PDHonline Course E315U (4 PDH)

2010 Industrial HVAC Control Case, Part I (Audio Version)

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2010 Industrial HVAC Control Case, Part I

Thomas Mason, P.E.

This course is being presented as the narration of a story of building a manufacturing plant and relocating the process to another site. There is an attempt to follow the "case" form, used in business school and being adopted in some engineering schools

What does he mean by "case" form ?
A long-standing form in engineering school has been to state a problem under three headings, GIVEN: FIND: SOLUTION: The form is very succinct and aids the student in focusing on the question and the data available. That is, essentially, what is being attempted in this course. GIVEN: Original industrial HVAC controls design in 1993 (with a lot of narration) FIND: 2009 HVAC controls design, using original panels and plc, but accommodating different number of fans and fan internal controls. SOLUTION: The efforts made by the designer are presented, with frequent pauses to discuss implications, enclosed in boxes, like this one. Sometimes, open-ended questions will be left for the student. EVALUATION: Not included. The scope of the project was changed substantially, after the construction documents were released for bidding. There will be a redesign, which will be reported in a promised Part II of this course.

THE 1993 FACILITY

The following chart summarizes the 1993 facility design, followed by explanation of the terms.

DESIGN 1
(1993)

EF 1-16, 3HP

9, 10 2-SPEED

SF 1-6, 5 HP

MUA 1, 2, 100HP
DIRECT FIRED

MUA 3-5, 30HP

COOLING TOWER

AC 1, 2, 350HP

PROC GAS INC SO2

PLC

HVAC CTL PNL
PUMP CTL PNL
PU HV IND PNL
4 STRIPCHARTS

H-O-A, RUN

where,
EF = exhaust fan, typical tags are EF-1, EF-2, etc. There were 16 in the first 1993 design.
EF-9 and EF-10 were two-speed motors. This gives two different rates of air flow and is discussed more later.

SF = supply fan, again tagged by SF-1, SF-2, etc. There were six in the first 1993 design. All of the 1993 SF's were considerably more complicated than the 2009 versions.

MUA = make-up air unit. By convention, this is an assembly, including heating and sometimes cooling.
Note that the 1993 MUA were BIG motors and utilized direct-fired heaters (you breathe the flue gas).

A cooling tower is an assembly which includes a big fan, a box with air slots containing "fill" which splashes the water around as it comes down, a catch tank at the bottom, at least 2 pumps and lots of accessories.

AC = air compressor. The process uses lots of compressed air and two big compressors were installed.

Process gas is a little out of the ordinary in manufacturing and deserves special controls and safety attention. Sulfur dioxide is toxic and has some unique characteristics.

The control system for the 1993 installation was based on a mid-sized programmable logic controller. None of the special capabilities of a plc were used in 1993. A hand-off-auto (H-O-A) selector switch sent at HAND signal to the plc or an AUTO signal. The plc sent a START command to the motor starter for the fan. The starter sent a RUN STATUS command back to the plc. The plc sent a RUN STATUS signal to a pilot light. There is no evidence that the AUTO position was any different from the HAND position. The only alarming was when a relay at a fan picked up a failure from a local pilot light and re-transmitted it to the plc. The plc then retransmitted it to an alarm light on the control panel. There was no horn or any of the normal annunciator features.

There was a big HVAC control panel. It had lots of selector switches and lights.

There was a big pump room control panel. We will look at it just a little, but not study the controls The pump room control panel included the cooling tower, tower pumps and air compressors.

There was a very big pump and HVAC indicator panel. The indicator panel was located outside the control room which contained all the control cabinets for the process machines.

The very big pump and HVAC indicator panel contained four z-fold stripcharts. Each stripchart had 3 channels and alarm relays for each input. The alarm relays were sent to the plc for relay to inciator lights.

What distinguishes the first 1993 controls design from what we will call the 1994 design is the use of H-O-A selector switches. Watch this line on the summary closely.

What would a controls design engineer do differently?
First, we must readjust our minds to the 1990 decade. The 1980 standard was to buy motor starters with a H-O-A selector and run status light on the door of the starter. The starters were grouped in a motor control center (a wall of the room or three or four rows of motor control centers down the middle of the room). Remote lights were operated by large bundles of wires which went to the control panel. Remote automatic start-stop and duplicate control stations were handled by large bundles of wires to the control panel also. This 1993 design was exactly the same, but it utilized latest available technology and had the advantage of easily being upgraded to complex control logic inside the plc and other plc functions being talked about in manufacturers' press releases and seminars.

It was a good design of the time and a bit innovative.

Except, there was no packaged annunciator or annunciator function within the plc.

A controls engineer is supposed to be a member of the Instrument Society of America (ISA), or at least read magazines on controls. A big advertiser was PanAlarm, maker of packaged annunciators.

An annunciator does not report run status, only trouble. In the simplest form, it is a row of lights and associated warning tags. When a light goes on, the operator reads the tag to see what the problem is. An annunciator always has a horn and flashing light. An annunciator has several other significant features, including, lamp test, latching on first-out, silence and reset buttons, continuing light until corrected and reset and re-flashing on second instance of an existing alarm.

These advanced features are near-universal and defined by ISA sequences.

Notice this detail, because it is one of the differences between Design-1, Design-2 and the photographs.

THE 1994 REVISION

Remember, we are writing the story in 2010. The people from 1993 and 1994 are not around any more. All we have is the construction documents they left behind.

When I got this assignment, I was given a book of drawings, most labeled, “As-Built”. Interestingly, the controls logic diagrams were also marked, “VOID”, and incomplete, unissued drawings of controls logic were appended to the end of the set.

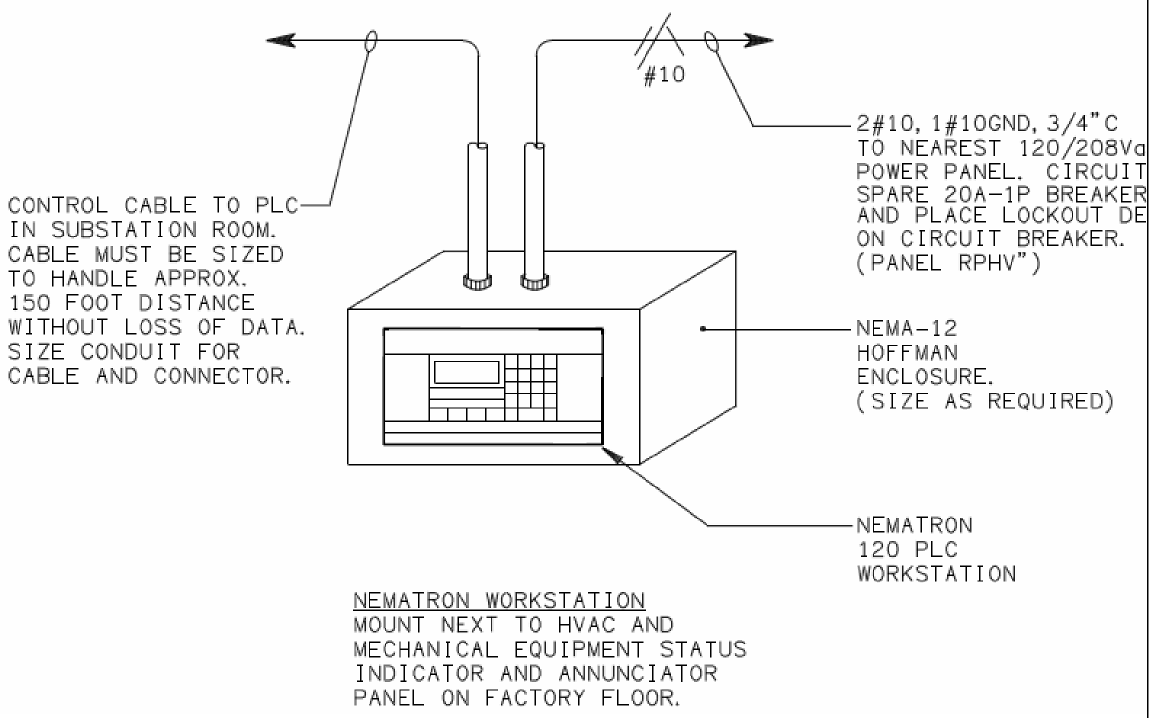
Below is a summary of the 1994 situation, along side the 1993 situation:

DESIGN 1 (1993)	DESIGN 2 (1994)
EF 1-16, 3HP	EF 1-16, 3HP
9, 10 2-SPEED	9, 10 2-SPEED
SF 1-6, 5 HP	SF 1-6, 5 HP
MUA 1, 2, 100HP DIRECT FIRED	MUA 1, 2, 100HP DIRECT FIRED
MUA 3-5, 30HP	MUA 3-5, 30HP
COOLING TOWER	COOLING TOWER
AC 1, 2, 350HP	AC 1, 2, 350HP
PROC GAS INC SO2	PROC GAS INC SO2
PLC	PLC
HVAC CTL PNL PUMP CTL PNL PU HV IND PNL 4 STRIPCHARTS	HVAC CTL PNL PUMP CTL PNL PU HV IND PNL 4 STRIPCHARTS
H-O-A, RUN	ST, SP, RUN
	NEMATRON

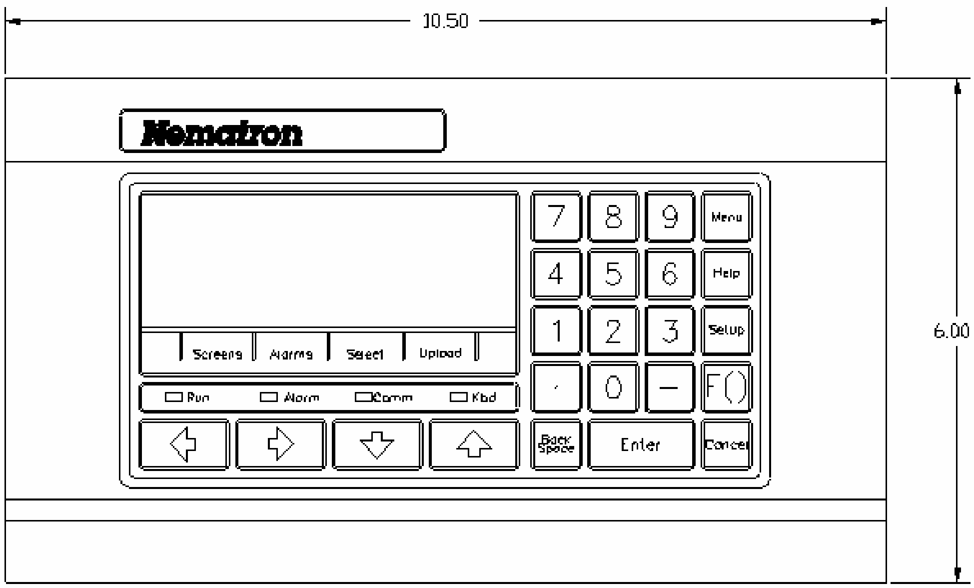
where the changes are,
H-O-A selector switches have been changed to Start-Stop pushbuttons and a "Nematron" was added.

