleasing appearance.

Enclosed Class 9500 Controllers usually consist of a single panel mounted in an individual enclosure. Doors are furnished in the front and either doors or removable covers in the rear. A cutout with a coverplate is furnished in the sides of the enclosure to permit mounting of a common bus when several controllers are mounted side by side.

Where a single controller consists of more than one panel, or where duplex or other special multiple panel controllers are involved; the several panels may be mounted in a common enclosure usually having an individual door for each panel.

RATINGS

Controllers are rated in accordance with NEMA steel mill standards and should be used with a d-c motor of the voltage and horsepower rating stamped on the controller nameplate.

NEMA resistor classifications are listed in Table No. 1 below. The operating time of the starting resistors should not exceed the values given in this table for the Class of resistor as indicated on the resistor diagram.

Table No. 1 NEMA RESISTOR CLASSIFICATIONS

PERCENT FULL LOAD CURRENT ON FIRST POINT	* STARTING TORQUE% OF FULL LOAD			RESISTOR CLASS NUMBERS—DUTY CYCLE						
	Series Motors	Compound Motors	Shunt Motors	5 Sec. on Out of 80 Sec.	10 Sec. on Out of 80 Sec.	15 Sec. on Out of 90 Sec.	15 Sec. on Out of 60 Sec.	15 Sec. on Out of 45 Sec.	15 Sec. on Out of 30 Sec.	Continuous (Not Necessarily At Full Load)
25	8	12	25	111	131	141	151	161	171	91
50	30	40	50	112	132	142	152	162	172	92
70	50	60	70	113	133	143	153	163	173	93
100	100	100	100	114	134	144	154	164	174	94
150	170	160	150	115	135	145	155	165	175	95
200	250	230	200	116	136	146	156	166	176	96

* Based on Westinghouse motors.

DESCRIPTION OF CIRCUITS

CLASS 9505 NON-REVERSING CONTROLLER

A Class 9505 elementary diagram is shown in Fig. 2. If the master switch is in the "Off" or "Stop" position and the main and control knife switches are closed, relay MR will pick up. Relays 1TR and 2TR are also picked-up.

When the master switch is moved to any of the "Start" positions, the MR contact keeps the MR coil energized and provides a low-voltage protection circuit. If one of the overload relay contacts (or the contact of another protective device) in the MR coil circuit is open, MR will be de-energized and the controller will not operate until the abnormal condition is remedied, the open contact closed and the master switch is reset by being returned to the "Off" or "Stop" position.

With the master switch on point 1, contactors 1M and 2M pick-up and the armature and the starting resistors are connected in series across the line. The starting resistor limits the current through the armature and an interlock of 2M de-energizes acceleration relay 1TR.

If the master switch is moved to point 2, the first accelerating contactor 1A will also be energized after sufficient time has elapsed since 1TR was de-energized to allow this relay to drop out. The energizing of 1A also de-energizes 2TR. Contactor 1A shorts out a portion of the starting resistor.

If the master switch is moved to point 3, the second accelerating contactor 2A will also be energized after sufficient time has elapsed to allow 2TR to drop out. Contactor 2A shorts out the rest of the starting resistor and full voltage is applied to the armature.

Pushbuttons may be used instead of a master switch.

Fig. 3 shows the speed-torque characteristics of a compound wound motor with a Class 9505 controller. Portions of curves to the left of the speed axis indicates overhauling loads.

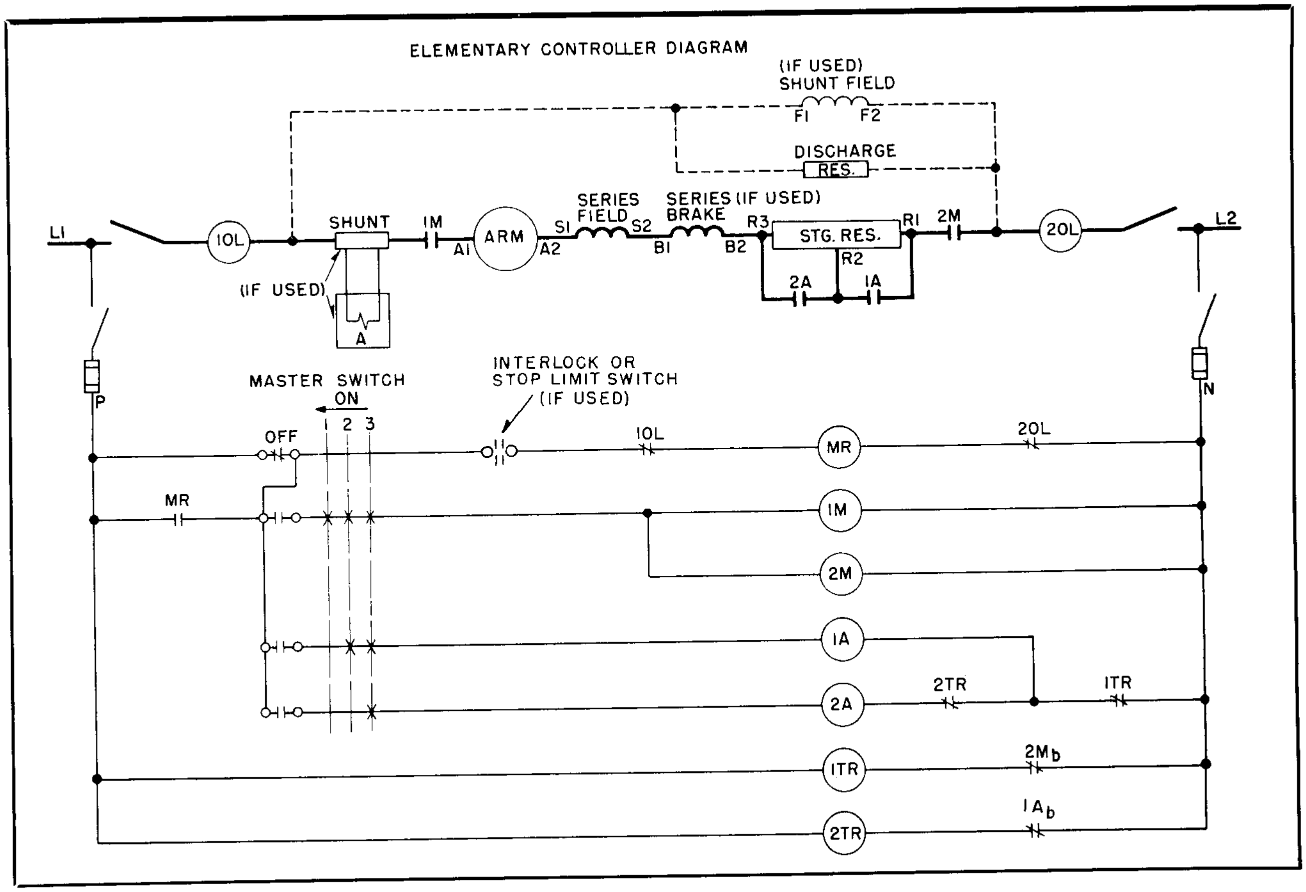
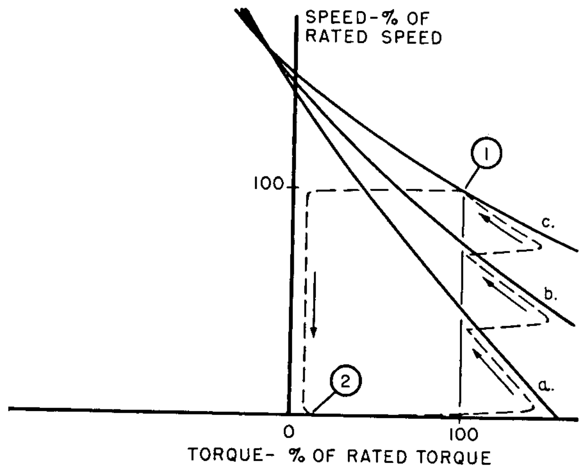


FIG. 2. Class 9505 Non-Reversing Controller



CURVE	CONTACTS x= CLOSED			
	1M	2M	1A	2A
a.	x	x		
b.	x	x	x	
c.	x	x	x	x

FIG. 3. Speed-Torque Characteristics of Compound Motor with Class 9505 Controller

