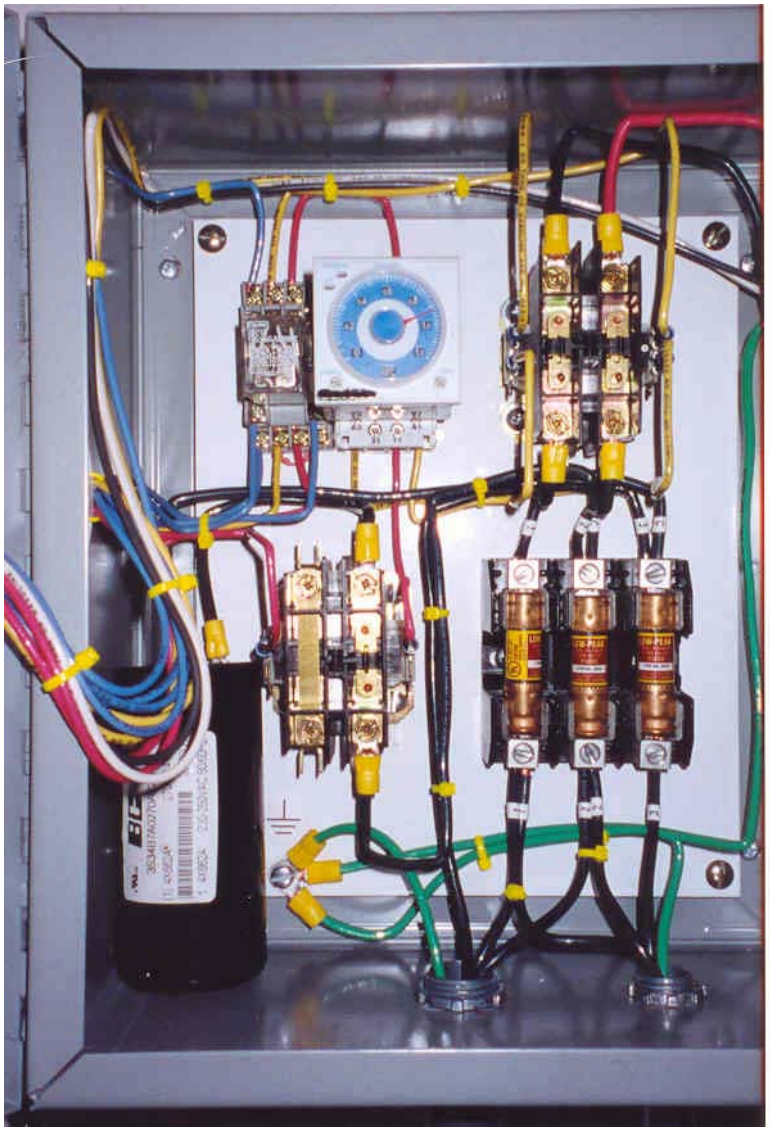
Building an Auto-Start Rotary Three Phase Converter

by: Matt Isserstedt



Disclaimer: Electrical wiring is inherently dangerous. No warranties are issued or implied about the safety or success of this system.

What I built is an automated-start version of a standard rotary phase converter with 3hp capacity. While the auto-start feature is not required and thus adds a little complexity, the general construction rules of a rotary phase converter still apply. One major benefit of the auto-start feature appears when it comes to expansion; I can start the converter from anywhere I can install another start/stop button.

General Rotary Converter Principles

Sizing

The general rule of thumb is that you can start and run a motor equal to the hp of your idler. My largest machine tool motor is 3hp and thus I bought a spare 3hp, three-phase motor to be my idler. The frame spec and shaft condition of the idler is not important so a surplus motor can be used.

Static Conversion

To get to rotary conversion we must first understand static conversion. The idler motor in the rotary converter starts and runs in a static mode.

In a typical household, 220 VAC exists on double-pole breakers. We say this has "2 legs".