There was a warning phrase in the text above about "VOID" sheets and unissued sheets. The set was internally consistent, though. The H-O-A selectors were on the VOID sheets and the panel fronts showed Start-Stop buttons and matched the unissued logic sheets.

What is a "Nematron"?
The only information in the 1994 construction set was an 8-1/2 x 11 addendum sheet with the drawing below:



I was able to get product information on the Model 120 at the Nematron website, as follows:



A Nematron is the brand name of what we now call an Operator Interface Terminal (OIT) or PanelView (Allen-Bradley brand). It reads values from the plc operating registers and can act as buttons or lights to the plc.

The pictures indicate that the Nematron was never purchased or installed.

Let's get a little out of order on the story now. When I got the assignment, I studied the "As-Built" drawings of the original design and the current HVAC design. As I was instructed, I updated the "As-Built" set to the current needs. I did not know about the photos.

Let's look at the photos. First the HVAC Control Panel, which houses the plc.

It is clear that there are many groups made up of a selector switch and a light. These are all the fans and HVAC equipment in the project. The few three-device groups at the top are trouble lights indicating a burner failure or dirty filter.

The "Lamp Test" button at the bottom is not on any of the construction documents. The only way to do this is to program the plc to force on all of the indicator light outputs. Individual push-to-test lights are available but no group-test light are available for 120VAC.

The use of selector switches means that the Nematron could not turn on or off individual fans. A pushbutton is momentary and a different pushbutton can give the plc or starter a different command. But, a selector switch is continuous and not amenable to multiple control stations. (In fact, there are spring-return selectors, like an auto ignition, but they weren't used here.)

There are two more important points to get from this picture. First that's a lot of fans. The number "27" sounds like a lot of fans, but seeing buttons for 27 fans is more impressive.

Second, some of the selectors are in the "Off" position and the light is on. This tells us that the plant is very good at replacing indicator lamps. (Bulbs burn out and don't get replaced unless someone orders them and puts them in.) This also tells us that something hinky is going on. Not just one or two, but many switches are in the "Off" position and the light on. Since the plant needs the fans to run, I suspect the lights are right, more right than the ones that say the fan is not running. I don't have an answer for this and it is disturbing.

Now, let's look at the Pump Room Control Panel.

These are groups of three lights, "Off," "On," and "Trouble". The middle four items are the two cooling tower pumps, the cooling tower fan and a heater for the catch tank. The other groups are process pumps.

The center light is "Common Trouble" and the button is "Lamp Test". The center functions are plc and not on the "As-Built" drawings.

This brings us up to the very large indicator panel. The formal name is Pump Room Indicator and HVAC Annunciation Panel, even though it appears to have no genuine annunciator functions beyond run status.

Notice the z-fold stripchart recorders along the top. Each displays three process variables and records each with a different color ink. These give a marvelous insight into what is important to the Client and to the plant operators. The stripcharts themselves each cost as much as a plc. The paper is a major continuing expense and it is a serious bother to keep the pens working and the windows clean. They made the original investment and the continuing investments to keep them running.

The inputs are called process variables but, in this case, they are header pressures, and cooling tower temperature.

What is a “header”?

When you generate steam to run a plant, you pipe all of your boilers into a manifold and distribute from the manifold. The manifold is a shared place to keep track of the pressure, which is the prime measure of how satisfactory the steam service is. (Carry-over solids is a quality measure which also has a corresponding measure for other process fluids. The easy way to measure other-than-water in steam is by pH of the condensate return.)

The distribution manifold is commonly called the steam header.

The same terminology is used on the main high-pressure and low-pressure manifolds or supply pipes in the plant. It is good to monitor these pressures with pressure gauges and recorders. The quality of utility-supplied natural gas is usually not suspect and not monitored.

These are the natural gas headers and two more inputs for the stripcharts.

The remaining indicators and recording channels are dedicated to compressed air, process gasses and cooling tower temperature.

The bottom photograph shows rows and rows of indicator lights, almost all of which are red and represent an operating problem. The white lights also represent trouble indicators, without higher or lower priority. The lights are from individual field switches or relays attached to stand-alone control panels.

Why two control panels and a very large indicator panel?
The HVAC Control Panel was in the electric room, next to the HVAC motor control center. The Pump Room Control Panel was in the pump room, next to the pump room motor control center. The very large indicator panel was on the plant floor, just outside the process control room

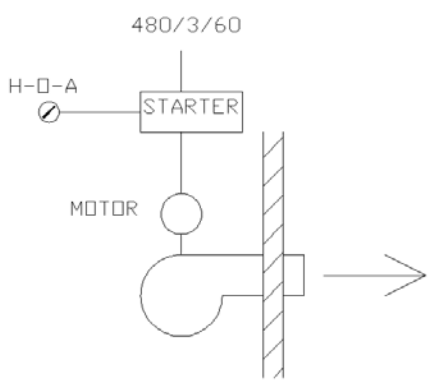
THE 1993 HVAC CONTROL SCHEME

In 1993, electrical designers had to know how HVAC equipment worked. The electrical designer created the logic diagrams and instructions for contractors to install the wires. The electrical designer had to answer field calls and visit the site to get the HVAC operating.

Today, these functions are handled by HVAC designers, unit manufacturers responding to mechanical specifications and temperature control contractors (TCC), also responding to mechanical specifications.

A TYPICAL EXHAUST FAN (EF)

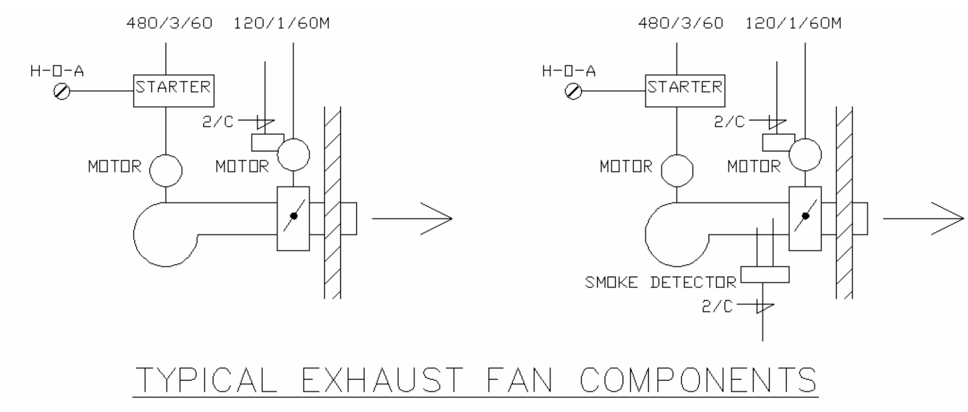
The following sketch begins our detailed discussion of exhaust fans:



EXHAUST FAN

This is representative of a very common form found in industrial and commercial occupancies. The fan is on a steel frame, bolted to the outside wall. It has a motor, either direct-drive or belted. The power wiring goes to a starter with a Hand-Off-Auto selector switch in the door. In very small sizes, the motor is 120 Volts and the starter is a special off-on switch in a wall box. Also, many small exhaust fans are self-protected and don't require an external starter, just the wall switch (disconnect).

This sketch represents the exhaust fans we have been talking about. But, it is not accurate for 1993. In 1993, someone in charge decided that exhaust fans must have powered duct dampers to lock out outside air when not in service. This may have been the result of the climate where the process was originally installed. The first sketch following illustrates this:



Please visualize, for a moment, a 3HP industrial exhaust fan. It converts 3HP of energy into mechanical force to move air. To overcome this force a motor is required to open the duct damper. Because of the force involved, it is better to open the damper first - before serious friction is created and then use a limit switch to permit the exhaust fan to come on.

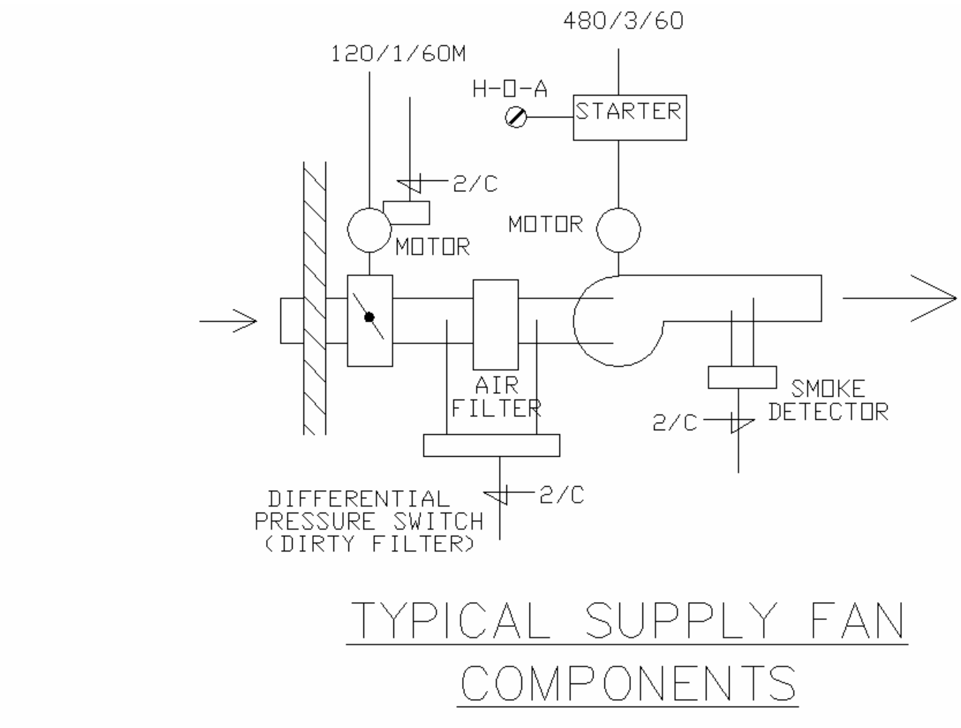
There are a range of ways to accomplish this, including gravity dampers that use some of the fan force to hold the dampers open and local logic on the fan power circuit. The most common 1980 method was to power the damper motor from the motor starter and use the limit switch in the starter circuit to inhibit the exhaust fan until the damper was full-open.

