Variable Frequency Drives

ACCFO
NORTH CAROLINA ASSOCIATION OF COMMUNITY COLLEGE FACILITY OPERATIONS
CHARTERED 1992
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What utilizes the most power in our facilities?

In the United States 50% of the total electrical energy generated is consumed by rotating equipment. 65% of this total is consumed by centrifugal and flow related applications such as fans, blowers, compressors, and pumps according to current estimates. Variable speed drive technology offers a cost-effective method to match driver speed to load demands and represents a state-of-the-art opportunity to reduce operating costs and improve overall productivity.

How many types of Variable Frequency Drives are there?

You can divide the world of electronic motor drives into two categories: AC and DC, a motor drive controls the speed, torque, direction and resulting horsepower of a motor. AC drives control AC induction motors. DC drives typically controls a shunt wound DC motor, which has separate armature and field circuits.

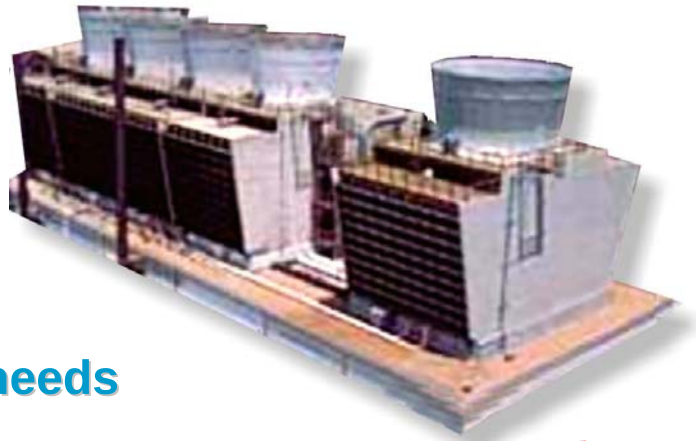
What other names are utilized when talking about Variable Frequency Drives?

Motor drives are also known as DC Drives, AC Drives, SCR Drives (Silicon Controlled Rectifier Drive) Variable Frequency Drives, Variable Speed Drives, Adjustable Speed Drives, Electric Motor Drives, Electronic Motor Drives, AC Motor Controllers, AC Inverters, Pulse Width Modulation (PWM) Drives and a few other names.

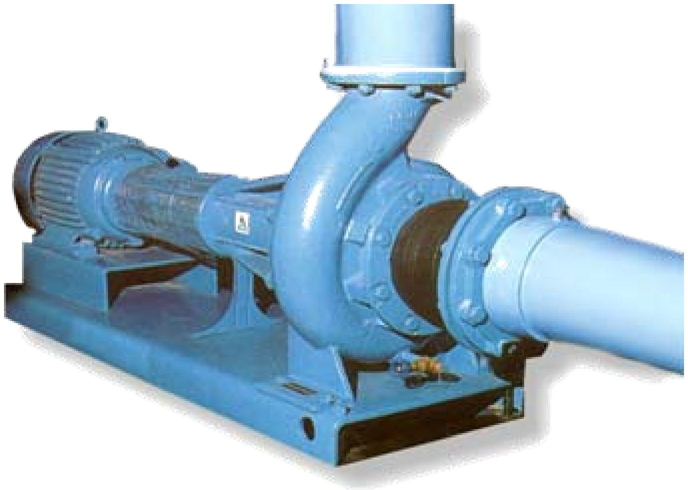
Where can I save energy and reduce my operating cost?

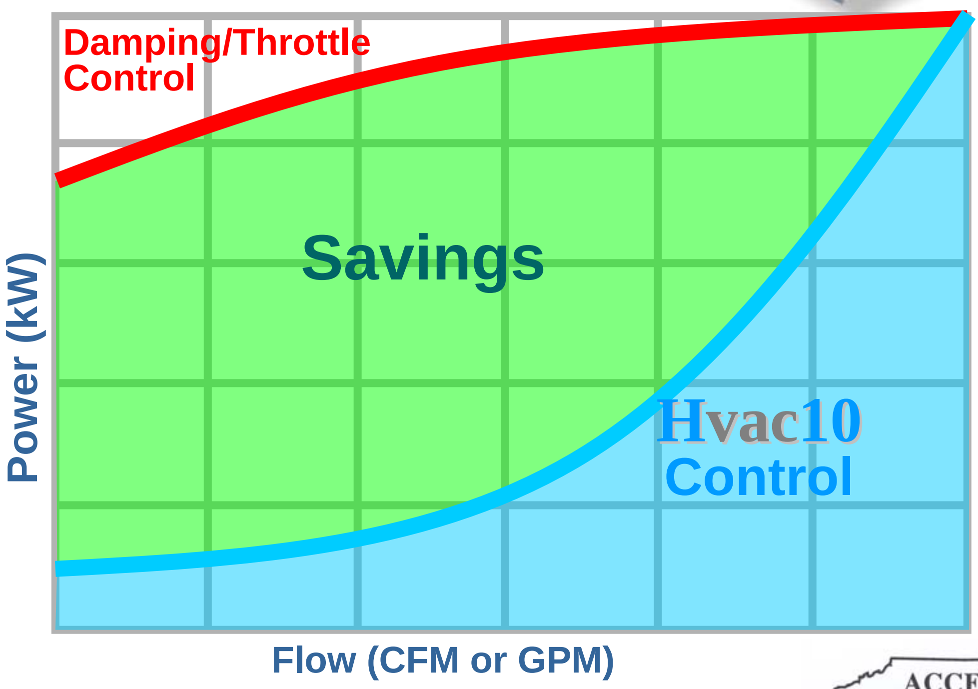
Motor-driven centrifugal pumps, fans, and blowers offer the most dramatic energy-saving opportunities. Many of these operate for extended periods at reduced load with flow restricted or throttled. In these centrifugal machines, energy consumption is proportional to the cube of the flow rate. Even small reductions in speed and flow can result in significant energy savings. In these applications, significant energy and cost savings can be achieved by reducing the operating speed when the process flow requirements are lower.

Air Handling Units
Cooling Towers
Chilled Water Pumping Systems



…for all of your HVAC needs





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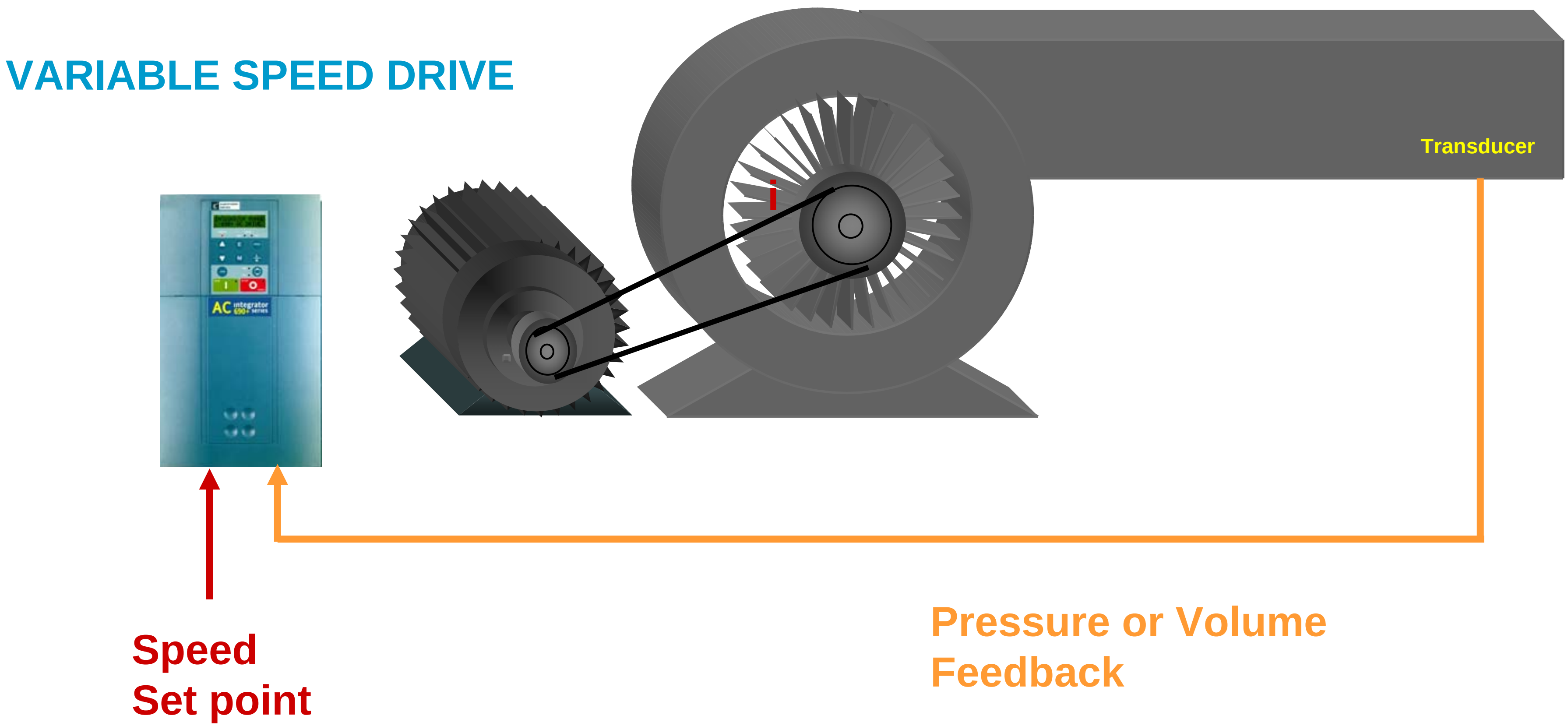
Variable Frequency Drive Operation

When a VFD starts a motor, it initially applies a low frequency and voltage to the motor. The starting frequency is typically 2 Hz or less. Starting at such a low frequency avoids the high inrush current that occurs when a motor is started by simply applying the utility (mains) voltage by turning on a switch. When VFD starts, the applied frequency and voltage are increased at a controlled rate or ramped up to accelerate the load without drawing excessive current. This starting method typically allows a motor to develop 150% of its rated torque while drawing only 50% of its rated current. When a motor is simply switched on at full voltage, it initially draws at least 300% of its rated current while producing less than 50% of its rated torque. As the load accelerates, the available torque usually drops a little and then rises to a peak while the current remains very high until the motor approaches full speed. A VFD can be adjusted to produce a steady 150% starting torque from standstill right up to full speed while drawing only 50% current.

DRIVE AIRFLOW CONTROL

SYSTEM WORKS BY CONTROLLING SPEED,
NOT RESTRICTING AIRFLOW !



Variable Frequency Drive Operation

With a VFD, the stopping sequence is just the opposite as the starting sequence. The frequency and voltage applied to the motor are ramped down at a controlled rate. When the frequency approaches zero, the motor is shut off. A small amount of braking torque is available to help decelerate the load a little faster than it would stop if the motor were simply switched off and allowed to coast. Additional braking torque can be obtained by adding a brake circuit to dissipate the braking energy or return it to the power source

Fairly involved control circuitry coordinates the switching of power devices, typically through a control board that dictates the firing of power components in the proper sequence. A microprocessor or Digital Signal Processor (DSP) meets all the internal logic and decision requirements. From this description, you can see a VFD is basically a computer and power supply.

A VFD converts 60 HZ power, for example, to a new frequency in two stages: the rectifier stage and the inverter stage. The conversion process incorporates three functions;

- 🛠 Rectifier Stage: A full-wave, solid-state rectifier converts three-phase 60 Hz power from a standard 208, 460, 575 or higher utility supply to either fixed or adjustable DC voltage.

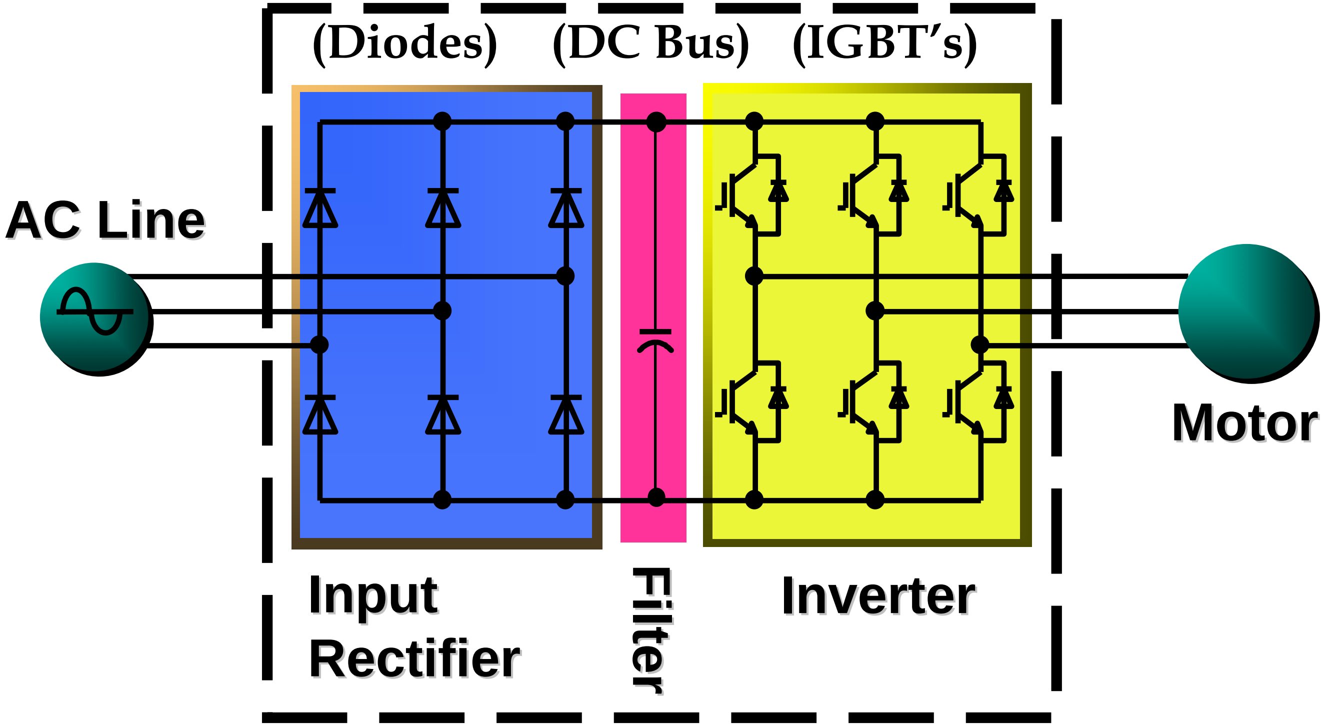
- 🛠 Inverter Stage: Electronic switches – power transistors or thyristors – switch the rectifier DC on and off, and produce a current or voltage waveform at the desired new frequency. The amount of distortion depends on the design of the inverter and filter.