A three-phase motor will RUN on only two of its three legs. Otherwise said, with single-phase power we can run a three-phase motor. The issue then becomes how to start said motor, because a three-phase motor will NOT START on single phase by itself.

Motor Starting

There are two ways to start a motor that is going to be run with static phase conversion. Most basically, we can start the three-phase motor mechanically by spinning its shaft with an outside source of power. This is typically a belt-drive arrangement from a smaller single-phase "pony" motor, and requires lots of design and safety considerations. The second, and simpler method is to start the motor electrically with a capacitor.

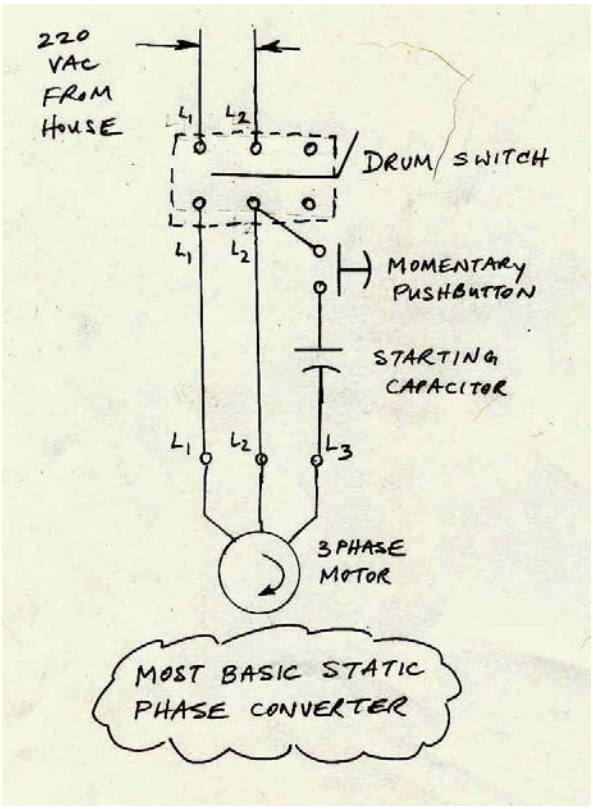
Power Control Issues – Starting and Running

There are only two basic functions in starting and running a three-phase motor in static mode.

1.) Switch single-phase power to two legs of the three-phase motor.

2.) Connect the starting capacitor to the 3rd leg of the idler motor long enough for it to start, then remove it from the circuit.

A momentary pushbutton, hand-operated by the user, can connect the capacitor just long enough to start the idler motor. In my case I automated this process using a timed relay to connect the starting capacitor to the circuit, then drop it out.



Rotary Conversion

Rotary conversion begins once a three-phase motor has been started and is running on single phase in static mode. Once running, if we measured all three voltages (L1-L2, L2-L3, and L1-L3) in the above diagram, after the motor is running, we'd find approx 230VAC for each measurement.