The 1993 method in the original plant installation was a hybrid of this and the plc, which we shall study in some detail.

The second, even more complicated sketch above is a 2005 standard detail from a major international engineering firm. I don't know why they have a smoke detector in the exhaust fan duct. The designer working on my project didn't know. The Chief Mechanical from the branch I was working with didn't know. No one was willing to contact Corporate and ask. We put in several hundred exhaust fans in water treatment plants, each with a smoke detector. (Water treatment plants are concrete and water, with just a little steel. There is something humorous concealed here, but the story is true.)

Errata: Missing disconnect safety switches on fan power leads.
In 1993, it was the duty of the electrical designer to provide a disconnect safety switch in the fan power leads, right at the fan. When the fan size changed, the electrical had to make sure his wire size and switch were big enough for the new fan. This was a critical safety item and a favorite Change Order request from the installing contractor if missed. In 2009, exhaust and supply fans are ordered with factory installed disconnect safety switches. It is the duty of the electrical designer to verify the HVAC ordering information, usually contained in a note on the HVAC Equipment Schedule sheet. Since it is now internal to the fan, I have not been showing the disconnect safety switch on these sketches.

A TYPICAL SUPPLY FAN (SF)
The following sketch begins our detailed discussion of supply fans:



The sketch shows exactly what was specified and installed in 1993. In 2009, there was no air filter, no differential pressure switch around the filter to indicate dirt build-up and no smoke detector. The inlet damper motor and end-of-travel limit switch remained.

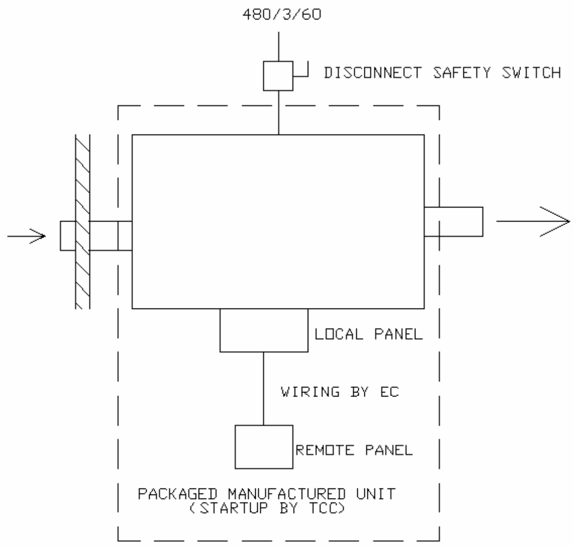
I think the extent of the annunciation system in 1993 now becomes more reasonable. They had six supply fans and five MUA, each containing filter alarms and smoke alarms, handled by the electrical controls. That is a lot of lights, but also, a lot of interconnecting wiring if they hadn't used the plc.

By the way, it was mentioned in passing, previously, that many different arrangements of fan components are commercially available and even more through field fabrication. The sketch shown is typical and representative of approximately 95% of the installations observed close-hand by your author.

Why invest in alarm lights and annunciation?
Alarm lights and annunciation are fairly recent innovations. I was in charge of HVAC controls maintenance for a large state university in the 1990's. Most of the buildings were from the 1950's and 1960's, or had HVAC renovations then. The standard installation had exhaust fans with local controls and large air-handlers, similar to the MUA's we will discuss next. The large air handlers each had one or more motor starters hanging on the wall and individual remote limit switches, pressure switches and thermostats. No indicators or annunciation beyond occasional strips of ribbon hanging from air supply registers. While I was in HVAC controls maintenance, I found three "lost" fan rooms, that had tripped out on one of the safeties, not been recognized and not been reset. Obviously, the filters had not been changed in many years, but that was also true of many of the fan rooms still in service.

A TYPICAL MAKE-UP AIR UNIT (MUA)

The following sketch begins our detailed discussion of make-up air units:



TYPICAL 2009 MAKE-UP AIR UNIT COMPONENTS

As best I can tell, the 1993 and 2009 MUA's were very similar. However, in 1993 the electrical designer had to run wiring and provide logic for the big fan, the direct-fired burner (and safeties) the filter and differential pressure switch and any other accessories provided. In 2009, the unit was specified with "single-point power" and all accessories and controls provided by the unit manufacturer.

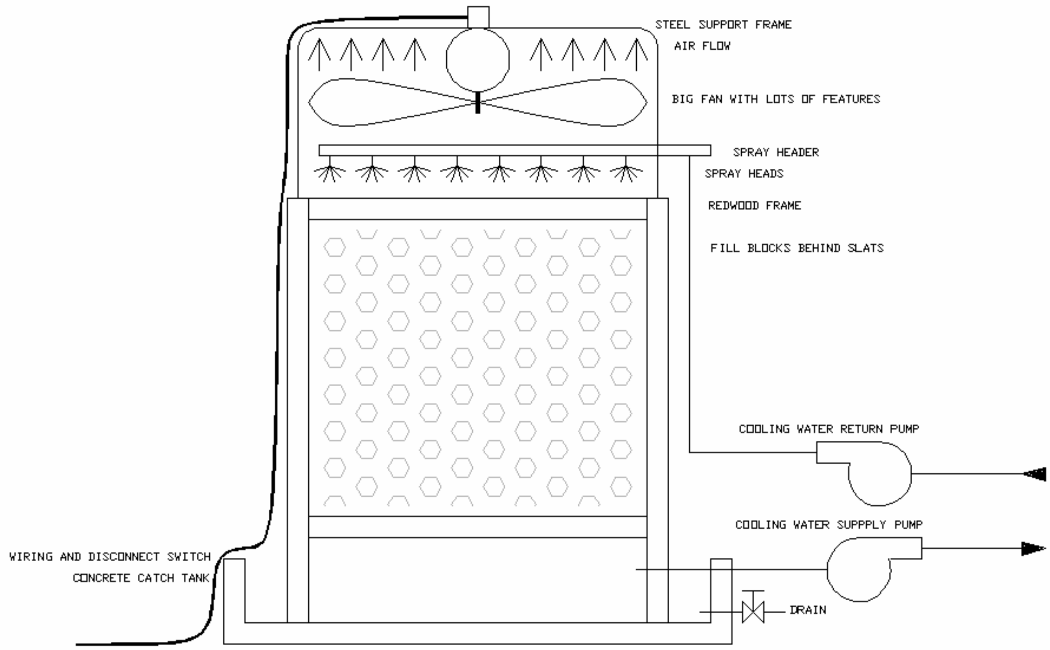
The Client, however, still wanted centralized alarms on unit failure, burner failure and dirty filter. The electrical designer responded by giving the electrical contractor a scope requirement of installing auxiliary relays on the MUA controls to report to the annunciation panels. The mechanical designer was hiring a specialized Temperature Controls Contractor (TCC) to handle details of the installation and the TCC was to help the EC with the annunciation task.

How to connect an auxiliary relay to controls packaged on a MUA?
First, we must recognize that the MUA is being bid against a very "thin" specification. That is, noting about the controls was specified. If it is cheaper for the successful bidder to use relays internally, he will. If he chooses to use a shoebox plc, he will. If he chooses to use a unitary HVAC controller, he will. The electrical contractor probably won't know until the unit is delivered. No one provides auxiliary contracts for status and alarms. Obviously, he has to bid his services at least six months before this time. The 1993 way to meet this requirement was for the electrical contractor to purchase some relays, relay bases and fairly large metal boxes. His men mounted the relay bases on a subpanel in the box, brought coil and contact leads to a terminal strip on the subpanel. Then his field people punched holes in the box for conduit entry and ran conduits and wires to the MUA controls and to the PLC. In 2009, there is an extremely economic, parsimonious purchased component that simplifies this task to the field connections only. It is called a Relay-In-A-Box. It is an encapsulated relay with coil and contacts conductors exiting through a conduit fitting. It can be mounted directly to the MUA control box or to a deep 4x4 junction box near the MUA control box. The hard part is getting a coil to match the indicator lights on the MUA control box. (See the Reference Links section for contact information for Relay-In-A-Box.)

A TYPICAL COOLING TOWER (CT)

Tragedy - Cooling towers have changed.
In 1993, people were still maintaining redwood cooling towers. The frame and slats were redwood, because it would survive twenty years or more of service immersed in water, with freezing and thawing. It was easy to un-bolt a connector and remove a damaged piece and replace it - more llike Tinker toys than Lincoln Logs. The 1993 purchase for the process was steel, also with a promised life approaching 20 years, but not component replaceable. Yes, you could buy a new fan or fan motor and you had to buy new pumps, but the enclosure and structure were throw-away. In 2009, the new cooling tower will be fiberglass. The structure and airways will last 20 years and more, but the steel that connects the pieces will begin rotting away after 10 years and cause serious problems by 20 years. Even though intact and still beautiful, it will be throw-away. This is because renting a big crane for $10,000 is less expensive than maintenance for 10 years.