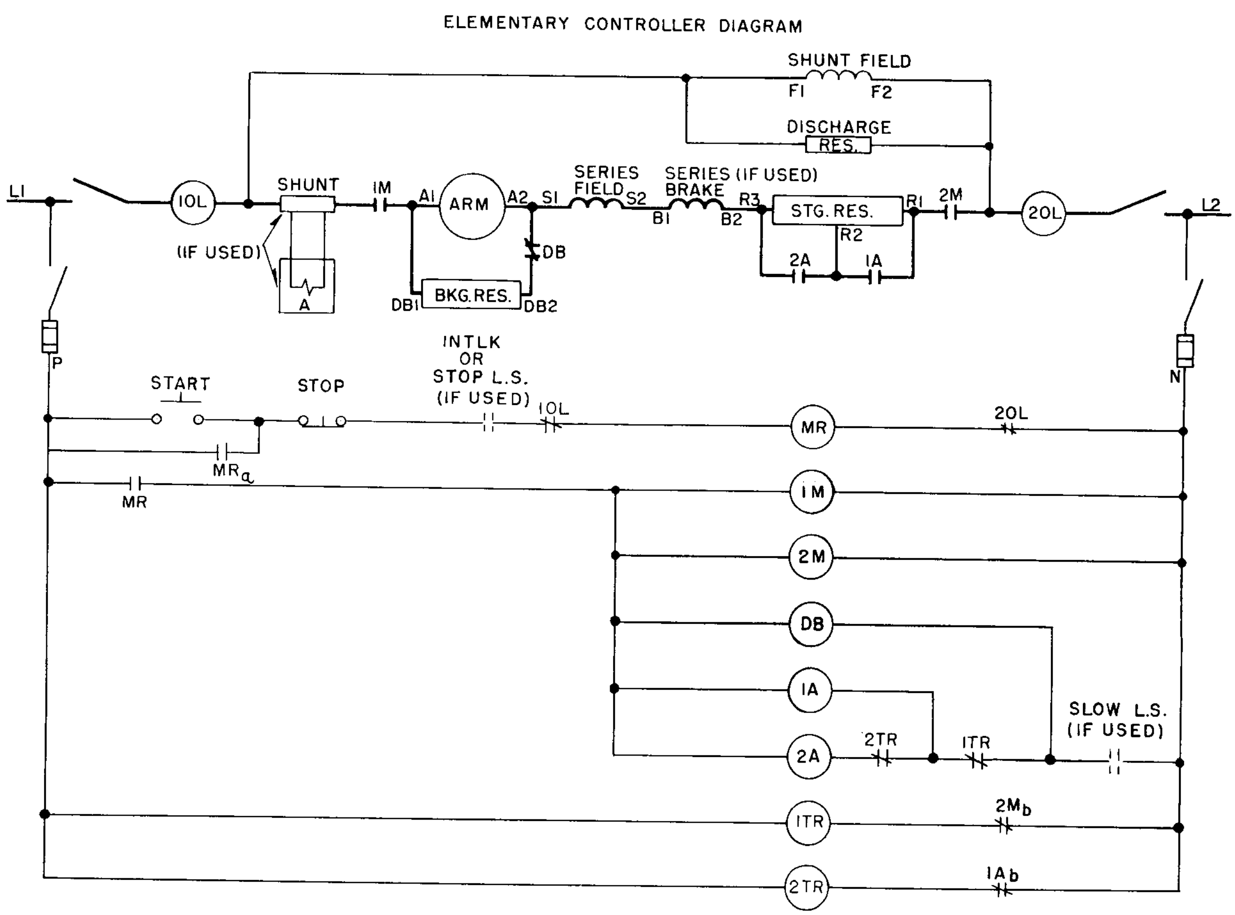
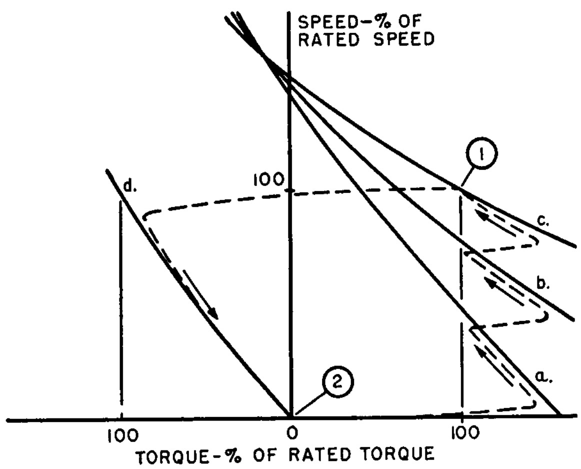


FIG. 4. Class 9510 Non-Reversing, Dynamic Braking Controller



TYPICAL TRANSIENT CHARACTERISTIC

ACCELERATE TO FULL SPEED (1)

DECELERATE TO STOP (2)

CURVE	CONTACTS x=CLOSED				
	1M	2M	1A	2A	DB
a.	x	x			
b.	x	x	x		
c.	x	x	x	x	
d.					x

FIG. 5. Speed-Torque Characteristics of Compound Motor with Class 9510 Controller

CLASS 9510 NON-REVERSING, DYNAMIC BRAKING CONTROLLER

A Class 9510 elementary diagram is shown in Fig. 4. With the main and control knife switches closed, the "Start" pushbutton is depressed to energize relay MR, which seals in around the pushbutton. A contact of MR picks up armature contactors 1M and 2M and dynamic braking contactor DB. The motor will now be started, with the full starting resistance in the circuit, and the dynamic braking resistor circuit open. Contact 2M in the 1TR relay circuit, will open, and 1TR will begin to time out. After a specified time (depending upon machine requirements), relay 1TR will open, and the first accelerating contactor 1A will pick up, and short out a portion of the starting resistance.

A contact of 1A will open in the circuit of relay 2TR, which will begin to time out. After a specified time (depending upon machine requirements), relay 2TR will open, and the second accelerating contactor 2A will pick up and short out the remaining starting resistance.

If one of the overload relay contacts (or the contact of another protective device) in the MR coil circuit should open, or the "Stop" pushbutton is depressed, relay MR will be de-energized. This causes the armature contactors 1M and 2M to open, disconnecting the motor from the line. The dynamic braking contactor DB will also de-energize, connecting the braking resistor across the motor armature. The motor will now act as a generator, with the braking resistor as its load, and will quickly come to a stop.

In order to restart the motor, the protective devices should be reset (if they have opened) and the "Start" pushbutton once again depressed.

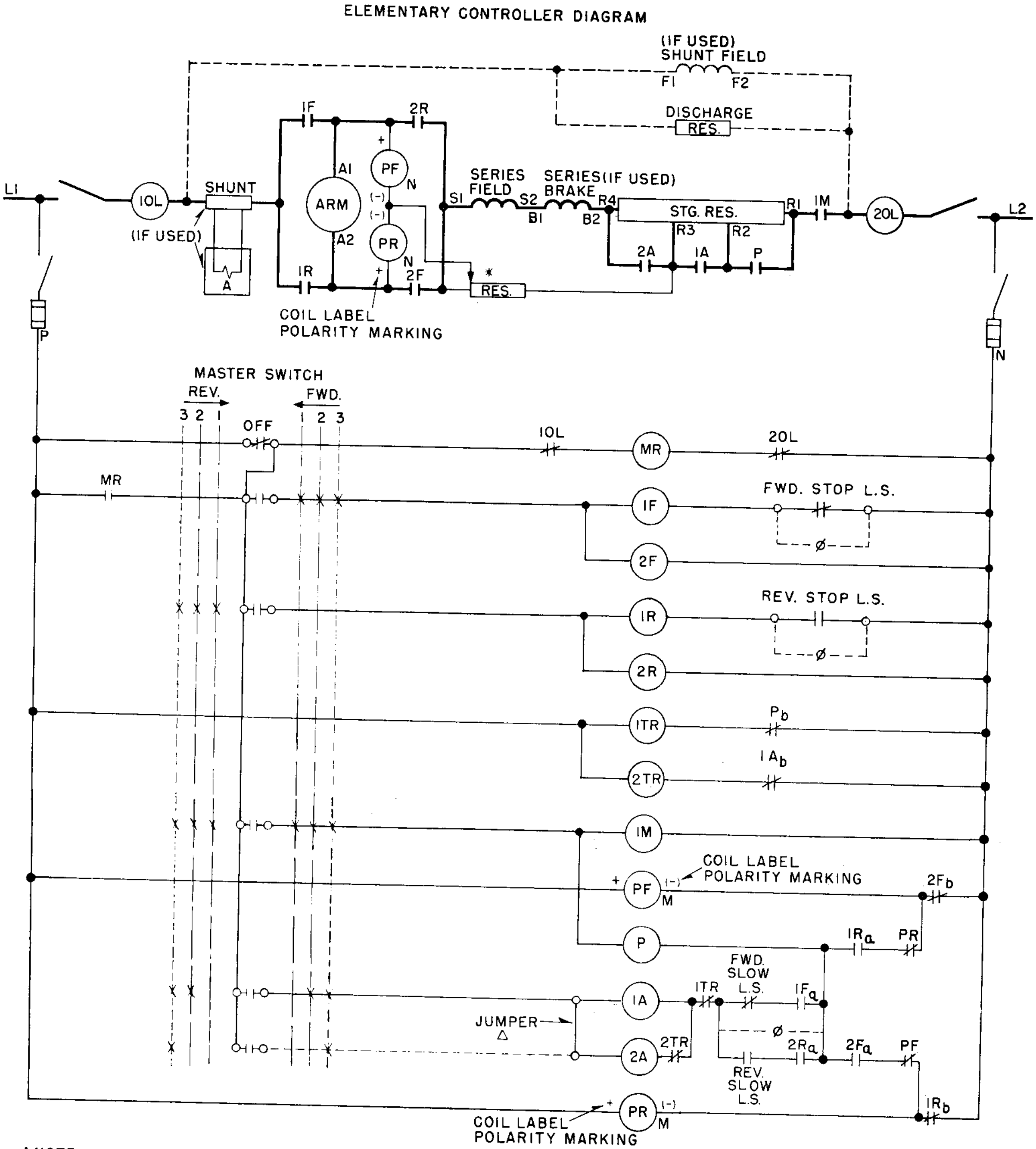
A master switch may be used instead of pushbuttons.

Fig. 5 shows the speed-torque characteristics of a compound wound motor with a Class 9510 controller. The braking characteristic to the left of the speed axis indicates that the direction of the torque is opposite the direction of rotation.

CLASS 9515 REVERSING, PLUGGING CONTROLLER

A Class 9515 circuit is shown in Fig. 6. When the master switch is moved to a "Forward" position, contactors 1M, 1F ,and 2F connect the armature to the power circuit. When the master switch is moved to a "Reverse" position, contactors 1M, 1R, and 2R connect the armature to the power circuit, the armature polarity is now reversed with respect to the polarities of the shunt field and series field; and the direction of rotation is reversed.

Contactor 1F and 2R are mechanically interlocked so that it is impossible to close both simultaneously. Likewise contactors 2F and 1R are mechanically interlocked.



ΔNOTE: WHEN A 3 POINT MASTER SWITCH IS USED, OMIT JUMPER AND ADD DOTTED CONNECTION.

*NOTE: IF IT IS DESIRED TO MAKE PLUGGING CONTACTOR CLOSE BEFORE MOTOR HAS COMPLETELY STOPPED, MOVE RESISTOR SLIDING CONTACT TOWARD R3.

ØNOTE: WHEN LIMIT SWITCH IS NOT USED, CONNECT DOTTED JUMPER AS SHOWN.

FIG. 6. Class 9515 Reversing, Plugging Controller

The functions of contactors 1M, 1A, 2A and relays 10L, 20L, MR, 1TR, 2TR are the same as their functions in the Class 9505 circuit.

The coil of relay 1TR is de-energized by the opening of contactor interlock P_b rather than by the opening of interlock 2Mb.

A d-c motor is plugged by reversing the polarity of the voltage applied to the armature of the motor while in motion. In this manner, power from the line can be utilized to decelerate and stop the motor. It will then accelerate in the reverse direction in the normal manner. This operation makes it possible to reverse the direction of rotation in a minimum of time. All steps of the starting resistor as well as an additional step known as the plugging resistor are inserted into the armature circuit to limit the armature current when the motor is plugged.

The plugging is controlled by two relays "Plug Forward" (PF) and "Plug Reverse" (PR). Each relay has a main coil to pick up the relay and a neutralizing coil. After the main coil is de-energized, residual magnetism is sufficient to prevent the relay armature from dropping out until the neutralizing coil is energized with the correct polarity to oppose the residual magnetism.