- 🛠 Control System: An electronic circuit receives feedback information from the driven motor and adjusts the output voltage or frequency to the selected values. Usually the output voltage is regulated to produce a constant ratio of voltage to frequency (V/Hz). Controllers may incorporate many complex control functions.

Pulse Width Modulation – PWM – Variable Frequency Drives

Converting DC to variable frequency AC is accomplished using an inverter. Most current available inverters use pulse width modulation (PWM) because the output current waveform closely approximates a sine wave. Power semiconductors switch DC voltage at higher speed, producing a series of short-duration pulses of constant amplitude. Output voltage is varied by changing the width and polarity of the switched pulses. Output frequency is adjusted by changing the switching cycle time. The resulting current in an inductive motor simulates a sine wave of the desired output frequency. The high-speed switching of a PWM inverter results in less waveform distortion and, therefore, lower harmonic losses. The availability of low-cost, high-speed switching power transistors has made PWM the dominant invert type.

Today's AC Drives are Pulse Width Modulated



- **Input Rectifier converts AC line voltage to fixed voltage DC.**
- **DC voltage is filtered by Capacitors to reduce ripple caused by rectification.**
- **Inverter changes fixed voltage DC to adjustable AC voltage and frequency which is fed to the motor.**

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What is a line reactor and what will it do for my application?

- A line reactor is an impedance device. Its benefits are reduction of drive cross talk, and interference.

- Input reactors will limit the waveform distortion and harmonic voltages. This will help improve the power factor due to reduction of the root mean square (RMS) currents in the system.

- Output reactors are generally good up to 100 feet in distance (drive to motor). The benefits are the damping of peak voltage overshoots, which will reduce internal motor heating and lessen the “noise” that a motor can produce when it is run by a drive. On installations where the distance is greater than 100 feet, filters are recommended for motor protection.

ABB Variable Frequency Drive

Screen

Keypad

AUTO/BYPASS Switch

ON / OFF Switch

Basic Operator Panel

Amperage

Screen
33 Hertz

Menu Key

Run Status

Reset Key

DOWN Key

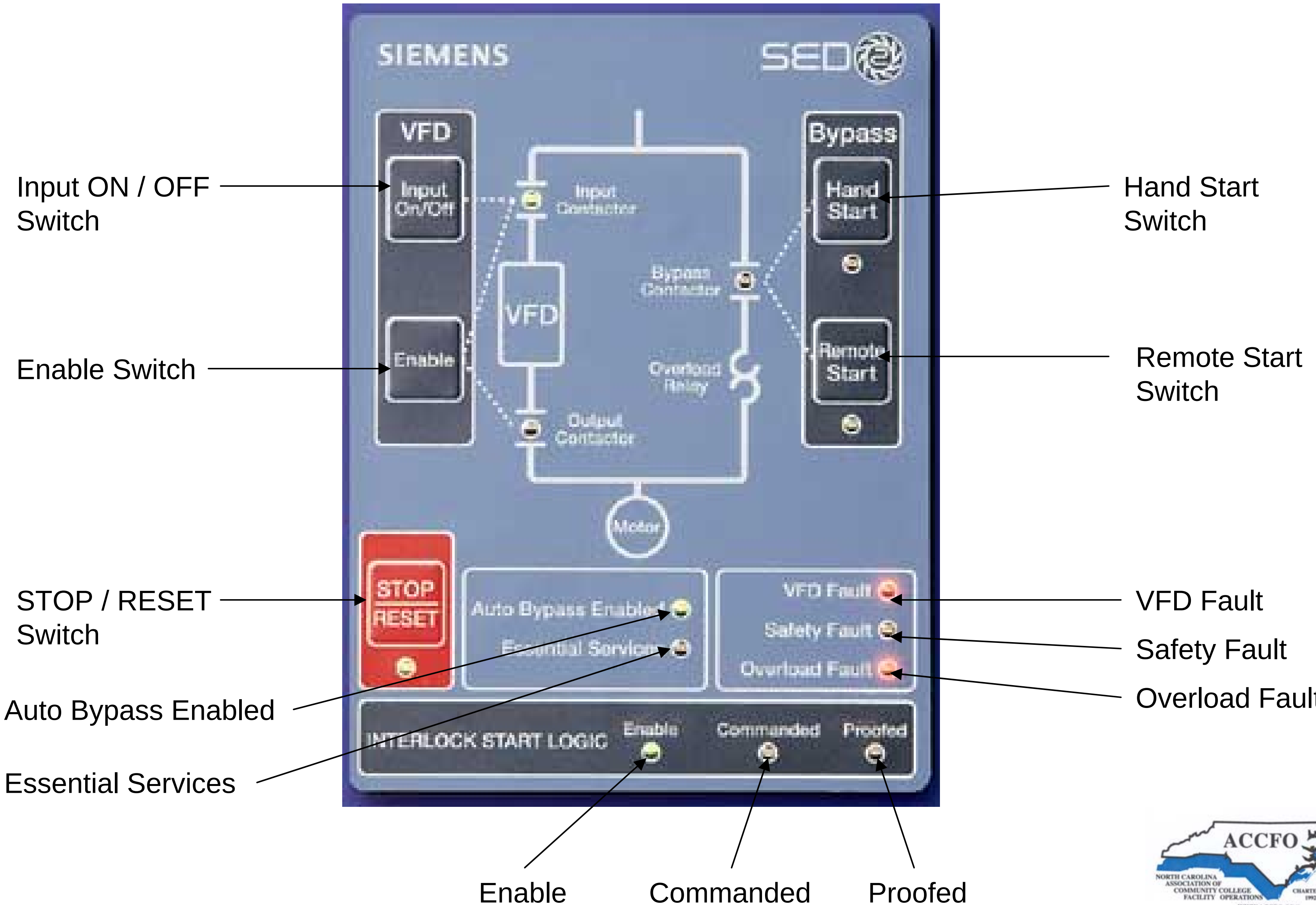
UP Key

Enter Key

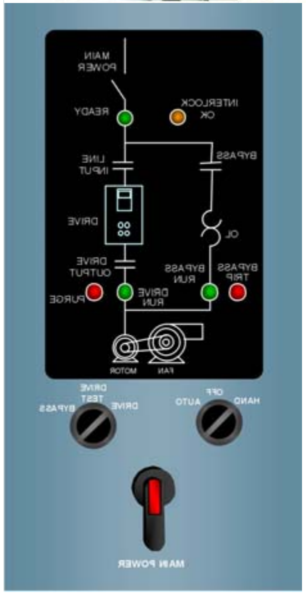
HAND Key

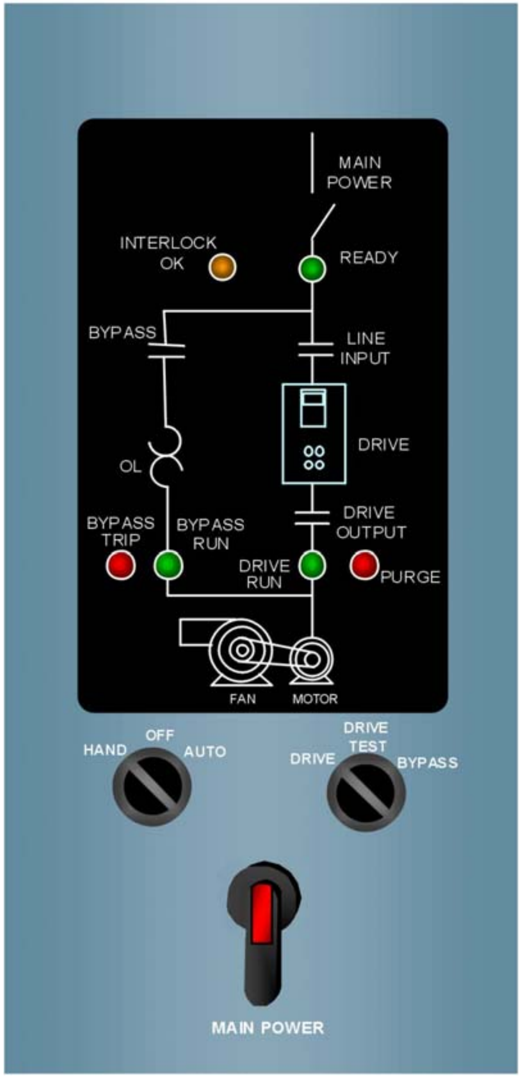
AUTO Key

OFF Key


SIEMENS
SED2
VFD
Input On/Off
Enable
Input Contactor
VFD
Output Contactor
Bypass Contactor
Overload Relay
Motor
Bypass
Hand Start
Remote Start
STOP RESET
Auto Bypass Enabled
Essential Services
VFD Fault
Safety Fault
Overload Fault
INTERLOCK START LOGIC
Enable
Commanded
Proofed
Input ON / OFF Switch
Enable Switch
STOP / RESET Switch
Auto Bypass Enabled
Essential Services
Hand Start Switch
Remote Start Switch
VFD Fault
Safety Fault
Overload Fault
Enable
Commanded
Proofed

SIMPLE OPERATOR CONTROLS





EASY TO FOLLOW GRAPHIC DISPLAY

Indicator lights for drive status

Industrial-grade switches for control modes

'Hand/Off/Auto' selection

'Drive/Bypass' selection with 'Test' mode

Main Power Disconnect

Keypad

Backlit LCD

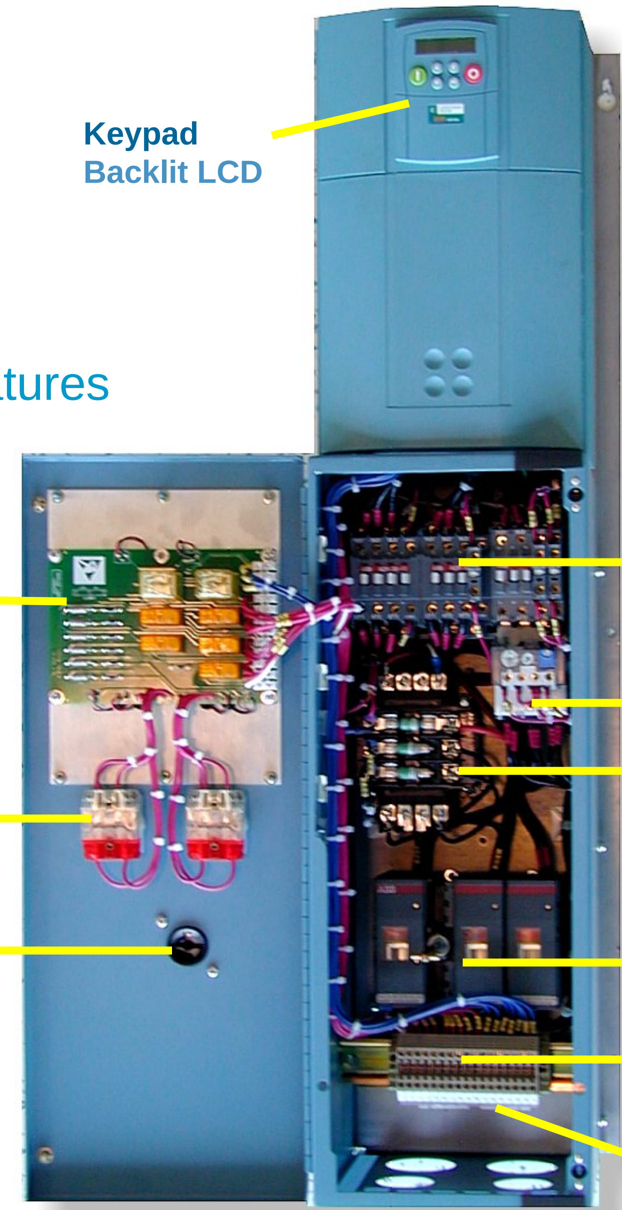
Dependable

3-Contactor Bypass Design

- provides electrical isolation in bypass
- allows for automatic or remote bypass switching
- drive can be serviced while in bypass