A sketch of a typical 1950's cooling tower follows. The internals of a steel or fiberglass unit should be similar. Smaller cooling water demands today often use glycol-water mixture and a closed system with a fin-tube heat exchanger outside instead of a cooling tower.



TYPICAL 1950's COOLING TYOWER COMPONENTS

These are the basic components, the structure, the fan, the water circuit, the water pumps and the drain. Not shown are the accessories to permit it to operate in freezing temperatures. Not drain and survive, but keep working and delivering cooling water at the same temperature as in the summer.

This was the first general application of variable frequency drives. It had always been a problem to maintain cooling water supply temperature in the face of changing outdoor temperatures and outdoor humidity, which greatly affects cooling water efficiency. With the availability of variable frequency drives, you just connect a cooling water supply temperature transmitter to the PID control built into the variable frequency drive and the problem is gone. Obviously, there had been high-temp and low-temp alarms before and they were kept. One of the stripcharts in the present installation is cooling water supply temperature.

But, variable frequency drives came in the 1970's. What did they do on the example 1950 cooling tower? DC drive?

No, no, no. DC drives have always been a really big hassle. You don't want to adjust commutator brushes while wrapping your legs around the structure at the top of a cooling tower. Instead, there were a range of multiple speed motor configurations and more and more complicated motor starters to start and run them safely. I had a book of twenty pages of motor starter control circuits for cooling towers.

In addition, cooling towers in below-freezing temperatures usually had momentary-reverse operation to break loose and shake off the ice.

Is the process continuous 24/7? If not, the controls must accommodate shutdown or minimum operation in the coldest part of the night. Heat trace (heating wires wrapped around pipes) was standard and catch tank heaters were common. You must alarm on heat trace failure and one of the stripcharts in the current example was for catch tank temperature.

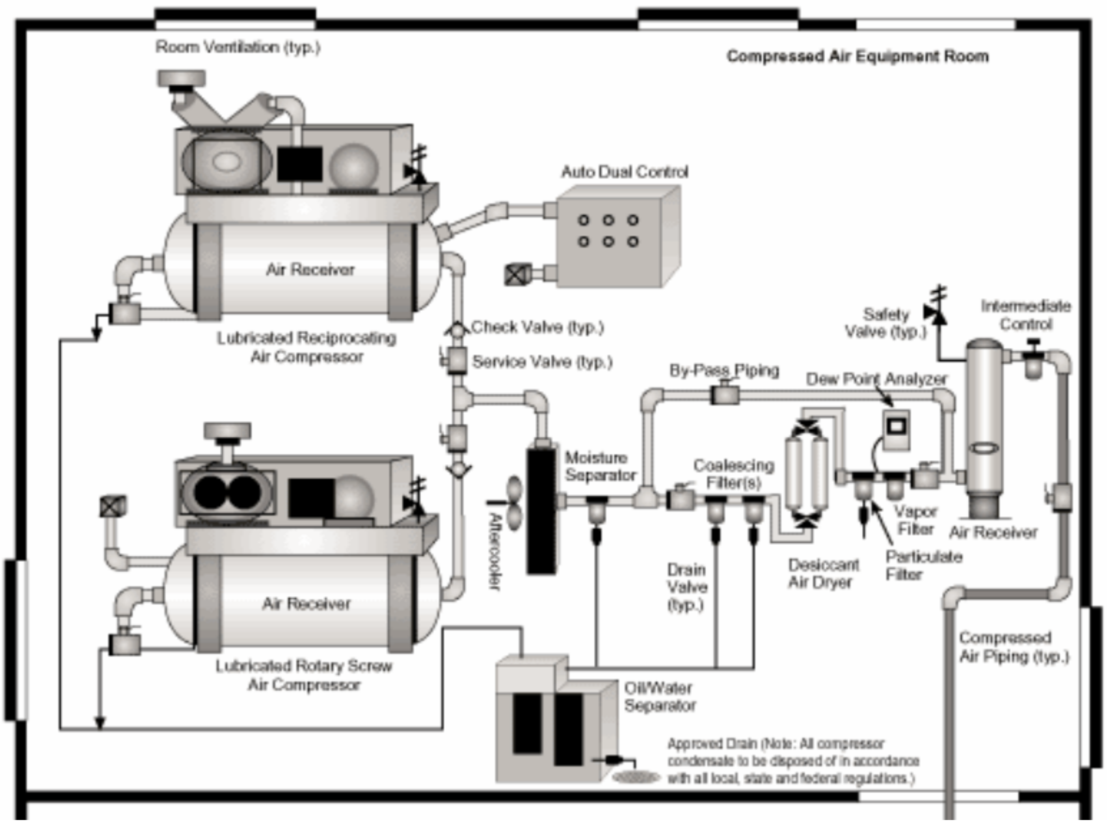
Trick question: does electric heat trace keep the water-filled pipe from freezing?
No. Electric heat trace with substantial insulation keeps the water-filled pipe from freezing. The electrical designer pays a lot of attention to the selection and installation of heat trace - especially fancy wrapping techniques at valves and in-line devices. It doesn't work, though, unless similar care is applied to the tightness of the pipe, the details of the insulation installation and the metal or plastic protective shell around the insulation.

The 2009 cooling tower for this process is being selected by the Client, possibly to supply other processes. I believe you now appreciate the incentives to switch from an open system to a closed, glycol-filled system. A packaged system is planned, with all the design choices being made by the manufacturer, to meet the performance requirements. As mentioned on the MUA, previously, the installing electrical contractor has been tasked with adding auxiliary relays to bring out alarms to the central annunciation panel. The temperature transmitter and stripchart recorder, with temperature alarms, will also be relocated to the new site.

A TYPICAL PLANT AIR COMPRESSOR

In the 1950's, you bought an air compressor and each of the accessories you needed. By 1993, it was a packaged unit, though all the components were exposed. The manufacturer made all the sizing and materials decisions in order to meet performance specifications. In 2009, it was still a packaged unit, but there was a shiny painted enclosure with a window to see the controls. The shiny painted enclosure helped meet OSHA workplace noise limitations.

The following sketch reports the components of a small plant air compressor:



Source: http://www.fluidenergy.com/images/03_LubCompDes.gif

Where,
The compressor is shown as an integrated unit mounted on top of the air receiver.
Note the sound enclosures.
Two complete, independent compressors are shown.
There is a silencer on the compressor air intake.
The compressor has a regulator (not shown) and an ASME relief valve on the line to the receiver.
The receiver has an automatic water drain and a diaphragm emergency relief.
The two compressor systems are manifolded with check valves so that both can be online normally.
The manifold is followed by an aftercooler with a fine moisture separator.
The aftercooler is followed by a precision dryer with several other filters and instrumentation. This can be bypassed to keep the plant on line if it gets finicky.
The compressor manifold and clean-up devices are followed by the major plant air receiver, with another ASME relief and another inline filter.
Not shown is the fact that the compressors operate at 150-200psi and the plant system usually runs at nominal 100psi. There will be individual filters, lubricators and regulators at each machine or tool. Machines and tools typically require 60psi.

The question for the controls designer is, “What items deserve annunciator alarms?” Typically, high discharge header pressure, low discharge header pressure and filter bypass (a limit switch on one of the bypass valves). A water level switch in the first receiver sounds like a good idea, but I haven't seen them installed.

The reasoning is that, when you have a machine or process problem, you want to see if it was preceded by a compressed air problem. A latched alarm gives you gross indication that something was going on, but a stripchart is better and an alarm log, with time-date stamp to a fraction of a second is best. The limitation of the stripchart, beyond constant attention to pens and paper, is the slow speed, precluding precise timing to the minute. This brings up the first and second major questions of the 2009 re-design (RELOC-2) and the future 2010 HMI design.

First question: Can we duplicate the stripchart function in the plc? The cost and hassles of the stripchart are substantial, but the value is real. Same value with no incremental cost makes the designer a hero.

Second question: Can we get an alarm log, with time-date stamp to a fraction of a second from the plc? This is extremely valuable information that was not available previously. Again, the no-cost feature marks heroism.

THE NEMATRON, 1994 (DESIGN-2) AND 2009 (RELOC-2)

We are speculating that the revision between 1993 and 1994, which added the Nematron, had a justification for the engineering time and capital cost. The first speculation is that the addition gave the Control Room operators better insight into the HVAC and Pump Room operations. Also, it gave an operator who had a password, the capability of changing the facility operation from just outside the Control Room.

It is also certain that the designer was thinking of storing alarms in the plc and using the Nematron to display them, with time-date stamp. Similarly, the capability existed to store a series of values of header air pressure, for instance, and bring them back after an upset. In 1994, this was possible, but difficult. The difficulties were in the lack of provided routines for the functions and the very, very limited memory in the plc.

The 1994 Model 120 Nematron did not have alarm log or trending capability. It was a kludge, and never implemented.

The 2009 Nematron is advertised as including alarm log and trending capability. Unfortunately, no one at the Nematron representative or home office knows anything about it. Before the HMI scope change landed, the secret plan of the RELOC-2 controls designer was to specify an OIT which included alarm log and trending and to include the OIT programming in the expected plc programming work. How this works out is the story promised in Part II of this course.

MONITORING PROCESS GASSES AND SULFUR DIOXIDE

They are called process gasses because the process needs them to produce good product. That's why the original design included stripcarts for pressure and alarms for high-pressure and low-pressure for each. Sulfur dioxide is special for two reasons - in large quantities it blocks the sense of smell, then kills you.

Blocking the sense of smell is important to the industrial hygienist and to the controls engineer because it argues against the intuitive response, "We will smell it and get out of there." No the first breath of concentrated SO2 blocks the smell capabilities. It doesn't kill you immediately, but you need to know you are in trouble to know to get out of there. This is the reason for the toxic gas alarm which is needed for this process, but not present in 1994 or 2009

It is a controls engineering responsibility to get a written statement from the Client that they don't want a SO2 alarm.
Is there a question regarding the toxicity of SO2? Is there a question regarding the quantity available for sudden release? Is there a question regarding the block-smell feature of SO2? Is there a question about commercially available toxic gas alarms? Is there a question of this effort restricting future design contracts with this Client?