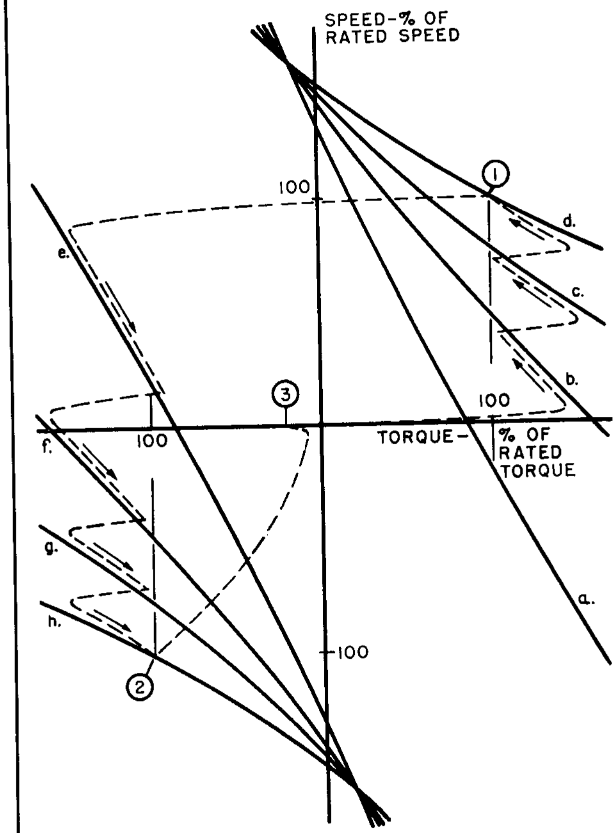
At standstill both relays are energized and if the master switch is operated to the "Forward" position, PF main coil will be de-energized and since its neutralizing coil is in parallel with the armature and the armature IR drop is of the correct polarity to neutralize the residual magnetism, PF will drop out which will allow the plugging contactor P to close and short out the plugging section of the starting resistor.

The controller then accelerates in the forward direction; the starting resistance being shunted out in steps as described previously for the Class 9505 controller.

If while operating in the forward direction, the master switch handle is moved to the "Reverse" position, the forward contactors 1F and 2F will open and the reverse contactors 1R and 2R will close. Relay PF main coil will be energized, *(which will drop out contactor P). Contactors 1A and 2A will also open. The combined starting and plugging resistance will limit the armature current to a safe value even though the motor counter emf and the line voltage are now in series.

The current through the neutralizing coil of PR is in such a direction to aid the residual magnetism until the armature speed is reduced almost to zero at which point the motor cemf is equal to the armature IR drop. Beyond that point the current through the neutralizing coil will reverse and oppose the residual magnetism. PR will drop out thus allowing P to reclose and short out the plugging section of the starting resistor again. The motor will then accelerate as before but in the reverse direction.

The potentiometer connected to the common point of the two neutralizing coils of PF and PR serves as a means of adjusting the motor speed at which the PF or PR relay will drop out. Moving the slider toward the starting resistor will in effect increase the armature IR drop and thus cause PF or PR to drop out before the motor reaches zero speed.



TYPICAL TRANSIENT CHARACTERISTIC

ACCELERATE TO FULL SPEED FORWARD (1)

DECELERATE AND ACCELERATE TO FULL SPEED REVERSE (2)

DECELERATE TO STOP (3)

CURVE	CONTACTS x = CLOSED							
	1M	1F	2F	1R	2R	P	1A	2A
a.	x	x	x					
b.	x	x	x			x		
c.	x	x	x			x	x	
d.	x	x	x			x	x	x
e.	x			x	x			
f.	x			x	x	x		
g.	x			x	x	x	x	
h.	x			x	x	x	x	x

FIG. 7. Speed-Torque Characteristics of Compound Motor with Class 9515 Controller

Fig. 7 shows the speed-torque characteristics of a compound motor with a Class 9515 controller. Curves below the torque axis are for reverse rotation.

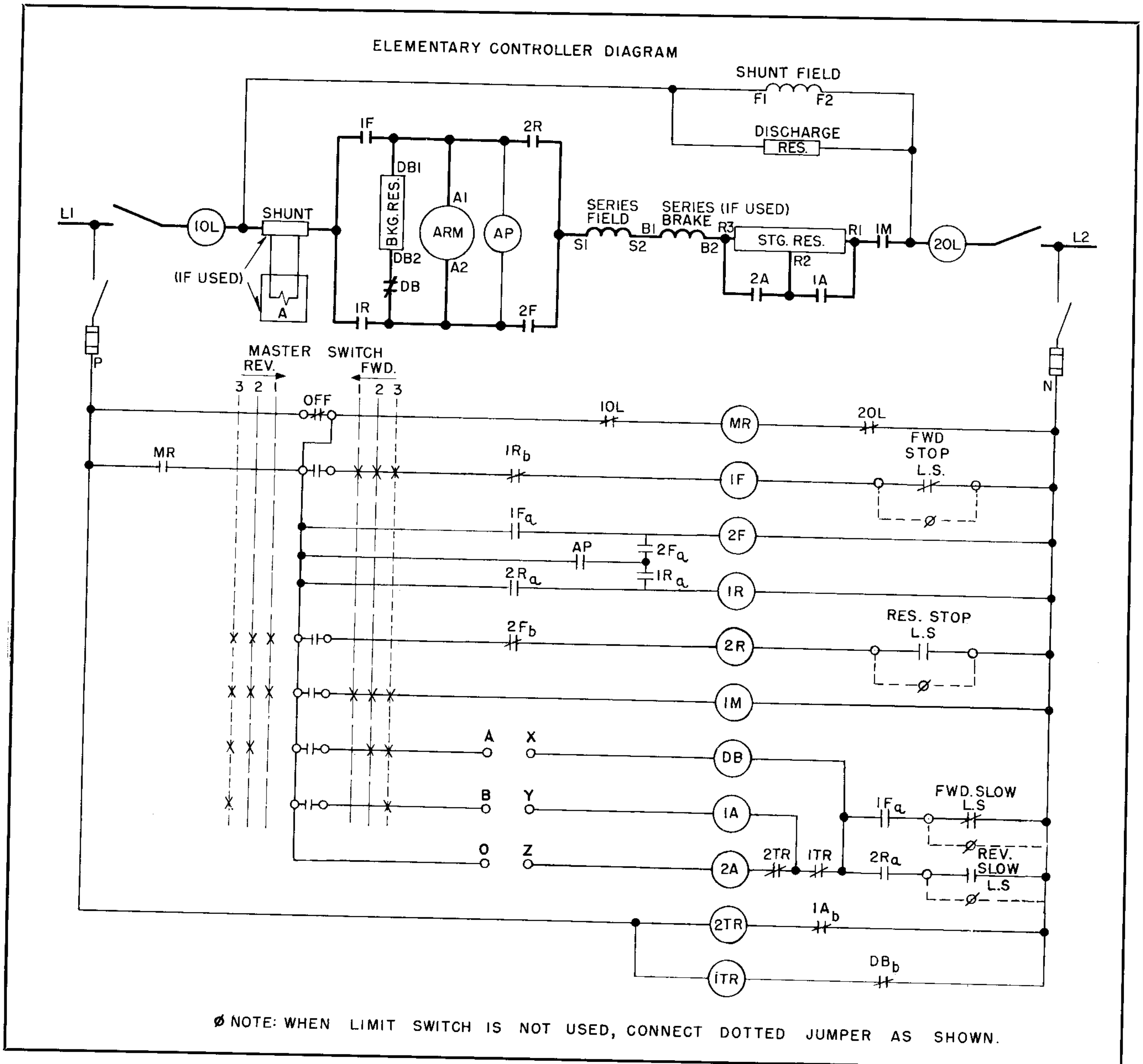


FIG. 8. Class 9530 Reversing, Dynamic Braking Controller

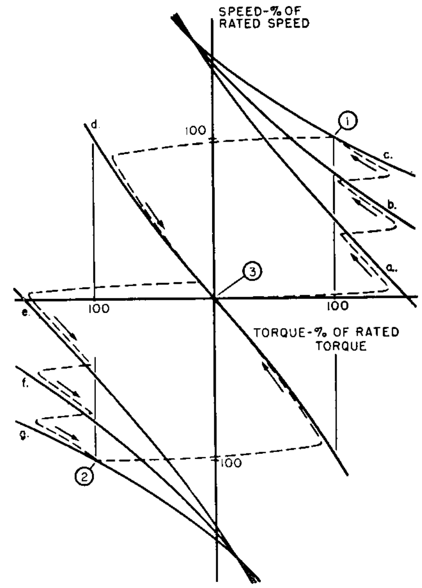
CLASS 9530 REVERSING, DYNAMIC BRAKING CONTROLLER

A Class 9530 elementary circuit diagram is shown in Fig. 8. The functions of all the devices are the same, as in the Class 9515 circuit with the exception of the dynamic braking contactor DB, and the anti-plugging relay AP.

When the armature is rotating at full speed in one direction, and the master switch is moved rapidly to the opposite position, relay AP insures that the armature will nearly stop, before the contactors close the armature circuit for the opposite direction of rotation. AP is a voltage sensitive relay, set to drop out at a low voltage.

Fig. 9 (a) shows the speed torque characteristic if the master switch is placed in the thrid point forward when the motor is at rest. Motor will accelerate to full speed forward. The master switch is then reversed and the motor dynamic brakes almost to zero, then plugs to zero and accelerates to full speed in reverse. The master switch is then centered and the motor dynamic brakes to rest.

Various speed torque characteristics are available with the controller in Fig. 8 by means of jumpering terminals A, B, O, X, Y & Z in various combinations as indicated in Fig. 9 (b). Note that curve (a) is for armature shunt using the dynamic braking contactor and resistor. Refer to the discussion on armature shunt on page 17.



