Rammstein Air Heater Trouble Shooting and Training Manual

08-09-2014

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1 Scope and Purpose

This manual (Training Manual) is intended to be a training and a troubleshooting supplement to the Installation Manual. This manual is not intended to replace the Installation, Commissioning, Operation, and Maintenance Manual (Installation Manual) for the heater. This manual is intended to be a trouble shooting tool for people who do installation, service, and repair work on heating systems.

This manual is also intended to be the general framework of the in house training program we offer to dealers/installers. Some dealers/installers may not need the in house training. They can use the Training Manual to learn system specific information of our products. After reading this manual you have to decide if you need the in house training or if you do not need it. If the information below is not completely clear or obvious to you, you should participate in one of our free in house training classes.

In house training

Primary goals:

1. General explanation of product liability and our responsibilities as manufacturers, dealers/installers.
2. Circuit trouble shooting
    - Teach you how to trouble shoot an individual circuit.
    - Do hands on trouble shooting on real, individual circuits. This is a test panels that we build for the training class.
    - Identifying circuits in real heaters and trouble shoot them.
    - Understanding safety circuits.
3. General overview of the various components we use in building heaters.
4. Overview of important system parameters:
   Air flow related
   Gas related

2 Equipment Safety – Product Liability

This is only a brief overview of product liability. For a more detailed analysis of your specific situation consult a professional who is a trained expert in product liability issues.

Equipment safety is one of our primary concerns. In order to keep hazards at an acceptable level, we follow standard industry practices. A general outline of this process is the following.

2.1. Consensus standards

A consensus standard is basically a long list of requirements. Heating systems cannot be made inherently safe. The Preface in ANSI z83.25 summarizes the issue well. The inherent risk in these appliances cannot be eliminated without compromising the usability of these appliances. If you would engineer these heaters completely safe, they would not be usable in our application. How do you make sure you are doing what you were supposed to do to make sure the equipment is as safe as it possibly can? How do you manage the risks associated with the equipment?

Most industries have at least one consensus standard. The consensus standard describes the safe operation, satisfactory construction, adequate equipment documentation and acceptable performance of the equipment. A consensus standard describes most of the risk management processes for a product. Some people do not like standards, rules and regulations. However, consensus standards are positive forces in an industry. As their name states, they set a standard for a particular piece of equipment. As long as the equipment is up to this standard, it is assumed that the equipment hazards are at an acceptable level. How is this done? We designed a system that conforms to the consensus standards. During manufacturing, we follow a quality control process prescribed by the consensus standard. You are responsible to install it according to codes and regulation and to make sure it performs as it was designed to perform. The operator is responsible for operating and maintain the equipment according to the requirements.

2.2. Nationally Recognized Testing Laboratories

Equipment testing is simply a process where a company compares a piece of equipment against the list of requirements in the consensus standard. There are third parties, Nationally Recognized Testing Laboratories (NRTLs), who are authorized to test certain equipment against the applicable standards. Some examples are UL, CSA and Intertek (ETL). If the equipment meets the requirements of the standard, the listing agency issues a listing for the product. The listing proves that the product met the requirements. It means that IF the equipment is manufactured, installed, operated and maintained according to the directions in the manual, the hazards the equipment presents are acceptable. It means that there is a system in place to manage and control these hazards.

Therefore you have to make sure the equipment is installed, commissioned and serviced in a way that it performs to the specifications detailed in the Installation Manual. If you do not install, commission, service, etc. the equipment and make sure it performs to specification, you may be creating a dangerous situation. You can be held liable.

The Installation Manual details the general responsibilities of all parties in the chain of commerce: manufacturer, dealer/installer and the customer. Read and understand your responsibilities! The Installation Manual is intended to give you most of the information you need in order to fulfill your responsibilities under the applicable standards. However, we still recommend that you consult with a product liability professional to make sure particular details of your situation are taken into consideration.

2.3. Authority Having Jurisdiction (AHJ)

Although the reasoning above is straightforward, there is one more factor that complicates things a little. The AHJ can override the consensus standard. If the AHJ sees it necessary, it can set stricter requirements. Gastrains are a good example. Most of the time the ANSI gastrain is accepted. However, some AHJs may require you to have a different style, for example FM, gastrain instead of the ANSI style gastrain. **Therefore it is imperative that you check with the local AHJ(s) to make sure you understand if their requirements deviate from the requirements of the consensus standard the system was tested against.**

2.4. Ensure safety - protect yourself from liability claims

Doing what you were supposed to do is not enough to protect yourself from liability claims. Written documentation is an important part of the protection process. Written documentation shows that you did what you were supposed to do. This is why it is imperative to document setpoints, initial operator training, and everything else that is required from you.

Operator training is an important part of what you have to do. The logic behind the process is simple. We have to identify hazards and we have to make sure that the operator(s) know how to protect themselves and they know how to avoid the danger. If a trained operator does something dangerous and gets hurt, it is their responsibility. Operator free will to make bad and dangerous decisions cannot be eliminated. However, if you can prove that you have done what you were supposed to do, the operator then made a decision to do something dangerous and got hurt, you will probably not be held liable.

3 Warranty

Make sure that you understand the equipment warranty. We have a one year, standard return-to-factory parts warranty.

4 Energy Efficiency

We identified the following factors that affect spray booth energy consumption:

1. **Local Climate**

The colder it is in your geographic area the more heat you will need. We don't have any control over this factor.

2. **Availability of turbulent air flow**

We needed this. Previously we just approximated the right kind of air flow…

Turbulent air flow is very important for spray booths. Turbulence decreases the length of time it takes to dry waterborne coating. Turbulence also enhances the convection process. Turbulence helps the heat transfer between spray booth cabin air and the panel temperature. It is a well proven fact that Bake times can be reduced if a turbulence creation device (waterborne paint drying system) operates during the Bake Mode.

3. **Heat Loss**

No insulation or poor insulation will have a substantial effect of energy usage.

4. **Operator behavior**

It is imperative to educate the painter on the importance of turning airflow on only when it is needed. There is little that can be done to engineer the human factor out. Administrative controls should be implemented. The painter has to be trained in the correct operation of the spray booth.

5. **Paint Product Used**

Paint products affect energy efficiency in two ways:

A. The length of required curing time.

Clearly a product that has a shorter drying or curing time will use less energy.

B. The required curing temperature.

A product that requires a lower curing temperature will use less energy.

6. **The air flow rate within the system**

You have to reduce the air flow rate inside the booth. For example, if the painter is not spraying, air flow should slow down. There is no reason to move more air than it is necessary. A lower air flow rate requires less electrical energy to move.

7. **Exhaust Air flow Rate**

This is the most important area. Large energy savings can be realized by carefully controlling spray booth exhaust rate. The goal is to reduce the flow rate of heated air that leaves the booth.

HANDS ON

Create various scenarios in software model. Compare various modes of operation.

5 How to use the Installation Manual

The Installation manual as well as the Trouble shooting manual uses section numbers to identify various parts. Review the table of contents to get a general idea of how the manuals are organized.

Understand the product line so that you can find the correct section. Our system has many options. The two main questions are:

A. Is it a Spray only system or a Spray/Bake system?
B. Does it have analog modulation or digital modulation?

System is only confusing if you don't understand it.
We are just switching things on and off.
All systems are similar because they are built to similar safety standards. All spray booths should have the same set of interlocks. Some jurisdictions require additional things.

6 Important Terms

6.1. Air Flow Related

We have to clarify some terms that are often used incorrectly in the finishing industry.
Ventilation means fresh air drawn in from outside of the spray booth. Generally measured in cfm.
Air flow rate can be fresh air (ventilation air) and recirculated air. All ventilation air is air flow but not all air flow is ventilation air.
For example, all air flow is ventilation air during Spray Mode. However, not all air flow is ventilation air during a recirculating Bake Mode.

There are at least three air flow rates you should work with when selling and commissioning a heater on the spray booth:

- Maximum theoretical air flow rate
- Maximum actual air flow rate
- Minimum air flow rate

Air flow rate or air velocity?

Air flow rate: It is a certain air volume flowing through the system. Air flow rate is measure in cubic feet per minute (cfm).

Air velocity: It is the speed at which the air flows through the system. Air velocity is measured in feet per minute (fm)

6.2. Pressure

Static pressure – Gas: The inlet gas pressure when heater is not firing.

Dynamic pressure – Gas: The inlet gas pressure when the heater is firing.

6.3. FLA – Full Load Amps

This is the name plate full load amp rating of the motor.

Motor specific and manufacturer specific.

Used for:

Determining what size service the equipment will need.

Setting the motor overload.

6.4. FLC – Full Load Current

This is in table 430.247 – 430.250 in the NEC (National Electric Code).

No differentiation between standard RPM motors.

Used for:

MCA (minimum circuit ampacity) calculations. Sizing feeder wires.

MOP (maximum overcurrent protection) calculations. Sizing feeder circuit protection device.

Sizing branch circuit wires.

6.5. Commissioning

Process by which an equipment, facility, or plant (which is installed, or is complete or near completion) is tested to verify if it functions according to its design objectives or specifications.

6.6. Write – PLC

Write to PLC. This is what you select when you are reprogramming a PLC from a programming chip.

6.7. Read – PLC

Reading the PLC memory. If you select this, you will copy the program from the PLC to the chip. You will overwrite the program on the programming chip!

6.8. Set value (SV) or setpoint

The temperature what we want the spray booth to reach and operate at.

6.9. Process value (PV)

The actual temperature inside the spray booth. The actual temperature of the process that is going on inside the spay booth.

6.10. Error – (temperature controller)
The difference between the set value and the process value.

6.11. Air flow VS amps
Amps drop when air flow is decreased. Air flow is decreased by adding static pressure.

7 Working on a System and Calling Tech Support

7.1. Safety first
Only operate or work on a system if you understand the system! This includes understanding the hazards a heating system has and knowing how to avoid those hazards. Read the Installation Manual in its entirety before attempting any service work.

7.2. Tools
Without proper tools you cannot trouble shoot a heater!

Do not call tech support is you don't have the following:

- common hand tools like screw drivers, pliers, etc.,
- multi meter,
- manometer,
- copy of the Installation Manual and a copy of this Training Manual.

7.3. General expertise
You have to be able to trace a circuit in the control system!

If you don't have a multi meter and if you don't know how to trace or go step-by-step through an electrical circuit, you will not be able to trouble shoot the heater. One objective of the Training manual is to teach you how to trace circuits in our equipment.

7.4. Report accurately
Trouble shooting over the phone is difficult because the tech support person doesn't see what is in front of the tech. The tech support person also doesn't see what the tech is doing. It is VERY important that the technician does EXACTLY what he is asked to do. Don't assume anything. Simply do EXATLY what you are asked to do as long as the task is not dangerous. If you don't understand what you were supposed to do, ask questions.

8 Trouble Shooting

The system has one standard general trouble shooting feature and one optional general trouble shooting feature. The standard trouble shooting feature is the PLC displays alarm messages. We also offer an optional indicator light feature for the flame controller limits. Based on these you can get a good idea of which circuit is causing the problem. After narrowing down the cause to a circuit, you have to do circuit level trouble shooting. You have to have the proper tools to do circuit level trouble shooting.

8.1. PLC Alarm Messages

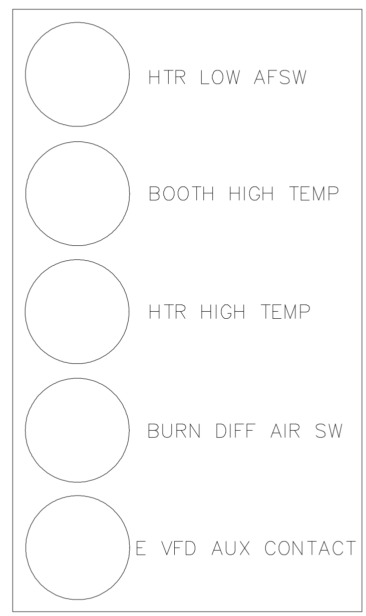
The system is designed for VERY easy trouble shooting. There are 4 alarm messages the PLC generates. Please reference the Installations Manual, Control Panel Display Messages section. The messages are based on inputs that the PLC was supposed to see. If he PLC does not see one of the required interlocks on, the PLC will display the interlock specific alarm message.

HANDS ON

Looks up PLC error messages in Installation Manual.

8.2. Flame Controller Limits Indicator Light Option

We offer a visual indicator light option for the flame controller interlocks. This is a column of 5 lights wired to the flame controller interlocks. If there is a problem, the first light that is off is where the problem is.



1. Auxiliary contact (first interlock)
2. Burner differential air pressure switch
3. Heater high temperature limit switch
4. Booth high temperature limit switch
5. Heater low air flow switch

HANDS ON – ON HEATER

1. Trip low air flow switch and show indicator light goes out.
2. Trip two different interlocks and show the effect on lights.

8.3. Trouble shooting circuits

Each control circuit carries a signal. The signal originates at a point and the signal has a destination. You have to be able to measure through the circuit step-by-step. Problems happen because signals do not get from their origins to their destinations. You have to be able to find the point where the signal is lost.

Trouble shooting is a simple 4 step process.

1. General system understanding
   The first step is to understand what the PLC was supposed to see for an event to happen. What inputs were supposed to be on? Tech support can tell you what PLC inputs should be on in a particular scenario.
2. Circuit identification
   The second step is to check the display for error messages and check the flame controller limits indicator lights for problems. You have to identify the circuit that caused the problem.
3. Problem identification – circuit testing

The third step is to use the correct individual circuit diagram, identify the beginning of the circuit and measure step by step to find where the signal gets lost. The signal is 110V most of the time. You simply have to measure for the presence of 110VAC step by step through a circuit.

4. Fixing the problem
   The fourth step is correcting the problem.

Tech support can help with identifying which circuits are causing the problem. Tech support can also help with instructions on how to correct a problem. **However, you have to be able to use a multimeter to measure for the signal. You have to be able to follow a wiring diagram and measure for the signal step by step.**

9 What is a Control System?

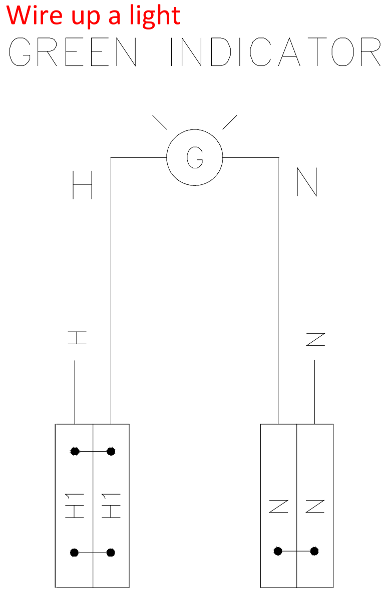
The control system is a combination of several circuits that create the required environment for a process or a mode. The building blocks of a control system is circuits. The control system simply turns circuits on and off.

As the name implies, a circuit is a complete electrical circle. Electrons go out and do some work then they come back. It can be divided into two parts: The signal half and the return half. The signal half includes the start of the signal and the destination of the signal and everything in between. The return part includes the neutral for AC or a common for DC to allow the electrons to flow back after the electrons did the work. Please take a look at the light drawing below. The signal half is going from the H1 terminal block to the light. The work is that the electrons will light up the light. The return is the N wire to the N terminal block.

There are several events that take place inside a spray booth: prepping the car, spraying the car, purging the booth, flashing off the base coat, baking the clear coat, cooling down the painted object, etc. These events require different environments. Activation of various combinations of circuits creates these different environments. For example Spray Mode needs 12,000cfm of fresh air and 70F setpoint temperature. Bake Mode needs 300cfm of fresh air, 2,500cfm of recirculated air and 140F setpoint temperature. The right combination of circuits will create the right combination of air flow and temperature during different modes. Again, the control system simply turns circuits on and off.

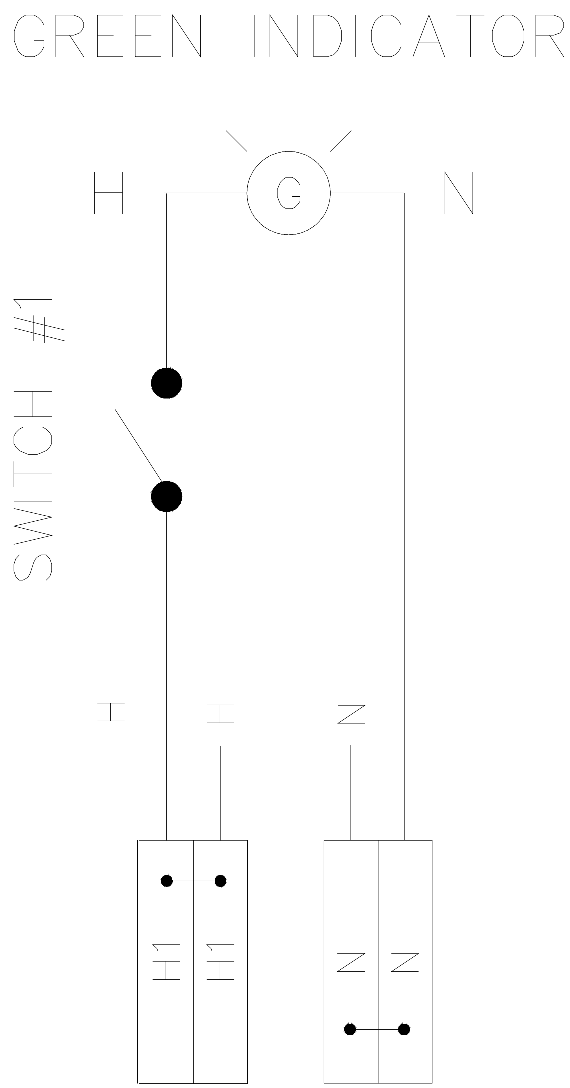
HANDS ON

1. Wire up a light



The above circuit is simply a circuit. It is probably the most basic form of a circuit. It is a circuit, but it is not a control circuit. We have no control over the light. If the power is on, the light will be on. To make it into a control circuit, let's wire in a switch.

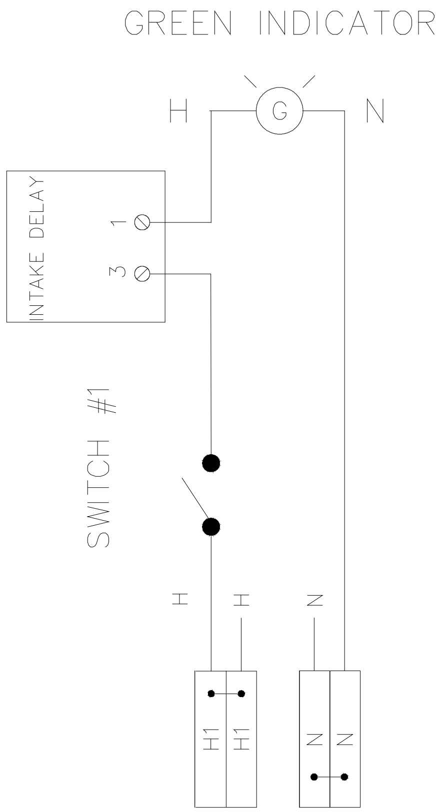
2. Wire up an on/off switch to light
   Interlocks etc. are simply switches.



Now we can turn the light on and off when we want to. Let's say we only want the light on when the system ramped up to full air flow. This takes 5 seconds. We need a timer that delays the light coming on for 5 seconds. These timers are called on delay timers since they delay the activation of a device. There are also off delay times. As they name states these times delay the turning off or the deactivation of a device.

We will use the same timer we use in the heater to delay the intake motor. Please take the installation manual and find the section that explains how to program the time delay for 5 seconds.