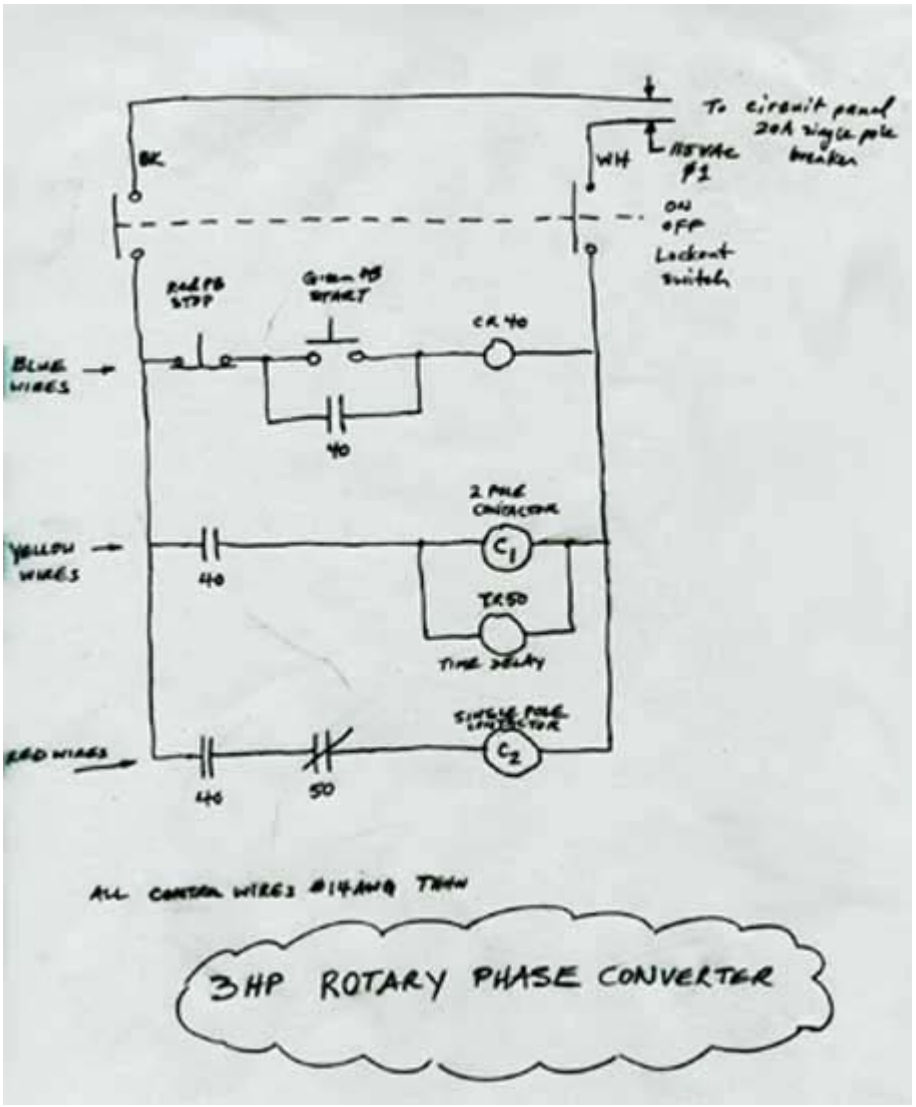
The points where we are measuring the three voltages is where three-phase power is now available! This is where to tie in the other machinery motors we want to run.

Automated Starting

In my converter, I elected to automate the drum switch and the manual pushbutton for the starting capacitor. Instead of the drum switch I used a two-pole 30amp contactor, and instead of the manual pushbutton I used a timed relay to drop out the starting capacitor (thru a single-pole contactor).

Below is the relay logic diagram for the controls, all of which are 120VAC. If you're new to "ladder" logic, consider that a "rung" (horizontal line) has continuity when the circuit is completed.