—→ TYPICAL TRANSIENT CHARACTERISTIC

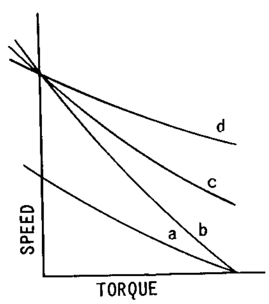
ACCELERATE TO FULL SPEED FORWARD (1)

DECELERATE AND ACCELERATE TO FULL SPEED REVERSE (2)

DECELERATE TO STOP (3)

CURVE	CONTACTS X = CLOSED							
	1M	1F	2F	1R	2R	1A	2A	DB
a.	X	X	X					
b.	X	X	X			X		
c.	X	X	X			X	X	
d.								X
e.	X			X	X			
f	X			X	X	X		
g.	X			X	X	X	X	

FIG. 9-a. Speed-Torque Characteristics of Compound Motor with Class 9530 Controller



MASTER SWITCH NO. OF POS.	MASTER SWITCH POS.	SPEED TORQUE CURVE	CONNECT JUMPERS
3	1	a	A-X, B-Y-Z
	2	b	
	3	d	
3	1	b	A-Y, B-Z, 0-X
	2	c	
	3	d	
2	1	a	A-X-Y-Z
	2	d	
2	1	b	A-Y-Z, 0-X
	2	d	
1	1	d	0-X-Y-Z

FIG. 9-b. Speed-Torque Characteristics of Compound Motor with Class 9530 Controller

Another feature of this circuit is that the anti-plugging relay AP only functions when the direction of rotation is reversed. The controller may be jogged repeatedly in the same direction without waiting for the motor to slow down.

CLASS 9535 REVERSING, DYNAMIC BRAKING, PLUGGING CONTROLLER

A Class 9535 circuit is shown in Fig. 10. This circuit is a combination of the Class 9515 circuit and the Class 9530 circuit with relay AP omitted. Relay 3TR, a time delay relay, keeps the dynamic braking circuit open when the master switch is moved rapidly through the "Off" position. If the master switch is moved to the stop position, DB will drop out and apply dynamic braking after 3TR drops out.

Fig. 11 shows the speed-torque characteristics of a compound wound motor with a Class 9535 controller.

CONTROLLERS FOR SERIES MOTORS

A Class 9505 or a Class 9515 controller may be used with a series wound motor. These circuits are the same as those of Figs. 2 and 6 respectively, except that the shunt fields and discharge resistors are omitted. The speed-torque characters are similar to those of Figs. 3 and 7 except that the slope of the curves is steeper. At no load, most series wound motors will exceed their maximum permissible speed.

CONTROLLERS FOR ADJUSTABLE SPEED SHUNT MOTORS

Class 9500 controllers are also built for use with adjustable speed, shunt wound motors. Fig. 12 shows a typical circuit for a Class 9505 controller for such a motor. This circuit is similar to the circuit of Fig. 2 with the addition of the shunt field rheostat, resistors, and relays FA, FD, FL and FP.

Field relays are usually relays having two operating coils and their pick-up and drop-out are adjustable over a wide range. Each coil may either be a strap wound coil capable of carrying the armature current of the motor or a wire coil suitable for the control voltage or the motor field current.

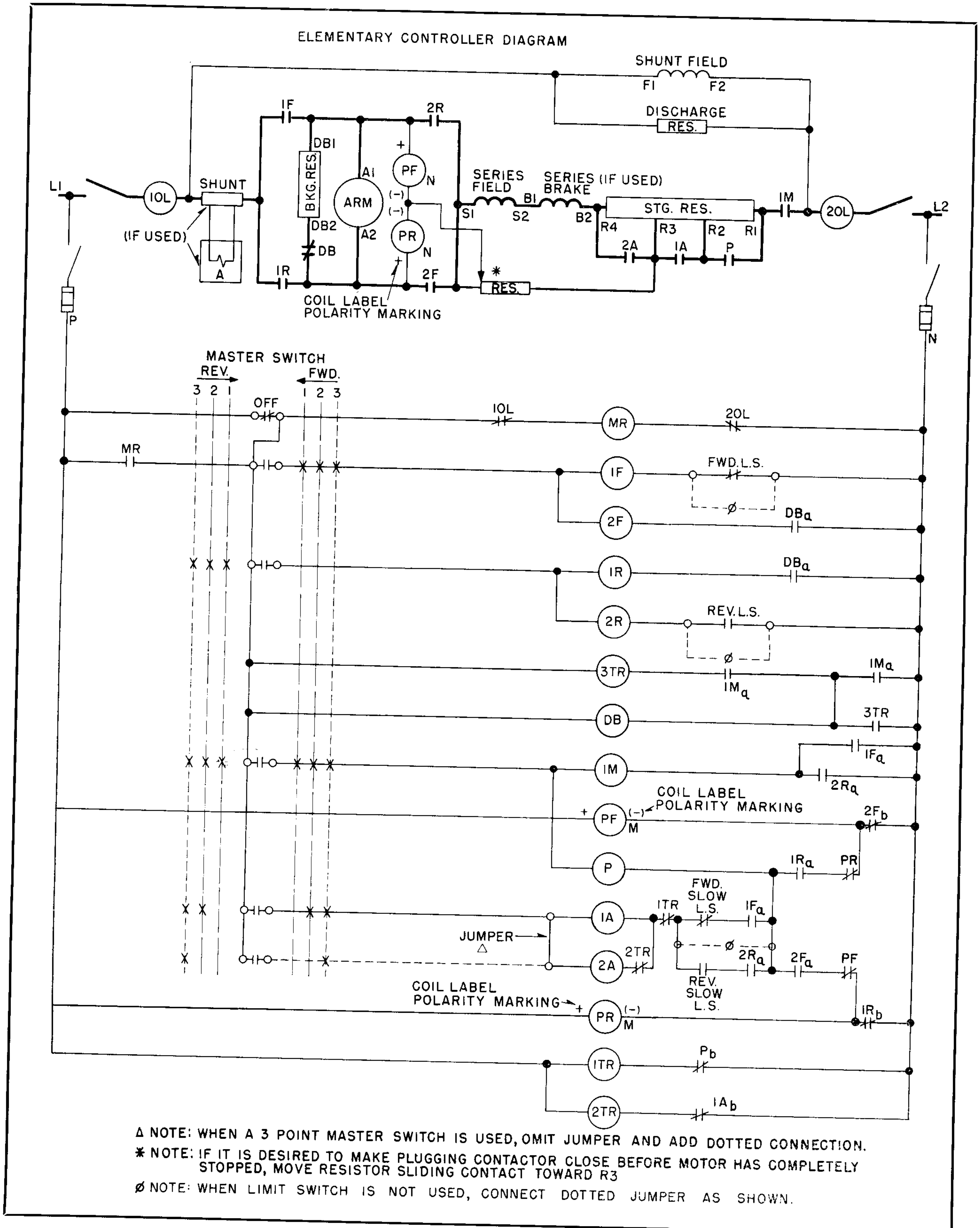
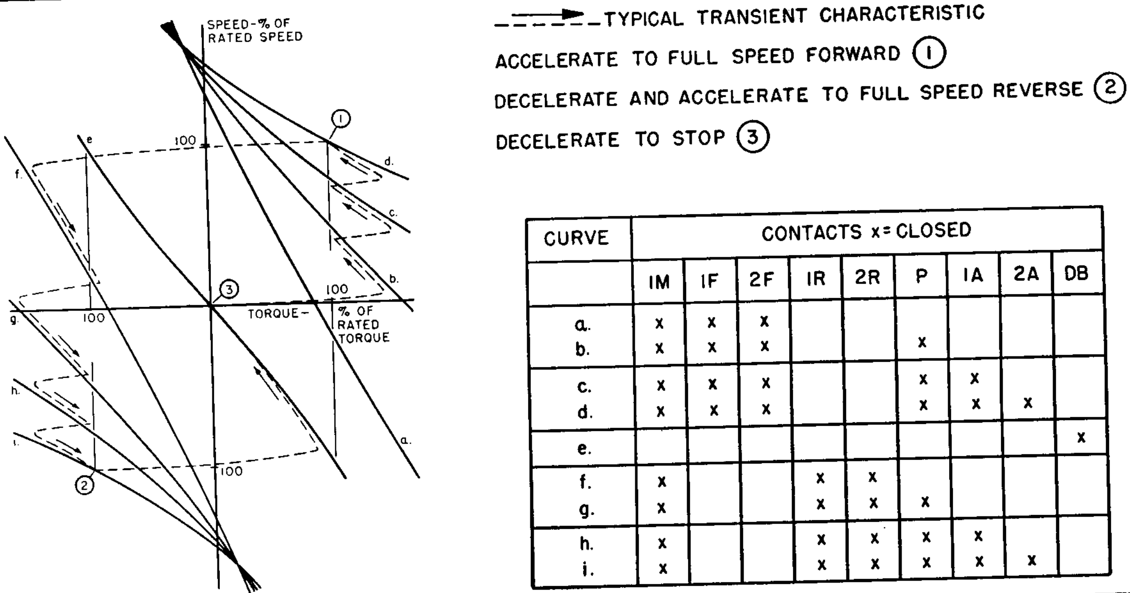


FIG. 10. Class 9535 Reversing, Dynamic Braking, Plugging Controller



CURVE	CONTACTS x = CLOSED								
	1M	1F	2F	1R	2R	P	1A	2A	DB
a.	x	x	x						
b.	x	x	x			x			
c.	x	x	x			x	x		
d.	x	x	x			x	x	x	
e.									x
f.	x			x	x				
g.	x			x	x	x			
h.	x			x	x	x	x		
i.	x			x	x	x	x	x	

FIG. 11. Speed-Torque Characteristics of Compound Motor with Class 9535 Controller

Field Protective Relay (FP), when required, inserts a resistance in series with the shunt field to reduce its heating when the motor is at standstill. This increased heating at standstill is due to the absence of ventilation from the internal fan on the motor armature.

Standard mill motors have fields which are continuously rated at standstill and therefore do not need FP Relay.

Field Loss Relay (FL) prevents operation of the controller, when the field current falls below a certain value, by opening the MR coil circuit, thus preventing dangerously high motor over speeds. NEMA standards require a field loss relay on all shunt and stablized shunt motors, and on mill type compound motors having 60% or more shunt field. Westinghouse mill compound motors have less than 60% shunt field (except in special cases), and therefore do not require field loss relays.

Field Accelerating and Full Field Relay (FA) is a field fluttering relay whose purpose is to keep the armature current from exceeding certain limits while the motor is accelerating above base speed due to field weakening. It accomplishes this by shorting out the field rheostat when the armature current gets too high, which strengthens the shunt field and limits the acceleration rate. The armature current starts to fall and FA contact opens which then weakens the field and the motor accelerates again. The cycle is repeated until the motor speed reaches the new rheostat setting. A second coil serves to pick up the relay below base speed and thus apply full field while accelerating.