3. Wire up an on delay timer to turn on the light



10 About Wiring Diagrams and Circuits

The PLC controls the circuits in the control system. The PLC has about 14 input circuits and about 10 output circuits. Individual circuit diagrams show every connection point of a circuit. Wiring diagrams show what wire number is connected to which terminal. When trouble shooting, the technician simply has to use a multimeter to find the connection point where the signal is not getting through.

There are two types of electrical circuits inside the heater.

1. Power circuits power the equipment: relays, PLC, flame controller, damper actuators, etc.
2. Control circuits control the equipment through analog and digital signals.

A circuit is similar to sending a messenger. We are sending a message to a specific location. For example we just sent the 100V message to a light to turn on. The wiring diagrams are the maps that tell us how the signal or message gets from its stating point to its destination. The wiring diagrams are step by step maps or point to point diagrams.

We do supply general wiring diagrams. These show all the control circuits. Besides the general wiring diagrams we also supply individual circuit diagrams to help with trouble shooting. Individual wiring diagrams detail out each control circuit step by step.

HANDS ON

Please look at the table of contents. Please find the general wiring diagrams. Look them up.

Please look at the table of contents again. Please find the individual wiring diagrams and look them up.

10.1. <u>Abbreviations, symbols and wire numbering</u>

AFSW = Air Flow Switch

ASV = Air Solenoid valve

C = can be in several places in a wire number

First digit: Combustion,

Second digit: Contactor. For example, IC-1 is the field wire that operates the Intake Contactor

Last digit: 24DC-C or 10DC-C In the last position, C indicates common for DC circuits

CP = Control Panel

D = Discharge

E = Exhaust

GTP = Gastrain Panel

I = Intake: For example, IC-4 is the #4 wire in the intake contactor circuit.

R = Recirc

RL = Relay

X = Generally used to indicate wires connected to the input of the PLC. For example X7 is connected to I7 of the PLC.

Y = Generally used to indicate wires connected to the output of the PLC

[ ] = Optional feature

--- = Field wiring

Many wires connected to relays follow the numbering system below:

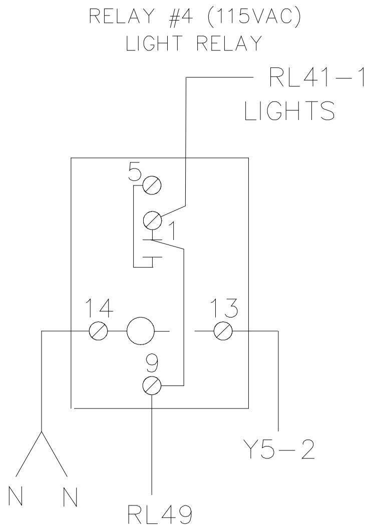
Let's look at wire RL41-1

1. RL at the beginning indicates that the wire is connected to a relay.
2. The third digit, in this case xx4 indicates that the wire is connected to the #4 relay (Light relay).
3. The fourth digit denotes the terminal where the wire is connected to. In this case xxx1 means the wire should be connected to terminal 1 on the #4 relay.
4. The last digit xxxx-1 means that this is the first piece of wire in this circuit.

RL41-1 means the first wire in a circuit. The circuit is connected to the #1 terminal on relay #4.

HANDS ON

Look at the wiring diagram relay base and ID the terminals.



Look at the relay base and ID the terminals.

Almost every wire has a unique number. This makes is possible to trace a signal through a circuit. You can start at the origin of the signal and move towards the destination of the signal step by step, connection by connection. Trouble shooting is like walking down a street house by house, address by address. Just like houses on a street, each piece of wire in a circuit has its own address.

HANDS ON

1. Looks up the Air Flow Switch (Mode #2) wiring diagram and follow the circuit.
    A. H2 terminal block is where the signal originates.
    B. H2 is connected to one side of the NO contacts on the AFSW
    C. The other side of the NO contact is wired to TB X4.
    D. TB X4 then is wired to the I4 on the PLC

    We can trouble shoot this circuit in 4 steps.

2. Look up and follow the Bake Mode Intake Contactor circuit.
    A. H2 terminal block is where the signal originates.
    B. H2 is connected to Relay #3, terminal 10. Terminal #10 and terminal #6 are normally open. When we are in Bake Mode, Relay #3 is turned on by the PLC and the signal will be present on terminal #6.
    C. From terminal #6 the RL36 wire goes to the RL36 terminal block.
    D. From the RL36 terminal block, the signal goes to the GTP through a field wire (IC-1). IC-1 means the Intake Contactor #1. IC-1 lands on the IC terminal block in the GTP.
    E. The IC-2 wire connects the terminal block to the intake contactor time delay.
    F. The signal travels from the intake contactor time delay to the intake contactor overload through IC-3.
    G. From the intake contactor overload the signal lands on the intake contactor coil through wire number IC-4.

We can trouble shoot this circuit is 7 steps.

10.2. Digital and analog circuits

A digital circuit is a circuit that carries an on/off signal. For example, the door interlock circuit is on when the doors are closed and off when a door is opened.

An analog circuit is a circuit that carries a signal that changes in intensity. For example the analog modulating valve signal changes from 0VDC to 10VDC.

10.3. Power circuit

1. Line power: 1 phase or three phase
2. There are tw 110VAC power circuits.
    a. H1 is the 110V circuit that powers devices we don't want to turn off when the switch is in the Off position. The PLC and the 24VDC power supply are powered from H1.
    b. H2 is the 110V power circuit that the Off switch controls.

3. 24VDC
4. 24VAC

10.4. Control Circuit

110VAC

0-10VDC

24VAC

10.5. Safety Circuits – Interlocks

Interlocks are generally switches that turn on or off if a condition exists. For example if the minimum air flow is present, the low air flow switch will turn on. When the switch closes, the signal will be able to go through it. High temperature limit switches are normally closed switches. If the temperature exceeds the rating of the limit switch, the contacts open. The electrical signal is cut off from the flame controller.

Interlocks are like draw bridges in the path of our messenger. If the draw bridge is down, the messenger can get through. If the draw bridge is up, the messenger cannot get through.

The safety circuit is part of the control circuit safety circuit. Various parts of the safety circuits prove the correct conditions for various parts of the system. For example, if the spray booth doors are open, there will be no power to the compressed air solenoid valve. The painter will not be able to paint.

HANDS ON

Please look at table of contents. Please find Compressed Air Power diagram. Please follow the power from H2 to the air solenoid valve. Identify how many switches can prevent the signal or the power from reaching the air solenoid valve.

10.5.1 Flame safety interlocks

There are several switches that are interlocked into the flame controller. If they do not prove, the controller will not start the lighting sequence or the controller will turn off the flame. The switches are connected in series. If any one of these switches does not prove, there will be no heat.

1. Exhaust fan: Usually interlocked through the auxiliary contacts on the exhaust VFD
2. Burner differential air pressure: differential pressure switch
3. Heater high temperature limit switch
4. Booth high temperature limit switch
5. Heater low air flow switch: air flow/pressure switch

HANDS ON

Please take a look at the Flame Controller Limits – Linear wiring diagram. There are five conditions that have to be present for the flame controller to keep the burner lit. These conditions are represented by five interlocks. Some of them are normally open, and some of them are normally closed. All five interlocks are in series or daisy chained. If one does not prove, the flame controller turns the flame off.

10.5.2 Door Switches

The door switches have two different functions:

1. **Spray Mode**

Effect: Spraying operation (compressed air solenoid valve)

During spray mode some jurisdictions require the following. If the door is opened the spraying operation has to be disabled. The spraying operation is disabled by turning off the compressed air solenoid valve. In our system we simply run the power to the compressed air solenoid valve through the door switches. If the door is opened, power is cut and the compressed air solenoid valve will close.

2. **Flash and Bake Modes**

Effect: Heat

During Class A oven modes (when the temperature is elevated above ambient) there is the danger of asphyxiation inside the booth. If the door is opened during these modes, the PLC references the Spray Mode temperature setpoint. After the door is closed the operator has to press the Reset button to reinstate the Flash or the Bake mode temperature setpoint.

10.5.3 Fire Suppression

Effect: spraying operation, heat, ventilation system (if required by specific fire suppression system)

If the fire suppression is activated, the PLC disables the spraying operation and turns the burner off. NFPA33 requires booth ventilation to be maintained. The exception is if the fire suppression system specifically requires ventilation to be turned off. For each installation you have to check with your fire suppression company to see if the ventilation system has to be turned off when the fire suppression system is activated.

10.5.4 Mode #2 Air Flow Switch – Spray Mode Air Flow Switch

1. **Spray Mode**

Effect: spraying operation

If the Mode #2 air flow switch does not prove during Spray Mode, the compressed air solenoid valve is turned off.

2. **Preignition Purge Mode**

Effect: PLC will not start the burner lighting sequence

The burner lighting sequence can only be started if the booth and the associated ductwork were successfully purged. Relevant code requires not less than 4 spray booth air volume changes for Preignition Purge Mode. The PLC looks at the Mode #2 Air Flow Switch input (X4). If the input is on, the Preignition Purge Mode countdown timer starts. If the input stays on for the duration of the Preignition Purge timer, the PLC will turn on the flame controller. If the X4 input drops out during preignition Purge, the PLC will not power up the flame controller.

10.6. General wiring diagram layout

Wiring diagrams follow a simple format. Please study the diagram below.

1. **Circuit component location**

On the left you can see where parts of the circuits are located: control panel, field wiring, gastrain panel, etc.

2. **Lines**

Lines represent the wires. Next to each wire is the wire ID. For example, RL36 or IC-1.

3. **Circles and ovals** around screws indicate the connection area of components. For example RL310 and RL36 represent the #10 and the #6 connections on Relay #3.

HANDS ON

Use the wiring diagram to identify the relay terminals.

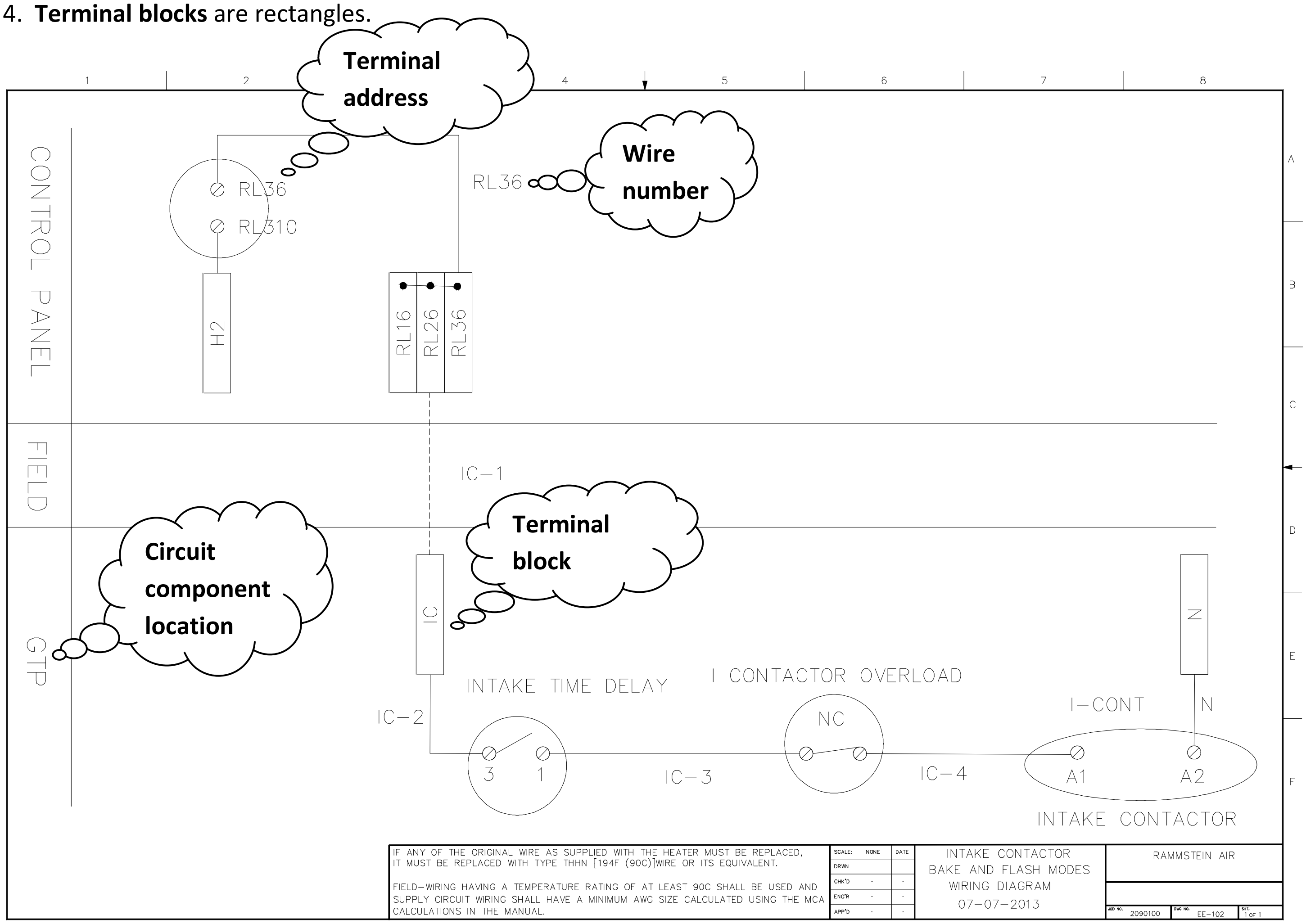
Use the wiring diagram to identify the intake time delay terminals.

Use the wiring diagram to identify the overload terminals.

Use the wiring diagram to identify the intake contactor terminals.

Look at the actual relay base, overload, and contactor and identify the location of the connections.

4. **Terminal blocks** are rectangles.



11 Key Components and how They Work

11.1. Relays

System relays

We use the following relays in our system. Some of them are optional:

RL1 = More #1 relay (Prep Mode relay)

RL2 = Mode #2 relay (Spray Mode relay)

RL3 = Mode #3 relay (Flash and Bake Mode relay)

RL4 = Light relay

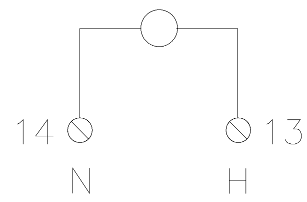
RL5 = Modulating valve off relay

What are relays?

Relays are electrically operated switches. They are made of two parts:

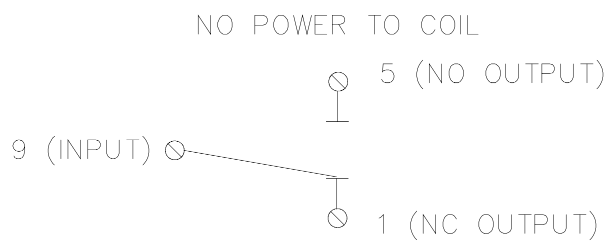
1. Coil section

Relays are switches. Instead of having a manual toggle switch you can move by hand, they need electricity on their coil to be activated. When you apply power to the coil terminals, in this case 13 and 14, the relay becomes energized or turns on.

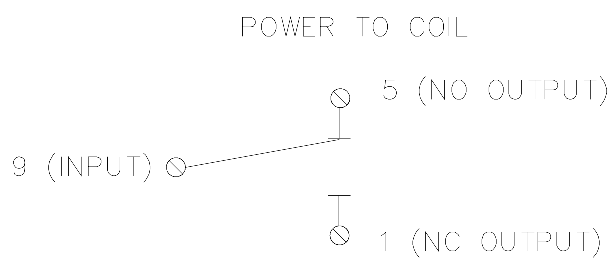


2. Contacts section

The contact section of a relay is made of the input and the outputs. We connect an input signal to terminal 9. Each input has two outputs. One output is a normally close set of contacts. The second output is a normally open set of contacts. Based on their name, it is easy to understand what happens to the signal. The normal state of the relay is off. So the normally closed (NC) set of contact is closed when the relay is off. The signal will be present on 1. The normally open set of contacts is open when the relay is off. There is no signal on 5.



When the relay is turned on, the NC contact open and the NO set of contacts closes. If you have something connected to the NC contacts, it turns off. If you have something connected to the NO set of contacts, it will be turned on.

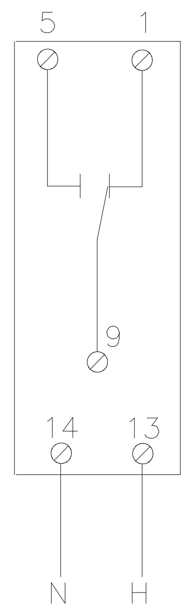


Take a look at the drawing. The signal goes in through 9. The signal can go to wither 1 or 5 depending on if the relay is energized or not. If the relay is not energized, 9 will be connected to 1 (NC terminal). If the relay is energized, 9 will switch to 5 (NO terminal). This means that when the relay is energized the signal will be present on the 5 terminal.

Poles – how many different circuits can one relay switch

The useful feature of relays is that they can have up to four different sets of contacts. Energizing one relay can switch 4 different things at the same time. Each set of input and output contacts is called a pole. Each pole can switch a different circuit. A two pole relay can switch two different circuits. A four pole relay can switch four different circuits. Basically sending power to the relay coil can switch 4 circuits at the same time.

Coil voltage



Relays are turned on and off by applying power to their coil. In this case13 is hot and 14 is neutral.

If there is no power on 13, 9 will be connected to 1. If there is power on 13, 9 will be switched to 5.

Relays are turned on when their coil is energized. For example, the relays we use have 110V coils. When the PLC energizes the 110V relay coil, the relay will turn on 24VAC to a damper. The same relay can turn on all of the following:

1st set of contacts: Turn the 0-10VDC speed reference signal on or off to the exhaust VFD.
2nd set of contacts: Turns the 24VDC on or off to operate the recirc damper.
3rd set of contacts: Turns the intake contactor on or off to start or stop the intake motor.
4th set of contacts: Turns the 24VDC signal on or off to the discharge damper.

Contactors are another example of relays. We use a control voltage to turn power on and off to a motor. The control voltage operates the relay coil. When energized, the contactor "pulls in" and connects the input power to the motor.

Relays have coil terminals. When the coil is energized the relay contacts change positions. Relays are voltage specific. For example, some relays are turned on by 110V, some by 12VDC, some by 24VAC, etc.

HANDS ON

1. Look at the relay. Identify coil terminal.
2. Look at the side of a relay. Identify the voltage markings.

HANDS ON

Take a 2 pole relay and a 4 pole relay and identify the coil terminals.

NO contacts

A normally open (NO) contact has no voltage on when the relay is not powered up. Whatever is connected to this contact will be off.

An example of a NO terminal is RL26 (relay #2, terminal 6). RL26 turns the intake contactor on in Spray Mode only. RL26 is off except in Spray Mode (and modes that require Spray Mode air flow). In Spray Mode RL26 is on and it sends 110V to the intake contactor.

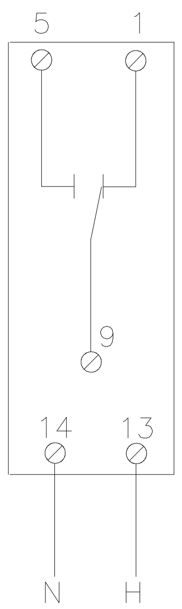
NC contacts

A normally closed (NC) terminal has voltage on it when the relay is not powered up. Whatever is connected to this contact will be on. When the relay is powered up, the power will be cut and the device will turn off.