Door Mounted Features

AC Drive Controller



System Status Panel

Mode selection switches

Input Disconnect Handle

Contactor Section

Drive Input

Drive Output

Bypass

Motor Overload

115V Control Transformer

Fused Input Disconnect

Single-point interfacing for all customer control wiring; 115v control logic

Power wiring Terminal Block

Bypass Cabinet

Communications Options

Communications Protocols

Johnson Metasys N2

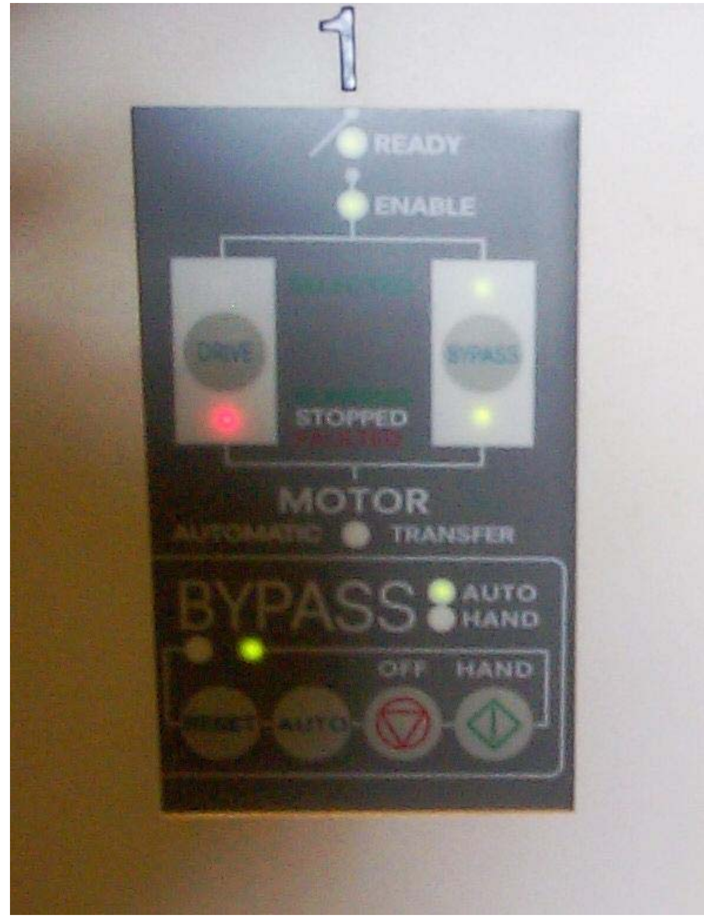
Echelon LonWorks

Modbus RTU

Siemens Apogee P1

Option to connect drive serial interface to a PC via RS-232 interface for drive configuration use.

ABB VFD



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Operator Panel for ABB Drive

ABB Variable Frequency Drive

TECHNOLOGIC Variable Frequency Drive

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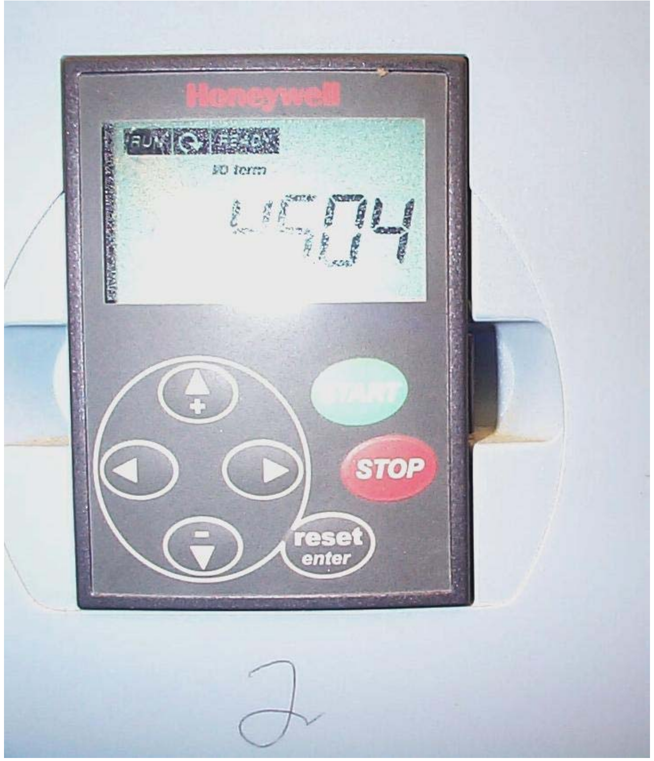
HONEYWELL Variable Frequency Drive



Honeywell Variable Frequency Drive

Reliance VFD Feeding a Water Heater

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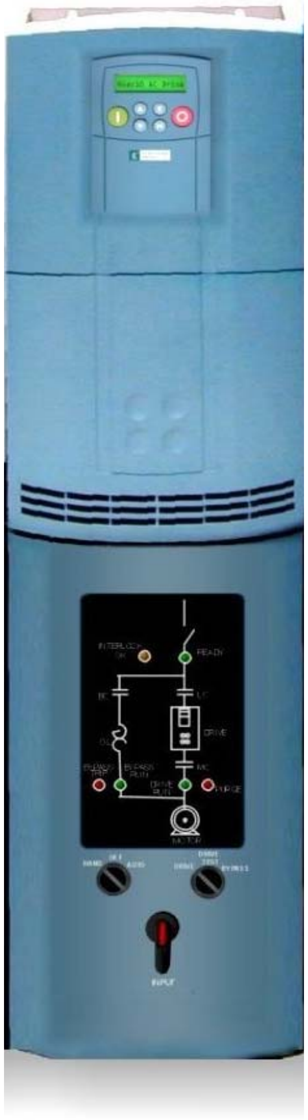
Danfoss Graham

Eurotherm Variable Frequency Drive



York Variable Frequency Drive Feeding a Supply Fan

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Interior of a Variable Frequency Drive

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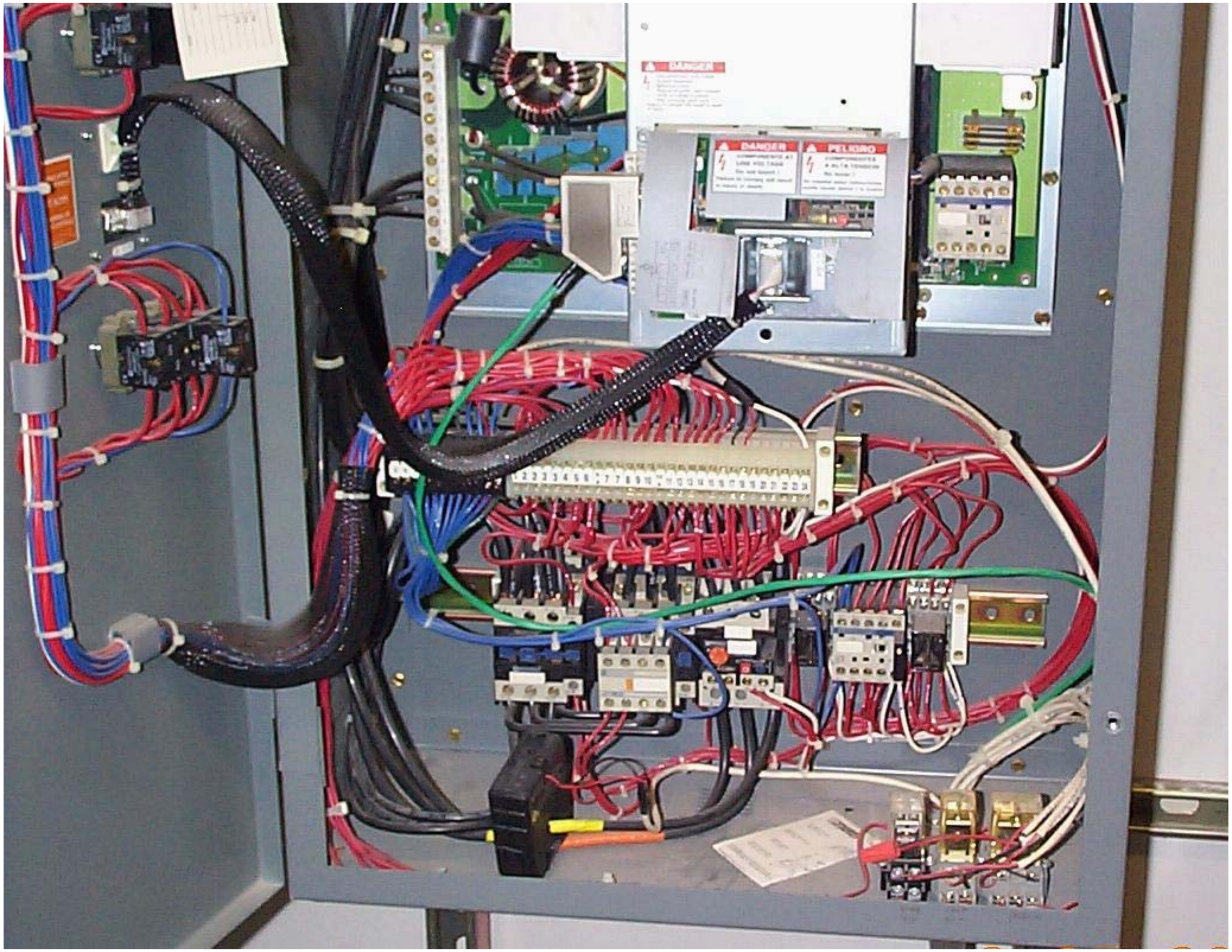
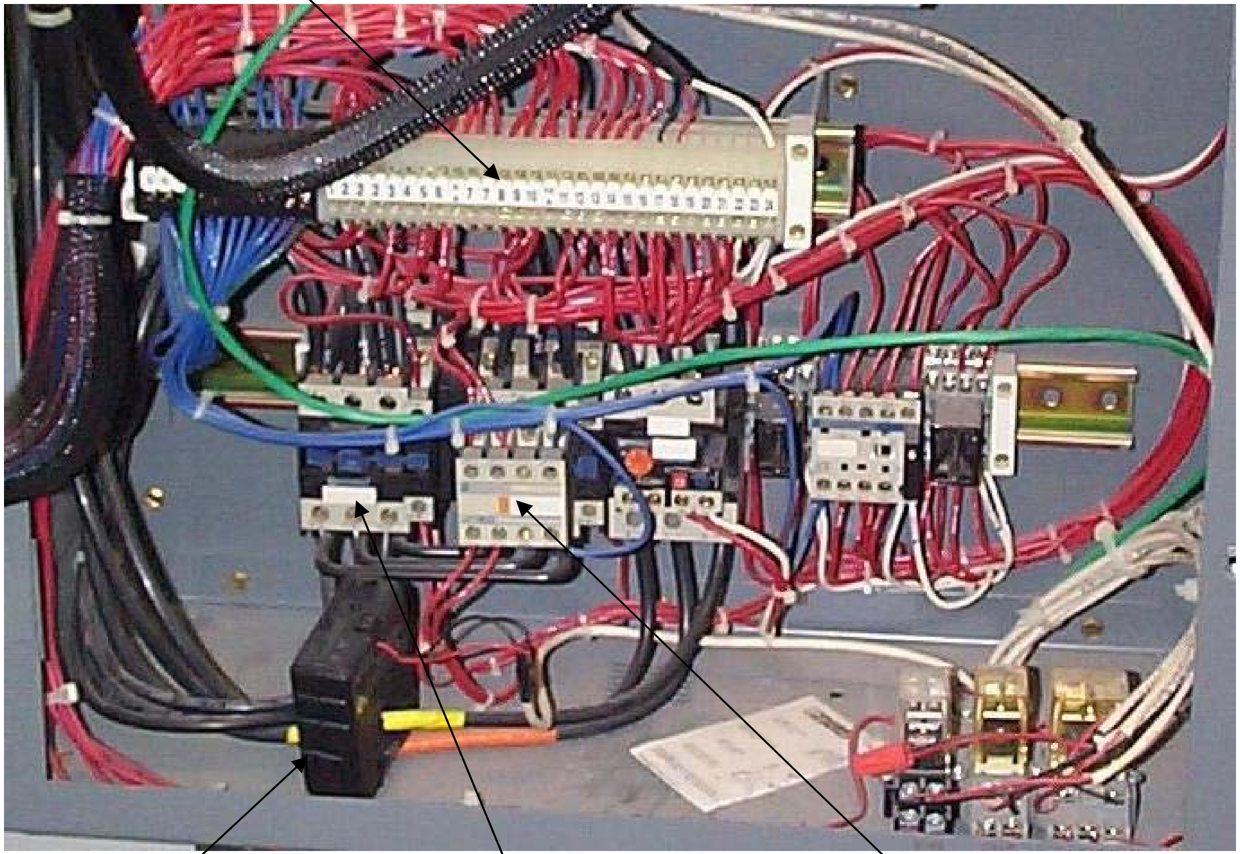
ABB Variable Frequency Drives