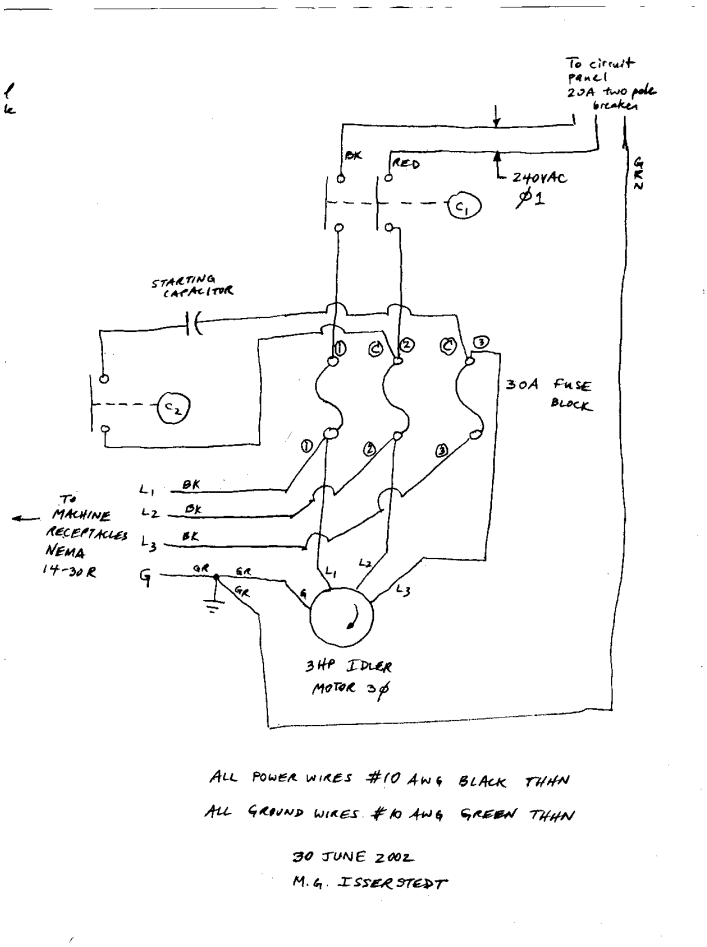
For example, on the first rung, the Red Stop PB has continuity being normally closed. Pushing the Green Start PB energizes the coil of relay CR40. When the normally open contact marked '40' closes, it then bypasses the Green Start PB (which will be released and go back to normally open). The coil of CR40 will then be energized until the circuit is broken by depressing the Red Stop PB.



There are two other normally open contacts on CR40. On Rung 2, when the run relay CR40 is energized, the two-pole contactor C1's coil is energized (performing the single phase power switching to the motor) as well as TR50's coil which is a time-delay relay.

On Rung 3, as soon as the coil of CR40 is energized, we already have continuity thru the normally closed contact of TR50. Subsequently contactor C2 is energized which brings in the starting capacitor. After the time delay, in this case around 1.0 second, TR50 will reverse state and the normally closed contact in rung 3 will open, effectively dropping out the starting capacitor.

Field Wiring



Here is the field or power wiring diagram.

If you look closely you will see all the basic elements from the very simple static phase converter diagram shown earlier.

Contactor C1 has replaced the drum switch, and Contactor C2 has replaced the momentary pushbutton for connecting the starting capacitor between L2 and L3.

I have also tapped off the three-phase power (horizontal lines) below the fuse block for distribution thru the shop to the various machines.

I have also added in the ground wires to the diagram which are very important and should not be ignored!

Design Considerations

Design of the starting capacitor was inline with the common guideline to use 100 uF per hp on the idler motor. It is important to use AC rated capacitors for 230 VAC.

Many phase converters use running capacitors. You'll note that my design does not include them. Running capacitors can be used to balance voltages between the three legs. The conversion process doesn't generate perfect three-phase as would come from the power company, but for most applications it isn't needed. I found my voltages to all be within 10% of the nominal 230VAC single-phase measurement, which I deemed acceptable.

9-lead motor wiring

Typical 3 phase motors come with 9 labeled wires inside the junction box, for either 220V or 440V hookups. This is industry standardized, and would be helpful for those who are about to wire up their first idler or machine tool.

For 220V, Leg 1 gets hooked to wires 1 & 7, Leg 2 gets hooked to wires 2 & 8, Leg 3 gets hooked to wires 3 & 9. Wires 4, 5, & 6 are all hooked together only.

For 440V, Leg 1 gets hooked to wire 1, Leg 2 gets hooked to wire 2, Leg 3 gets hooked to wire 3. Wires 4 & 7 are connected, wires 5 & 8 are connected, and wires 6 & 9 are connected. Many tools formerly used in industry come to home shop users wired this way...we just need to unhook all nine wires and then re-wire as above.

To reverse rotation on any three-phase motor, just reverse any two hookups of L1, L2, or L3. For example, swap L1 and L3 motor connections to power.