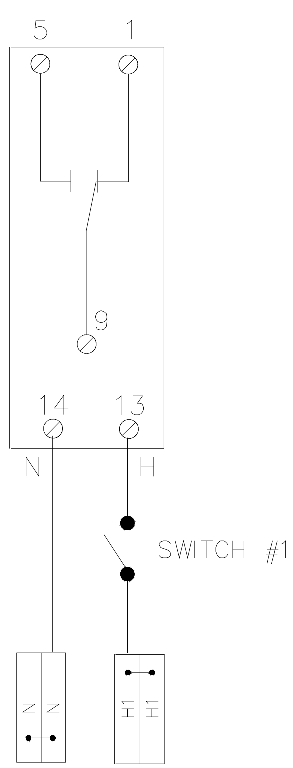
An example of a NC contact is RL41 (light relay). If the relay is not powered this contact is closed. What this means is that there is always power on this contact when the coil is not energized. This is our automatic light switch. The PLC has to turn off the light in Flash and Bake. The power to the light contactor comes from RL41. There can be power on RL41 in all modes except in Flash and Bake. The RL4 relay is energized in Flash and Bake. When it is energized, the RL41 terminal turns off. Therefore the operator cannot turn on the lights. We turn the relay on in Flash and Bake to make sure the lights cannot be turned on. When we turn the relay on, we break the circuit that powers the light contactor.

HANDS ON

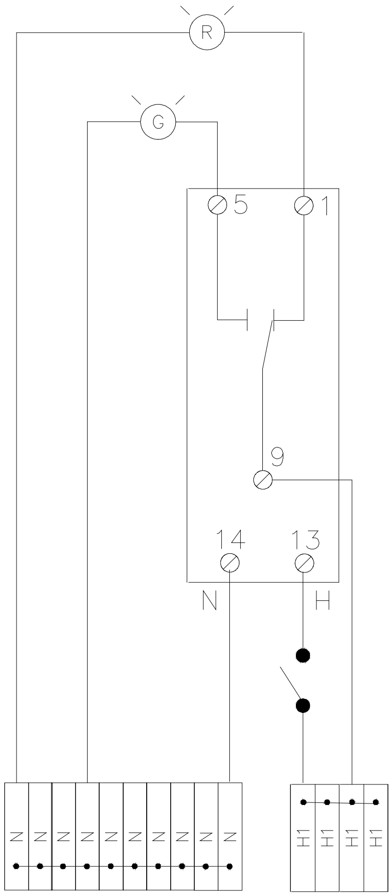
1. Wire up power to a relay through a switch as per drawing.



2. Wire a switch to activate the relay



3. Wire the red light to 5 and a green light to 1. Turn the relay on and off.



Relay terminals follow a numbering system. Please take a look at the Relay Terminals drawing. Make sure you always check the relay terminal layout specs if you are not sure what a terminal does. There are differences in terminal numbers based on different brands and based on number of poles. For example 13 and 14 are not always the coil terminals.

HANDS ON

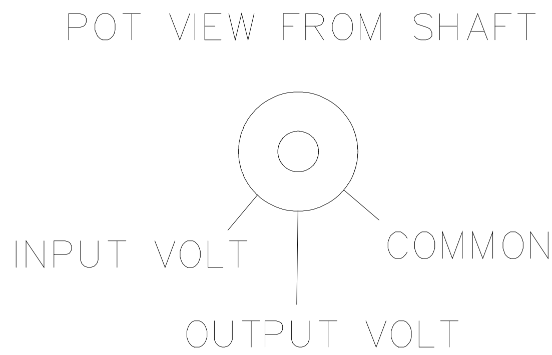
Relay wiring (1.5hr)

1. Power relay
2. Wire red light to run on when relay is on
3. Wire green light to turn off when relay is on.
4. Wire Belimo to change position when system is on.
5. Wire contactor/overload to turn motor on when system is on.
6. Wire SW#1 and SW#2 in series with the green light or relay to simulate flame controller safety circuit.

11.2. Potentiometers (pots)

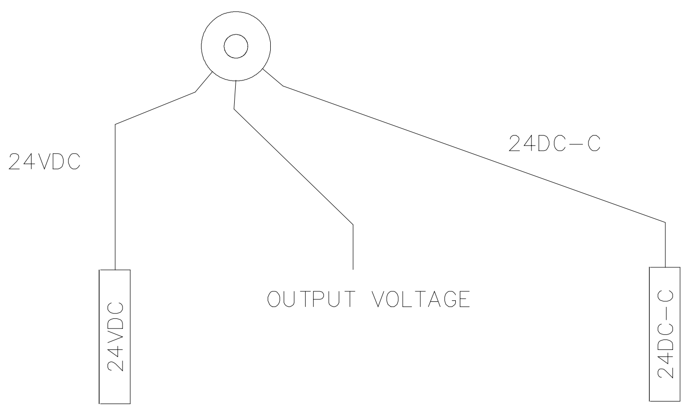
Potentiometers simply vary the intensity of a signal. Just like you turn the volume up and down on your radio, you can make a signal stronger or weaker by using a pot. For example, you can increase the exhaust VFD speed by turning up the strength of the speed reference signal to it. You can slow the VFD down by decreasing the strength of the speed reference to it.

A potentiometer is a three-terminal resistor with a sliding contact that forms an adjustable voltage divider. What does this mean? It means that you have 3 terminals. View pot from shaft side. You feed voltage into the L hand terminal. You connect the R hand terminal to common. You will be able to regulate the output voltage on the center terminal. The center terminal is also called the wiper.



HANDS ON

Get a pot. Look at the pot from the side where the shaft is on. You feed the control voltage in on the left. You connect N on the right. The pot cuts down the control voltage and sends it out on the center terminal (wiper). Connect the following circuit.

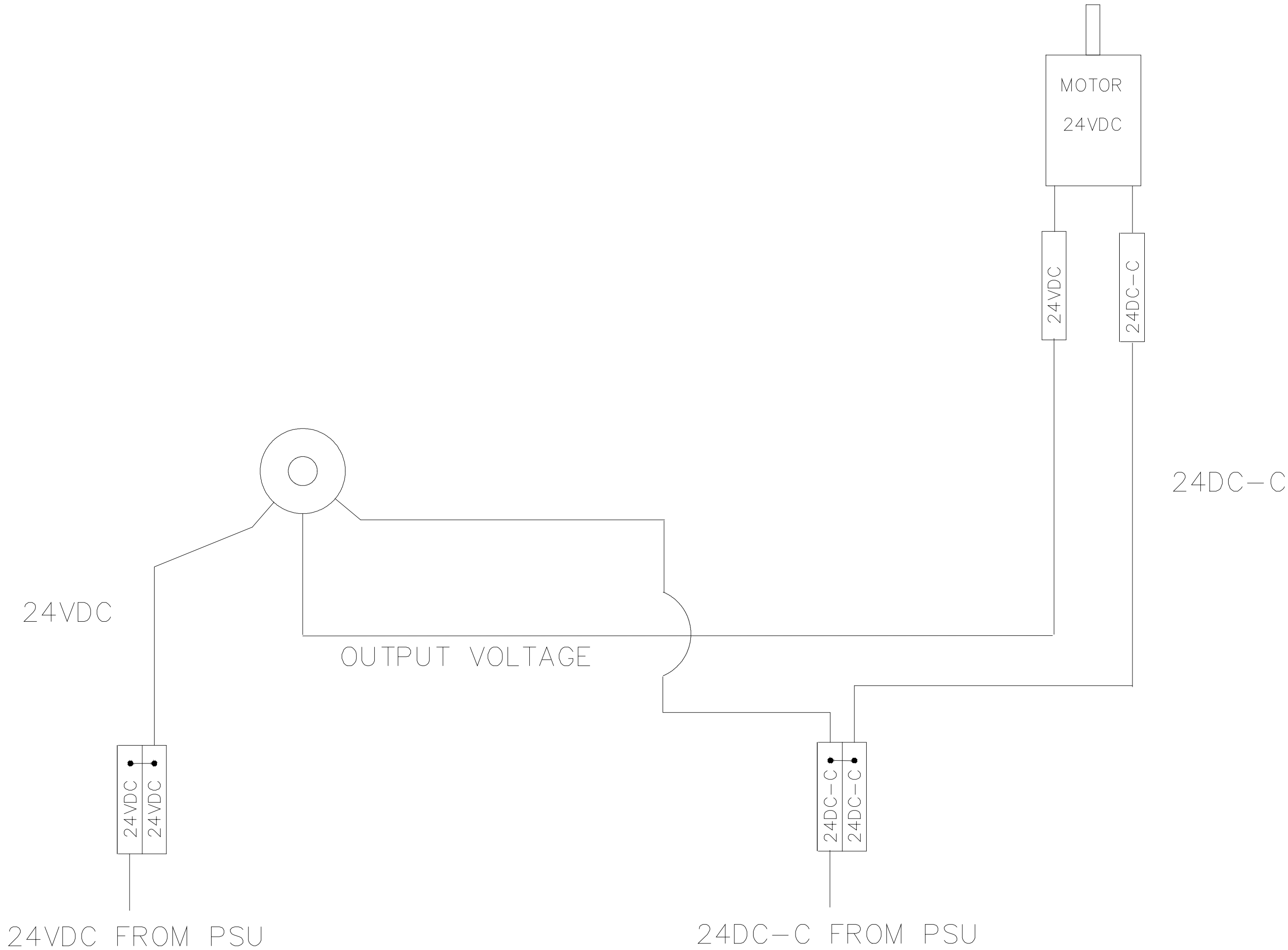


Measure DC on the center terminal while turning the potentiometer L to R.

In case of exhaust VFDs, we take the 10VDC internal voltage of the VFD. This is switched through one of the relays. In Bake Mode RL3 switches the 10VDC to the pot. The 10VDC is connected to the left hand side pot contact. We connect the VFD common to the right hand side. Now we can turn the knob and get voltage between 0V and 10VDC on the center terminal. This voltage (0-10VDC) is our speed reference signal. We send out the speed reference signal to the exhaust VFD through the E-VFD circuit.

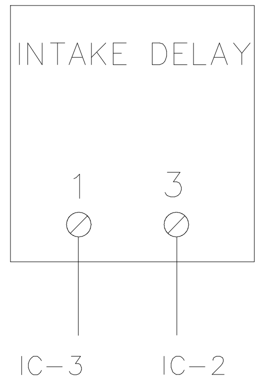
HANDS ON

Build a circuit that controls the DC motor speed with the pot.


MOTOR
24VDC
24VDC
24DC-C
24DC-C
24VDC
OUTPUT VOLTAGE
24VDC
24VDC
24DC-C
24DC-C
24VDC FROM PSU
24DC-C FROM PSU

11.3. Intake fan time delay

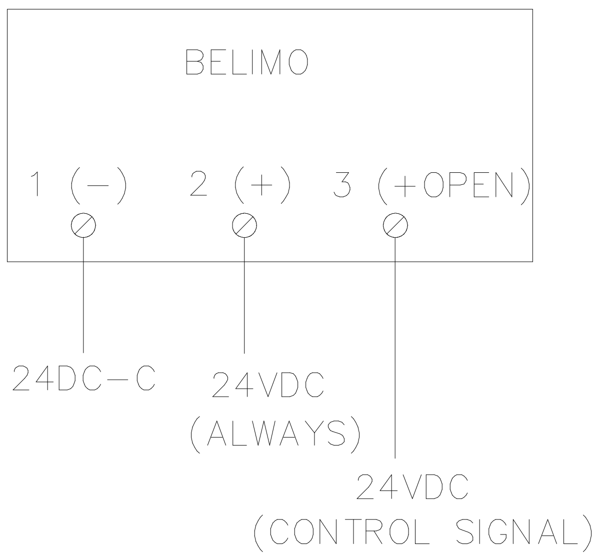
The time delay is a specialty relay. We connect the 110VAC line that is going to the intake contactor to terminal 3 of the time delay. We can program the duration of the delay through the dip switches. When 110VAC is present on terminal 3, the timer starts the countdown. When the timer expires, an internal contact is closed and the 110VAC will be present on terminal 1. From here it will go though the intake overload contact and then turn on the intake contactor.



11.1. Damper actuators – Belimo

We use damper actuators made by Belimo. We only use actuators that need electrical power to run in both directions. We do not use spring return actuators.

We power the actuators from a 24VDC power supply.



The basic Belimo terminal layout is the following:

Terminal 1: 24VDC-

Belimo uses black in their wiring harnesses for 24VDC Common.

Terminal 2: 24VDC+

Belimo uses red in their wiring harnesses for 24VDC. When the system is powered up, this terminal has power on it. Power to 2 moves the actuator to one extreme position. This can be clockwise or anti clockwise depending on the direction indicator dial on the actuator.

Terminal 3: 24VDC or 0-24VDC (position control terminal)

Belimo uses white in their wiring harnesses for the conductor that is connected to the position control terminal of the actuator.
We use two different control methods.

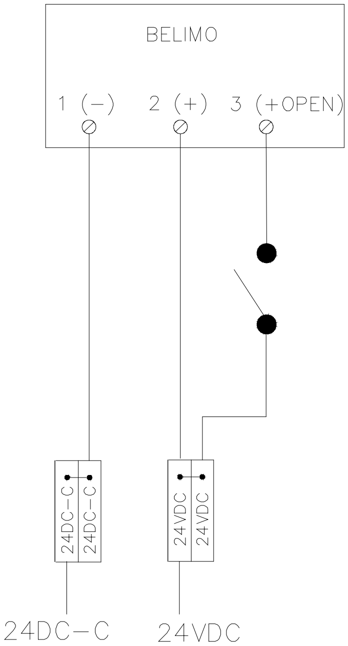
Control method 1: Used for two position dampers (LMB24-3-T). We simply apply 24VDC to terminal 3 if we want the actuator to move to the second position. When we use this method, the actuator simply moves the damper between two extreme positions.

Control method 2: Used for three and four position dampers (LMX24-MFT programmable actuators). We apply a 0-24VDC analog signal to terminal 3. We use a potentiometer to be able to accurately set up damper positions between the two extreme positions. This enables us to create more than just two damper positions.

HANDS ON

Wire up Belimo on the practice panel. Wire it to switch positions.

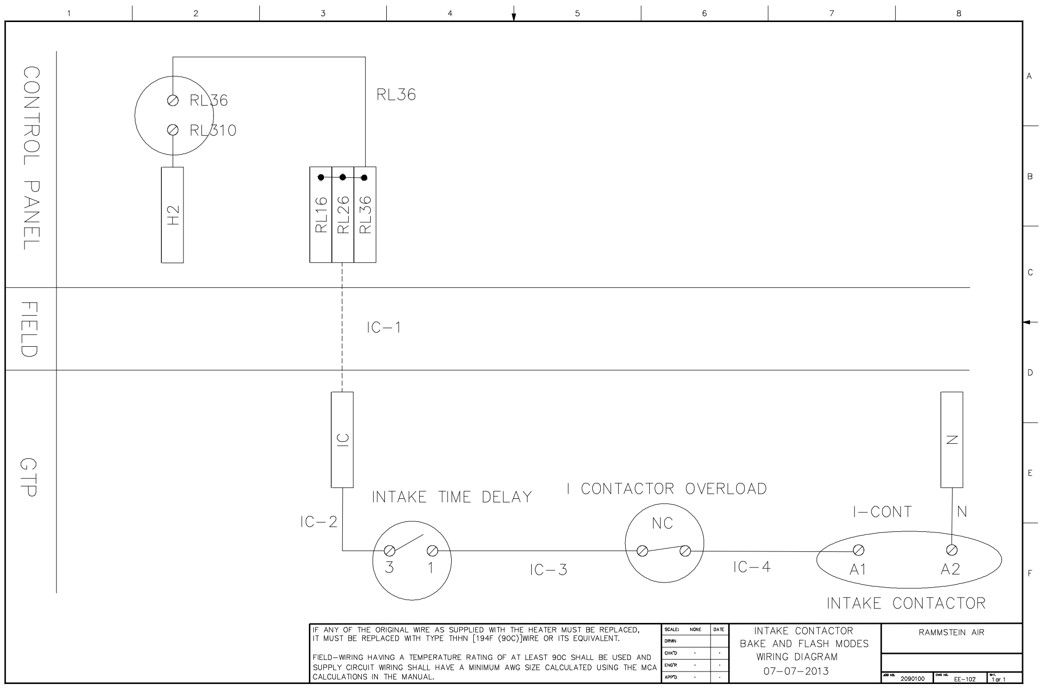
Bake Mode discharge damper – 2 position

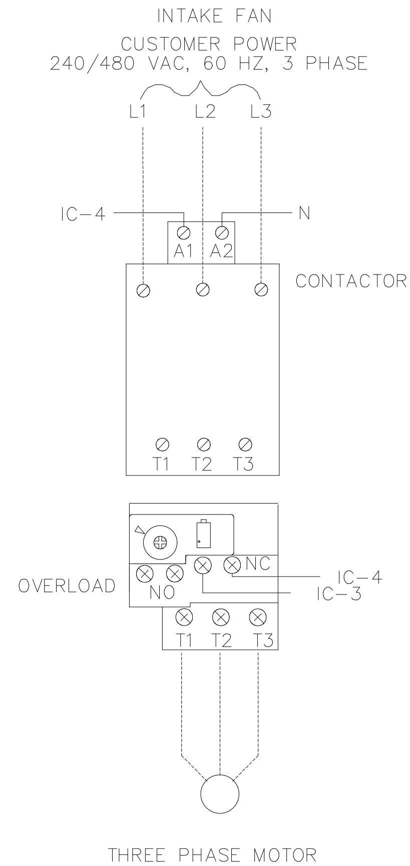

BELIMO
1 (−)
2 (+)
3 (+OPEN)
24DC−C
24DC−C
24VDC
24VDC
24DC−C
24VDC

11.2. Contactors and overloads

When you trouble shoot a motor contactor circuit, you have to remember that before the circuit is connected to the contactor coil, it goes through the NC contacts on the overload. IC-3 leaves the #1 contact on the intake time delay (see picture above). IC-3 lands on one of the NC terminals on the overload. IC-4 leaves the NC terminal of the overload and lands on the A1 terminal of the contactor.

The drawing on the right shows the contactor overload combination. The drawing below shows the complete circuit.





HANDS ON

Wire above circuit.

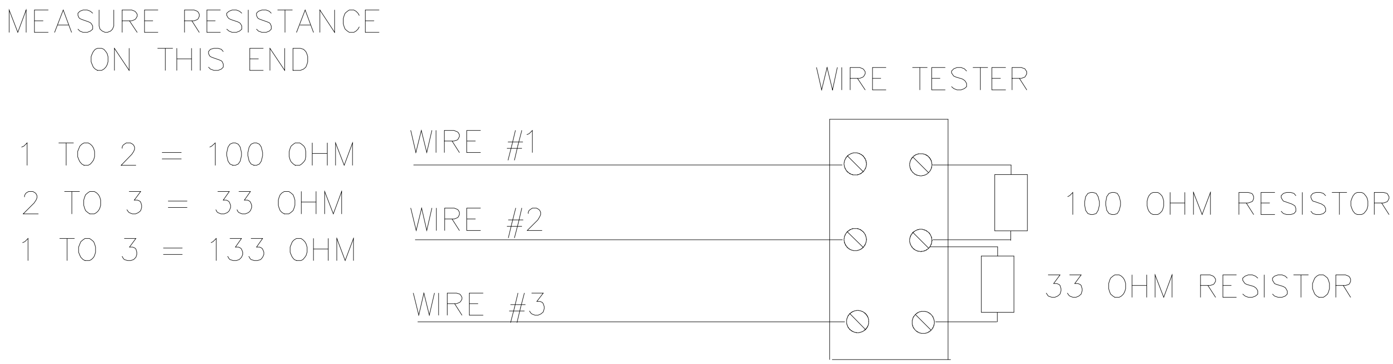
Use the contactor circuit already wired to simulate what happens when the overload trips.