Inside of a variable frequency drive panel



Terminal Strip – Voltage measurements can be make at this location

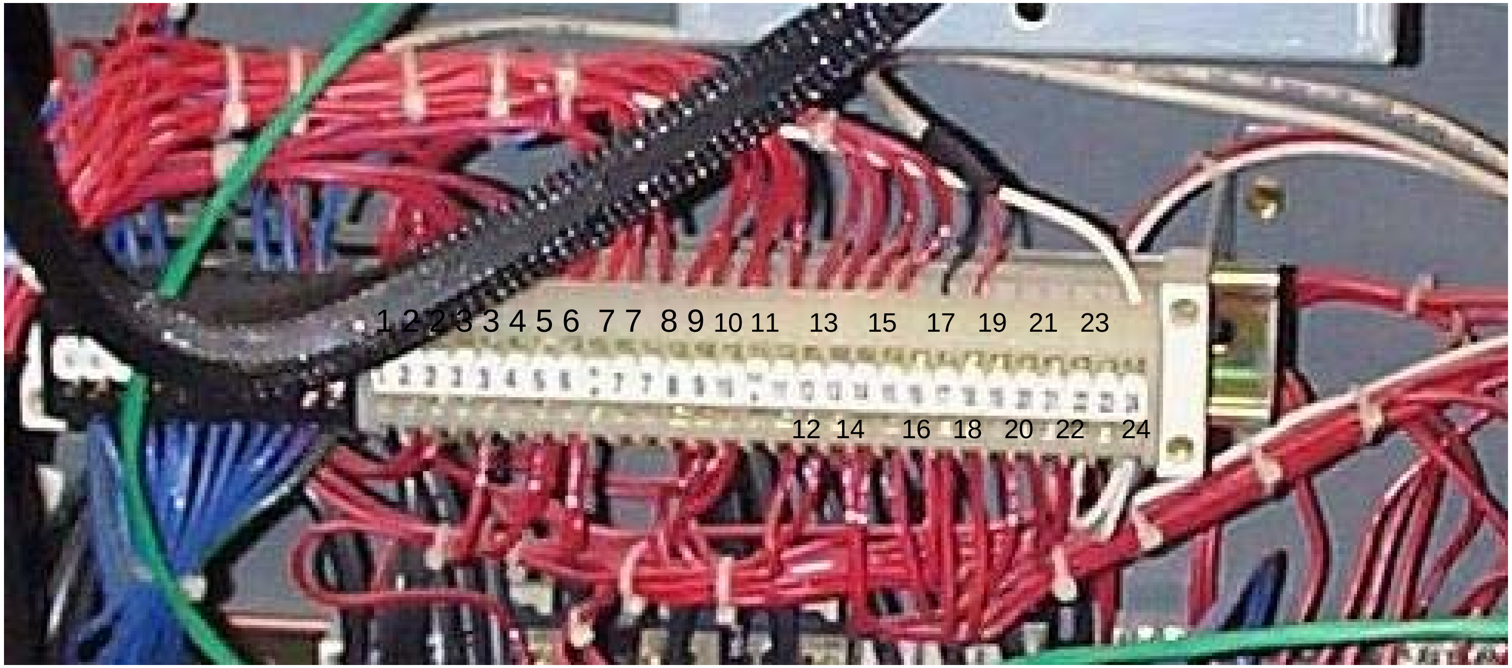


CT - Current Transformer

Main Motor Contactor

VFD Contactor

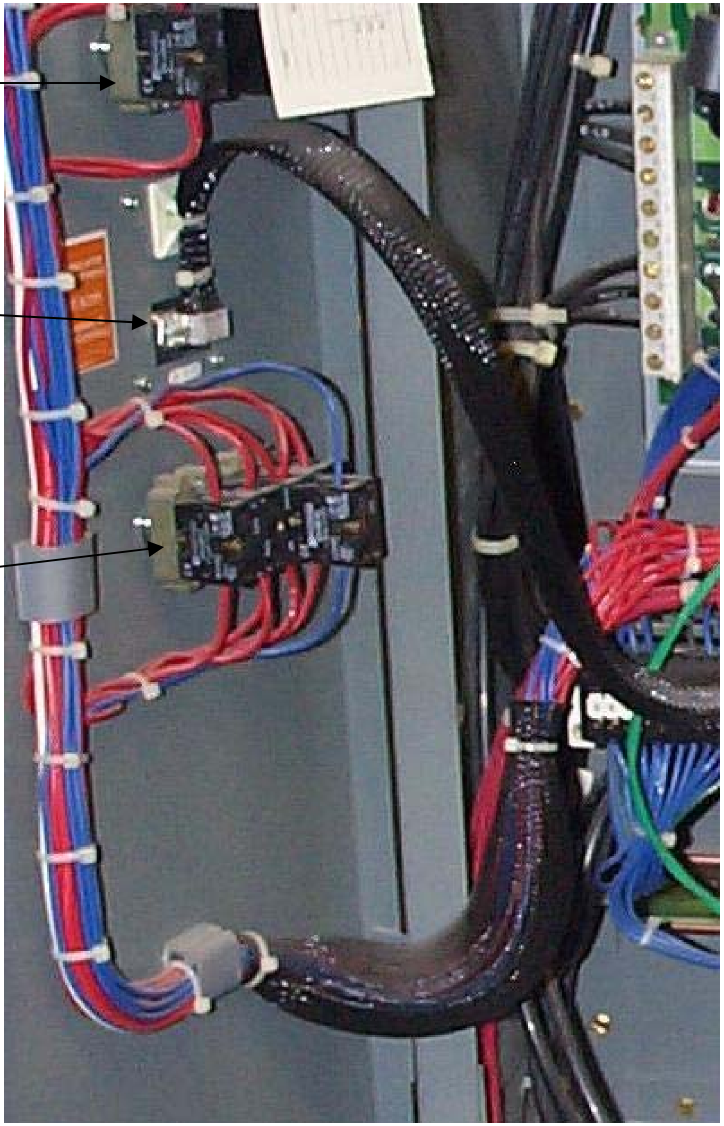
TERMINAL STRIP



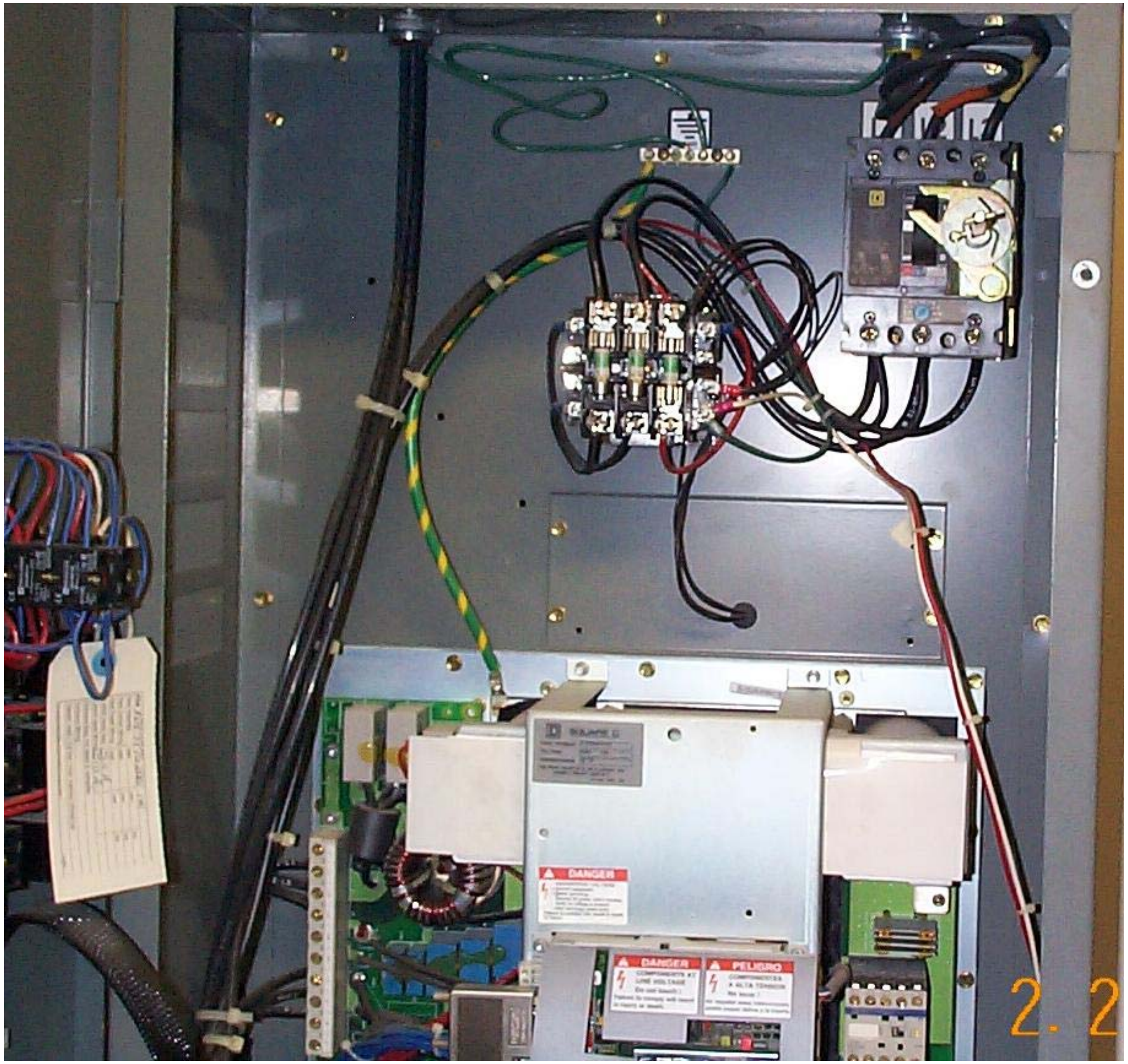
OPERATOR PANEL

RESET / AUTO SWITCH

ON / OFF SWITCH



Inside of a variable frequency drive panel



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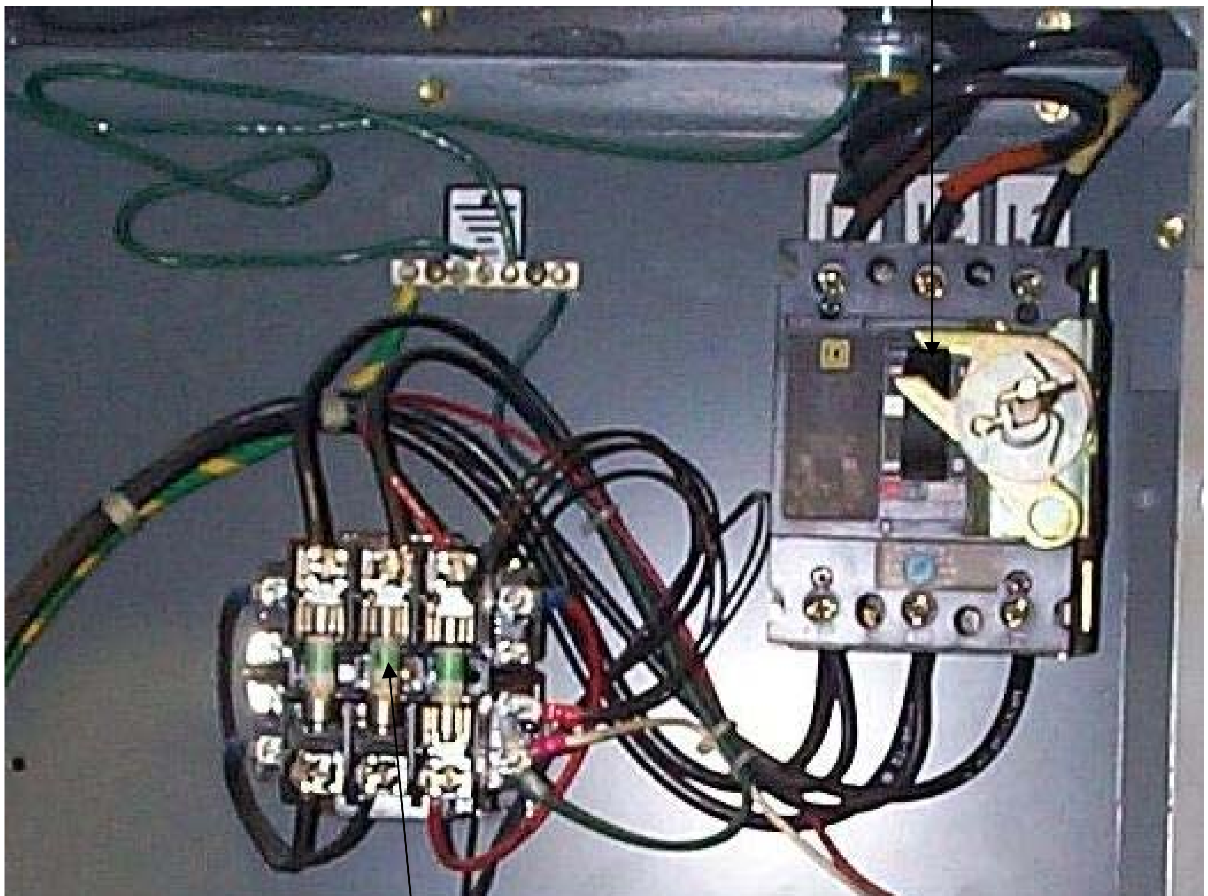
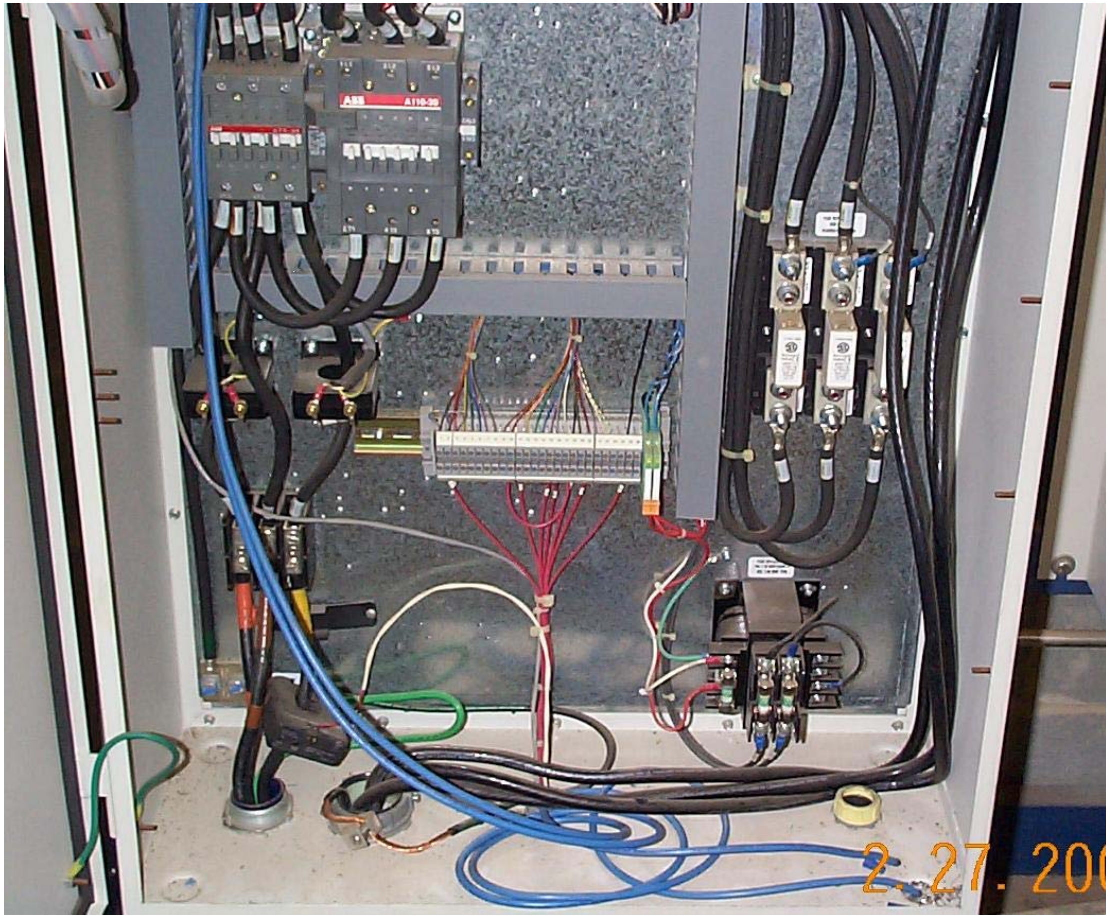
MAIN DISCONNECT