Field Decelerating Relay (FD) is a field fluttering relay similar to FA except that it operates to limit armature current while the motor is decelerating due to increased field strength. This is accomplished by FD relay contact opening to insert resistance in the field circuit which weakens the field and limits the deceleration rate. The armature current starts to fall and FD contact recloses, which again strengthens the field and the motor again decelerates. The cycle is repeated until the motor speed reaches the new rheostat setting. A polarizing coil prevents FD from picking up on accelerating currents.

The circuit shown is a typical circuit, but there are many modifications and features which may be added to suit individual applications.

Fig. 13 shows the speed-torque characteristics of a variable speed shunt motor with a Class 9505 controller.

CONTROLLERS FOR CONSTANT SPEED SHUNT MOTORS

The circuit for a Class 9505 controller for a constant speed, shunt wound motor is similar to that of Fig. 12 except that relays FA, and FD are not required, nor are the field rheostat or the decelerating resistance.

ARMATURE SHUNT

Resistors in series with the armature reduce the motor speed in direct proportion to the voltage drop across the resistor. This drop is numerically equal to the product of the resistance and the armature current; therefore, on light loads (either

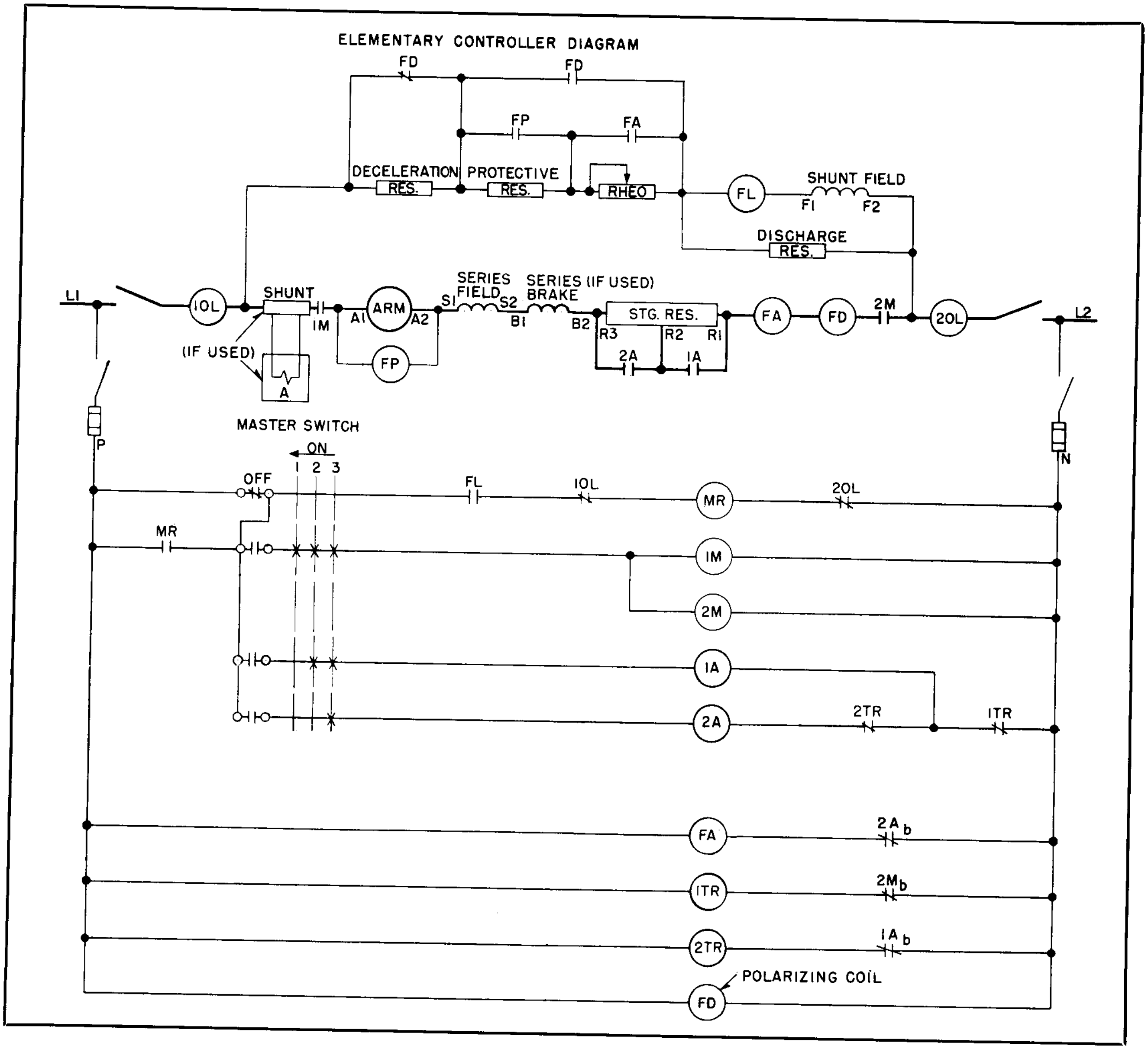


FIG. 12. Class 9505 Non-Reversing, Adjustable Speed Controller

motoring or overhauling), the resistance will have little or no effect on the speed.

However, if a second resistance is connected in shunt (or parallel) with the armature, sufficient current can be drawn by this "armature shunt" resistor to secure sufficient voltage drop in the series resistor to obtain the lower speed desired.

In practice, the series resistor is usually the starting resistor and the armature shunt resistor a part or all of the dynamic braking resistor.

Fig. 14 illustrates a Class 9510 Controller with a separate armature shunt contactor as contrasted to the circuit in Fig. 8 which is arranged so that the dynamic braking contactor is also the armature shunt contactor.

Where the separate contactor is used as in Fig. 14, the armature shunt and dynamic braking resistance can be adjusted independently (within limits).

In the other method the same resistor is used for both armature shunt and dynamic braking and any change in one will affect the other. In most cases a compromise value of resistance can be used which will be entirely satisfactory for both functions.

Class 9510, 9530 and 9535 controllers can use either method. Class 9505 and 9515 require a separate armature shunt contactor and resistor since they do not have dynamic braking.

Referring again to Fig. 14, the armature shunt contactor AS, which connects part of the dynamic braking resistor arcoss the motor armature, is picked up by the armature shunt relay ASR.

The armature shunt relay may be any type of auxiliary relay but the type usually employed has provision for two coils, either of which will pick-up the relay.

The armature shunt contactor pick-up may be initiated by the master switch or by limit switches or a combination of both.

The dual coil relay is used in conjunction with the forward and reverse slow-down limit switches on reversing controllers so as to pick-up the armature shunt contactor slightly in advance of the "Stop" position in either direction thus slowing down the drive so that a smooth, accurate and quick stop can be made when the "Stop" position is reached. The two coils permit arranging the forward and reverse slow-down circuits independently so that slow down is accomplished only when *approaching* the "Stop" position.

Fig. 15 shows the speed-torque characteristics of a compound wound motor controlled by a controller as shown in Fig. 14. Note that with the armature shunt connected, the armature speed is low even with an overhauling load.

SERIES BRAKE

Any Class 9500 controller may have a series brake connected in series with the motor series field provided the motor load is never less than 10 percent of full load. A series brake so used would set when the motor load dropped to less than ten percent, then release as the motor load picked up and motor speed dropped due to the setting of the brake. The brake would continue to set and release.

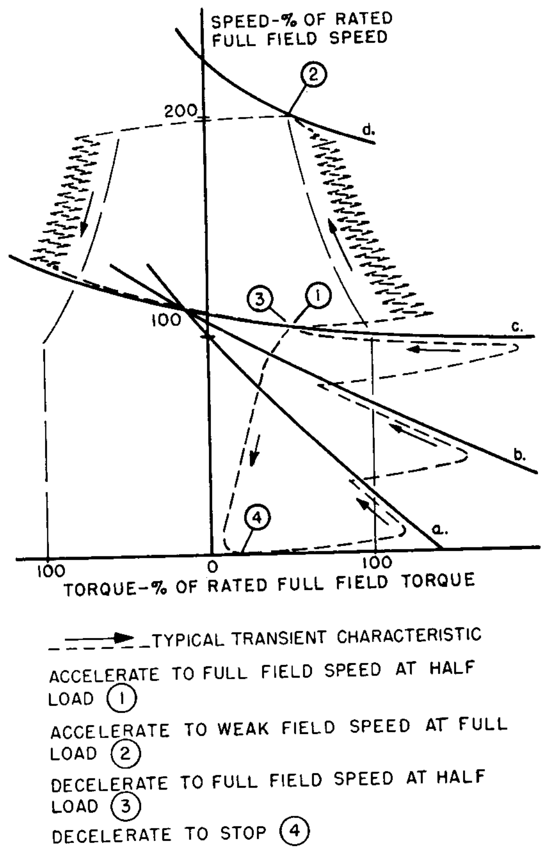
SHUNT BRAKE

Any Class 9500 controller may have a shunt brake. The coil of the shunt brake is energized from the control bus by the normally open contact of a brake relay (BR).

MASTER SWITCHES

A master switch is a manually-operated switch by which the operator causes the controller to start, stop, reverse or otherwise change the operation of the motor being controlled.

A master switch may be a Mill Type Master Switch such as shown in Fig. 16 or the Desk Master shown in Fig. 17 (pistol grip handles are also available for this switch)or it may be a control switch or pushbuttons mounted on a desk or operator's station. Pushbutton operation may require the use of control relays to secure the desired operation.



CURVE	CONTACTS x = CLOSED				
	FA	1M	2M	1A	2A
a	x	x	x		
b	x	x	x	x	
c	x	x	x	x	x
d		x	x	x	x

FIG. 13. Speed-Torque Characteristics of Adjustable Speed Shunt Motor with Class 9505 Controller

LIMIT SWITCHES

Limit switches are devices for electrically controlling or limiting the movement of mechanical apparatus. They may be used to limit the travel of a machine, to stop it at a given point; to provide slow-down ahead of the designated stopping point; to alter the motion of a machine during phases of its cycle or to provide interlocking between two or more drives to name some of the common uses.

The three common types of limit switches used with constant voltage controllers are the lever type, the rotating cam, and the traveling nut.