11.3. Umbilical cord testing – wire tester

Use the wire tester to test long runs of cable like the umbilical. The wire tester will prove if you:

1. selected the right pair of wires,
2. there is continuity through the wires.

Connect three wires at a time. The tester installs a known resistance into the line. When you measure resistance, you know if you will know if you selected the right pair. You can also isolate individual wires by taking two resistance measurements.


MEASURE RESISTANCE
ON THIS END
1 TO 2 = 100 OHM
2 TO 3 = 33 OHM
1 TO 3 = 133 OHM
WIRE #1
WIRE #2
WIRE #3
WIRE TESTER
100 OHM RESISTOR
33 OHM RESISTOR

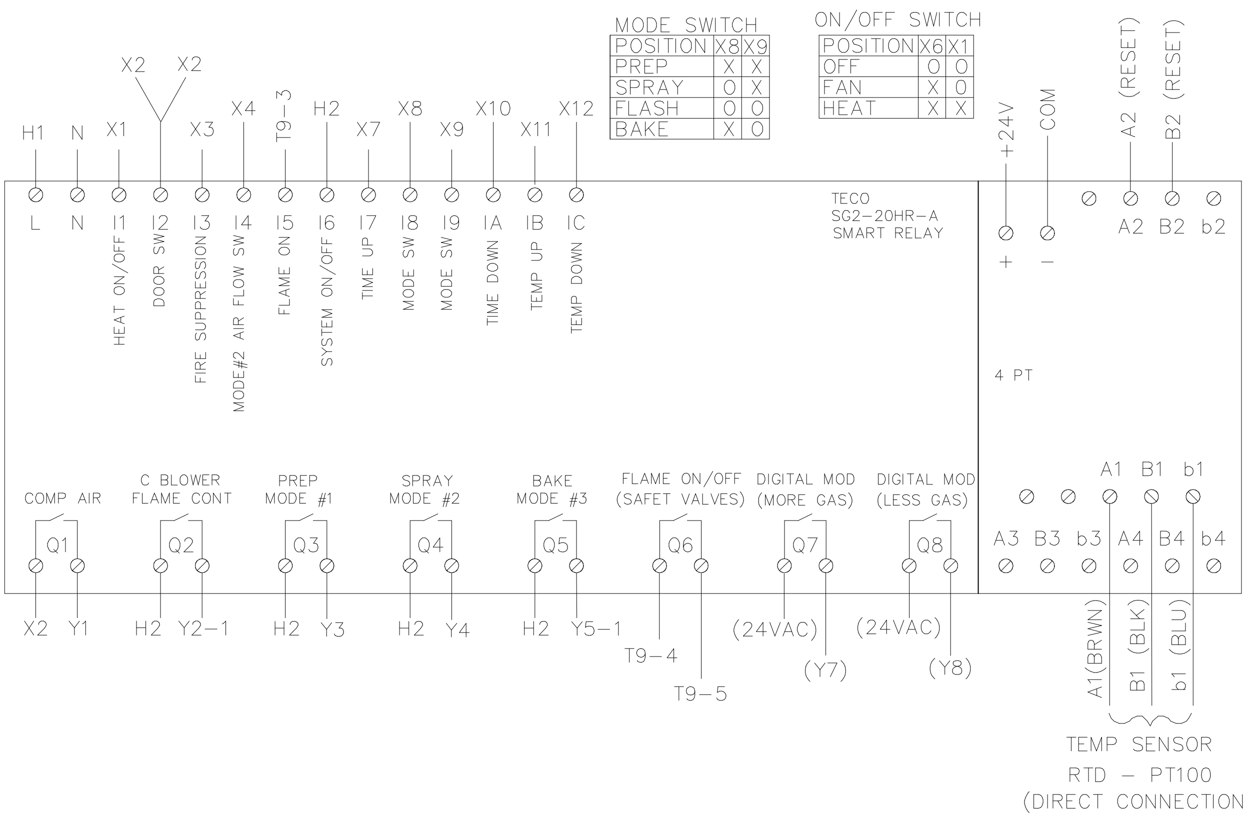
11.4. PLC

The PLC is similar to a person. The PLC is a brain with a mind, eyes and hands. The PLC is put together from a main module and expansion modules. In our case we use the TECO SG20-HR-A main module. We also use a temperature control module: 4PT. Sometimes the system also includes an analog output module: 2AO.

The drawing below shows the PLC. The main PLC is on the left. On the right you can see the temperature controller module connected (4PT). The PLC is powered through L and N terminals in the left upper corner.

The inputs are on top of the PLC. These are I1 through IA. These are not 11 to 1A. <u>The first digit is an I for Input, not a 1</u>.

The outputs are on the bottom of the PLC. The digital outputs are numbered as Q1 to Q8.



<u>HANDS ON</u>

Look at the PLC and find the part identification marks on them.

Mind = Program

The mind that operates the PLC is the program. The program makes decisions based on what the PLC sees on its inputs.

Inputs = Eyes

The inputs are the “eyes” of the PLC. The inputs we use are digital inputs and a thermocouple input. What does actually the PLC sees? The PLC is looking for 110V on all of its input terminals except the temperature controller input terminals. The program makes decisions whether there is 110V present on each input terminal or if 0V is present on each input terminal. 110V means the interlock is ON and 0V means the interlock is OFF.

HANDS ON

Disconnect some inputs from the PLC and look at error messages on display.
Select Spray Mode and disconnect the fire suppression jumper on the H end. Looks at the wire number on top of PLC and find the correct terminal block.
Still in spray mode, disconnect the mode #2 air flow switch jumper.
Switch to Bake Mode. Disconnect the door switch jumper and obsever the error message.
In Bake Mode disconnect the Flame On signal to the PLC.

Measure for 110VAC on the PLC to see which inputs do not prove.

Outputs = Hands

The outputs are the "hands" of the PLC. The PLC takes action based on what it sees on its inputs and what the PLC program is designed to do. The action is nothing else but turning outputs on and off. The digital outputs are switches. The voltage that is connected to the L hand side of the output will be switched on to the R hand side of the output when the output is activated. If it is 110V on the L then the output will have 110V on the R when it is turned on. If it is 24VAC on the L then it will have 24VAC on the R hand side when the output is turned on. Again, the output here is a digital output. It is nothing but a switch without a manual actuator. The PLC turns the switch on and off.

The mind is the program inside the PLC and an expansion module. The mind makes decision based on what it sees on its inputs.   For example, the PLC knows that it is in Spray Mode when I8 is off and I9 is on. Based on what the PLC sees, it takes action with its hands or outputs. For example if I8 is off and I9 is on (Spray Mode), the PLC will turn on Q4 to provide the proper air flow.

HANDS ON

Check for 110VAC on I8 and I9. Put into Bake Mode. Look at the Mode Switch table. In Bake I8 is on and I9 is off. Measure the inputs to verify that this is what is happening.

Factory reset/Reprogramming

There is no factory reset feature. The PLC can be reprogrammed using a programming chip.

HANDS ON

1. Switch PLC between various modes and check which outputs are turning on and off.
2. PLC programming through Setup screens. Reference Installation manual.
3. PLC reprogramming using the programming chip.

Measuring voltage on the PLC inputs and outputs (1hr)

Each input means something to the PLC. The technician has to know what each input means.

For example, the Mode Selector switch is pointing to Prep Mode. The PLC is programmed to decide that it is Prep Mode when I8 is ON and I9 is ON. However, the booth seems to be running at maximum air flow, we have compressed air to the spray gun and the display shows Spray Mode. If the PLC sees that I8 is ON and I9 is ON, this should not happen.

In order to trouble shoot the system we have to understand what the PLC was supposed to see in order to go into Prep Mode. When you look at the Mode Switch Position table we see the following. I8 and I9 were supposed to be ON (have 110V) in order for the PLC to see that the operator wants to be in Prep Mode.

HANDS ON
Go to the Control Panel wiring diagram in this book. Find the Mode Switch Position Table.

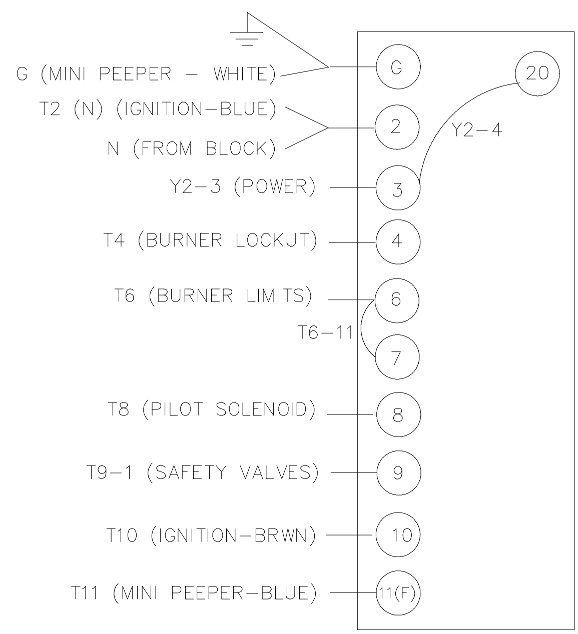
The trouble shooting is pretty simple. We have to measure I8 and I9 for 110V. When we measure on I8 we notice that there is 0V. When we measure on I9 there is 110V. So clearly the problem is that the PLC is not receiving 110V on I8. For the PLC 0V on I8 and 110V on I9 means it is Spray Mode. The next step is fairly simple also. Wire X8 is connected to the I8 input. The other end of this wire is connected to one of the contact blocks on the Mode Selector switch. The switch was supposed to switch 110V to X8. We simply follow the wires in this circuit and measure for 110V at each connection point. The problem is where we lose the 110V signal.

11.5. Flame controller

The flame controller is a specialty PLC. For simplicity's sake we will call it flame controller in this document. References to PLC in this document mean the system control PLC made by TECO.

The flame controller does what its name states. The flame controller controls the flame. The flame controller's primary responsibility is flame safety. There are 5 critical parameters that have to be continuously monitored:
- exhaust VFD auxiliary contact
- burner differential pressure switch,
- heater high temp limit,
- booth high temp limit,
- low air flow switch.

These interlocks are hard wired into the flame controller (terminal 6). If one of these interlocks does not prove, the flame controller knows that it is unsafe to ignite the burner.



The PLC works with the flame controller to safely heat the spray booth. The PLC turns on power to the flame controller. The flame controller first evaluates if it is safe or if it is not safe to turn the burner on. The evaluation is simple. The flame controller looks at terminal 6 for 110V. All interlocks are daisy chained and connected to this input. If any of the interlocks are not on, the flame controller will not see 110V on 6 and will not start the ignition process. If it is safe to turn the burner on, there will be 110V on 6 and the flame controller will ignite the burner. If the operator calls for heat, the main burner is ignited from the pilot. If the operator does not call for heat, only the pilot is ignited. The PLC has control over the safety valves. Lighting the main burner is not necessary for satisfying flame safety requirements. Therefore we turn it off if heat is not called for. We simply use the pilot to make sure we have a supervised flame. If heat is called for, we can immediately light the main burner from the pilot. The PLC controls this process by controlling the opening of the safety valves through output 6 (Q6).

The flame controller is responsible for flame safety but it does not control the intensity of the flame. After the burner is ignited, the PLC starts regulating the spray booth temperature. Through the mod valve, the PLC increases or decreases he fuel supply to the burner to create more heat or to create less heat.

HANDS ON

1. Review the flame controller connections on the above drawing.
2. Look at actual flame controller base. Show how voltage can be measure through side slots.

HANDS ON – ON HEATER

Measure UV scanner voltage on flame amp.

11.1. Air Flow Switches

Air Flow Switch Calibration (0.5hr)

The NS2-xxxx-00 air flow switches have replaceable springs to be able to use the same air flow switch body for different air flow ranges.

The low air flow switch has to be field calibrated.

PN	Color	Set Point Range ("wc)
61523	Black	0.10-0.30
61513	Natural	0.30-0.90
61514	Yellow	0.90-2.50
61515	Red	2.50-5.00
61524	Blue	5.00-10.00

11.2. VFD

VFDs control 3 phase motor speed. VFDs are very similar to each other. They have similar terminal connections and they do similar things.

11.2.1 VFD programming process

Some parameters can be programmed while the VFD is running. Other parameters can only be programmed while the VFD is in a standby mode. Standby mode is when the VFD is powered up but it is no running.

Generally VFDs have 6 buttons:
RUN
STOP/RESET
UP
DOWN
FUNCTION/DATA
PROGRAM

When programming a VFD you usually use the Up and DOWN buttons to find the parameter you want to change.
You press the FUNCTION button to enter the parameter you want to change
You use the UP and DOWN buttons to set the value for the parameter you accessed.
You press PROGRAM to save the new value.

HANDS ON

Program an exhaust VFD with the parameters our system needs. Find relevant section in Installation Manual.

11.2.1 Factory reset

You have to know how to load the factory defaults. In case someone programmed the VFD and you are unsure if the VFD programming is correct, you have to re set it. You have to load the factory default settings. Then you have to reprogram the VFD with the values specified by the Installation Manual.

Factory reset

WWE:

F_134 = dEF60

Hyundai:

B12 = 1

HANDS ON

Do a factory reset.

11.2.2 Motor overload value

The motor overload value cannot be more than 1.25 time motor FLA (name plate).

Hyundai: H05

B04 = service factor of motor

11.2.3 Maximum Hz

Although VFDs can be programmed to drive the motor at more than 60Hz, the VFD will start losing torque above 60hz.

Hyundai: A04

Should be set to 60Hz.

11.2.1 Cooling Fan Off - Hyundai

The cooling fan will wear out on a VFD. There is no reason for the cooling fan to run when the VFD is powered up but the VFD is not running. The following will turn the VFD cooling fan off when the VFD is idle.

1. Navigate to A65
2. Press “FUNC” key
3. Change the value from 0 to 1
4. Press “STR” key

11.2.2 Noisy motors – carrier frequency

If the motor is “noisy” you can use the carrier frequency parameters to quiet the motor down.

The carrier frequency, often referred to as “switching frequency” is the term used to denote the frequency of the square-wave pulses produced by the inverter section of the drive. The firings of the transistors are determined by the microprocessor and can usually be set from 1 kHz to 16 kHz. This setting will determine how often the drive sends the pulse groups to the motor. As the setting on the switching frequency is set higher, the resulting current waveform is tighter in resolution or “smoothed”. However, carrier frequencies less than 3 kHz are audible (and unpleasant) to the human ear, therefore carrier frequency is commonly set within the 4 to 8 kHz range, and sometimes higher. At these frequencies the carrier frequency closely approximates a pure sine wave. The more closely the current delivered to the motor resembles a pure sine wave, the cooler the motor will run.

If the motor runs hotter, the motor capacity may have to be de rated. Read the VFD manual to see how to derate the motor capacity

Hyunday: B11

HANDS ON
Find the carrier frequency code in the VFD manual. Create noisy motor operation and fix it.

11.2.3 VFD error messages

HANDS ON - Hyundai

1. Find Error message table in VFD manual.
2. Simulate the RUN command present upon power up message (USP error E13)
3. OL errors.
4. Regenerative errors: too much paint on exhaust fan (I think this is E5).
5. VFD overheats error: cooling fan stopped working (E21)
6. How to look at error history (protective functions): D13-D17.

11.2.4 Using a 3 phase motor on a single phase supply

You can only connect a 3 phase motor to a VFD. However, you can connect a 3 phase VFD to a single phase line. VFD manufacturers usually make 230V single phase VFDs up to a 3hp or a 5hp size. You can use 3 phase motors on 230V single phase supply if you do the following. You can connect a 230V 3 phase VFD to the 230V 1 phase supply. You have to double the VFD capacity to do this. For example, if you have a 10hp 3 phase motor that you want to run off of a 230V 1 phase line, you have to use a 20hp 230V 3 phase VFD.

11.2.5 Using a VFD at a higher than 60Hz speed

Motor loses torque. Have to derate motor capacity.

11.3. Temperature controller

Some of the control systems use temperature controllers instead of PLCs: Spray only, Prep/Spray, Bake only.

Temperature controllers have three function modes:

1. Regulation Mode
2. Operation Mode
3. Initial Setting Mode

8 Display, LED and Key Pad

PV Display: To display the process value or parameter type.

SV Display: To display the set point, parameter operation read value manipulated variable or set value of the parameter.

AT: Auto-tuning LED, flashes when the Auto-tuning operation is ON.

OUT1 / OUT2: Output LED, lights when the output is ON.

ALM: Alarm output LED, lights when one of the alarms is on.

°C, °F: Temperature unit LED. °C: Celsius °F: Fahrenheit

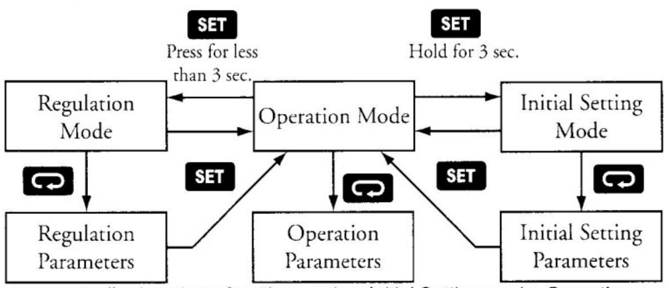
SET Set Button: Press this key to select the desired function mode and confirm the setting value.


Rotate Button: Press this key to select parameters within the function mode.


Down Button: Press this key to decrease values displayed on the SV display. Hold down this key to speed up the decrement.


Up Button: Press this key to increase values displayed on the SV display. Hold down this key to speed up the increment.

9 Key Pad Operation



The SOLO temperature controller has three function modes: Initial Setting mode, Operation mode and Regulation mode. When power is first applied to the temperature controller, the module information splash screen appears. This screen shows the firmware version on the PV display and the two output types for that particular model on the SV display. After three seconds, the controller will automatically proceed to the Operation mode main screen. Press and hold the SET button for three seconds to go into the Initial Setting mode. Press the SET button for less than three seconds to access the Regulation mode. Press the button while inside any of the three function modes to access the individual parameters for each function mode. Use the and buttons to change the individual parameter values. Pressing the SET button saves the parameter values. Press the SET button again to return the controller to the Operation mode.

In order to be able to work with temperature controllers, first you have to understand the display. Some of the display letters/characters are unusual.

Letters on the temp controller display

A = A

b = B

C = C

E = E

F = F

H = H

Ī = I

J = J

Ⱶ = K

L = L

n̄ = M

n = N

o = O

P = P

ㄏ = R

S = S

T = T

U = U

u = V

ꞟ = X

y = Y

Temperature controller programming parameters

The following parameters have to be programmed into the temperature controller:

tPUn: temperature unit of measure = F

tP-H: Upper limit of temperature range = 180F

P0: PID control P value = xxx

I0: PID control I value = xxx

d0: PID control D value = xxx

tPoF: process temperature offset = program in offset value to correct difference between measured and actual process temperature.

CrHi: Analog high adjustment (page 3-13) – Prep Mode: set to 3V

2V = -6071

3V = -5312

4V = -4553

5V = -3795

Temp controller is limited in display capability. Can only display -2,000 before it "rolls over" to -0. Two roll overs equal -4,000.

When decreasing the parameter value for Analog High Adjustment below -1999, the SOLO display will "roll over" to -0, indicating a value of -2000. Two "roll overs" equal a value of -4000 and so forth. For example, to enter a value of -5312 for Analog High Adjustment, hold the ▽ button until the SOLO display "rolls over" two times and the display reads -1312.

HANDS ON
Use the temp controller manual to program the above parameters.
Create a large error (large difference between PV and SV). Increase the SV to the maximum value (167F). Measure the analog output of the controller. Verify that the programming limited the analog output to 3VDC.