Incoming 3 Phase Power

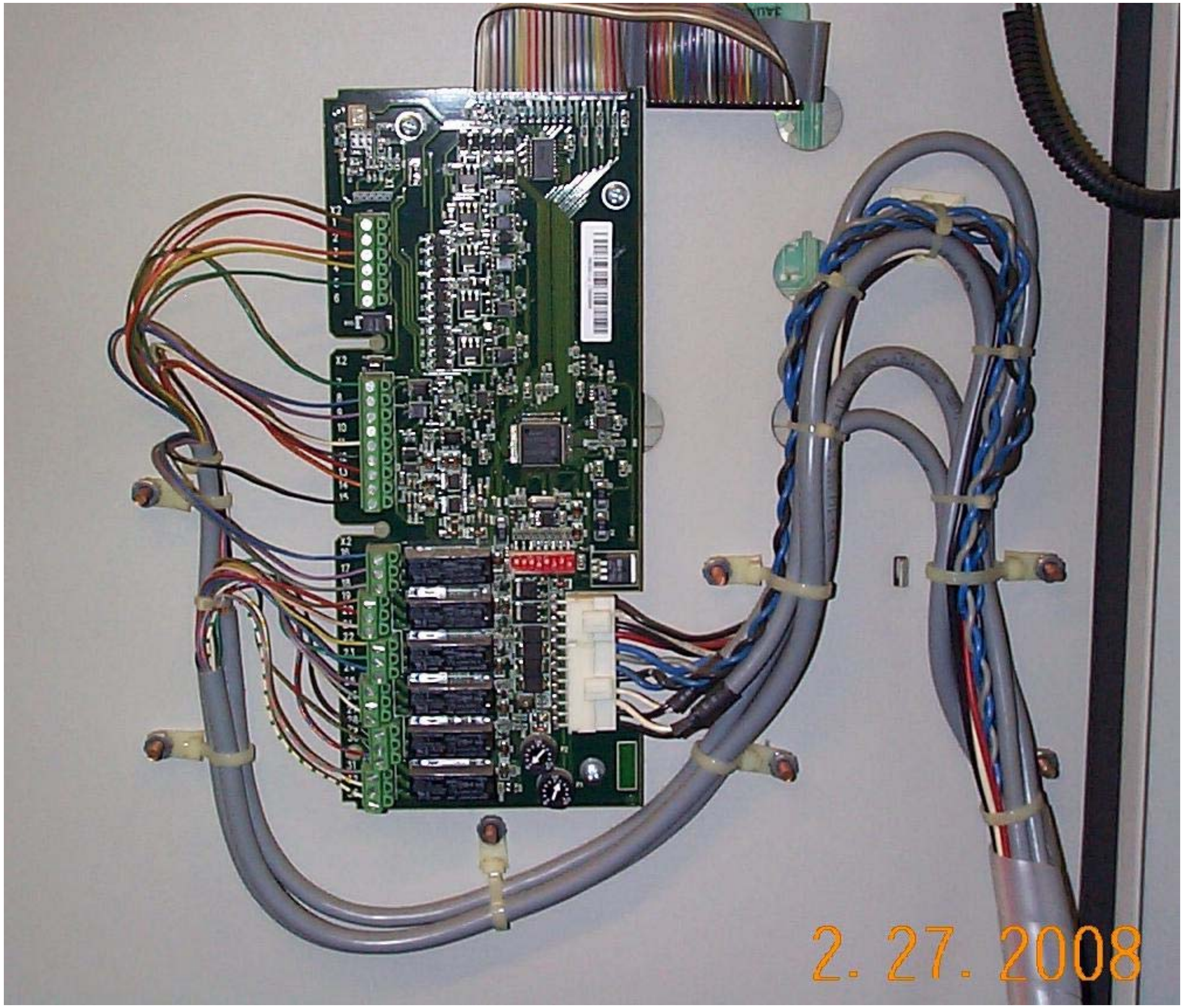


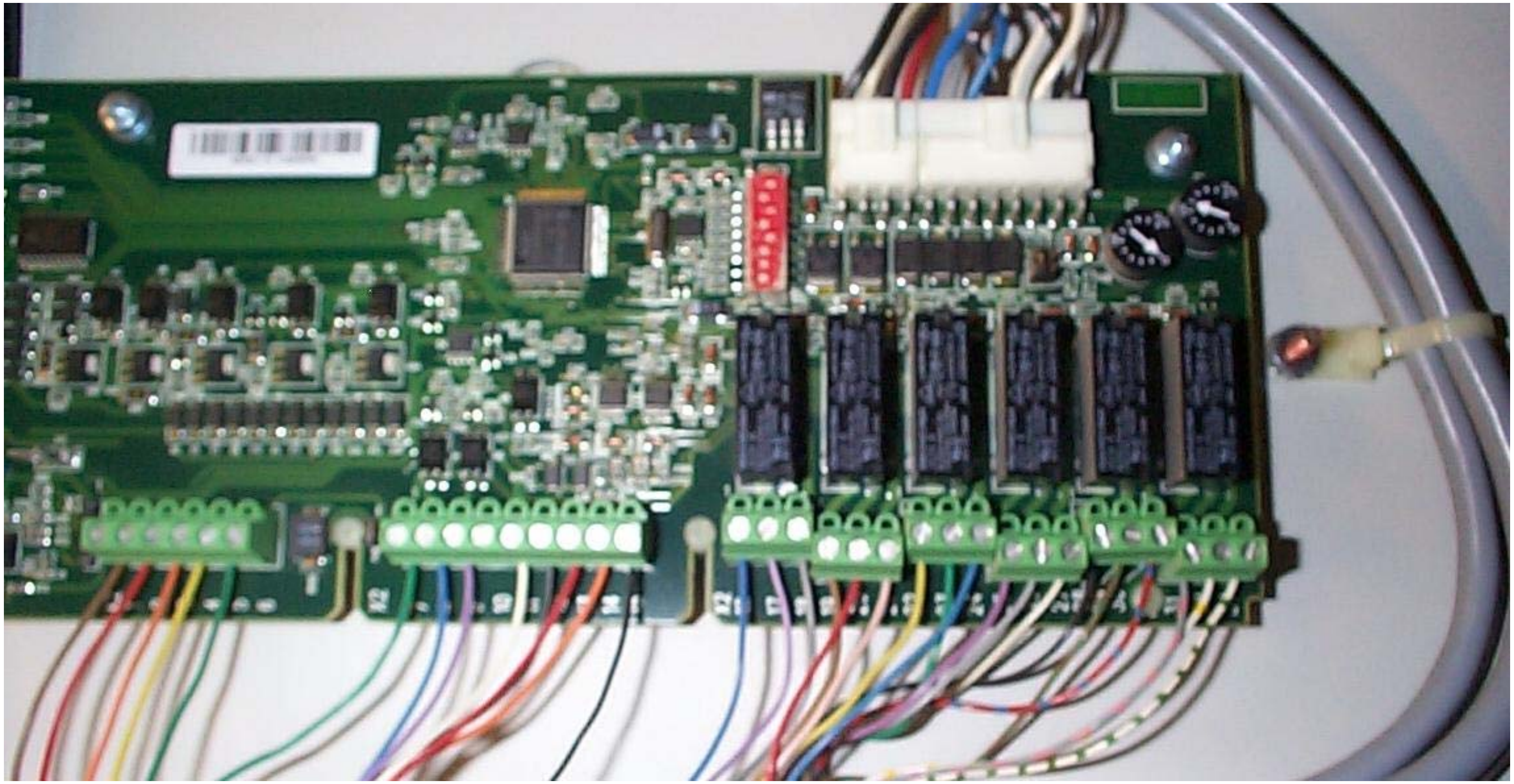
Main Fuse Block

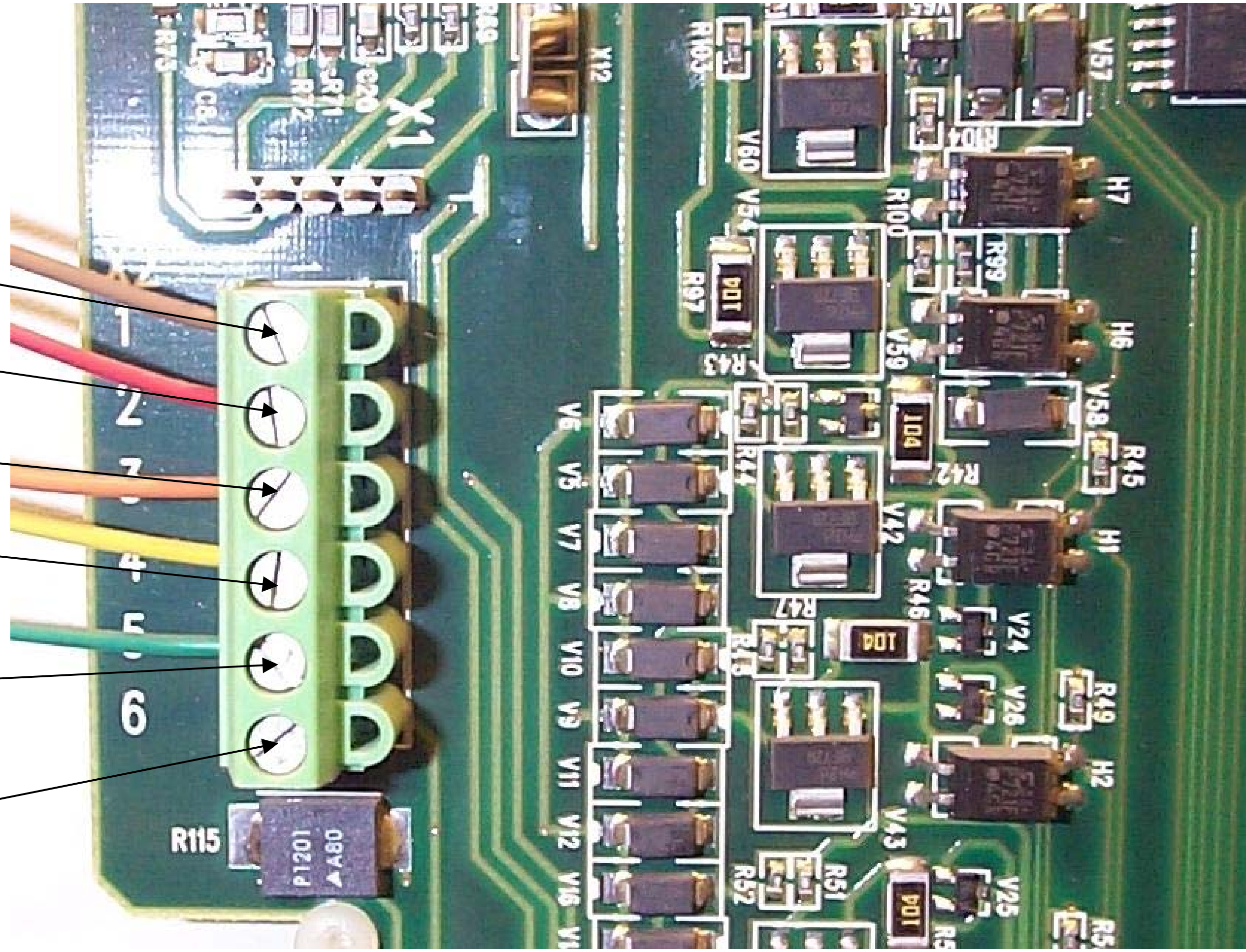
Inside of a variable frequency drive panel