User Interface

Here is the user interface for the phase converter. It is mounted next to the garage distribution panel. I have the two pushbuttons for start and stop, plus a disconnect switch for control power.

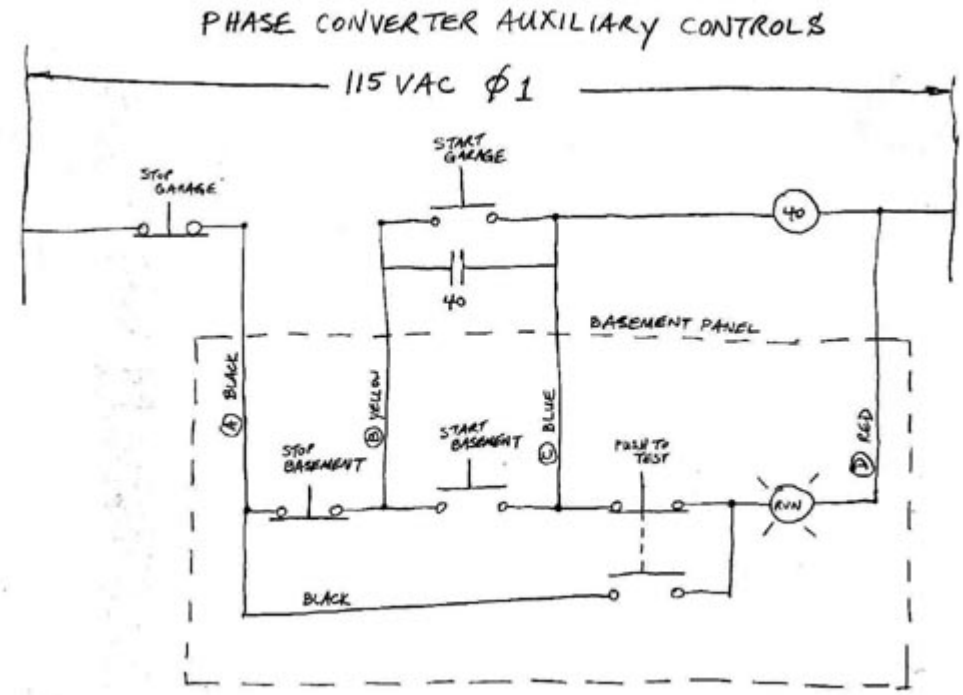
The liquid-tight flex conduit at left goes to the idler motor.

Power is wired thru the shop thru ½" EMT. I originally started with four NEMA 14-30 twistlock receptacles. Here are the #10 AWG power wires being pulled thru the conduits:

Remote Control

I had mentioned earlier that one of the benefits to automated starting was that the converter could be started from anywhere a set of stop/start buttons could be placed. I had originally wired the phase converter for my garage. With my expanding lineup of machines, I found it necessary for three-phase power in my basement. Rather than incur the expense of building another converter, I opted for the following solution.

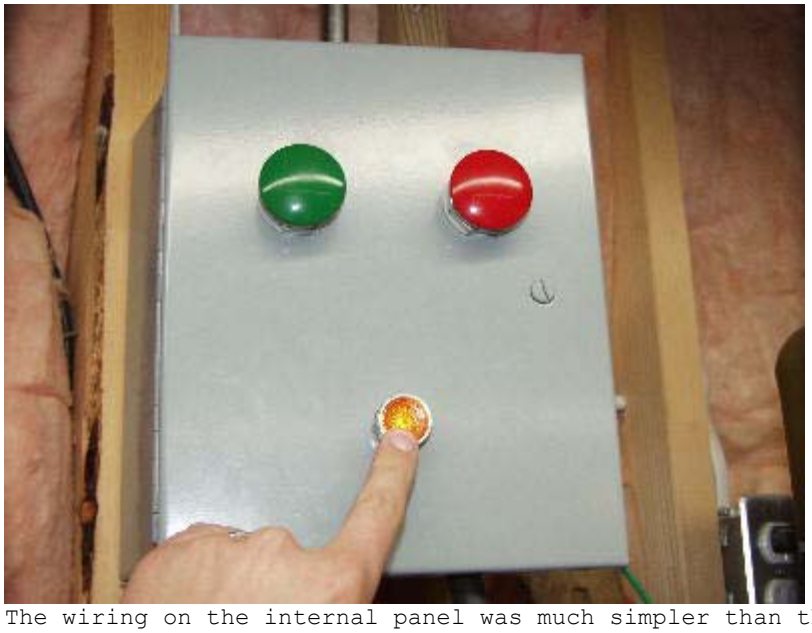
The diagram below shows how the first rung only of my original ladder logic was modified for a second set of start/stop buttons, plus an indicator lamp to inform me when the idler motor is running.