<u>Factory reset: Delta and SOLO temp controllers</u>

Warning: Erasing the user entered values may result in a safety hazard and system malfunction.

Note: Resetting the Temperature Controller back to factory default erases all of the values entered by the user. Record any necessary settings before proceeding

The following instructions reset the controller to the factory default.

1. In Operation Mode press the ↻ button until the parameter loC appears.
2. Use the △ button to select loC1.
3. Press the SET button.
4. Press and hold the ▽ and △ buttons simultaneously for one second and release.
5. Press the ↻ button until the PV display shows PASS.
6. Use the ▽ button to change the value on the SV display to 1357.
7. Press the SET button.
8. Cycle power on the controller to reset to factory default mode. All user set values are erased.

HANDS ON
Do a factory reset.
Reprogram controller with parameters.
Do a factory reset again.
Reprogram controller again.

12 Important Operating Parameters

12.1. Ventilation related

12.1.1 Match heater to booth – Maximum theoretical air flow rate

Myth: NFPA33 requires 100fm of air velocity in a horizontal air flow booth. NFPA33 does not require this. NFPA33 2011 Section 7.2 specifies two things:

1. Ventilation has to be capable of confining and removing vapors, mists and combustible residues to a safe location. Important to understand that danger comes from two sources: vapors and dust.
2. The exhaust air stream concentration of flammables cannot exceed 25% of the Lower Flammability Limit (LFL).

Read NFPA33 2011 Annex B.2 Spray Booths.

It is a problem for a lot of jurisdictions that there is no clearly defined air velocity for a spray booth in NFPA33. Local jurisdictions sometimes use 100fm as the target air velocity through a spray booth. First make sure you understand what your local AHJ requires for air velocity and how they measure it. Then verify that the heater is capable of producing the required air flow rate.

12.1.2 Actual air flow rate

After installation, measure the actual air flow rate either in the exhaust or in the intake stack to verify that the required air flow is present.

Velocity Pressure Measurement

The easiest way to measure air flow rate is to use an air flow sensor like the Sensocon JFM-P-E-30-0-A. The instrument measures velocity pressure. You should take two readings at 90 degrees to each other and average the results. Please refer to the table for approximate air flow rates.

Velocity Pressure in 30" Duct ("WC)	Air Flow Rate (CFM)
0.100	6,214
0.125	6,947
0.150	7,610
0.175	8,200
0.200	8,788
0.225	9,321
0.250	9,825
0.275	10,304
0.300	10,762
0.325	11,202
0.350	11,625
0.375	12,033
0.400	12,427
0.425	12,810
0.450	13,181

Air Velocity Measurement

You can calculate the air flow rate by measuring air velocity in a duct. If you know the air velocity and the duct diameter, you can calculate the air flow rate using the following formula.

Duct area of 30" duct = 4.91fm

Air flow rate (CFM) = duct area (sq ft) x air velocity (FM)

The issue is that for accurate results, you need to take a transverse measurement. It is time consuming and cumbersome to do.

Air flow rate - 30" duct	
Air speed (fm)	**Flow rate (cfm)**
250	1,228
500	2,455
550	2,701
600	2,946
650	3,192
700	3,437
750	3,683
1,000	4,910
1,500	7,365
1,750	8,593
2,000	9,820
2,250	11,048
2,500	12,275

HANDS ON – ON HEATER

Measure maximum air flow rate with air flow sensor.

Without doing a transverse measurement, we will measure air velocity in duct with a hot wire anemometer and see how close our results are to the previous test.

12.1.1 Minimum air flow rate – Prep Mode

After installation, verify that the minimum air flow rate specified is present. If the heater operates below the minimum specified air flow rate, it will generate excessive combustion byproducts. This will create an unhealthy and potentially dangerous situation for operators.

HANDS ON – ON HEATER

A. Measure and adjust minimum air flow rate with air flow sensor.
B. Adjust low air flow switch.

12.2. Gas and temperature related

Gas related parameters that have to be set up and verified during commissioning are the following. For specifications and step-by-step instructions refer to Installation Manual.

1. Gas supply pressure

   Cannot exceed ½ psi.

Static and dynamic pressure

Static pressure is the gas pressure when the gas is not flowing. For example, the gas inlet pressure when the burner is off. **Dynamic pressure** is when the gas is flowing. For example the gas inlet pressure when the burner is on.

2. Burner negative air pressure

Needed to calculate and set burner manifold gas pressure.

HANDS ON
Look up info in Installation Manual.

3. Burner manifold maximum gas pressure
   This is the high fire gas pressure. Gas regulator has to be adjusted to provide the correct gas pressure for high fire based on the following formula.

   burner high fire gas pressure = burner negative air pressure + maximum manifold pressure

   if burner negative air pressure = -0.4"WC
   if burner maximum manifold pressure (from name plate) = 3.5" WC

   burner high fire gas pressure = -0.4+3.5
   burner high fire gas pressure = 3.1" WC

4. Pilot gas pressure
   Has to be 0.2" – 0.25" WC.

HANDS ON – ON HEATER
Measure and adjust on heater.

5. Combustion air differential pressure
   This is the pressure drop over the burner.

HANDS ON – ON HEATER
Measure and adjust on heater.

6. Maximum temp rise at maximum air flow – High fire adjustment

HANDS ON – ON HEATER
Measure and adjust on heater.

7. Burner low fire adjustment

HANDS ON – ON HEATER
Measure and adjust on heater.

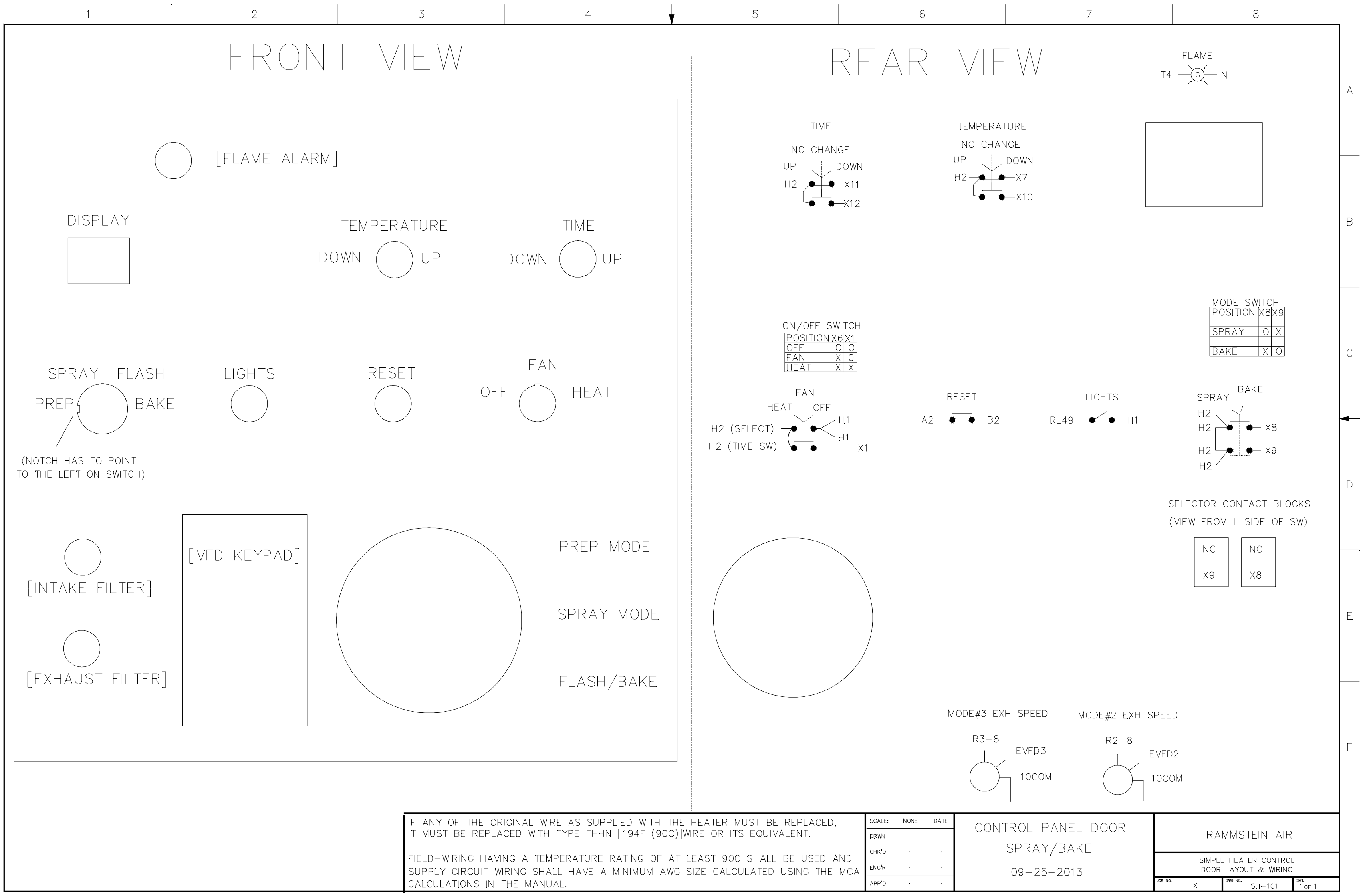
8. Maximum temp rise at minimum air flow
   Limit maximum valve opening in Prep Mode through Setup Screens.

HANDS ON – ON HEATER
Measure and adjust on heater.

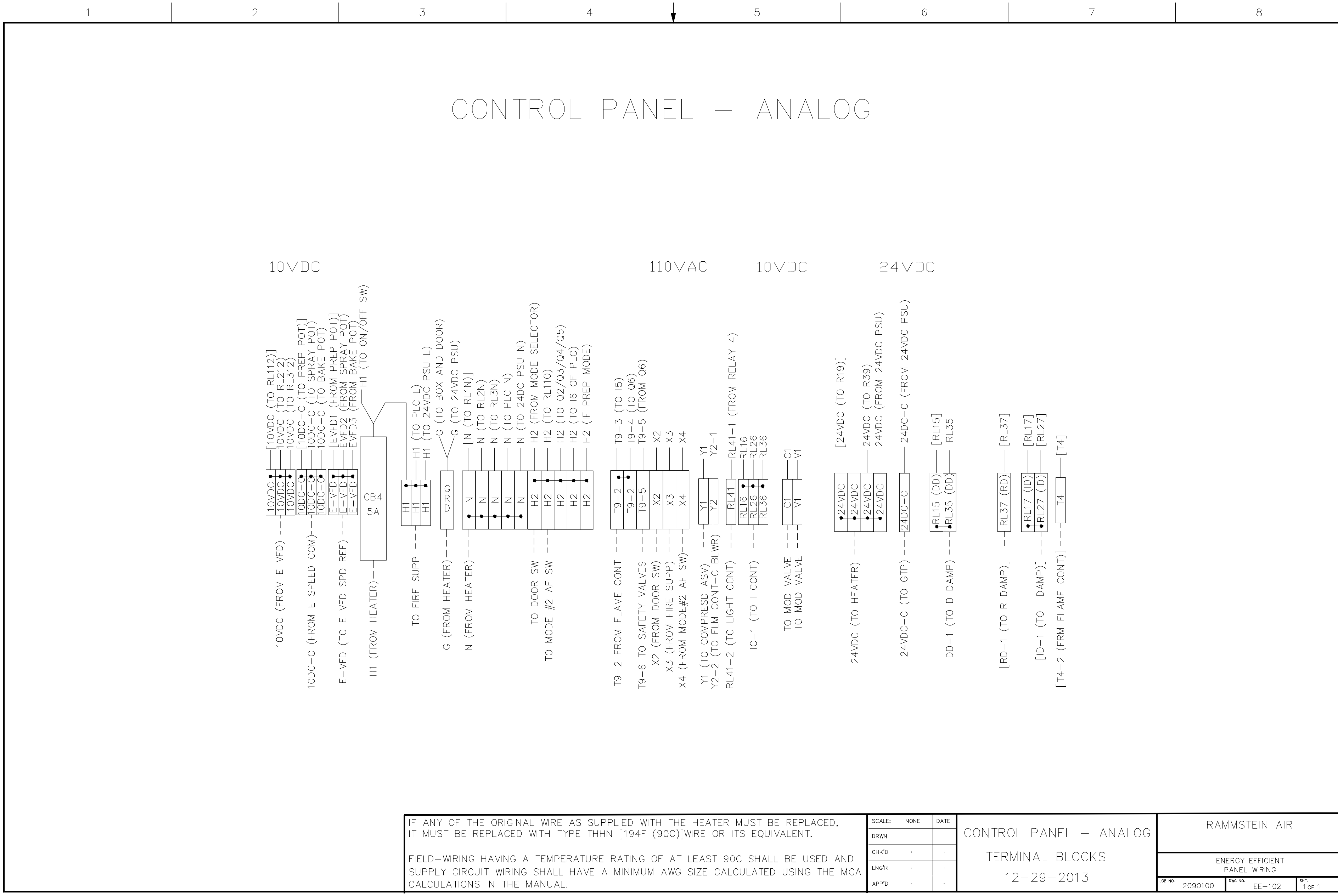
13 Wiring Diagrams

13.1. System wiring diagrams

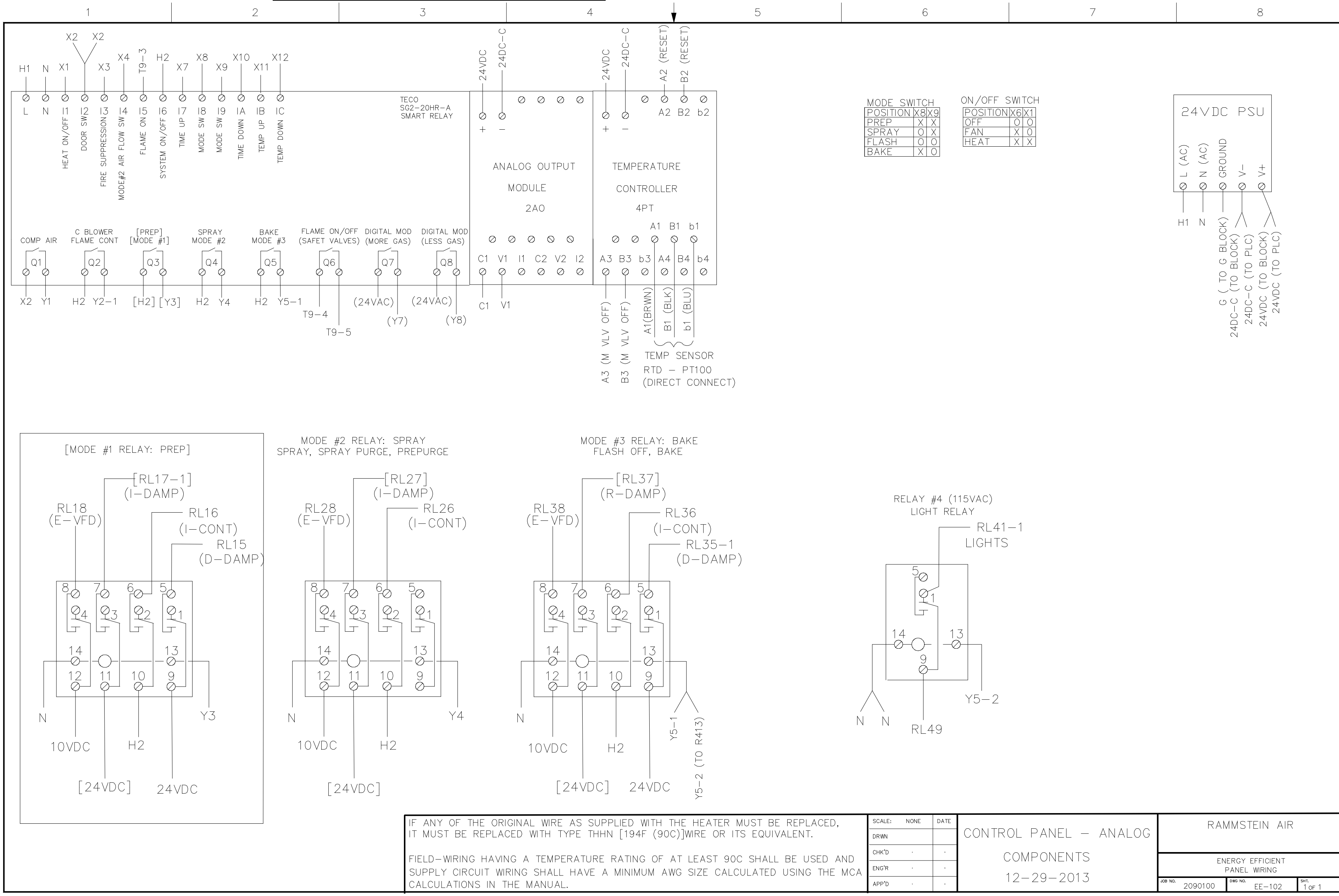
13.1.1 Control panel door



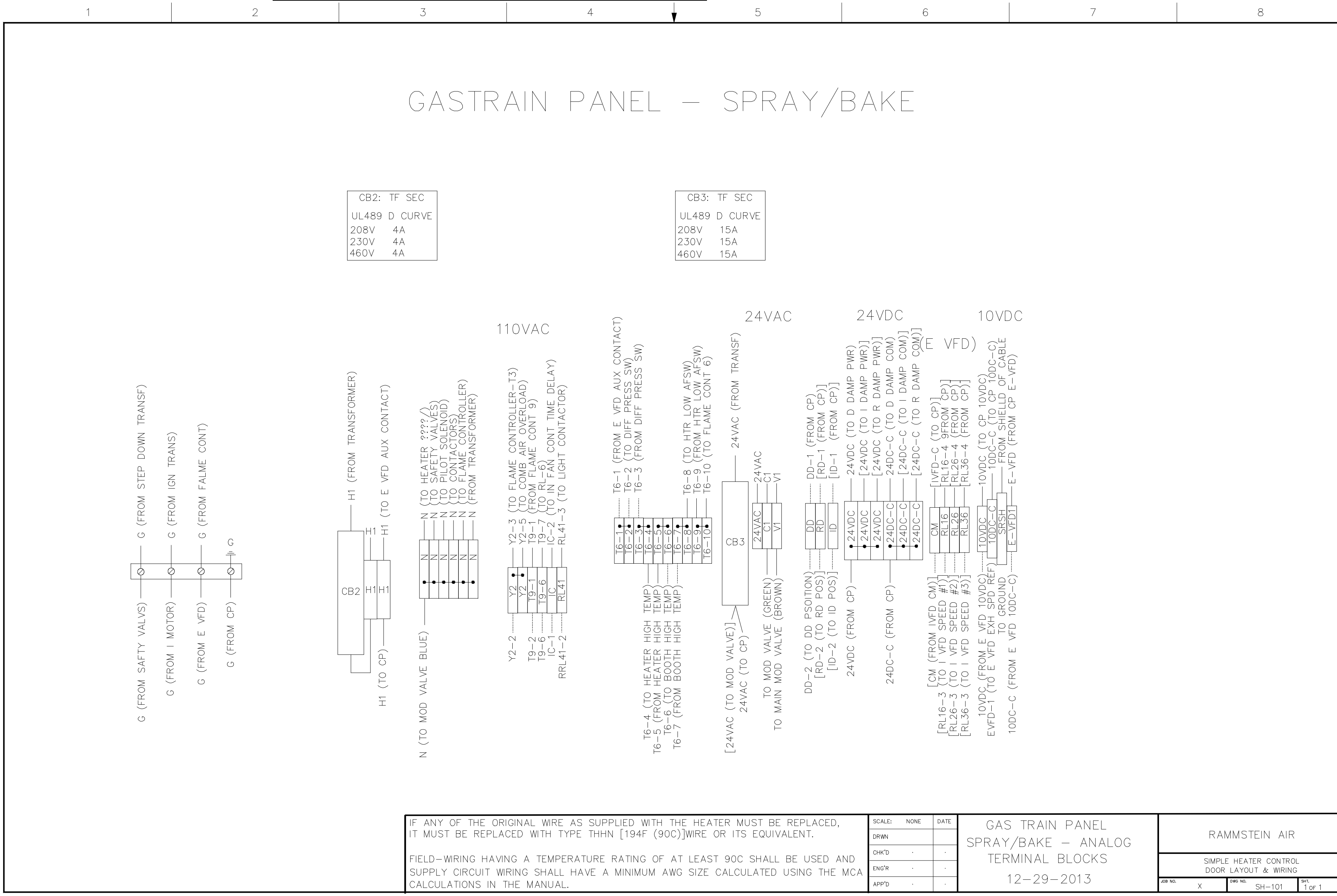
13.1.2 Control panel terminal blocks – Analog