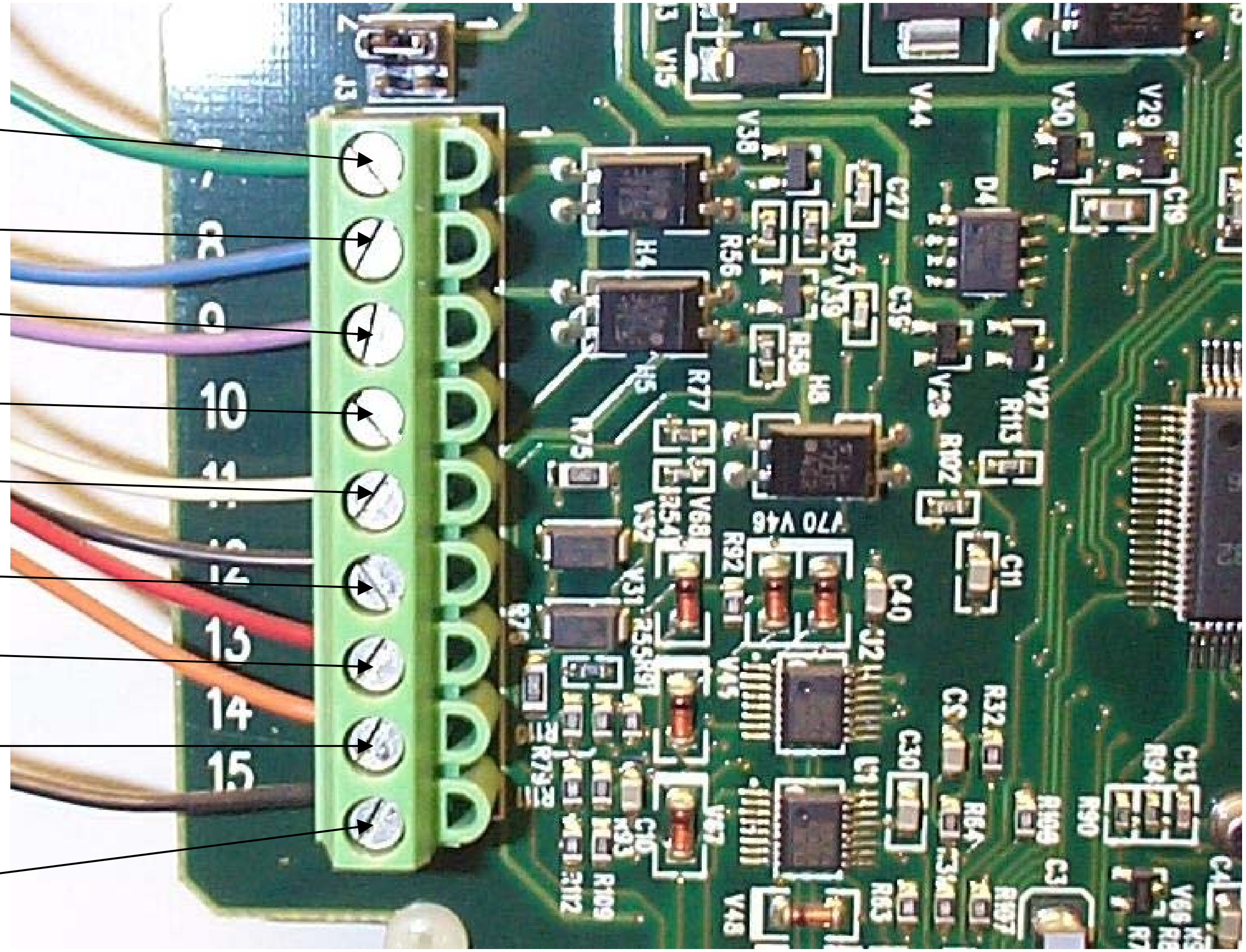


CONTROL CIRCUIT BOARDS






Start / Stop
Run Enable
Safety Interlocks
Override 1 – Fireman’s Override
Override 2 – Bypass Override
I/O Power Supply – Not Used


ACH 400 24V Voltage Supply
Start / Stop 2
Run Enable 2
Safety Output
Drive R01 – N.O.
Drive R01 – Com
Drive R02 – N.C.
Drive R02 – Com
Common – Used ONLY with 24VDC Supply

R01 – Bypass Fault – N.C.

R01 – Bypass Fault – N.O.

R01 – Bypass Fault - Com

R02 – System Run – N.C.

R02 – System Run – N.O.

R02 – System Run - Com

R03 – System Started – N.C.

R03 – System Started – N.O.

R03 – System Started - Com

R04 – Mode / Override – N.C.

R04 – Mode / Override – N.O.

R04 – Mode / Override - Com

R05 – Drive Fault – N.C.

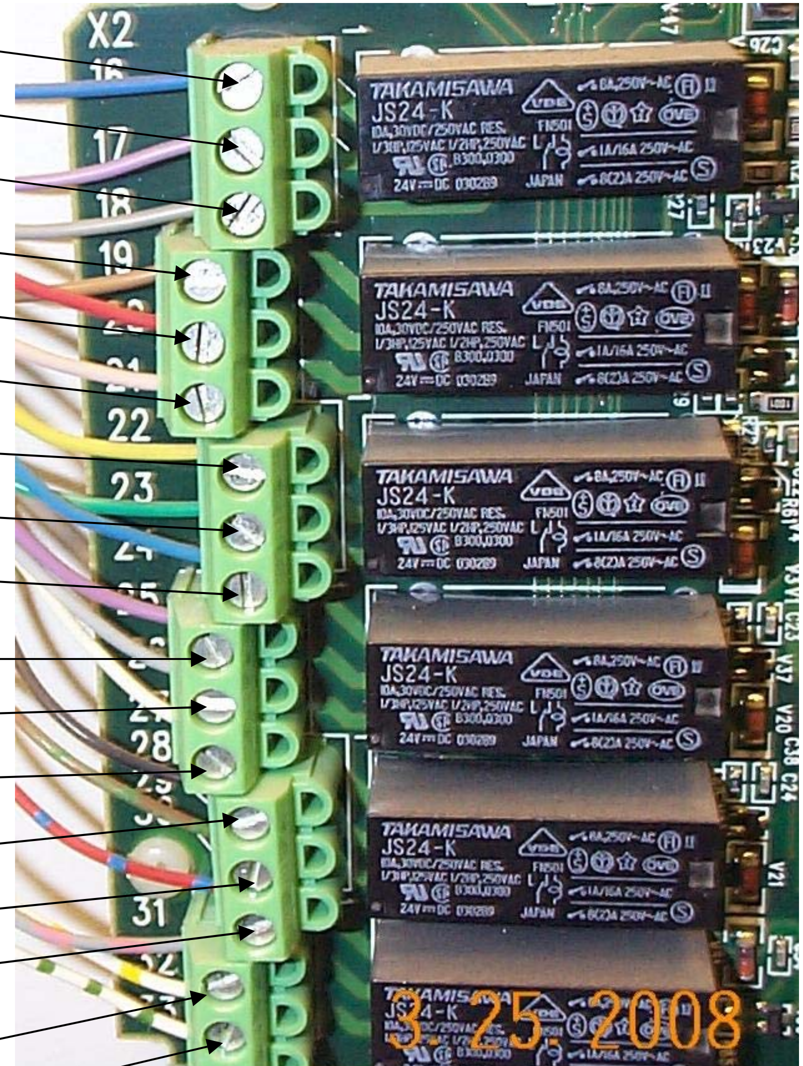
R05 – Drive Fault – N.O.

R05 – Drive Fault - Com

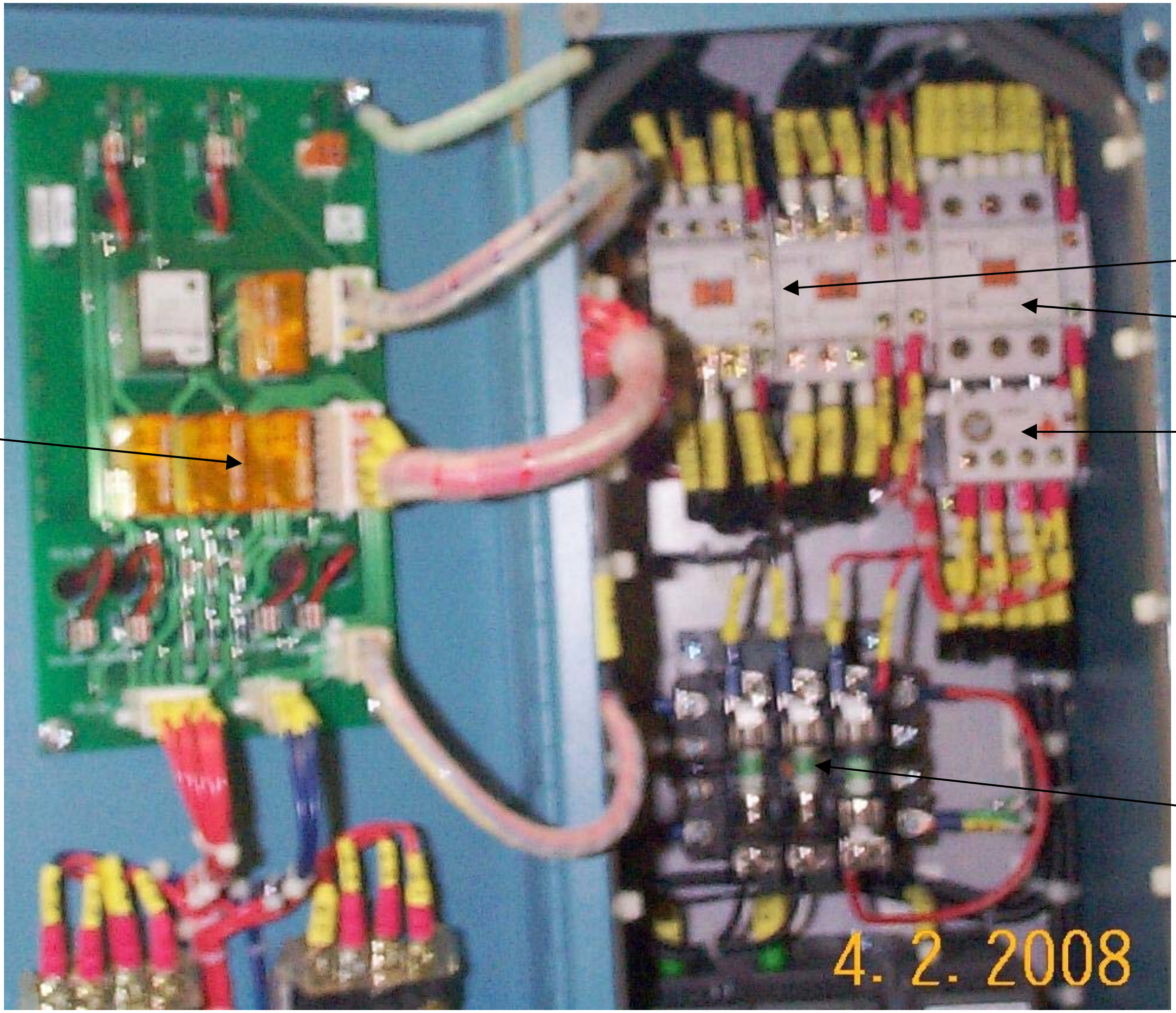
R06 – Hand / Off / Auto – N.C.

R06 – Hand / Off / Auto – N.O.