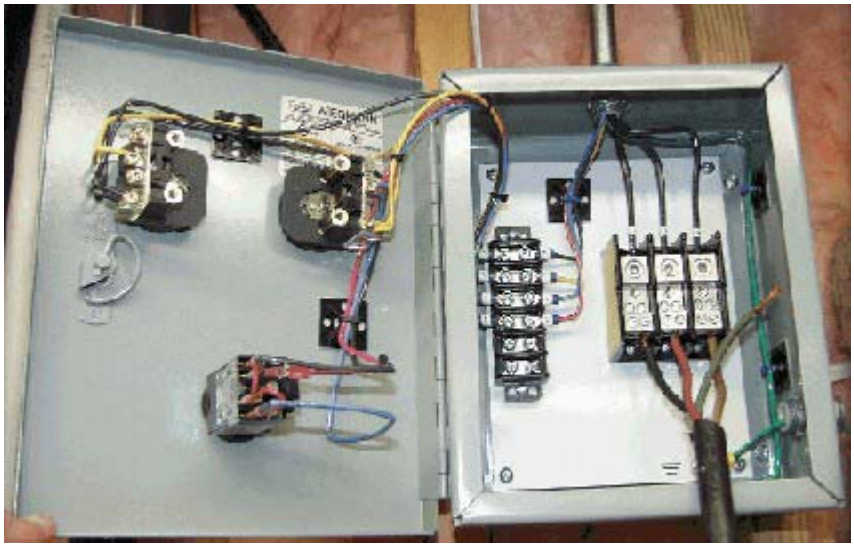
In general, stop buttons are wired in series and start buttons are wired in parallel. Note that wires A-B-C-D are quite long, approx 60 feet in this case.

The lamp has an internal switch for “push-to-test” that had to be wired such that it did not act as a “start” switch.

This is the auxiliary control and distribution panel.



The wiring on the internal panel was much simpler than the original panel with all of the starting controls. I have a machine "temp'd" into the panel for a test, and I did hookup the ground wire before actually proceeding.