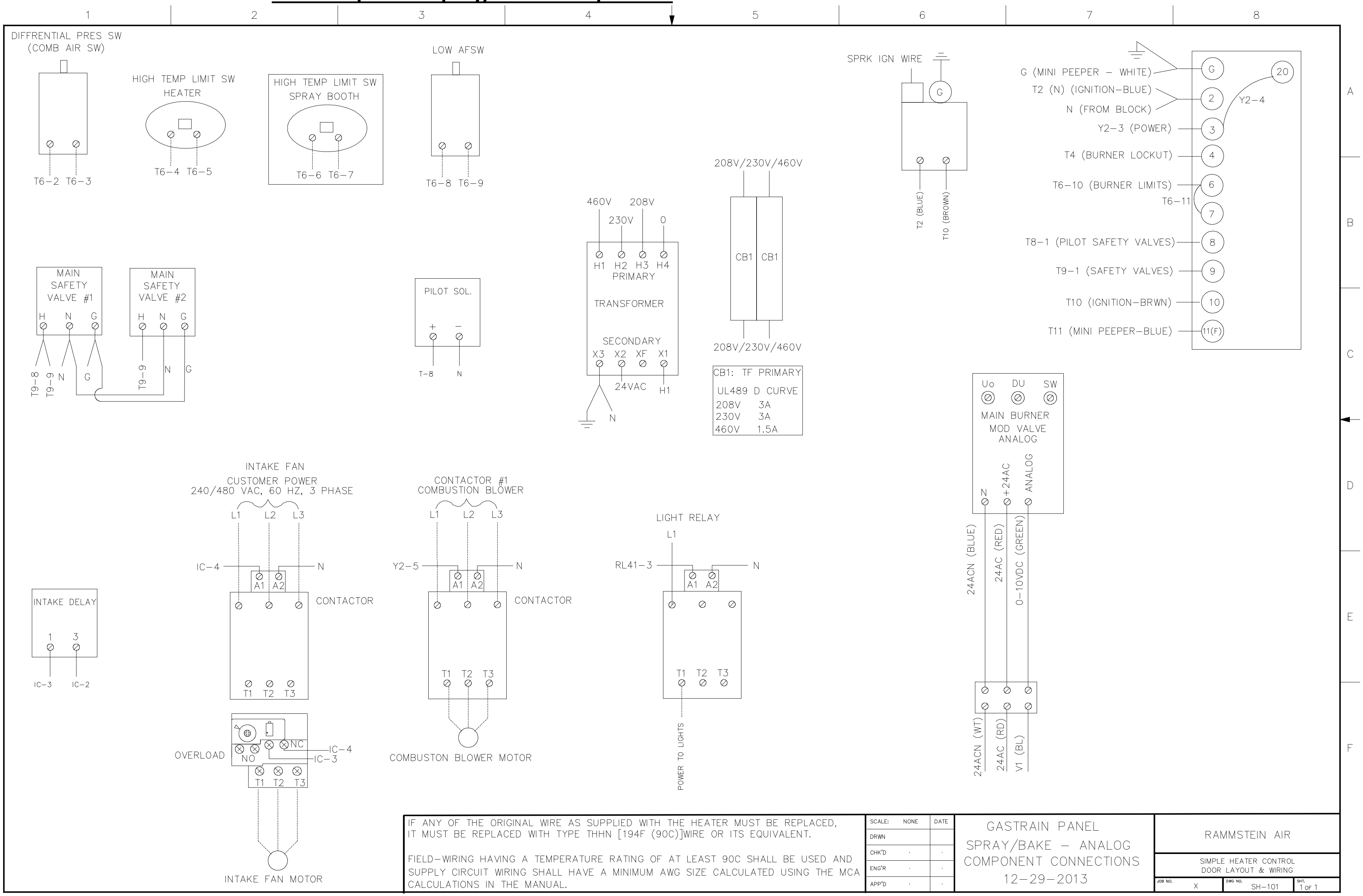
13.1.3 Control panel components - Analog



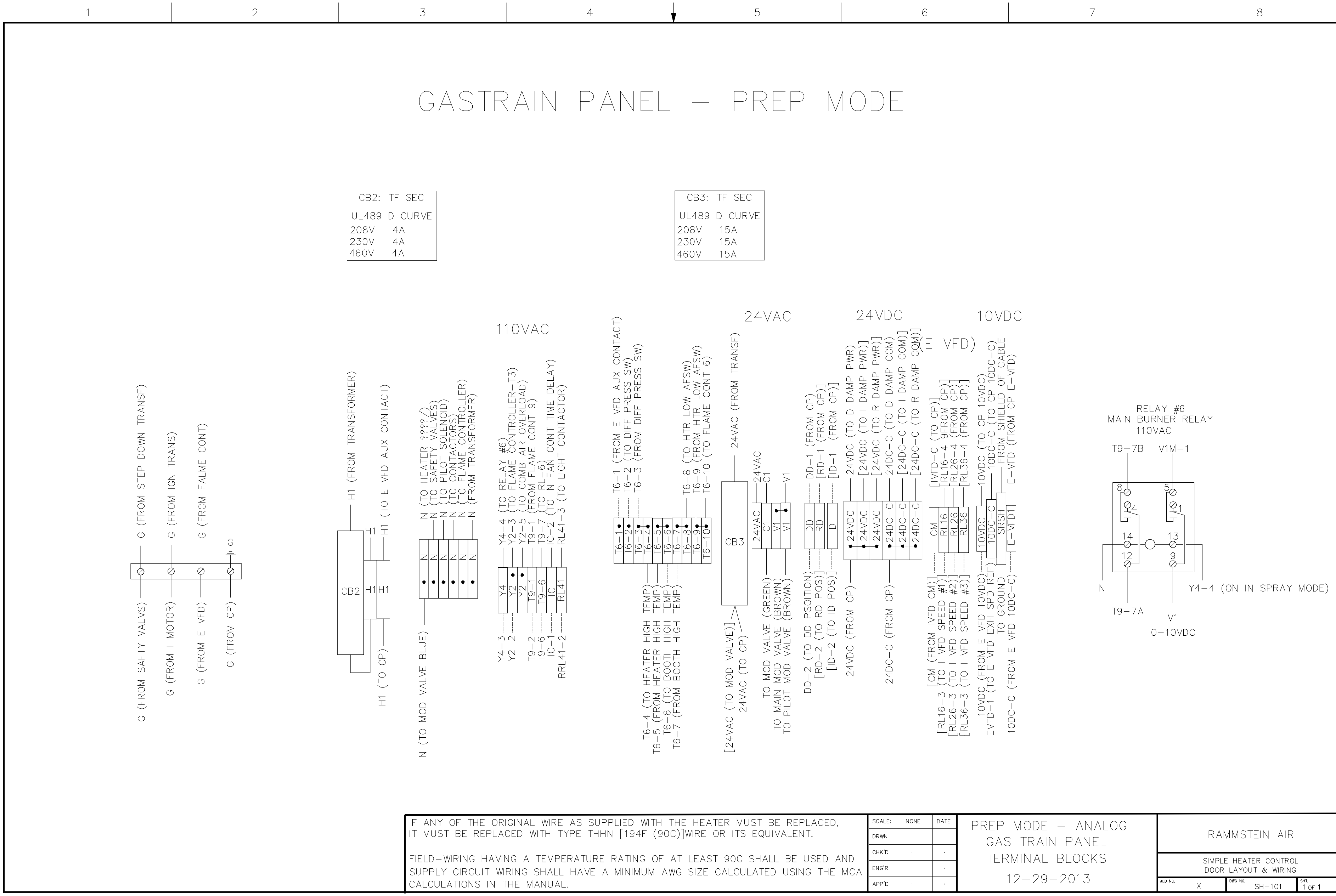
13.1.4 Gastrain panel – Spray/Bake – terminal blocks



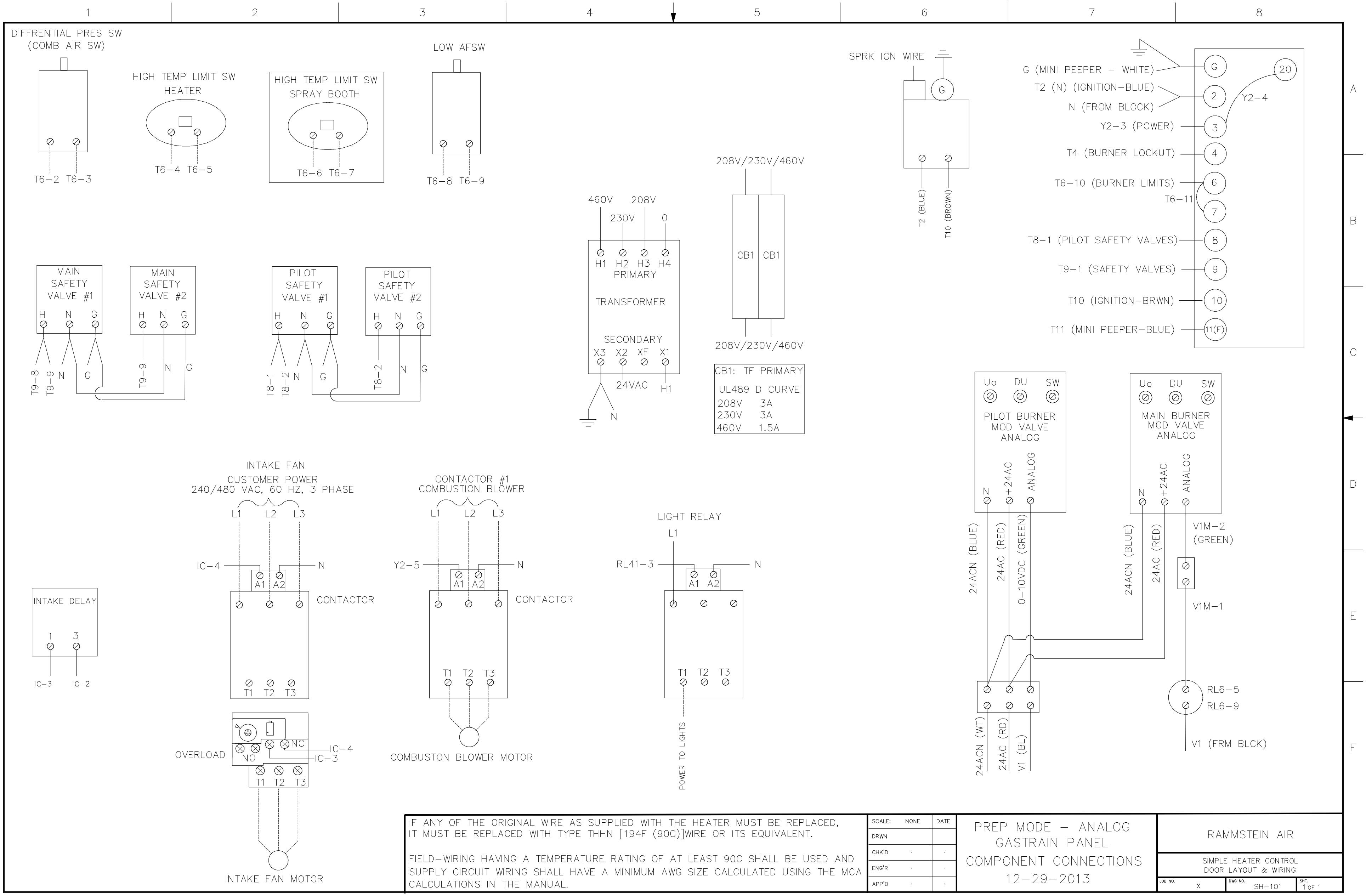
13.1.5 Gastrain panel – Spray/Bake - components



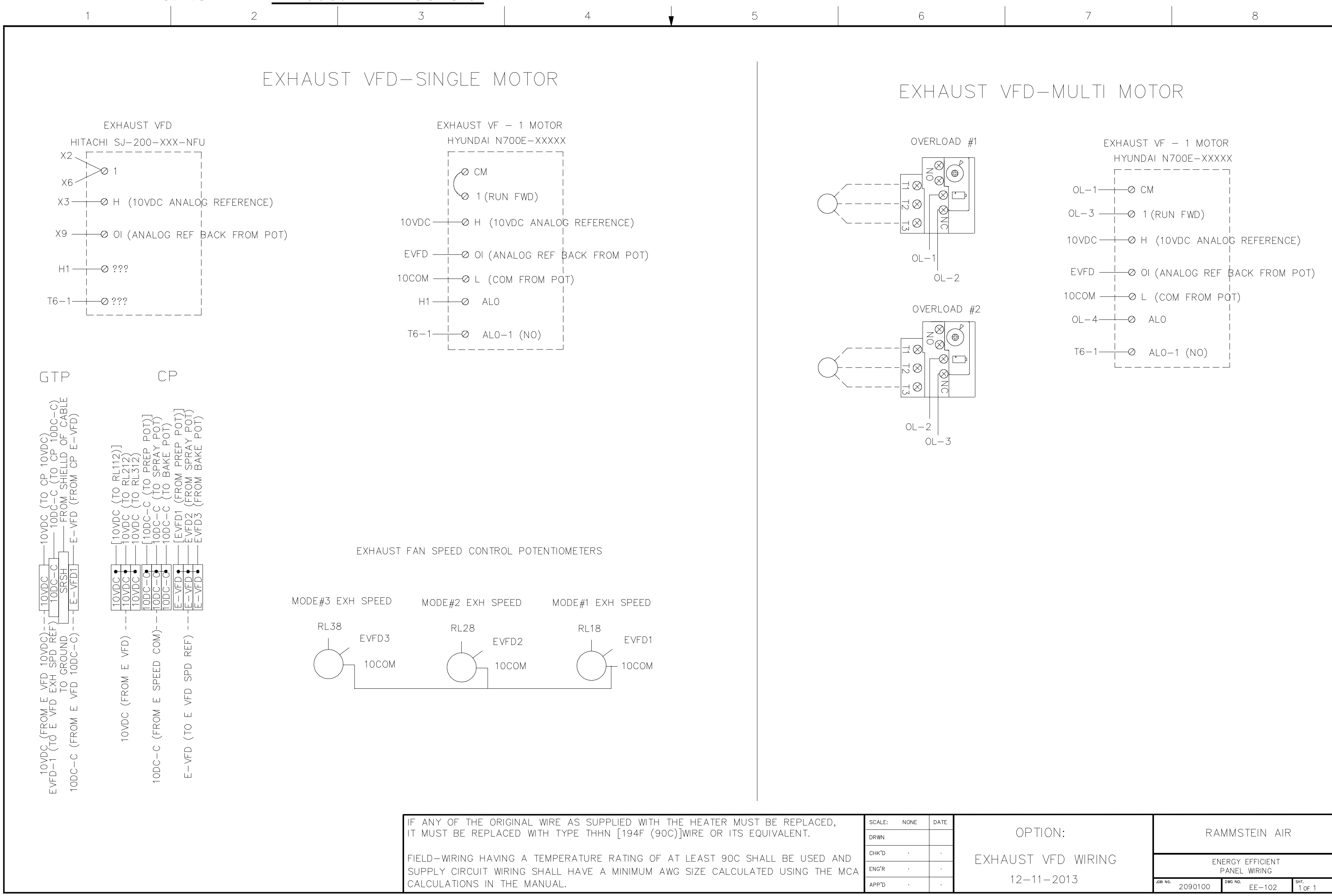
13.1.6 Gastrain Panel – Prep Mode – terminal blocks



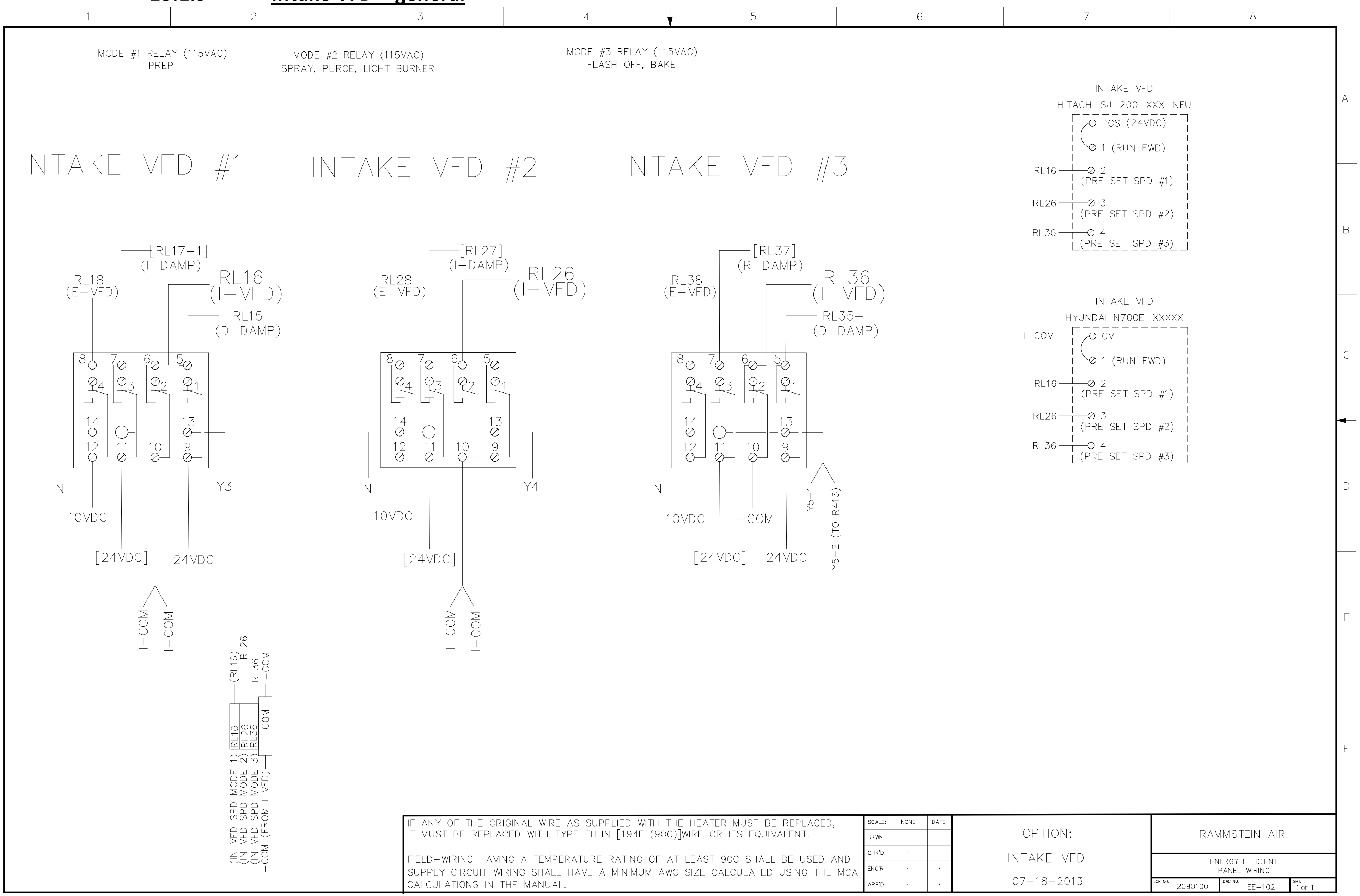
13.1.7 Gastrain panel – Prep Mode – components