Lever Type Limit Switch. The lever type consists of a set of contacts operated by a lever. The limit switch is placed so that the mechanism to be controlled (or a projecting arm or shoe)will strike the lever when it reaches the desired position and

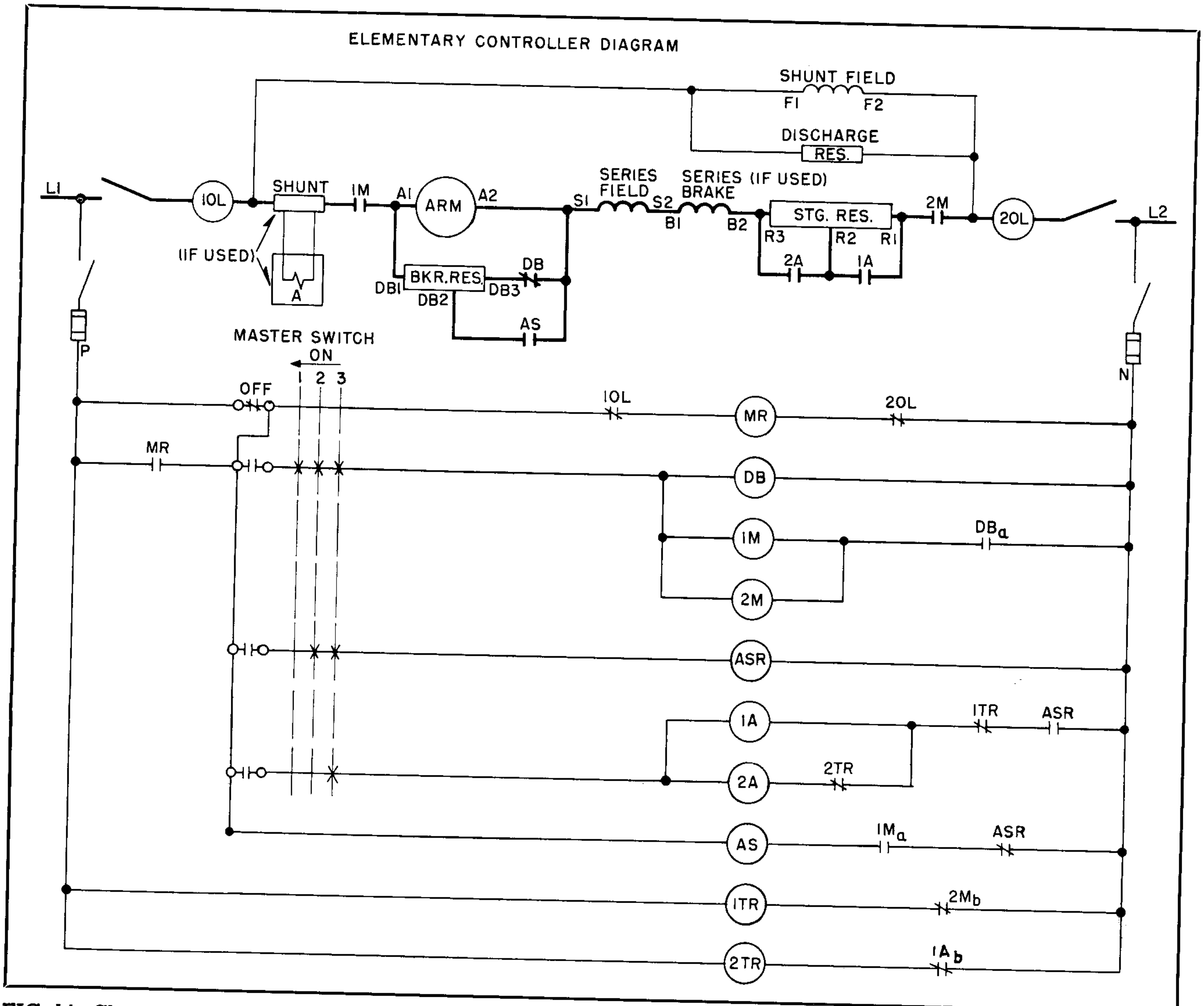
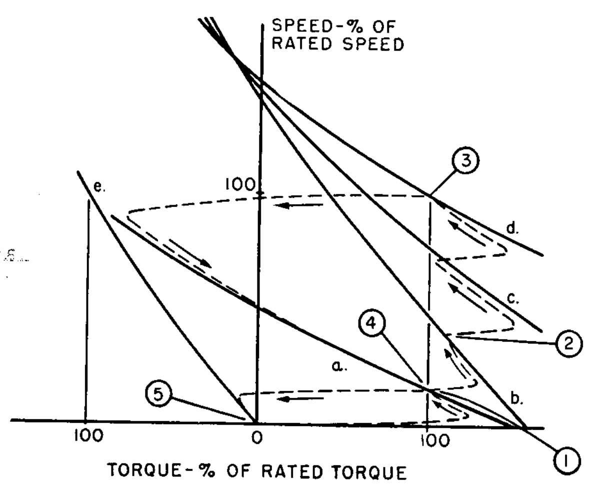


FIG. 14. Class 9510 Non-Reversing, Dynamic Braking Controller with Separate Armature Shunt Slow Down Contactor



TYPICAL TRANSIENT CHARACTERISTIC

ACCELERATE TO SLOW SPEED (1)

ACCELERATE TO INTERMEDIATE SPEED (2)

ACCELERATE TO FULL SPEED (3)

DECELERATE TO SLOW SPEED (4)

DECELERATE TO STOP (5)

CURVE	CONTACTS x = CLOSED					
	AS	1M	2M	1A	2A	DB
a.	x	x	x			
b.		x	x			
c.		x	x	x		
d.		x	x	x	x	
e.						x

FIG. 15. Speed-Torque Characteristics of Compound Motor with Controller as Shown in Fig. 14.

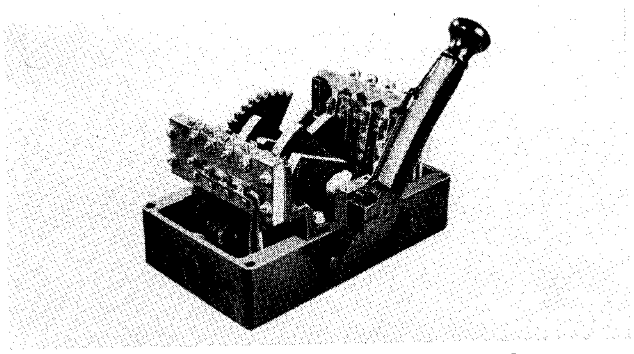


FIG. 16. Type SM Mill Master Switch

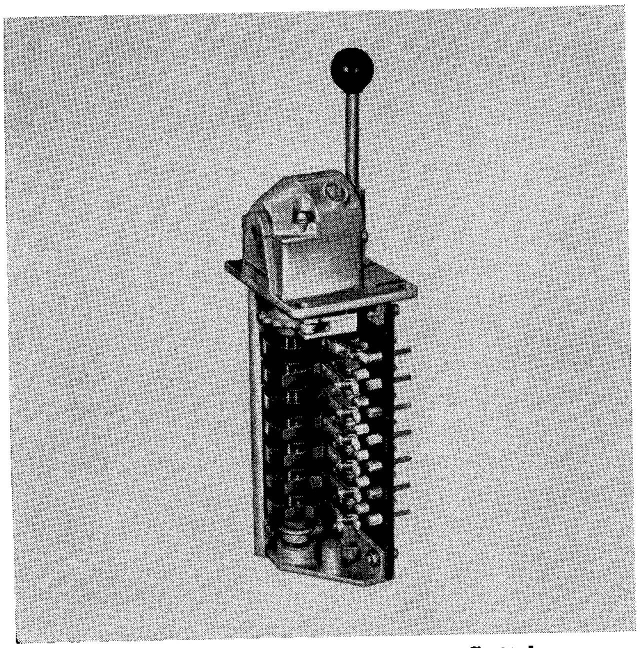


FIG. 17. Type DM Desk Master Switch

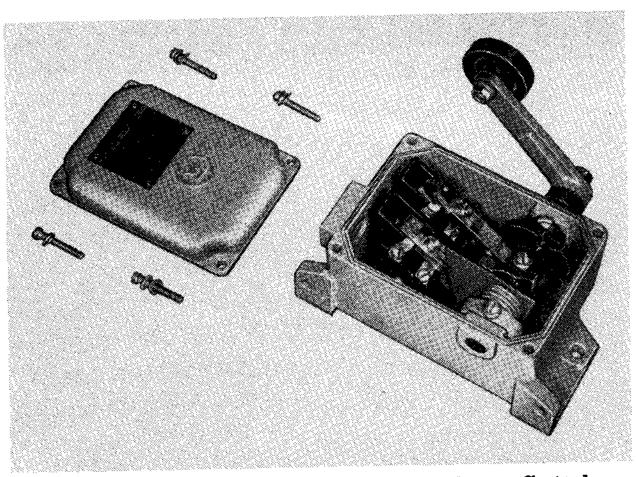


FIG. 18. Type HDH Hatchway Type Limit Switch

thus effect whatever change in the motion or interlocking is desired at that point. This type of limit switch is frequently used where the moving mechanism travels with linear motion such as a transfer car on a track.

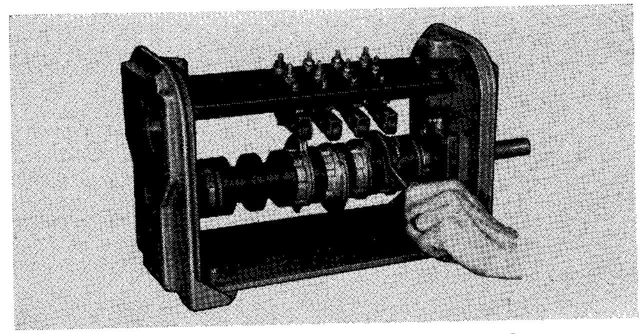


FIG. 19. Type A Cam Limit Switch

There are two types of lever limit switches. The hatchway type (see Fig. 18) has a spring return lever. The track type has a forked lever and has a stayput action which requires the mechanism to strike it on the return stroke to return the limit switch to its original state.

Care must be taken in selecting which type of lever limit switch is employed as well as the design of the arm or shoe which operates the limit switch. If, for example, the hatchway type is used for slowdown action; care must be taken that the limit switch lever is not released before the stop limit switch is reached or the motor will accelerate again.