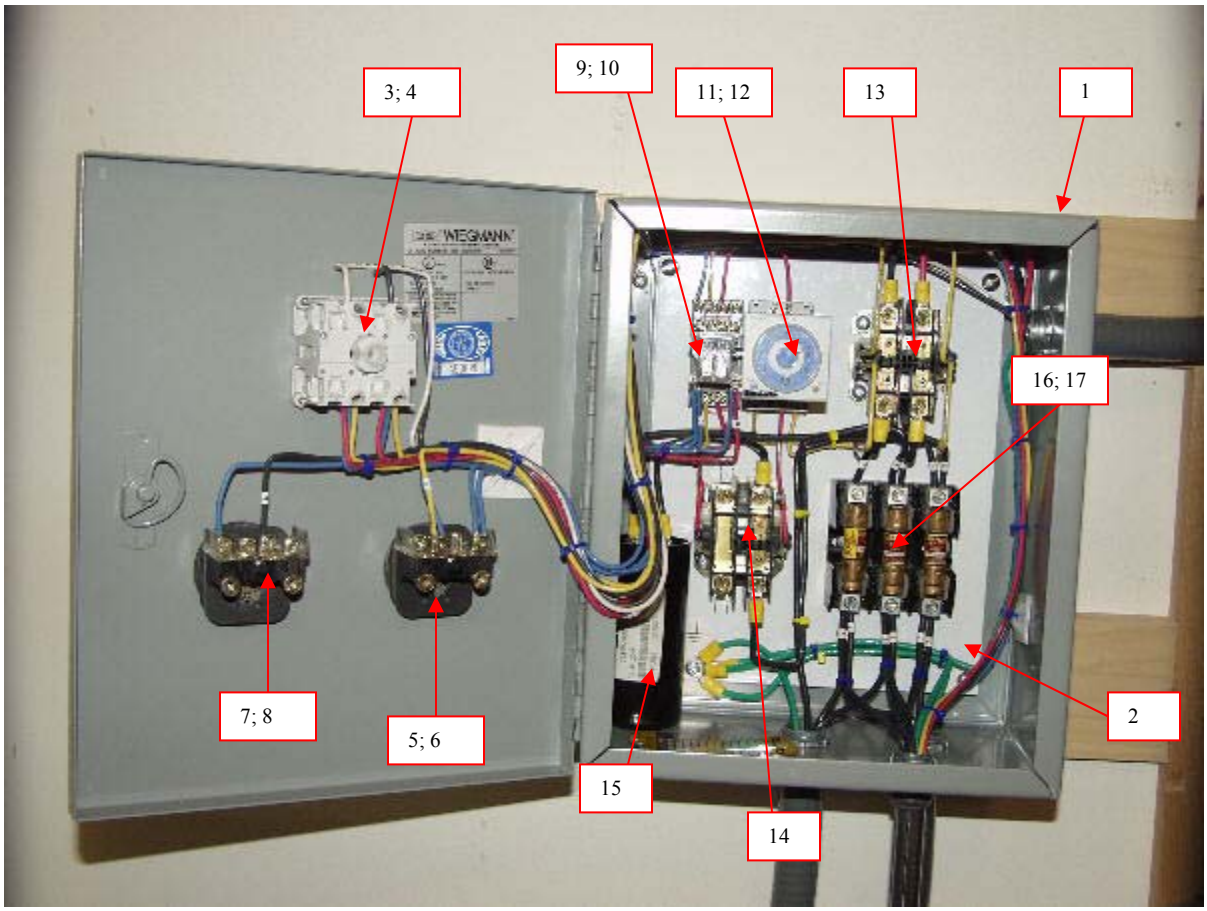


Construction Specifics – Main Panel

Below is a table indicating all the elements needed to duplicate my main starting panel. I purchased all the Grainger parts and extracted the Allen-Bradley parts from a piece of scrapped factory equipment. Note that the Allen-Bradley parts are very expensive to buy new, and less-expensive versions from Grainger or another electrical supplier could be substituted. I have specified equivalent parts from the Grainger catalog, but please check these carefully before using as I have not actually tested the alternate parts for compatibility with the original Allen-Bradley.