13.1.8 Exhaust VFD – General

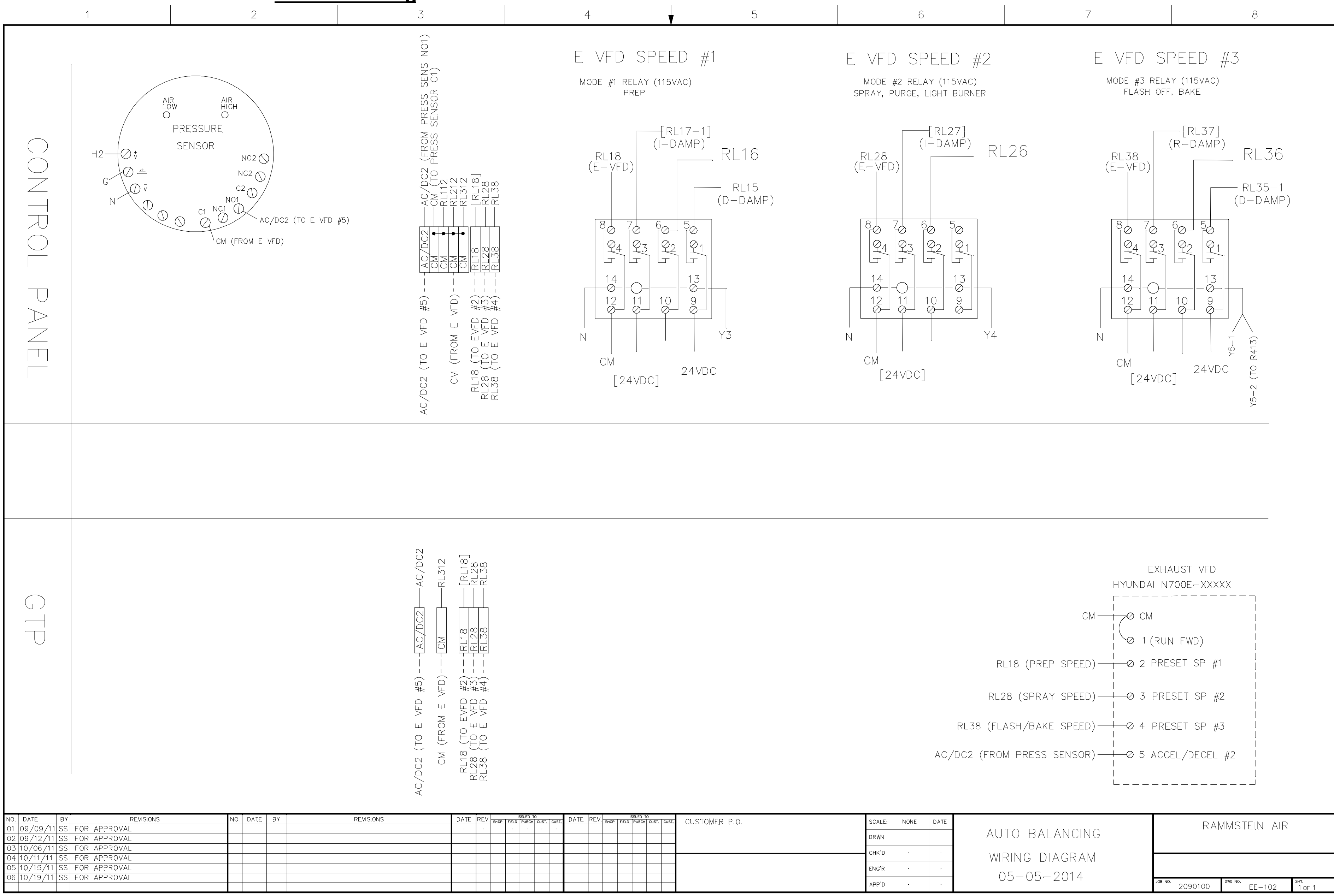


13.1.9 Intake VFD – general

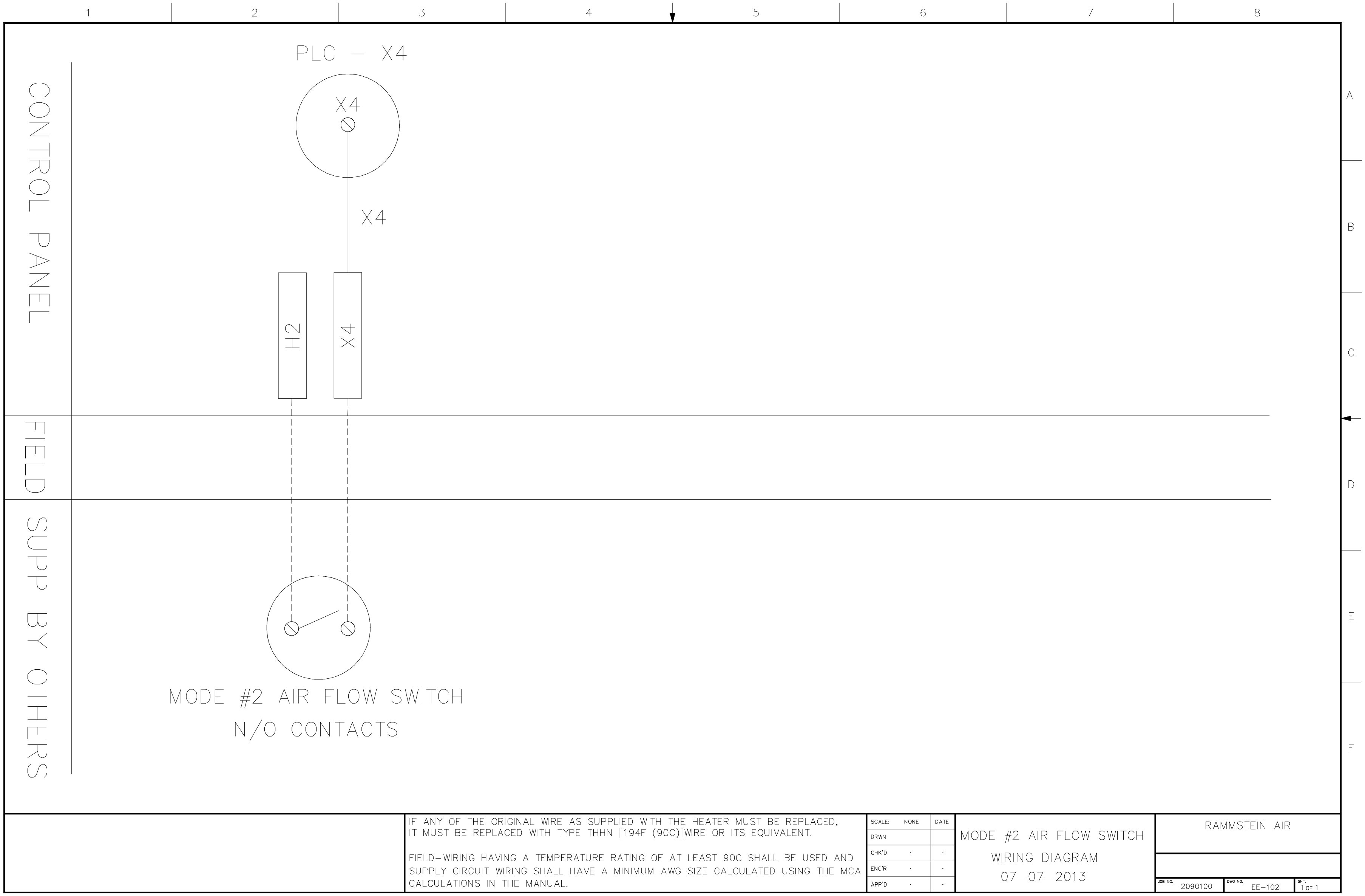


13.2. Individual circuit diagrams

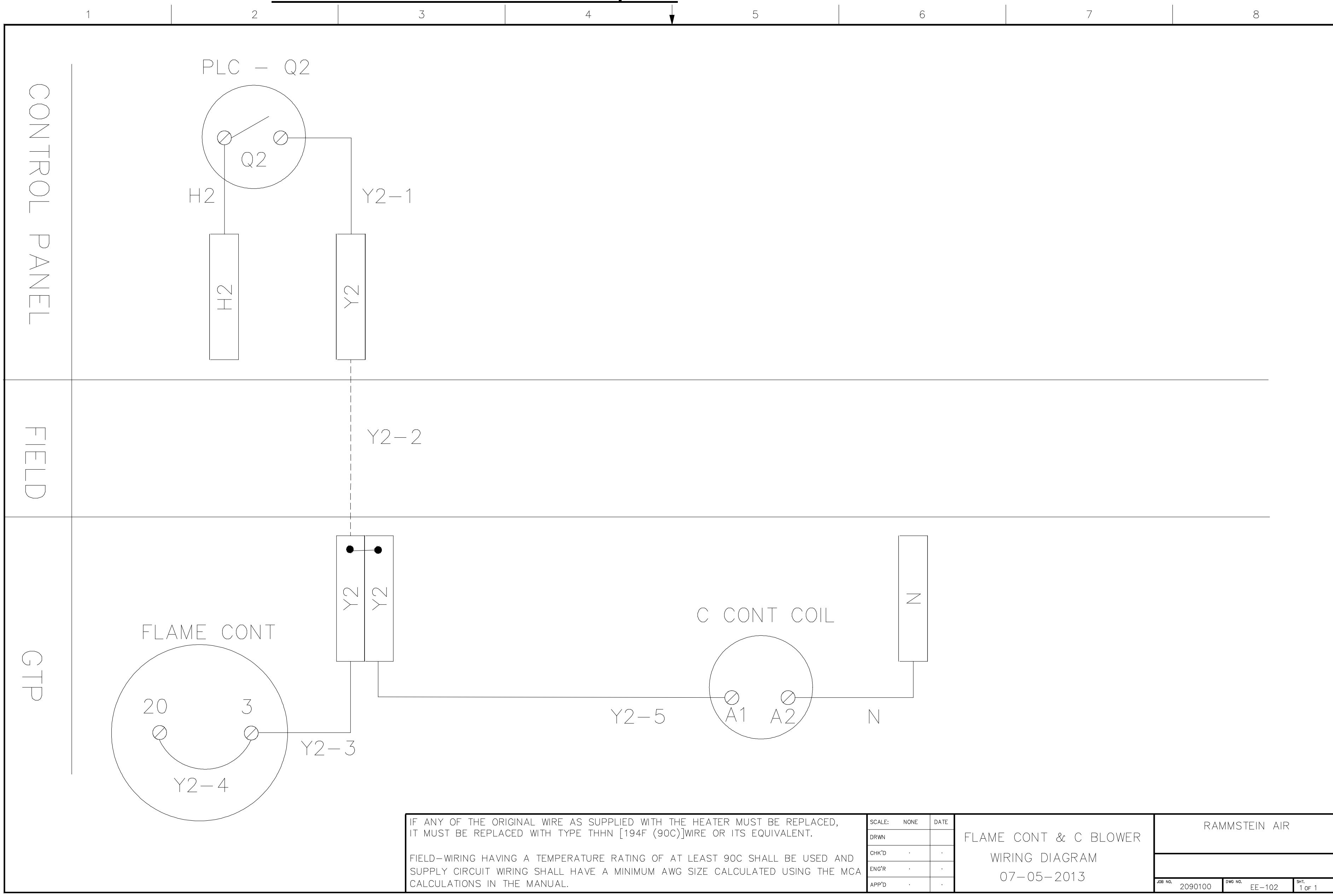
13.2.1 Auto Balancing



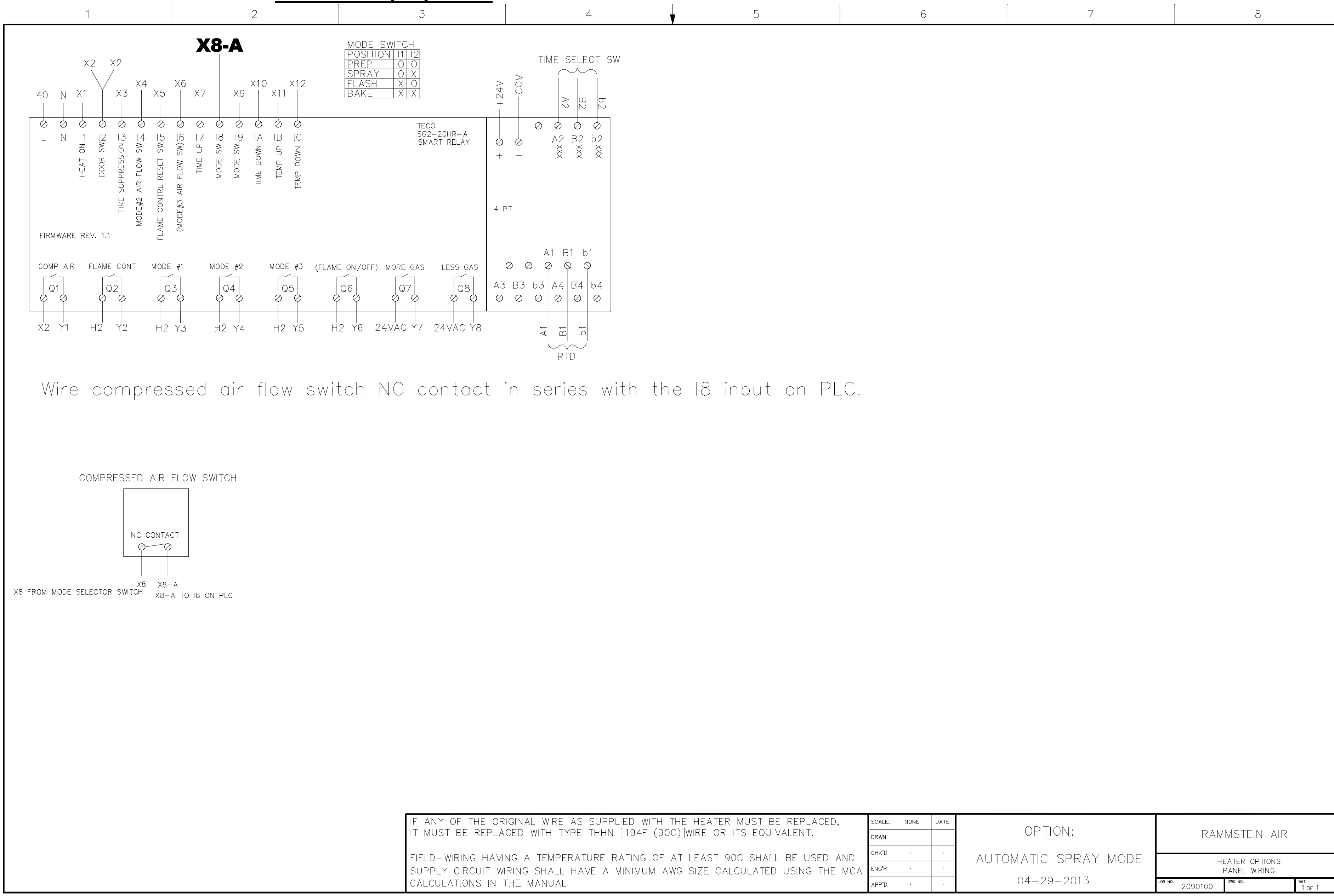
13.2.2 Air Flow Switch (Mode #2)



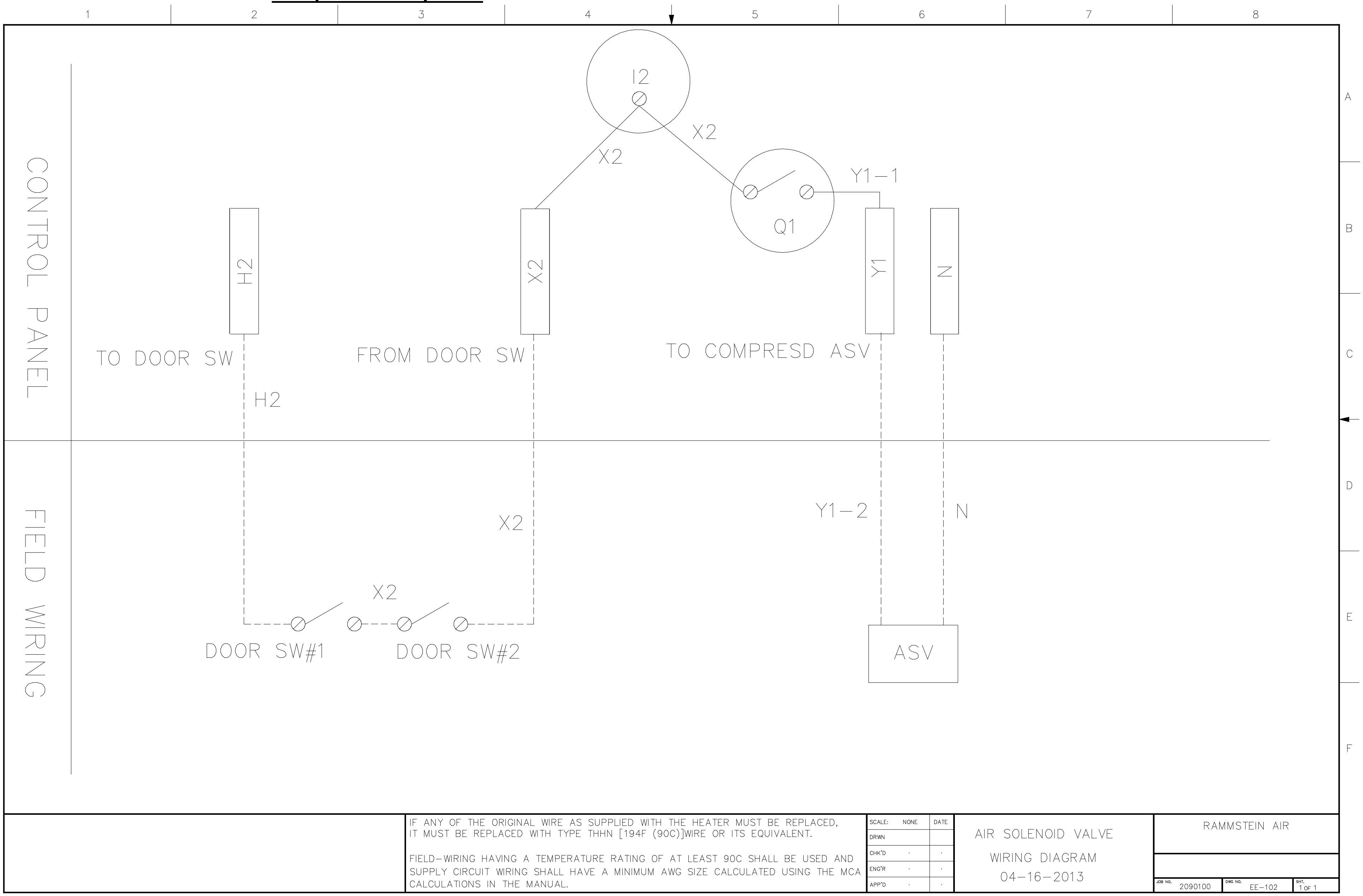
13.2.3 Combustion air and flame controller power