Cam Type Limit Switch. The cam type limit switch (see Fig. 19) consists of a number of contacts each operated by separate independently adjustable cams mounted on a common shaft. The shaft is connected to the mechanism to be controlled either directly or through gears so that the complete travel of the mechanism is somewhat less than 360 degrees rotation of the limit switch shaft (usually around 300 degrees). There are also some applications such as a crank driven mechanism on which the limit switch shaft rotates 360 degrees for one operation.

Each cam has two adjustments. The cam length may be adjusted to provide any degree of contact operation within the limits of the particular cam as described below. The cam may also be rotated on the shaft so that the contact operation period occurs in the correct part of the cycle.

The cams consists of two identical halves each from 10 to 180 degrees in periphial length in standard sizes. The contacts are spring closed and either half of the cam will open the contact. Thus a 10-degree cam, for example, can be adjusted so that the contact will be open anywhere from 10 to 20 degrees depending upon the amount the cam halves overlap, if any.

Each individual cam half is split so that it may be removed from the rotor shaft and replaced without disassembling.

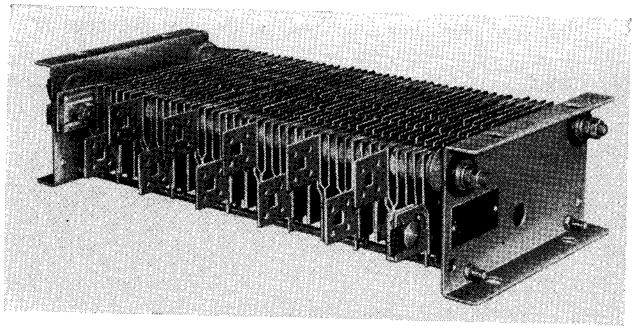


FIG. 20. Type LG Punched Steel Grid Unit Frame Resistor

Traveling Nut Limit Switch. The traveling nut limit switch consists of a threaded shaft, a nut in this shaft which is prevented from turning, and a number of switch units which are operated by the nut as it travels along the screw. The shaft is geared to the moving part, and after the proper set-up is made, the nut is the exact measure of the position of the moving part.

The position of the switch units along the threaded shaft may be adjusted so as to provide indication to the control that the mechanism is in the corresponding position.

Adjustment of Limit Switches in the Field. From the above description it will be obvious that the correct operation of a drive using limit switches depends upon the switch being mounted in the correct position and having the correct relationship with the mechanism.

Cam limit switches, for example, can be delivered from the factory with the correct cams in place but in almost every case the individual cams will have to be adjusted so that the contacts open and close exactly as required.

Refer to the instruction leaflet for instructions for each individual type of limit switch.

RESISTORS

Each controller requires a STARTING RESISTOR and where applicable a DYNAMIC BRAKING, ARMATURE SHUNT or PLUGGING RESISTOR in addition.

The type LG unit frame, punched stainless steel grid (see Fig. 20) is employed for all horsepower sizes except very small motors. The grids are unbreakable and are suitable for rugged duty even though they are light in weight and capable of dissipating large amounts of power.

A "unit frame" resistor is one in which all of the grids in a given frame are the same. A small number of different standard frames are available which are employed in combination if necessary to make a resistor for any application. This minimizes the number of spare resistors required.

PART THREE

INSTALLATION AND OPERATION

Location. The location of the controller should provide protection, accessibility, and ventilation. The controller should be located as near the controlled machine as possible and preferably in sight of the operator. The master switch should be in sight of the controlled machine.

Open control panels and panels with general purpose enclosures should be located in a clean dry atmosphere. Various kinds of atmospheric contamination are permissible for special enclosures as indicated by the NEMA names for these enclosures—dust-tight, dustproof, watertight, etc. Particular care should be taken during installation in a building still under construction to protect the controller against dust, dirt, and falling objects. The degree of protection provided against injurious elements, such as dust, water, oil, or acid, will to a large extent determine the life and dependability of the controller.

Accessibility requirements for connecting and servicing controllers vary for different designs. Check the outline drawing carefully to determine the minimum space requirements. Allow space for a service man to stand, to use tools, to remove arc boxes, and to open hinged cabinet doors.

Open control panels should have an ambient temperature of 40°C or less. Enclosed controllers should have an ambient temperature less than 30°C. Locate ventilated enclosures so that walls and other structures do not obstruct the ventilation openings. Provide a flow of air for controllers which dissipate a large amount of heat—such as resistance starters for motors which reverse frequently.

Foundation. Foundations for floor mounted controllers should be level. Supports for wall mounted controllers should be vertical. Foundations and supports should be free of excessive vibration.

The foundation should include conduits or other means for connecting the controller to the controlled machine, master switch, and other devices. Check the outline drawing to determine the location at which conduits may enter the controller. Check the external connection diagram to determine the number of conduits and their termini. Check the National Electric Code or other applicable code to determine the conduit size for the required number of conductors of the required size. Ground all conduits.

Mounting. Set the controller in place, level it, and secure it by means of imbedded bolts, through bolts, or other suitable hardware. If a floor mounted controller has a channel base, it should be grouted to the floor.

If desired, adjacent separate controllers or shipping sections may be bolted together through holes provided in the side of the panel and/or the frame. Controllers having factory assembled bus usually has bus extending the length of the shipping section and "splice" plates are provided to connect to the bus in the adjoining section. The "splice" plates are bolted to the frame for shipment and should be placed beneath the bus clamps on either side of the split and the clamps tightened. Bolts should also be installed in any holes provided.

It is recommended that the panel of each steel panel type controller be grounded.

Connection. Connect the apparatus according to the external connection diagram. If this diagram specifies a maximum allowable resistance for any particular set of connections, choose a wire size which will keep the resistance of these connections below the limit. For the connections between a d-c ammeter shunt and a remotely mounted ammeter, choose a wire size which will give the lead resistance specified on the dial of the ammeter. A remotely mounted ammeter may have a calibrating resistor to compensate for insufficient lead resistance. In this case choose an oversize wire and adjust the calibrating resistor to obtain the correct lead resistance. Choose all other wire sizes from the National Electric Code or other applicable code.

Wires can be pulled through conduits most successfully if all the wires in any one conduit are the same size. Therefore, armature circuit connections and shunt field circuit connections should usually be in separate conduits.

Place both wires of a single phase a-c circuit in a single conduit. Place all wires of a polyphase a-c circuit in a single conduit.

Preparation. Open the circuit to the power supply, Remove blocks and ties from all contactors, relays, instruments, and other devices. With a clean dry rag, clean thoroughly the contact surfaces and magnet gap surfaces of all contactors and relays. The gap surfaces of some a-c magnets are coated at the factory with a film of petrolatum to inhibit rusting in storage. Remove this film to prevent the magnet from collecting dust. Tighten any hardware which may have worked loose during shipment.

Check the controller nameplate to be sure the controller rating agrees with the motor rating and the power supply.

Operate all contactors and relays manually to be sure that they are free of friction, that the contact surfaces seat properly, and that the various springs work properly. Check mechanical interlocks to be sure they prevent the contacts of one contactor from touching when the other contactor is closed. Release the brake manually and rotate the motor manually to be sure that they are free of friction and free of foreign matter.

Tests Preliminary. Open the circuit from the controller to the controlled machine. Close the circuit from the power supply to the controller. Operate the master switch and other pilot devices. Check the sequence of relay and contactor operation. This sequence has been checked at the factory. An additional check will call attention to any faulty external connections or to any damage that may have been done during shipment. Open the circuit to the power supply, and reclose the circuit to the controlled machine.

Close the circuit to the power supply. If a motor controller has separate switches for the power circuit and for the control circuit, always close the power circuit switch first and the control circuit switch last; this sequence will prevent picking up the contactors and then line-starting the motor with the power switch.

Tests-Operational. Before the motor is started, provision should be made to insure that the motor will operate at slow speeds for the initial operations until the controller and limit switch adjustments can be made and to be sure that the electrical and mechanical portions of the drive are in correct operating condition. This will avoid hazard to equipment or personnel.

Field rheostats or resistors should be set at minimum resistance and any field weakening or full field relays blocked temporarily to apply only full field to the motor. Since the first operation of the motor should be with the entire starting resistance in series with the motor armature, 1A and 2A should be prevented from picking up by blocking 1TR and 2TR open if this can not be accomplished by the master switch.

The operator should also be prepared to stop the motor quickly if the direction is incorrect, the armature current is excessive, the speed is too high or there is any other indication of electrical or mechanical trouble.

If the limit switch is required to stop the drive at a critical position, make the following tests away from the critical position if possible. If not, set the limit switches as described later before proceeding.

Check the polarities of the shunt and series fields by first jogging the motor with and without the shunt field connected and observing the direction of rotation in each case. If the direction is the same, the relative polarities are correct. Mill type compound motors having approximately 50 percent series and 50 percent shunt field should have the series field temporarily shorted when the shunt field is connected in order to check the polarities.

Also observe the relationship between the drive movement and the master switch. If this is incorrect, reverse the motor armature connections A1 and A2 (do not change internal connections of the motor).

Remove the blocking on relays 1TR and 2TR (if it was used) to permit 1A and 2A to pick-up. Observe the current peaks during acceleration from rest to base speed. Usually the starting resistor is designed to limit the current on starting to 150 percent of full load (NEMA resistor classes 153P, 155, 163P & 165). If the starting resistance is correct, the first peak should not exceed 150 percent.

On a controller with two accelerating contactors, the three peaks corresponding to the three steps (1A and 2A both open, 1A closed and 2A open & 1A and 2A both closed) should be approximately equal with full load on the motor. This indicates that the motor speed is correct when 1A and 2A close so that the Back E.M.F. is high enough to limit the current. If the second peak is higher than the first, it indicates that the motor needs more time to accelerate on the first step and that 1TR should be set for a longer time. Conversely if the second peak is lower, the time on 1TR should be decreased. The third peak should be compared with the second and relay 2TR adjusted in a similar manner.

If the controller has relays FA and FD, check the coil polarities as follows: Remove the blocking on full field or field weakening relays and set the field rheostat or resistor for the motor top speed. Accelerate and decelerate the motor from base speed to weak field speed. Check to see that FD does not pick up during acceleration and that it flutters during deceleration. Check FA to see that it flutters during acceleration. This test should be made in several steps from base speed to the highest speed. Relays FA and FD are set in the factory to pick up at 150 percent and drop out at 120 percent of full load (approximately).