Legend	Part Name	OE Mfgr	OE Part #	Technical description or notes	Source	Source Part #	Alternate #
1	Enclosure	Weigmann	N1C101206WW	Nema 1, 10" x 12" x 6" deep, hinged enclosure	Grainger	3A905	
2	Backplane	Weigmann		Backplane for above enclosure	Grainger	3A937	
3	On-Off Switch Handle	Allen-Bradley	194L-HE6N-175I	On-off lockable, red/yellow, 2 position disconnect	McNMcK		6A611
4	On-Off Switch Contact Body	Allen-Bradley	194L-E25-1752	25A, front/door mounting, 2 poles	McNMcK		same as 6A611
5	Start Pushbutton	Allen-Bradley	800T-D1A	green mushroom head, 1 NO & 1 NC momentary contact	McNMcK		6HT45 & 6HX27
6	Start Pushbutton Legend	Allen-Bradley	800T-X547	for 30.5mm switch above	McNMcK		6JC64
7	Stop Pushbutton	Allen-Bradley	800T-D6A	red mushroom head, 1 NO & 1 NC momentary contact	McNMcK		6HT49 & 6HX27
8	Stop Pushbutton Legend	Allen-Bradley	800T-X550	for 30.5mm switch above	McNMcK		6JC45
9	Run Relay	Dayton		4 pole, 1 NO & 1 NC per pole, 5A contact 120vac coil	Grainger	5ZC16	
10	Run Relay Base	Dayton		14 pin screw terminal relay base	Grainger	2A584	
11	Timed Relay	Allen-Bradley	700HRM12TA17	ON-delay, 100-240vac coil, 0.05sec to 60 hour timer interval	McNMcK		5YZ86
12	Timed Relay Base	Allen-Bradley	700HN100	8 pin octal socket, screw terminals	McNMcK		5X852
13	2 pole Contactor	Square D	8910DP32V02	compact style definite purpose contactor	Grainger	5B126	
14	1 pole Contactor	Square D	8910DP31V02	compact style definite purpose contactor	Grainger	1V596	
15	Starting Capacitor	Beyschlag Centralab	3534B7A0270A220A6	270-324 mfd rating @220-250vac, 3 second start x 20 per hour	Grainger	4X662	
16	Fuse Block	Bussmann	R25030-3CR	with boxed-screw lugs	Grainger	1FG08	
17	Fuses	Bussmann	LPN-RK-30SP	Time delay fuse for starting motors	Grainger	4XF56	
	Motor	Baldor		215YZ frame, 3hp @1725 rpm, 230/460vac	Ebay		
	Control wires			# 14 AWG THHN stranded wire, jacket color to suit	HomeDepot		
	Power wires			# 10 AWG THHN stranded wire, jacket color to suit	HomeDepot		
	Note: McNMcK = McNaughton McKay Electric Supply Co., parts are the same as Allen-Bradley OEM Part Numbers						

Here are the corresponding legend numbers for the parts table.



Construction Specifics – Auxiliary Remote Panel

Here is the parts list and legend for the Auxiliary Remote Panel. The same issues apply here: I have listed alternate parts from the Grainger catalog that could be substituted for the expensive Allen-Bradley components. However, I have not verified the compatibility by physical testing, just selecting from the catalog.

Legend	Part Name	OE Mfgr	OE Part #	Technical description or notes	Source	Source Part #	Alternate #
18	Enclosure	Weigmann	N1C081004	8" x 10" x 4"D NEMA 1 hinged enclosure	Grainger	3A903	
19	Backplane	Weigmann		interior backplane panel for above enclosure	Grainger	3A904	
20	Start Pushbutton	Allen-Bradley	800T-D1A	green mushroom head, 1 NO & 1 NC momentary contact	McNMcK		6HT45 & 6HX27
21	Stop Pushbutton	Allen-Bradley	800T-D6A	red mushroom head, 1 NO & 1 NC momentary contact	McNMcK		6HT49 & 6HX27
22	Push-to-test Indicator Lamp	Allen-Bradley	800MR-PT16	22mm orange push-to-test indicator lamp, 1NO & 1NC contact	McNMcK		6HR51 & 6HR40
23	Power Distribution Block	Bussman	16220-3	3 pole 175 amp power distribution block, 4 connect per pole	Grainger	5A672	
24	Terminal Strip	Ideal	89-206	6 pole screw terminal 30 amp rated @600V	Grainger	6YH65	
	Control wires			# 14 AWG THHN stranded wire, jacket color to suit	HomeDepot		
	Power wires			# 10 AWG THHN stranded wire, jacket color to suit	HomeDepot		
	Note: McNMcK = McNaughton McKay Electric Supply Co., parts are the same as Allen-Bradley OEM Part Numbers