RELIABILITY OF LARGE CONTROL PANELS, OPERATOR INTERFACT TERMINALS AND HUMAN-MACHINE INTERFACES (PC-HMI)

Experience indicates that large control panels, fabricated of steel enclosures and heavy-duty oil-tight operators last almost forever. The components do not wear in any noticeable fashion. However, the nameplates change to felt marker notation and the lamps are always burning out.

It is not uncommon to have additional buttons and lights added by sloppy field installation or in another steel box bolted to the side of the first.

Large control panels have operated American industry for the 60-years I have been making observations and on historic installations back to the 1930's. (I see a lot of open switchboards in use before then. Don't ask.)

Nematrons and OIT of competitive manufacturers, especially the Allen-Bradley PanelView, were introduced shortly after the plc. People noticed that an awful lot of plant operation could be done from the programming console. This operation and initial adjustments were done during commissioning. Why not find a reliable way to make a restricted form of plc access available to plant operators?

The early OIT were easy (but tedious) for plc programmers to setup and change when they changed the plc program. They were not easy for plant maintenance to update. The big problem was the "point list". The nature of computers (both plc and OIT) is to handle numbers. Field device contacts, coils, etc, are connected to output and input points of the computer. Each gets a unique number for internal processing. The "point list" relates the English name and perhaps tag number of the field device to the input card terminals and to the internal number used for plc stuff. Tolerable, if you have a fairly good memory.

The early OIT had a new point list, relating the input numbers, the plc calculated numeric storage registers and the English name and perhaps tag number. Until very recently, it was necessary to convert among the point lists. The numeric names had to be typed; cut-and-paste didn't work and drag-and-drop hadn't been invented.

Keep in mind that the early OIT were as reliable as the plc and had no disastrous failure modes. They died gracefully - just quit working. It was common to have more than one in different locations and easy to duplicate the configuration on a replacement unit, available locally or air-freighted from the factory.

HMI is the sexy version of HMI. It has a bigger, better computer and more memory, usually a much larger screen and often, touch screen operation. It does not have the reliability of a plc and there is a problem with having duplicate machines online together. The manufacturers insist on a master-slave arrangement. This means that when the master goes down, the system goes down. The standby HMI must be reprogrammed or reconfigured as a master. This is not something your want the third-shift operator doing.

The IT-centric version of the HMI is the HMI server. Everything looks like an OIT or HMI installation. The plc runs the fans and pumps and compressors and such. The control system talks digitally with the plc and extracts values from input points, output points and register values. It can provide input commands and enter register values as recipe targets or whatever.

The HMI server is a first-class computer, almost always in the information technology (IT) kingdom. Remote HMI client pc's get input and output and register information from the HMI server. The remotes can send commands and recipe targets. There can be many remote clients, and even internet browser access.

In addition, the HMI server nicely links to a corporate database. It is convenient and valuable to make available data for monthly EPA reports, EPA disturbance reports, daily, weekly and monthly operations reports. In fact, corporate or contract engineers can access the HMI server with little chance of causing a process upset, but doing historic troubleshooting.

Some view the major benefit of the HMI server that it is in the IT kingdom. Only authorized IT technicians have access to the hardware and software. Depending upon who has responsibility for the EPA reports, this may be a good thing. IT certainly has well-honed skills in protecting turf and balancing then eeds of management, operations and maintenance.

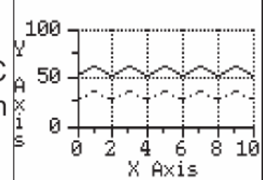
Please check your personal experience with corporate e-mail responsibility before endorsing HMI over OIT.
Or, better yet, let the chains of management make their best decisions, but insist on OIT for backup.

ADVERTISEMENT FOR PART II OF THIS COURSE - 2010 PLC AND OIT

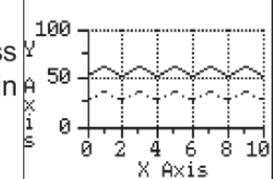
The preceding discussion OIT vs HMI leaves a large amount of ambiguity. What do you believe? What is real? Are the alarm log and trend charts on an OIT usable and valuable. Are they easy to configure? Can an OIT provide a good indicator and control vehicle for this industrial HVAC system?

Rather than talk more, your author has taken on the personal task of programming a 2010 plc and 2010 OIT. This became possible when a major manufacturer introduced a newest-and-greatest plc with large memory and remarkably low prices and free programming software which runs on a home laptop. For a little more, you can get the newest-and-greatest graphic touchscreen OIT with free configuration software. The supplier claims they share a common point list. The OIT live and historic trendchart and panel meter functions are reproduced below from the configuration manual.

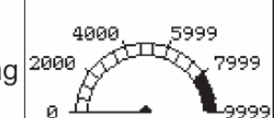
The **Real Time Graph** object displays the value stored in up to two PLC tags, over a history of up to 24 points each. One point is added at each refresh.



The **Line Graph** object displays the values of up to 24 PLC address points. Up to two address arrays can be displayed. The line is drawn in its entirety at each refresh.

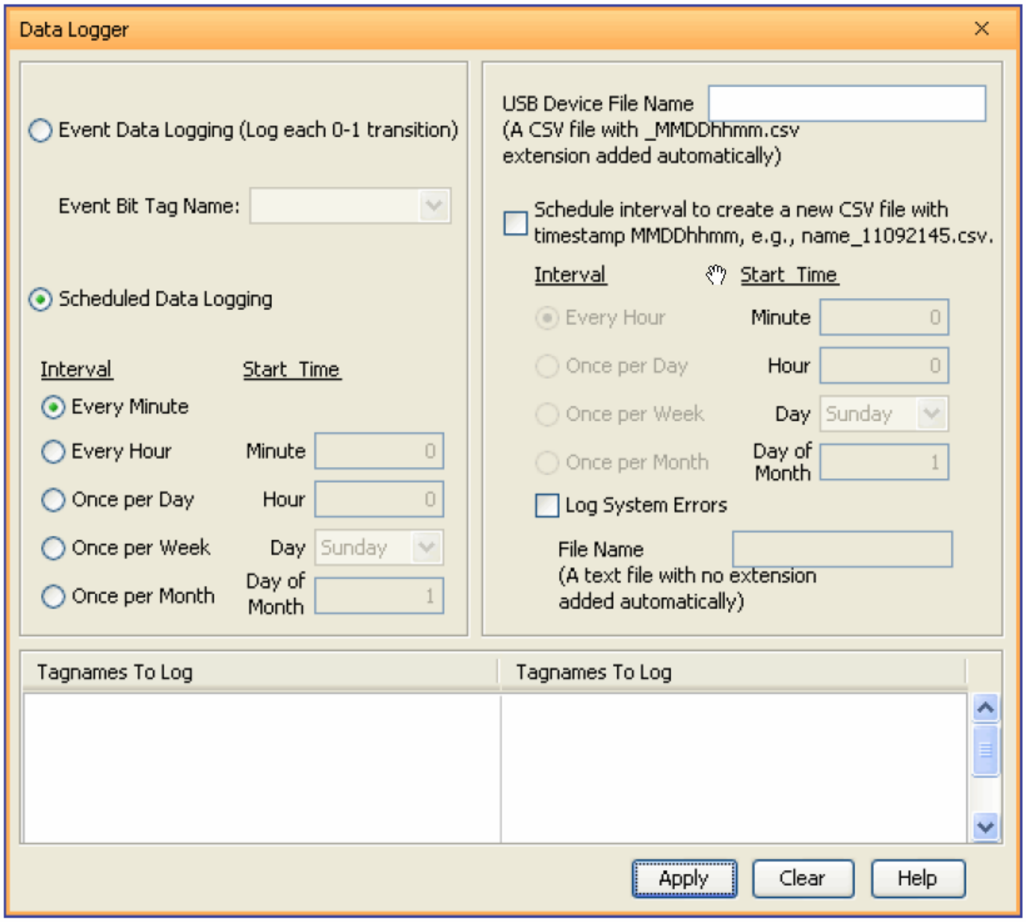


The **Analog Meter** object is used to display the current value of a Tag Name.



Source: Automation Direct C-More Manual ea1tclm.pdf

In addition, the plc contains a built-in function to store selected alarm events and trend data on a removable USB memory stick, as shown on the plc setup screen below:



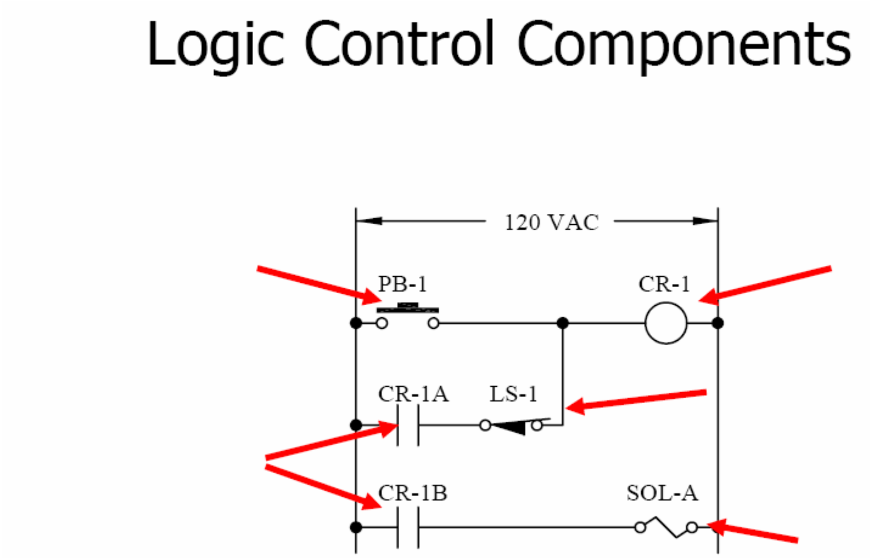
Source: Automation Direct Productivity 3000 PLC Manual p3userm.pdf

Experiences by an old-guy who hasn't programmed a plc since a Modicon in 1980 will make up
Part II of this course.