Lever, cam or travelling nut limit switches should be adjusted to provide slow down and stop and any other function required. Try the limit switches by hand (lever type) and at slow speeds (all switches) to make sure the correct contacts are used and the switches are wired correctly. Make sure the mechanical equipment (such as gearing on the cam limit switches and the arm or shoe which operates the lever switches) will operate the limit switch correctly. If hatchway type lever limit switches are used for slowdown, make sure that the switch is not released by the mechanism before the stop is reached or the motor will speed up again. Also check to make sure the slowdown is initiated sufficiently ahead of the stop point to allow time for the drive to slow down before the stop is initiated even with the heaviest load at top speed. Make sure that armature shunt slowdown is used if the load can be light or is overhauling.

Check the blowouts on all type AV relays used in the field circuit to make sure the arc is blown upward. If not, reverse the blow out magnets.

PART FOUR

MAINTENANCE

Equipment well cared for will provide satisfactory and dependable operation with a minimum of trouble. It cannot, therefore, be too strongly emphasized that good maintenance will prove to be a profitable and highly important factor in satisfactory controller operation.

All possible safety precautions should be taken before working on electrical apparatus, and only skilled personnel should service the electrical equipment.

Minimum controller maintenance will be required if the equipment is located in the most favorable of all possible locations as outlined in the installation and erection instructions, Part Three of this book. A plan should also be worked out and put into practice whereby the controller equipment is provided with a periodic and systematic inspection. This type of preventative maintenance will often avoid expensive replacement of complete apparatus under breakdown conditions.

Suggestions for the maintenance of each type of relay contactor, and switch are given in the corresponding instruction leaflets.

Preventative maintenance by means of periodic inspection and servicing should include the items covered in the following paragraphs.

CLEANING

Thoroughly clean all dust from the apparatus, preferably by blowing it out with compressed air. In the absence of an air supply, clean the equipment by brush or by any other acceptable method. It should be noted that oily rags or waste should not be used as they will leave an oil film on the equipment which will collect dust particles.

LUBRICATION

Except for special equipment, controllers require no lubrication. This is especially true of contactors and relays. In the few cases where lubrication is desirable such as on built-in rotating machines, bearings for large master switches, etc., it should be used sparingly and great care should be used in applying it. The use of oil on contactors and relays will cause dirt to collect in the bearings and moving parts, and may cause operating difficulties because of increased friction. A-C magnet faces may have a thin film of light oil to prevent rusting.

MECHANICAL INSPECTION

Moving parts should be checked and operated where possible in an effort to locate loose pins, bolts, and weak springs; and to locate parts which are developing excessive friction and are becoming hard to operate. Parts subjected to the greatest wear should receive special attention, and should be replaced when the wear has become excessive.

CONTACTS

Current-carrying contacts should be inspected for wear and for signs of excessive heating. Deeply pitted and burned contacts, as well as those worn thin, should be replaced with new ones. When making replacements, it is desirable to replace contacts in pairs rather than to install a new contact to operate with one that is partly worn. In general, the condition of a contact should be judged from its shape and the condition of its contact-making surface, bearing in mind that contact surfaces need not be entirely smooth. A slightly roughed surface, if clean, is entirely satisfactory. Contact color is not necessarily an indication of condition as the color is often due to oxidation of the contact material. A dark copper contact may have an undesirable high contact resistance due to the formation of copper oxide and it would be wise to clean it, whereas, a dark silver contact still has low contact resistance and need not be cleaned.

When replacements are made, surfaces for seating the new contacts should be clean. Contacts which are burned, but not badly, may be cleaned with a fine file. Do not use emery cloth or sandpaper as abrasive granules may become imbedded in the contact surface. The use of a file should be avoided where possible, and when it is used, care should be taken to maintain the shape of the contact. Replacements must be tightly secured, as a loose contact will soon overheat.

Arc shields, when removed for the inspection or replacement of contacts, must be fixed firmly in their proper position after the replacement or inspection is completed. Otherwise, they will not function as effectively in interrupting currents flowing through the contactor.

SPRINGS

In connection with maintenance, springs (and especially contact springs) are often overlooked. Weak springs may cause bouncing contacts and in many cases is the chief cause of frozen or welded contacts; and they are also a contributing cause of overheating resulting from low contact pressure. It is important, therefore, that springs be systematically checked for signs of deterioration. There are two methods which may be used; one is by comparison with new springs of the same design; and the second is by measuring contact pressures for comparison with the recommended values of the manufacturer.

By comparison with a new spring as to size, shape and tension, it is readily possible to determine when a spring has been so overstressed or overheated as to have lost its efficiency. This comparison cannot be expected to indicate minor deficiencies or small reductions in tension.

Where there is any doubt concerning the condition of the spring, or where there is evidence of overheating, the contact pressure should be measured as noted in the following paragraph.

To measure the contact pressure, a spring scale should be attached to the moving contact at, or near, the point where it touches the stationary contact. A thin piece of paper is then placed between the contacts and the contactor is mechanically closed. A pull is then exerted on the moving contact through the scales in a direction vertical to the contact surface, so that the line of pull projects through the center of this surface. The contact pressure is then the measure in pounds required to separate the contacts sufficiently to permit the paper to be removed from between them.

When a spring is proven inefficient, it should be immediately replaced, and spring washers should be added or taken out as required to provide the recommended contact pressure. For recommended contact pressures, refer to the instruction leaflets included for the various contactors used.

LOOSE CONNECTIONS

As loose connections are an evasive and annoying source of trouble, they should be checked—especially on those applications subject to changing temperatures and vibration. As many connections as possible should be checked, and it is especially important that connections to external leads be tightly made.

REPLACING PARTS

The replacement of defective coils requires that coil leads be disconnected. In instances of this kind, and especially where multiple coils are used, it is important that the connections to the replacement coil be the same as to the original coil. Otherwise, relative polarities may be changed and the device may become inoperative. Similarly, other replacements involving connections should be made to provide the same circuits as on the original equipment.

It should be kept constantly in mind that any change or replacement should improve the operation of the control and associated motor-driven equipment. Replacements, if carelessly made, may result in less dependable operation than existed before they were made.

DASHPOTS

When dashpots are used, they should be kept free from dirt, friction or anything that will cause sluggish action.

The proper oil level should be maintained at all times.

The oil for dashpots is a special grade that changes very little in viscosity with wide temperature changes. Only the special oil should be used. If substitute oils are used, the calibration of the relay will be changed and the relay may not operate properly.

SHUNTS

Flexible shunts of fine stranded copper must be tightly connected and must not have broken strands. Broken strands increase the current on the remaining strands and cause overheating.

MAINTENANCE CHECKS

Preventative maintenance will prove well worth while, yet there will still be occasions when contactors or relays fail to function properly. When this occurs, a check should be made for the following causes which are among the more common reasons for such failures:

A. Failure to close may be caused by:
   1. Disconnected power supply or voltage too low.
   2. Loose or broken connection to the operating coil.
   3. The operating coil may be open or short circuited.
   4. There may be mechanical friction or interference between parts which may prevent it from closing.

B. Failure to open may be caused by:
   1. Mechanical interference between parts.
   2. Contact tips may have welded together due to overheating.
   3. Residual magnetism may be holding magnet because of low kickout spring pressure.

Table No. 2. DEVICE TYPE AND SUPPLEMENTARY PUBLICATIONS

DEVICE AND TYPE	PUBLICATION	APPLICATION*
Contactor		
M-310, M-410, M-510, M-610, M-710	I.L. 15-800-2	Line, Accelerating, Reversing, Plugging and Armature Shunting Contactors.
M-810, M-910	I.L. 15-800-3	
M-301, M-401, M-501, M-601, M-701	I.L. 15-800-1	Dynamic Braking Contactor.
Contactor or Relay (M contactor 50 ampere frame)		
M-010, M-110, M-210	I.L. 15-800-M010/110/210-1	Master Relay (MR) and Control Relays, Field Relays (High Current Fields), Shunt Brake and Clutch Relays, Solenoid Control
M-011, M-111, M-211	I.L. 15-800-M011/111/211-1	
M-020, M-120, M-220	I.L. 15-800-M020/120/220-1	
M-021, M-121, M-221	I.L. 15-800-M021/121/221-1	
M-022, M-122, M-222	I.L. 15-800-M022/122/222-1	
M-001, M-101, M-201	I.L. 15-800-M001/101/201-1	
Electrical Interlock		
L-46	I.L. 15-829-L46-1	Int. for 50 Amp. M. Contactor
L-61	I.L. 15-829-1	Int. for M-310, etc. and M-301, etc.
Relays		
AP	I.L. 15-827-1-AP	Plugging Relay (PF and PR)
AV	I.L. 15-827-11	Dual Coil Field and Adjustable Voltage and/or Current Relay (FA, FD, FL, ASR, etc.)
AYC	I.L. 15-827-4-AYC	Control Relay (CR, 1CR, etc.)
AYJ	I.L. 15-827-5-AYJ	Jamming Relay
AYK	I.L. 15-827-8	Multi-Contact Control Relay (CR, 1CR, etc.)
AYV	I.L. 15-827-6-AYV	Anti-Plugging Relay (AP)
AZ	I.L. 15-827-7-AZ	Timing Relay (1TR, 2TR, etc.)
TI-2	I.L. 3487	Overload Relay (1OL, 2OL)
Master Switches		
SM-Master Switch	I.L. 2672	
W-Control Switch	R.P.D. 37-150-CS	
W-Instrument Switch	R.P.D. 37-150-IS	
DM-Master Switch	R.P.D. 15-110	
Pushbuttons		
F	P.L. 15-025	
HD	D.B. 15-010	
OT	D.B. 15-022	
Limit Switch		
A	I.L. 3253	Rotating Cam Limit Switch
TN	I.L. 1651	Traveling Nut Limit Switch
HDH	I.L. 15-075-4	Lever Type Limit Switches
438	I.L. 2621	
Field Rheostat		
LR & LK	I.L. 14-515-1	Manual
RK	I.L. 14-516-2	Motor Driven Operating Mechanism
RKM	I.L. 15-516-3	
SO	▲	Motor Operated
SM	▲	
Ammeter Shunt		
G	I.L. 43-850-A	50 Millivolt
Brakes		
SA	I.L. 15-331-1	Shunt or Series
Resistors		
Unit Frame	Application Data 14-990	
LG (Steel Grid)	I.L. 16-600-1	

* Refer to "General Description", Part One of this book.

▲ Not available at Present.