R06 – Hand / Off / Auto - Com



Interior of a Variable Frequency Drive



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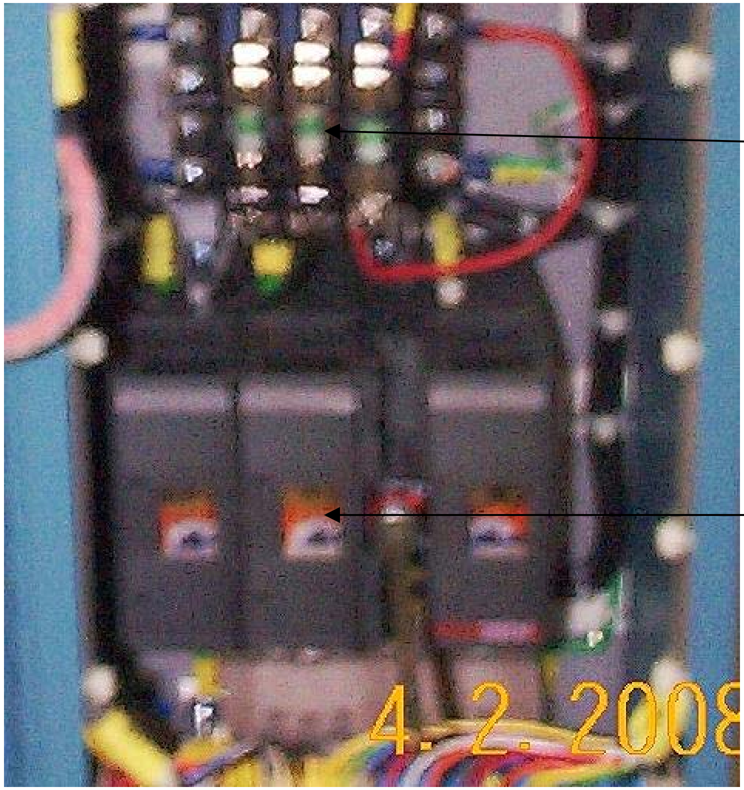
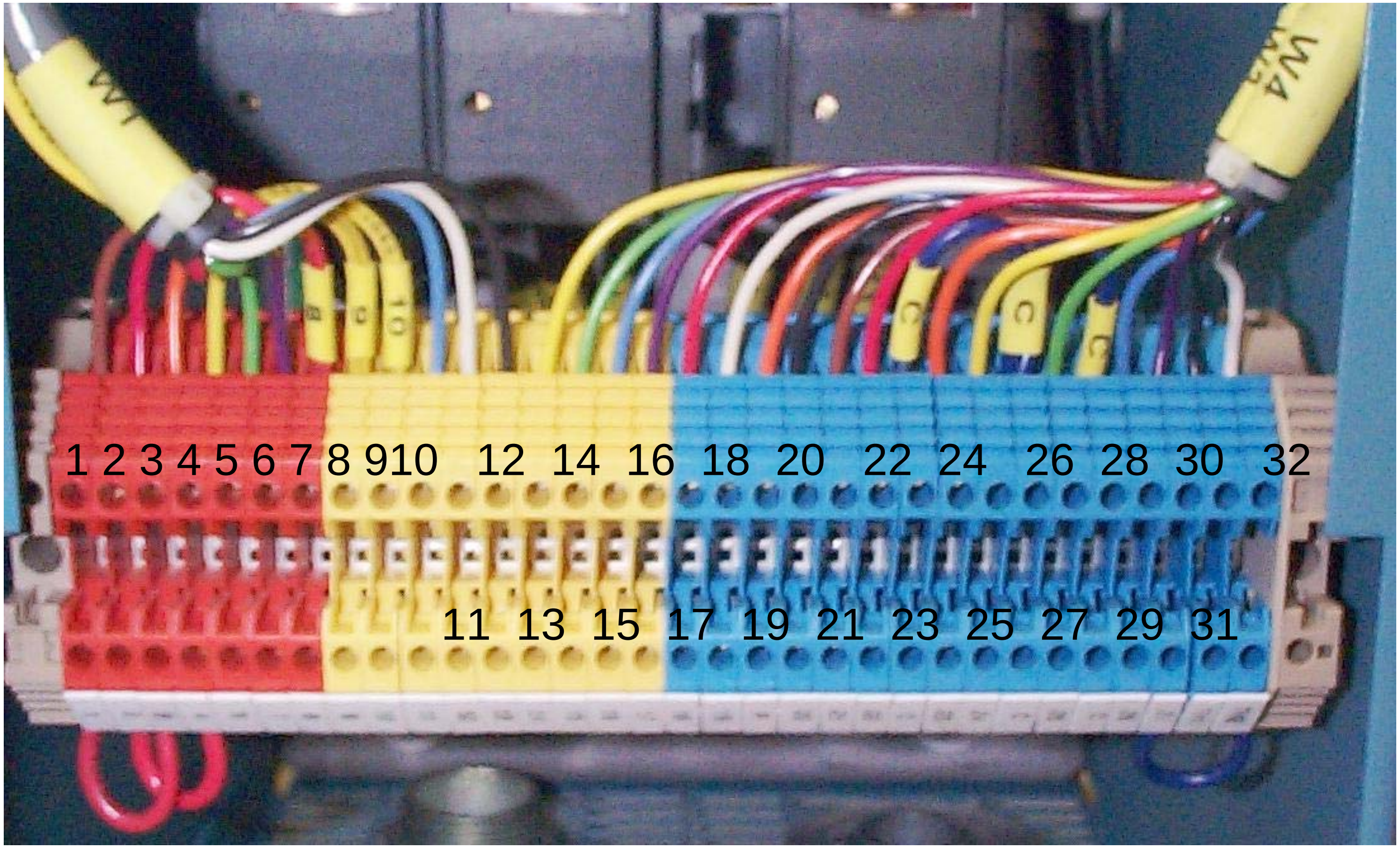
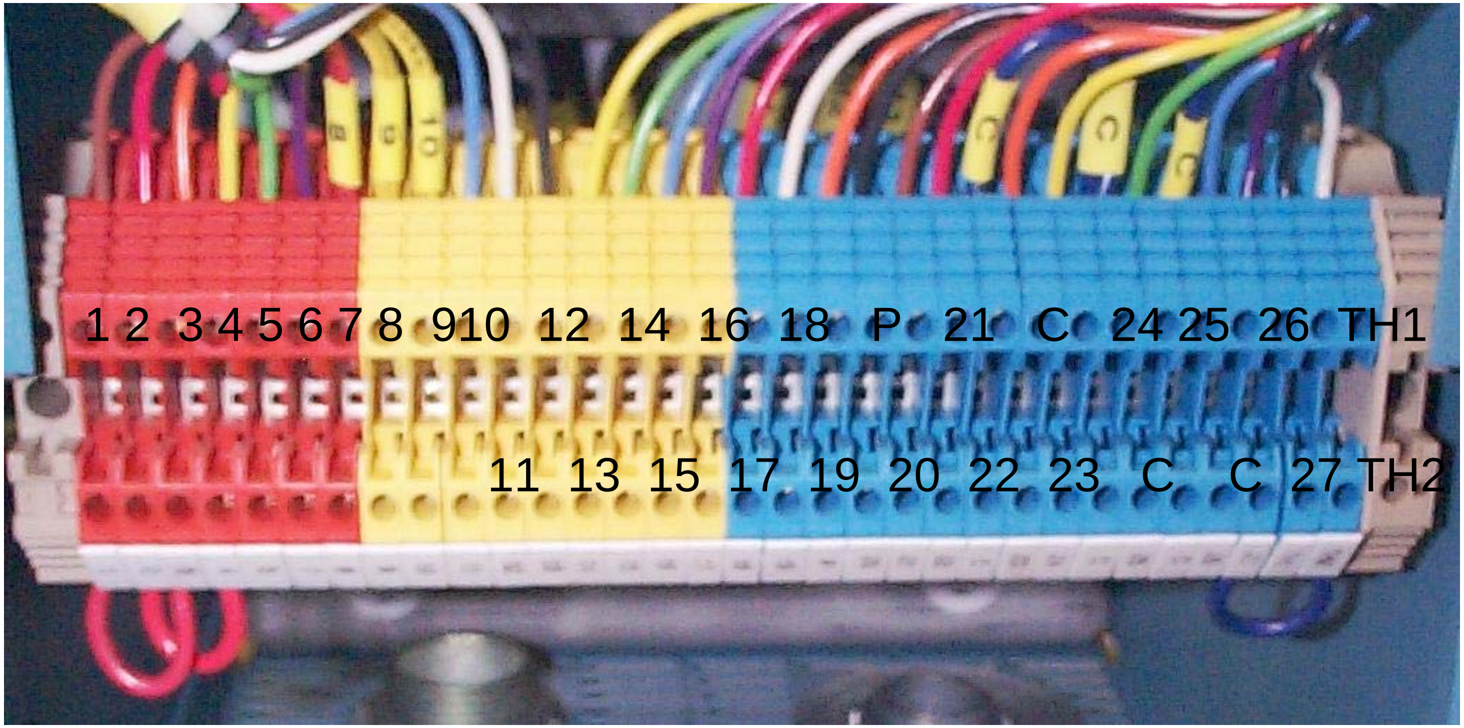
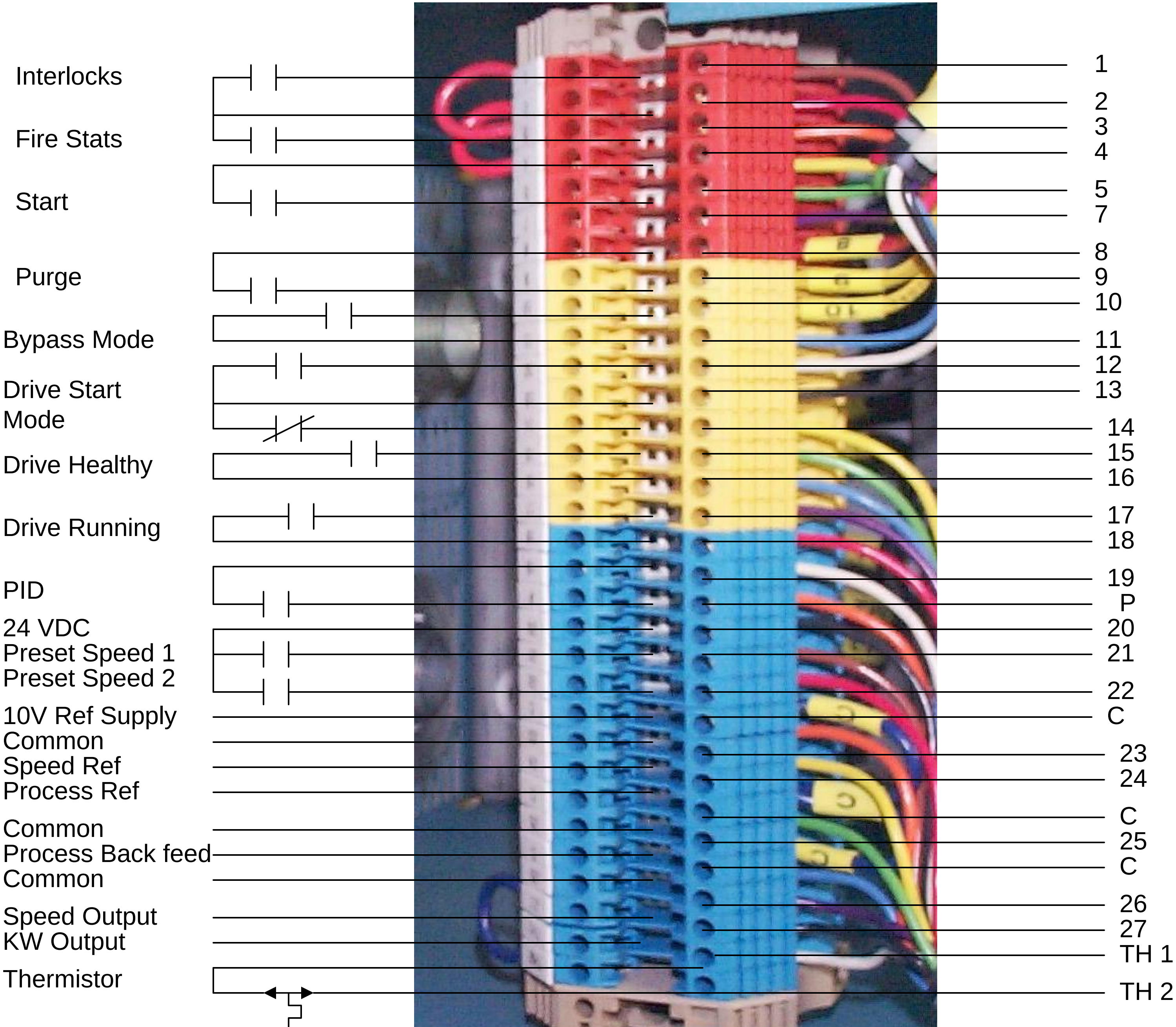