Is this an advertisement and endorsement for Automation Direct?
No. I first investigated the plc used in 1993. That model is still current and well regarded in the user community. Unfortunately, buying the programming software cost more than the entire project at Automation Direct and required a Windows 2000 pc. Automation Direct is well regarded in the user community, as are Allen-Bradley, Square D, Siemens, General Electric and many Japanese brands marketed under their own names.

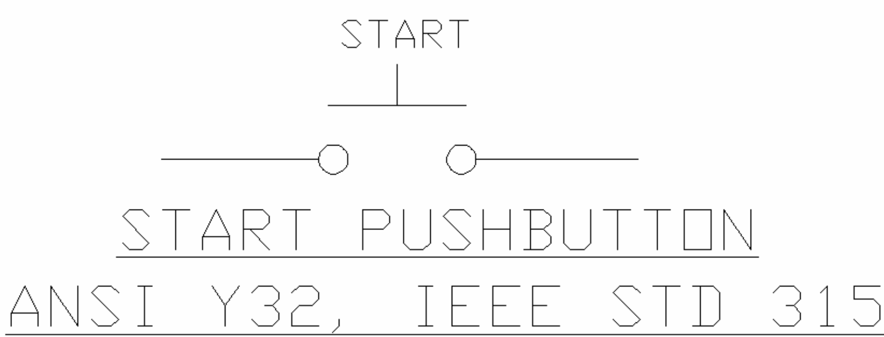
RELAY LADDER LOGIC

What is relay ladder logic (RLL) and why do we care? RLL started as a standardized representation of buttons and lights and motor starters and the pieces and parts that must be connected together for motor controls. The standardized form used an attractive set of standard symbols, a portion of which are reproduced below:



Source: me.ua.edu/me360/spring05/Notes/Topic22-RelayLadderLogic_sv.pdf

This example represents two serious problems. First, ANSI symbols are not used.



The solenoid valve is stretched-out vs the ANSI standard. There are further deviations, as the course materials continue.

The second problem is that this is representative of higher education in the United States. The professors make up their own ideas and teach them to engineering students. No, it is not our goal that engineers be super-technicians, but engineers should use the ANSI-approved language of industry.

Beyond these small problems, the example illustrates the original concept of relay ladder logic. 120V supply and neutral. Control devices on the source side. Load devices on the return side. There are some closely-followed conventions for safety devices and a wealth of logic options.

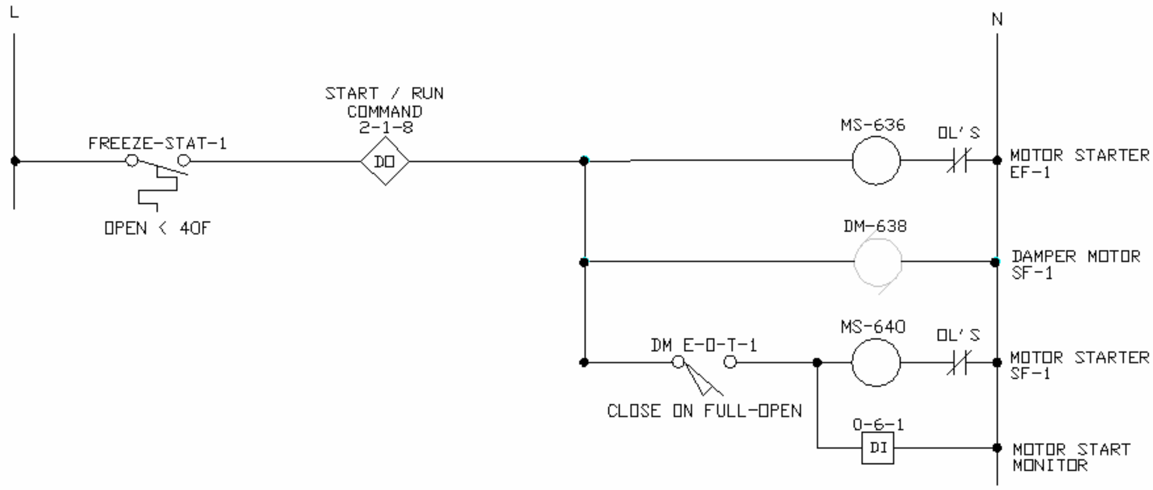
This is very close to what was designed for the industrial HVAC controls in 1993 and to be replicated in 2010. Industry, however has advances significantly since this form was introduced.

We will not address these changes in detail here, but the automotive manufacturing industry switched to 24VDC control in the 1980's. Between the major manufacturers and their very safety conscious unions, it was decided that 24VDC is safer. This immediately created a market for 24VDC plc inputs and outputs. This change supported much higher point density on the input and output cards. 24-circuits per card are common today.

Another change came from internationalization. Europe uses several different logic representation forms. Again, we will not investigate the forms or implications, but most plc programming software supports multiple languages and permits switching a given program between them. They all instruct the computer on data manipulations and certainly get translated to binary machine code before being executed.

PLC INPUTS

The plant plc controls construction documents contain the following illustrations.



FIRST PASS RELOC-3 RE-DESIGN
SUPPLY AIR FAN SF-1 / EXHAUST FAN EF-1
FULL VOLTAGE NON-REVERSING
MCC-HV

The freeze-stat is a room thermostat used to lockout the supply fan and exhaust fan when room temperature is below 40F. A convention I insist upon is indicating the setpoint of a switch, as "opens on temp below 40F.

Start / run command is a discrete output (DO) from the plc. It originates on rack 2, card 1, point 8. These are NOT internal plc representation of the point.

The exhaust fan motor starter is on the first line, followed by its overload protective relay contacts. This notation is a bit peculiar and hard to justify, but long-standing and impossible to change without a revision to the National Electrical Code.

The control voltage flows through freeze-stat, through the DO (if enabled), through the motor starter coil and through the protective relay contacts. Following it with your finger is the special value of relay ladder logic.

If the freeze-stat is made and the DO is made, then voltage is present at the vertical line before the motor starter coil. That means it is available to the damper motor.

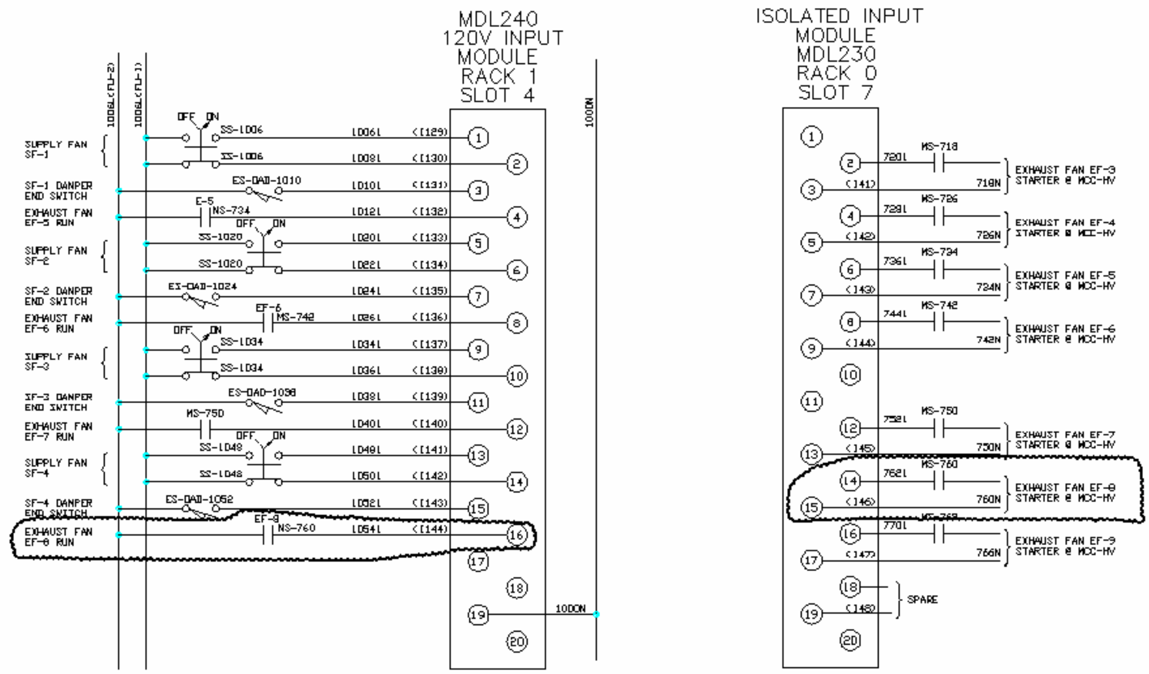
The voltage available on the vertical ladder rung is on the "hot" side of the damper motor end-of-travel limit switch. After the damper motor (actually a gearmotor) runs for about a minute, the e-o-t switch makes and voltage is available to the supply fan motor starter.

In addition to voltage being available to the supply fan motor starter, it is available to the plc discrete input (DI). This does NOT mean the fan is operating. It means that voltage is available to the starter coil.

Some designs use an auxiliary contact of the motor starter to drive the DI. Again, this does NOT mean the fan is operating. It means that the motor starter contactor has pulled in.

This is a hybrid notation. It is mostly field wiring, with the addition of plc inputs and outputs and field devices. It clearly explains how the controls are supposed to work. This is control logic. Unfortunately, this is not the form initially issued for construction in 1993.

The actual information issued to the field was as illustrated below:



SAMPLE PLC INPUT MODULE
COMMON RETURN
ca. RELOC–1 STAGE

SAMPLE PLC INPUT MODULE
ISOLATED RETURN
ca. RELOC–1 STAGE

This is a portion of the bid package issued in 2009. It has additions and deletions from the 1993 package (because it has selector switches instead of start-stop buttons).

A lot of information is expressed here - the wire numbers, the field device tags, the plc rack, slot and terminal numbers and the internal plc programming tag. There are at least two serious problems, however.

First, note the EF-4 circuits that I clouded. I chose these two modules to demonstrate the difference between common return inputs and isolated return inputs. After I copied them into the course material, I noticed that the same fan is on both. Well, that answers the question, “Which form is better?” Obviously, for any particular circuit both are acceptable.

The second problem is that the 1994 installation crew claimed they could not figure out how to wire the controls. A wiring matrix was hastily prepared and issued to the field. Either it met their needs or they figured out how to use the original construction documents. The wiring matrix is partially reproduced below:

DATE: 08-31-1994

DRAWING	DIGrr AI.		ANALOG		VO	WIRE NUMBER	DEVICE	DEVICE DESCRIPTION
	IN	()UT	IN	OUT	Number		NUMBER	
								RXHAUST FAN "RF-l"
E-16.3				AO	4-3-2	11241 / 11251	DMC-700	DAMPER MOTOR CONTROLLER
E-16.3	DI				1-5-7	11201 / l000N	SS-1120	EXHAUST FAN SELECTOR SWITCH (HAND)
E-16.3	DI				1-5-8	11221 / l000N	SS-1120	EXHAUST FAN SELECTOR SWITCH (AUTO)
E-16.3		DO			3-1-9	l006L / 11281	IL-1128	EXHAUST FAN "ON" PILOT LIGHT (RED)
E-16.1		DO			2-3-3	702L / 7021		MOTOR STARTER (ALL CONDITIONS MET
E-16.1		DO			2-3-4	7021 / 7022		MOTOR STARTER (DAMPER OPEN)
E-16.1	DI				0-6-7	7041 / 702N		MOTOR START MONITOR

Please let me address the question of common return inputs and isolated return inputs.

Each input responds to a voltage between two terminals. When energized, one terminal is "high" and the other terminal is a return, to provide reference for the first. If an input is being picked off a contact midway down a string of safeties, then it is essential that the return be isolated. Otherwise, it will short out the circuit.

On the other hand if the input is only meant to recognize a voltage present from the common return (neutral), then all the returns can be tied together, made common. This takes a little bit of attention, but works pretty well. Since a common return does not duplicate the return connection for each input, it is easy to put many more on the same size input card. Also, it is less expensive.

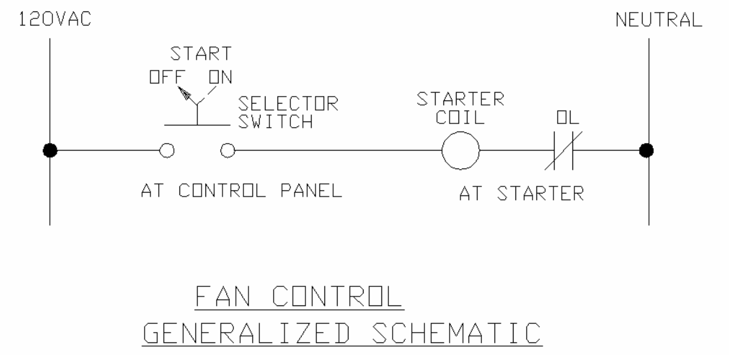
Bogus concern over "foreign voltages".

There are National Electrical Code provision forbidding foreign voltages. 430.74 for motor starters, 409.30 for control panels and OSHA 1910.333. What they mean is that the disconnect on a box is supposed to turn off all the voltages inside the box.

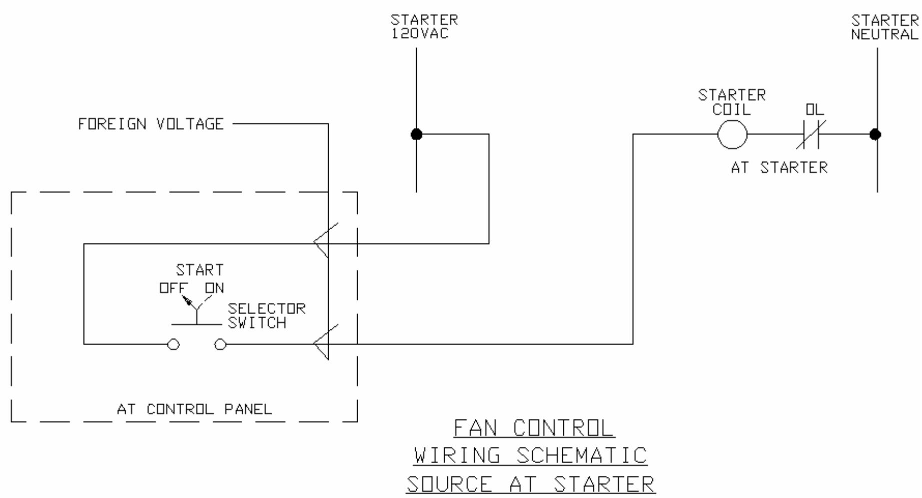
This is a good idea and it is the law and everybody agrees. However, it is also impossible and everybody ignores it.

Consider our present situation. We want a plc to turn on a lot of fans individually.

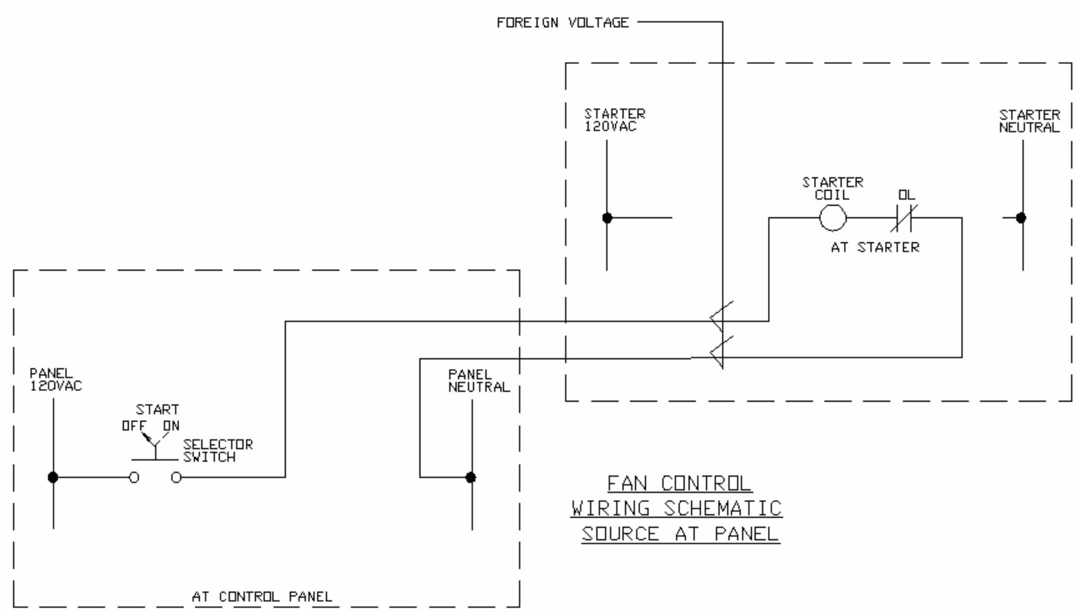
The basic fan control is as follows:



If we source it from the starter, we get foreign voltages in the panel, as follows:



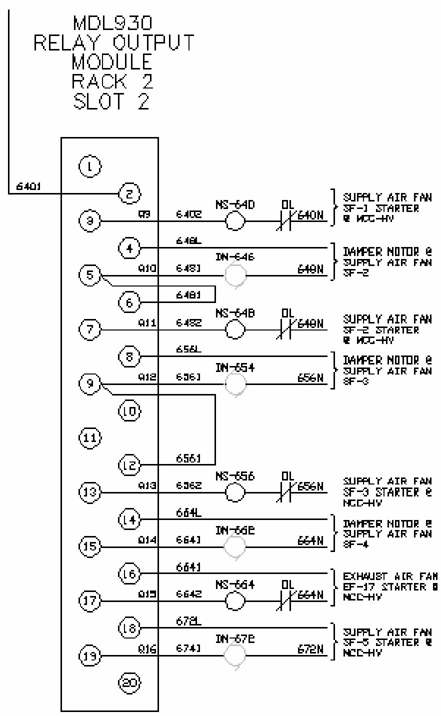
If you source it at the panel, you get foreign voltages in the starters, as follows:



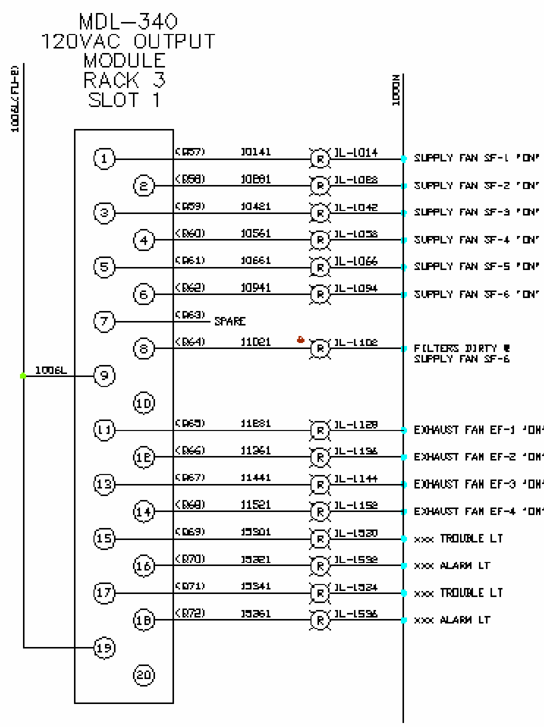
So, you decide which end you are willing to accept foreign voltage. There is not a choice of "no foreign voltages". As we saw in the EF-8 plc module example, both choices are valid, but not for the same fan.

PLC OUTPUTS

Our example of isolated and common return plc cards was for inputs. Exactly the same priciples apply to outputs. The following graphic is a comparison of two output cards and wiring issued for the industrial HVAC control project:



SAMPLE PLC OUTPUT MODULE
ISOLATED RETURN
ca. RELOC-1 STAGE



SAMPLE PLC OUTPUT MODULE
COMMON RETURN
ca. RELOC-1 STAGE

Note that the isolated output card still needs panel power to operate, even though all control power comes from the motor starter. This isolated output card is a relay isolated card instead of a opto-isolated output card. Both are available and the price is about the same. I am new to solid state electronics and still feel more comfortable with relays. The reliability of the relay is less than half that of the opto-isolator. That is, the mean time to failure (MTTF) is less than half.