Fuse Block

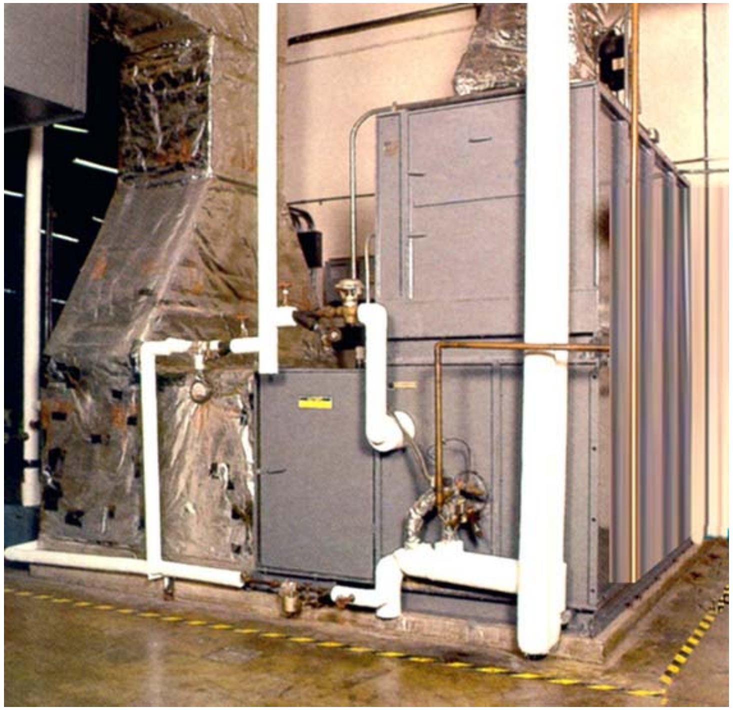
Main Fuses


1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24 26 28 30 32
11 13 15 17 19 21 23 25 27 29 31


1 2 3 4 5 6 7 8 910 12 14 16 18 P 21 C 24 25 26 TH1
11 13 15 17 19 20 22 23 C C 27 TH2


Interlocks
Fire Stats
Start
Purge
Bypass Mode
Drive Start Mode
Drive Healthy
Drive Running
PID
24 VDC
Preset Speed 1
Preset Speed 2
10V Ref Supply
Common
Speed Ref
Process Ref
Common
Process Back feed
Common
Speed Output
KW Output
Thermistor
1
2
3
4
5
7
8
9
10
11
12
13
14
15
16
17
18
19
P
20
21
22
C
23
24
C
25
C
26
27
TH 1
TH 2

...gives you more advantages



Soft Mechanical Starting & Stopping

Repeatable Flow

Building Automation interfacing

Overspeed protection

Reduced Noise

Less Maintenance Coordinated Supply & Return

Coordinated Supply & Return

Operator Panel for a Carrier VFD System

Carrier VFD Monitor Section with Display

Hertz

Percent

Seconds

KW / AMPS / VOLTS

SETUP
PROGRAM
MONITOR

UP Key

Run Key

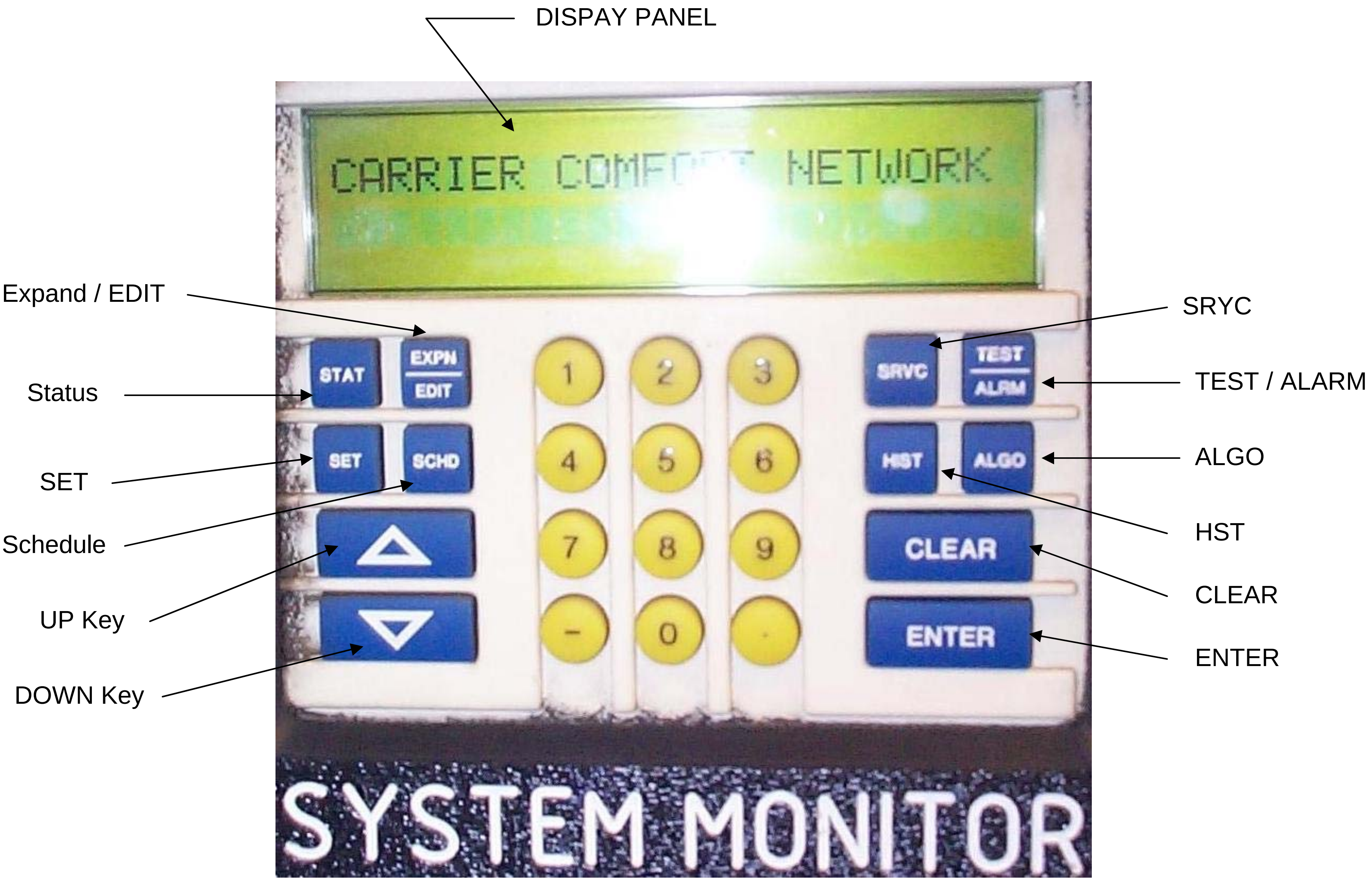
DOWN Key

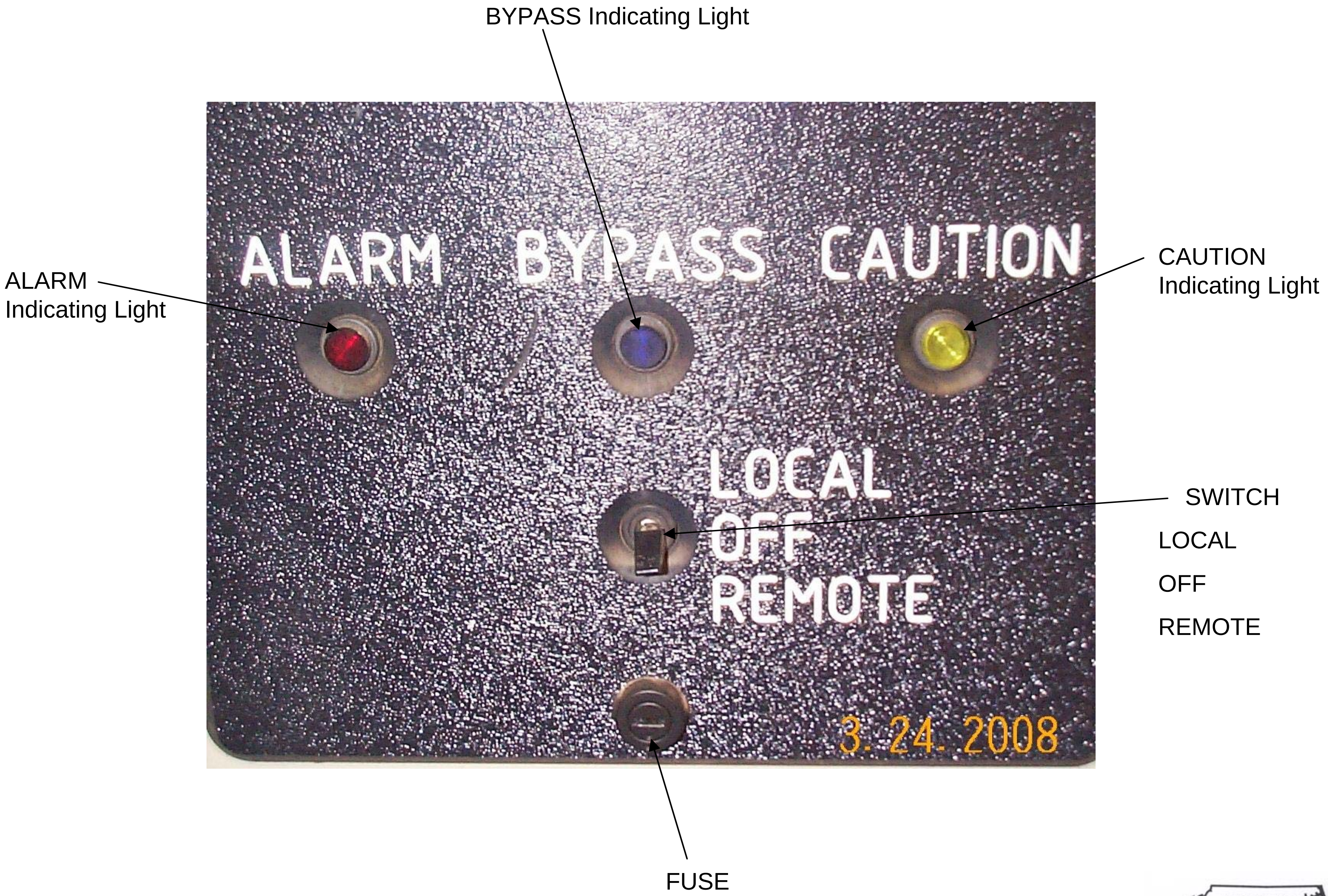
STOP – RESET

READ / WRITE

LOCAL/REMOTE
SPEED CONTROL

MANUAL/AUTO
RUN MODE


DISPAY PANEL
Expand / EDIT
Status
SET
Schedule
UP Key
DOWN Key
SRYC
TEST / ALARM
ALGO
HST
CLEAR
ENTER
CARRIER
NETWORK
STAT
EXPN
EDIT
SET
SCHD
SRVC
TEST
ALRM
HST
ALGO
CLEAR
ENTER
SYSTEM MONITOR


BYPASS Indicating Light
ALARM Indicating Light
CAUTION Indicating Light
ALARM
BYPASS
CAUTION
LOCAL
OFF
REMOTE
SWITCH
LOCAL
OFF
REMOTE
3.24.2008
FUSE

Dust on an electronic device can cause malfunction or even failure. Dust absorbs moisture, which also contributes to failure. Use cans of non-static generating compressed air since most compressed air from a compressor will contain oil and water.

Bad connection eventually lead to arcing. Arcing at the VFD input could result in nuisance over voltage faults, clearing of input fuses, or damage to protective components. Arcing at the VFD output could result in over-current faults, or even damage to the power components. Loose control wiring connections can cause erratic operation. For example, loose START/STOP signal wire can cause uncontrollable VFD stops. A loose speed reference wire can cause the drive speed to fluctuate, resulting in scrap, machine damage, or personnel injury.

Loose Connections

Arcing caused by loose output contacts

As part of a mechanical inspection procedure, don't overlook internal VFD components. Checking circulating fans for signs of bearing failure or foreign objects – usually noise or shafts that appear wobbly.

Blown capacitor

Inspect DC bus capacitors for bulging and leakage. Either could be a sign of component stress or electrical misuse.

CONFIDENCE

I've seen some people with confidence that were not good troubleshooters, but I've never met a good troubleshooter who wasn't confident. In general, the person that expects to resolve a problem is the person that will solve the problem. **Confidence:** I don't think you can be much of a troubleshooter without it.

ORGANIZATION

Lack of organization when troubleshooting will produce havoc. Wires that are removed must be marked. You must know whether or not you've already changed a particular circuit board, and when changing parts, you must install them correctly. All of us with technical troubleshooting backgrounds know that loose wire and connections are the number one reason for failures, and are careful to ensure that any connections we make or break while installing parts are properly reconnected. Same with changing programming parameters; it's a great idea to save all of the original parameters on a disc prior to troubleshooting. That way, at least, you can easily get back to the starting point. Troubleshooters must be organized.

OPEN MIND

The human mind is very peculiar organ, and we so often “see” only what we expect to see. If your “guts” tell you what the problem is, fine, spend a few moments and check it out. However, if that doesn’t do it, then you have to back away from your assumption and open your mind. Poor troubleshooters just keep plugging away, certain they’re on the right track. Good troubleshooters don’t ignore the evidence.

People that won’t take the time to learn their craft are never going to be good troubleshooters. There are no shortcuts, and experience alone, without study, usually won’t cut it. If you don’t know what an adjustment does on a machine, then don’t touch it until you learn.

Look for the simple things first. Another very peculiar human trait is to always assume the most complicated thing imaginable as the reason the machine is down. I remember the embarrassment of trying to get a system going, with my instruments all attached, my fine mind thinking high technical thoughts, using all of my great skills, and an operator strolling over and saying, “is that red wire suppose to be lying in the bottom of the cabinet?” Of course, it wasn’t, it had come loose, and that’s why the machine was down. Most electronic problems are due to loose or dirty connections… look for the simple things first. Save yourself some embarrassment.