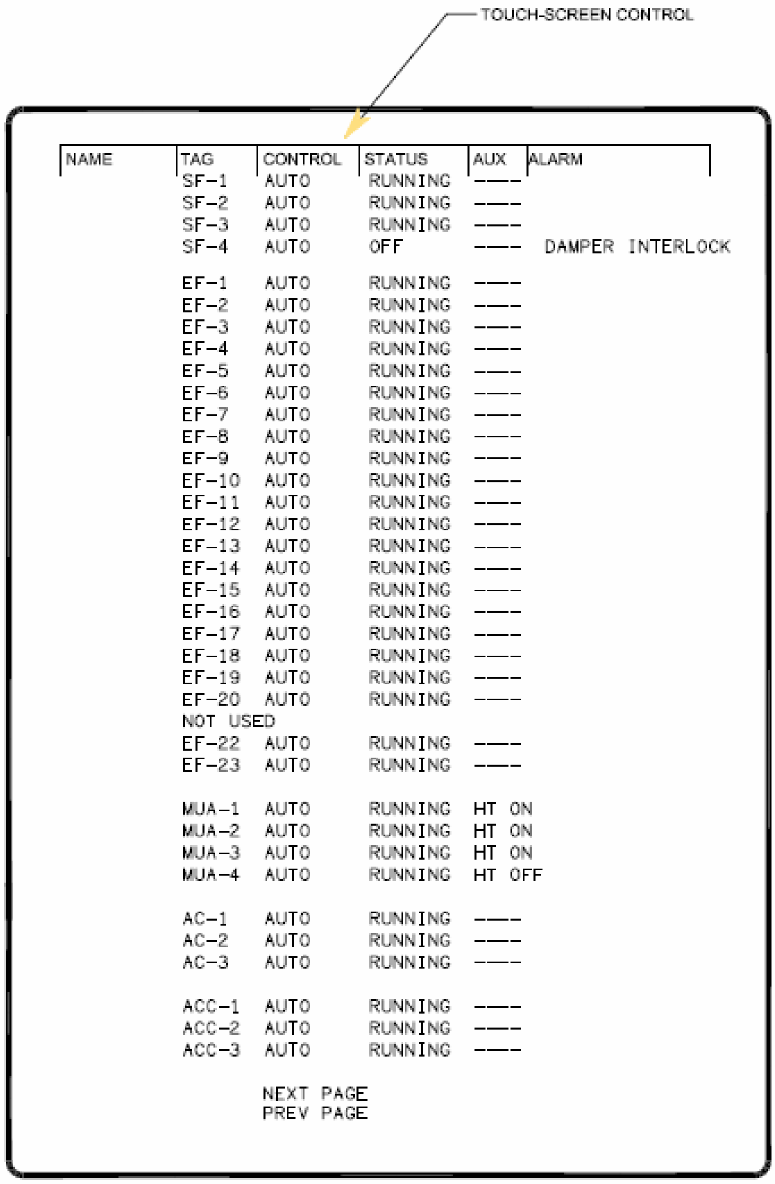
The common output card illustrates the higher card density and implied lower cost of this form. The requirement is that all outputs have the same neutral. If you send the neutral over from the panel, this is easy. If they are a stack of motor starters (mcc), you must send over a neutral for each. It is not fair to recognize that all individual starter control transformer neutrals are tied to the frame and connecting panel neutral effectively ties to all. To my knowledge, no one has ever sent a single neutral to the mcc and fanned out from a big wire nut or terminal strip.

FINAL DISCUSSION OF CONTROL UTILITY TO OPERATOR

We started with big control panels of switches and lights and a very big panel of lights only. This was Client preference in 1993 and 2009. For 2010, the Client wants an HMI. As indicated previously, an HMI is a sexy graphic interface with lots and lots of features and the reliability of Microsoft Windows. That is to say, everything else in the HMI is more reliable than the hard disc and the operating system. (Hard disks have a MTTF of 5 years. We used to rate Microsoft Windows in how many blue screens per day. It is better now.)

This question for this particular application will be going on for the next few months, as this course is being written. The Client's decision will be reported in Part II, along with commentary.

In the meantime, your author is proposing a touch-screen graphic OIT with text only. It is illustrated below:



OPERATOR TERMINAL INTERFACE (OTI) SKETCH
nts 29DEC09

The NAME column is not filled in because operators call things differently than engineers do. I wanted to fill in operator preferences. The CONTROL column is dynamic text accepting touch screen input. That is, an operator touches the control point for EF-1 and it toggles from AUTO to HAND to OFF. I probably need separate SELECT and ENTER functions. (This is very preliminary, based on mouse-consol prototypes.)

The STATUS column is the light from the old control panel. The aux is a place for status of associated auxiliary functions, as HEAT ON for a MUA. The ALARM column will display the text version of each of the old alarms lights on the big annunciation panel. Each of the faults is well defined - a relay input from BURNER FAILURE or duplicating a local panel GENERAL ALARM. The OIT ALARM column reports this in words.

My current thinking is how much of the ISA annunciator form do I duplicate? This is not especially easy. PanAlarm and other manufacturers have been optimizing this for over 50 years. To duplicate it on-the-fly is non-trivial. My present concern is how to alarm when we tell the damper motor to open but not alarm until it has a chance to achieve full travel. Sounds like a time-delay-relay for each alarm function. (This was called de-bounce when we found out we had to do it for pushbuttons.) There may be a software function built in to the plc software or the OIT configuration software. Again, this is the task to be reported in Part II.

CONCLUSION

This completes Part I of 2010 Industrial HVAC Control Case. Please fill out the survey form following the quiz. I want these courses to meet your needs and answer questions you have. Please help

Links and References

HVAC
http://en.wikipedia.org/wiki/HVAC

Exhaust Fans
http://www.industrialfansdirect.com/IND-FA-EF.html?gclid=CJnBnpH7i58CFQ4MDQodNEtIhg

http://www.swifterfans.com/red/SWSEproductinfo.html

Supply Fans
http://www.industrialfansdirect.com/IND-FA-EF.html?gclid=CJnBnpH7i58CFQ4MDQodNEtIhg

http://www.grainger.com/Grainger/wwg/search.shtml?searchQuery=supply+fan&op=search&Ntt=supply+fan&N=0&sst=All

Make-Up Air Units
http://www.greenheck.com/products/detail/55
https://www.rezspec.com/catalog-6_Heating_Cooling_Makeup_Air.html

Motorized Duct Damper

http://www.emwhouston.com/industrial-dampers.htm?kc=MIf0W&_vsrefdom=ppcgoogle&tsid=googleppc&ex=g8d5di-eep549-gd0y1w&gclid=CN6q4PeDjJ8CFQoNDQod1yyG2Q

http://www.hvacsolutionsdirect.com/product.php?productid=447&cat=0&page=1

Damper Actuator
http://www.greenheck.com/media/articles/Product_guide/actuators.pdf

http://www.greenheck.com/media/articles/Product_guide/actuators.pdf

Auxiliary Relays
http://hvac.functionaldevices.com/chartRelays.html

http://www.veris.com/docs/Installs/v222_i0b.pdf

http://www.lineelectric.com/relays/index.html

Cooling Tower
http://www.lineelectric.com/relays/index.html
http://www.cti.org/whatis/coolingtowerdetail.shtml
http://spxcooling.com/en/

Air Compressor
http://www.aircompressor.com/products.html

http://www.aircomo.com/

Toxic Gas Detector
http://www.draeger.com/US/en_US/products/gas_detection/portable/sensors/cin_draegersensor_xs.jsp?showBackButton=true

(This is the plug-in sensor for a comprehensive system.)
http://www.sensorelectronics.com/

http://media.msanet.com/NA/USA/PermanentInstruments/GasSensorsTransmitters/UltimaXSeriesGasMonitors/07-2079.pdf

SO2
http://en.wikipedia.org/wiki/Sulfur_dioxide

http://www.epa.gov/air/sulfurdioxide/

http://www.chemtradelogistics.com/MSDS/Sulfur_Dioxide-English.pdf

Heavy-Duty Oil-Tight indicators, buttons and switches
http://www.hubbell-icd.com/icd/pushbutton/files/2040Catalog.pdf
http://www.ab.com/en/epub/catalogs/12768/229240/229244/2531081/229759/tab3.html
http://www.cooperbline.com/product/electricalenclosures/NewProducts/SSPushbutton.asp

PLC
http://en.wikipedia.org/wiki/Programmable_logic_controller

http://www.automationdirect.com/adc/Overview/Catalog/Programmable_Controllers?source=google&keyword=programmable%20logic%20controller&type=search&gclid=CMCDkq2IjJ8CFQjyDAoddhBIOQ

http://www.ab.com/programmablecontrol/

PLC Common-Input, common-output, isolated-input, common-input, relay-output Cards
http://www.automationdirect.com/adc/Shopping/Catalog/Programmable_Controllers/Productivity3000_%28Programmable_Automation_Controller%29/AC_I-z-O_%28Relay_Outputs%29

OIT
http://www.automationdirect.com/adc/Shopping/Catalog/Operator_Interfaces/C-more_Micro-Graphic_Panels/C-more_Micro-Graphic_Panels_-a-_Keypad_Bezels_%28all_types%29/EA1-T6CL
http://nematron.com/

HMI
http://global.wonderware.com/EN/Pages/WonderwareHMISCADA.aspx

http://www.ge-ip.com/products/3311

http://www.atvise.com/?gclid=COGJ-4eKjJ8CFRAeDQod7mI1NQ

Relay Ladder Logic
http://en.wikipedia.org/wiki/Ladder_logic

http://ecmweb.com/ops/electric_basics_ladder_logic/

http://download.cadinfo.net/CAD-Manager/General/Symbols/Electrical-ANSI-Y322-Symbols.html

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