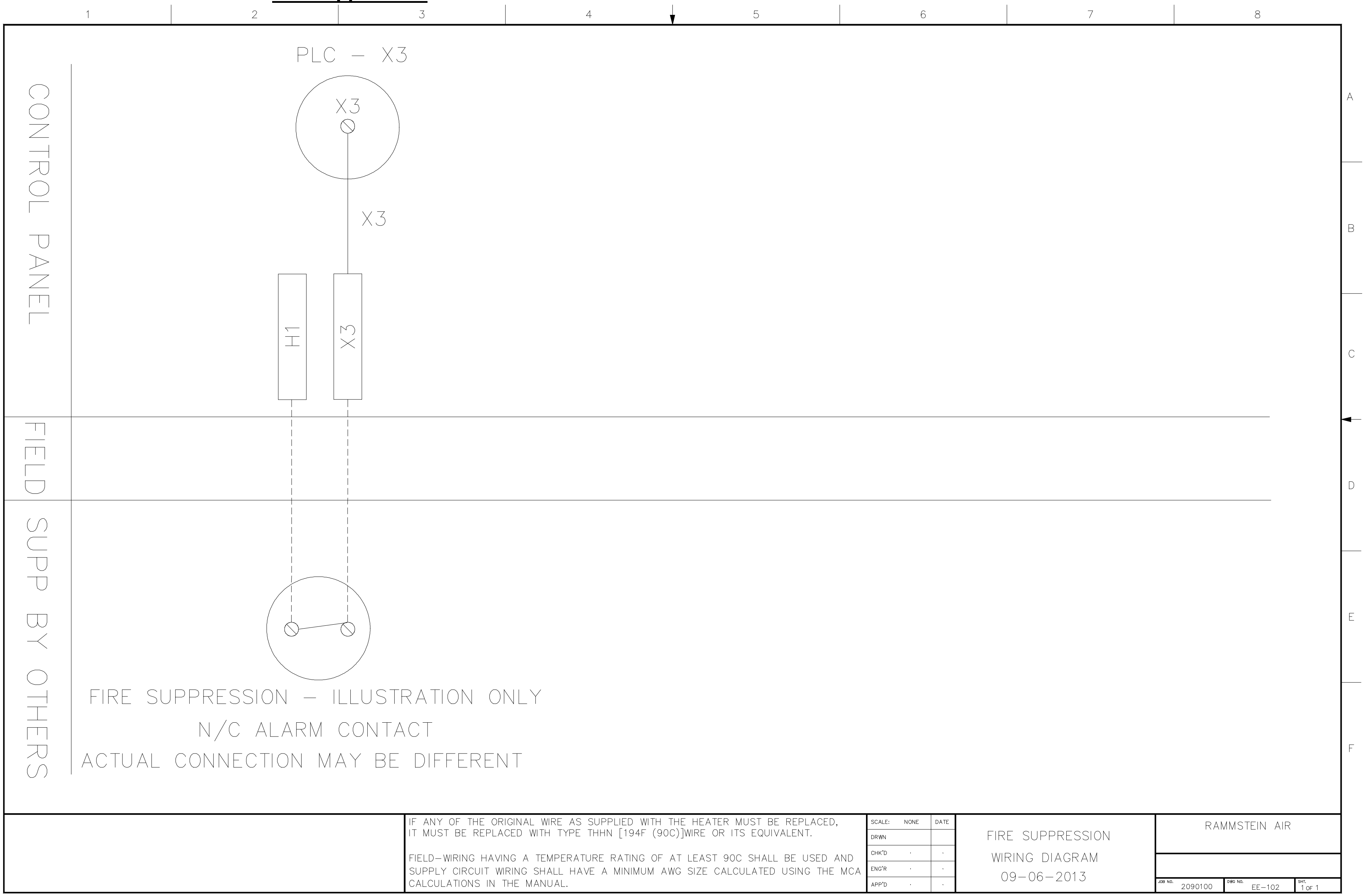
13.2.4 Automatic Spray Mode



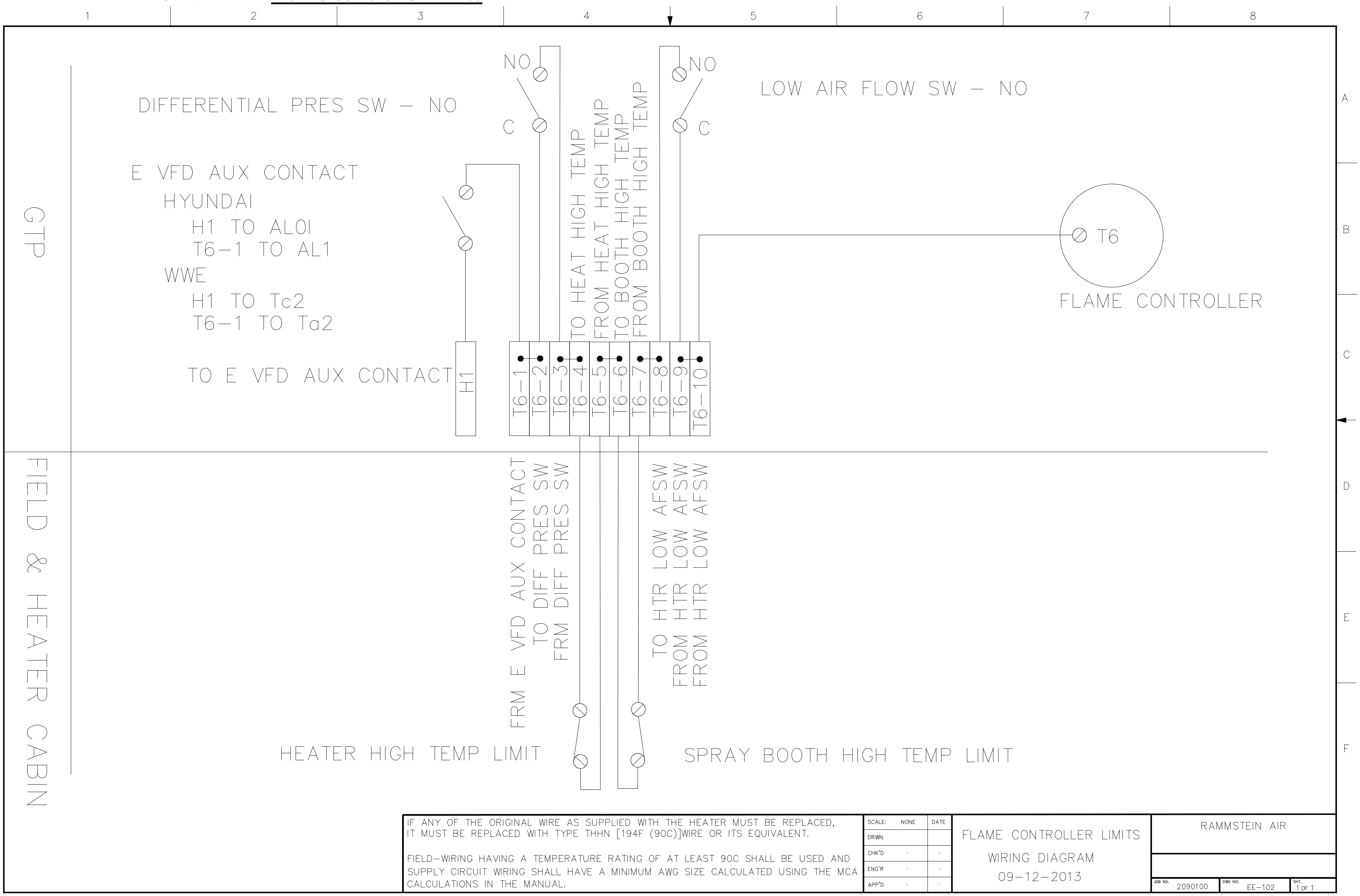
13.2.5 Compressed air power



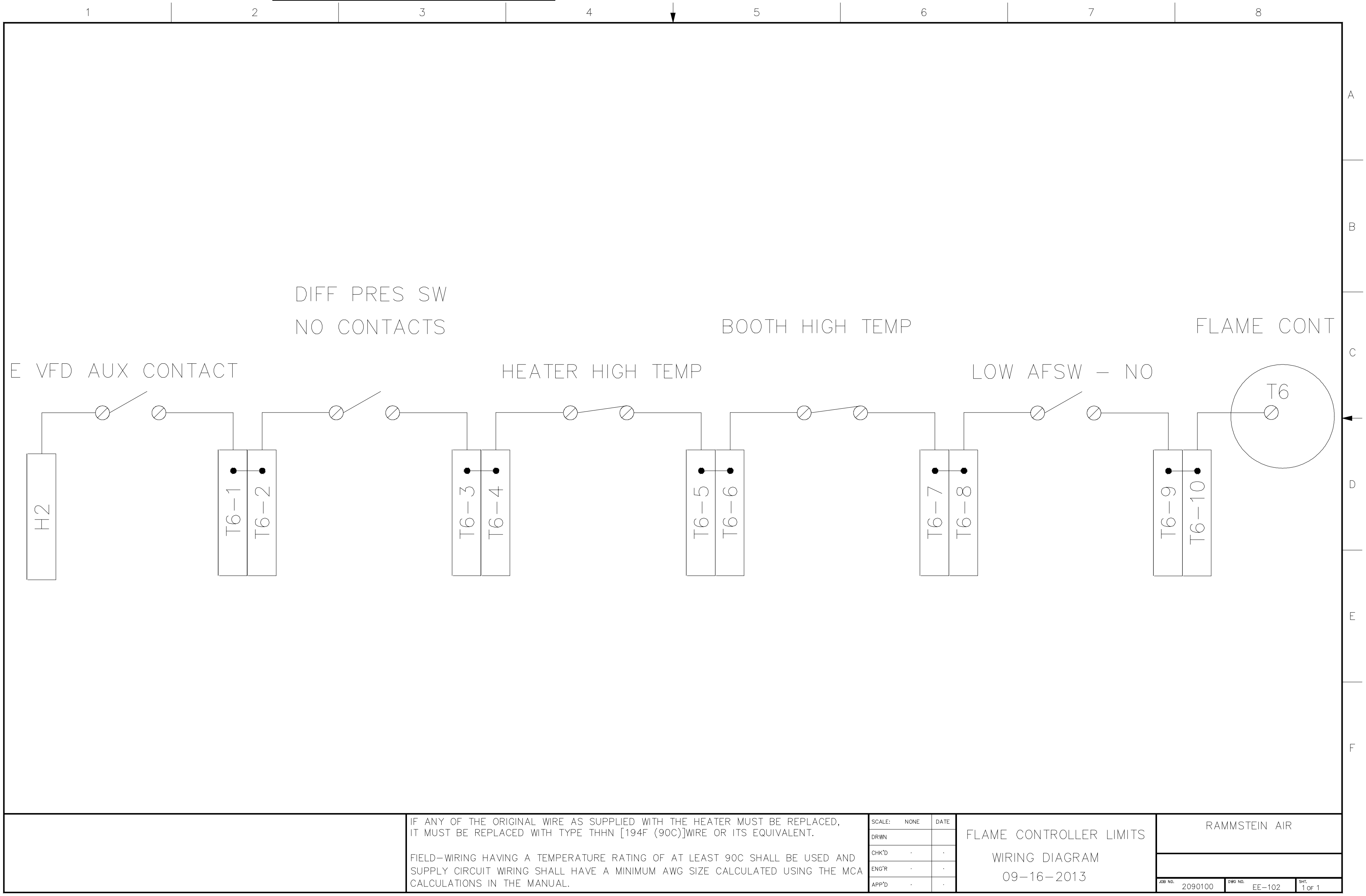
13.2.6 Fire Suppression



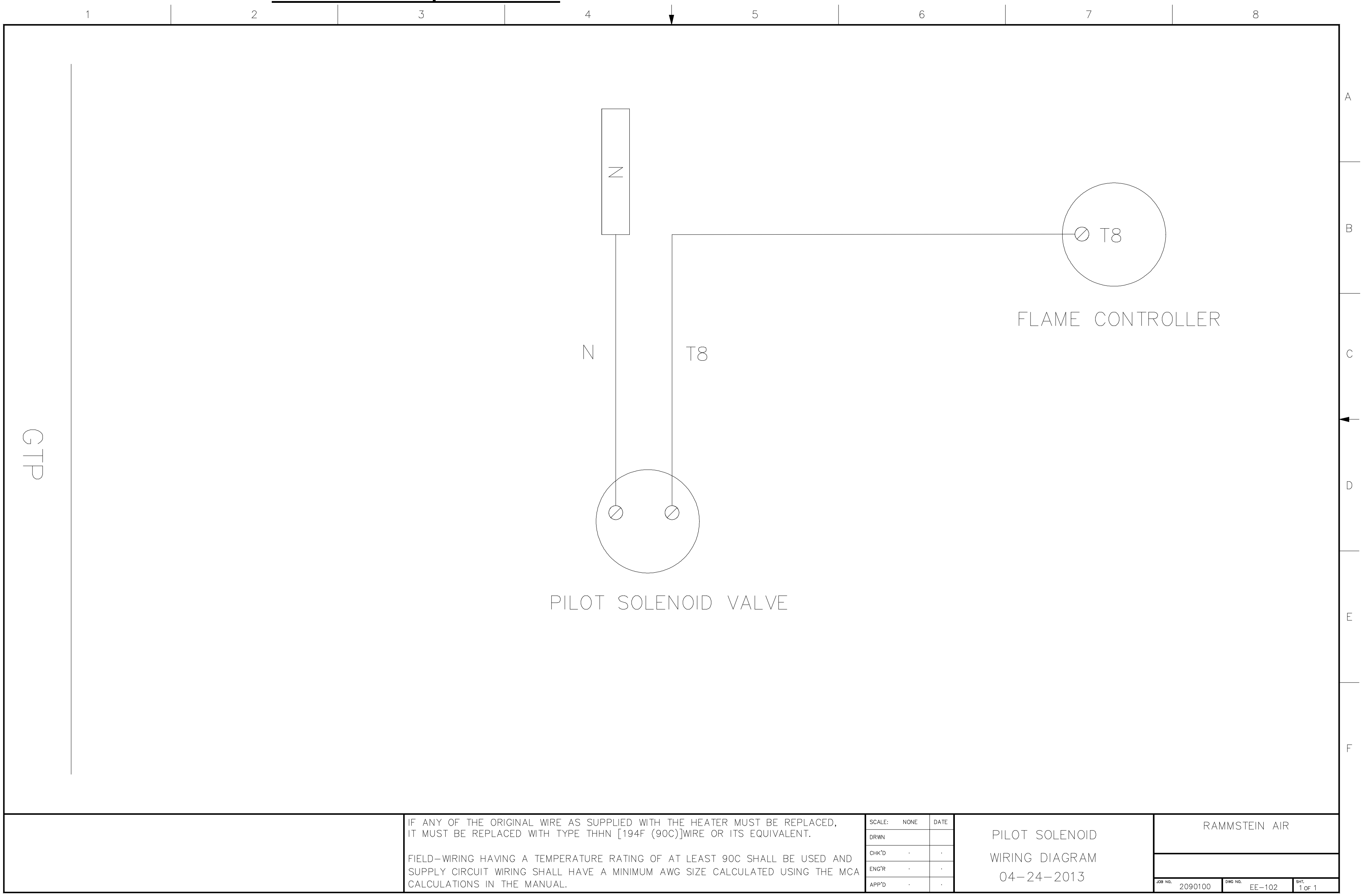
13.2.7 Flame controller limits



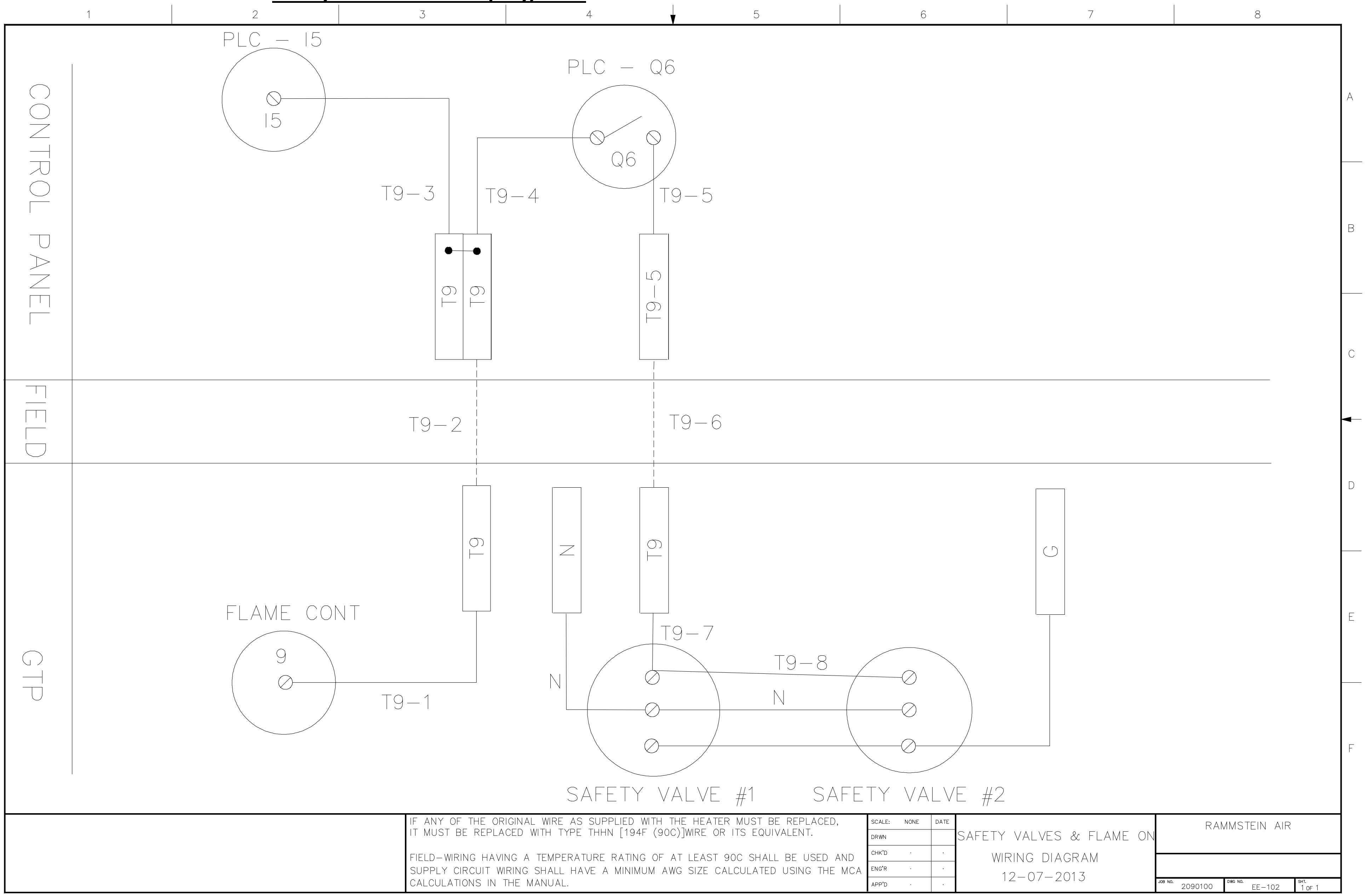
13.2.8 Flame controller limits - linear



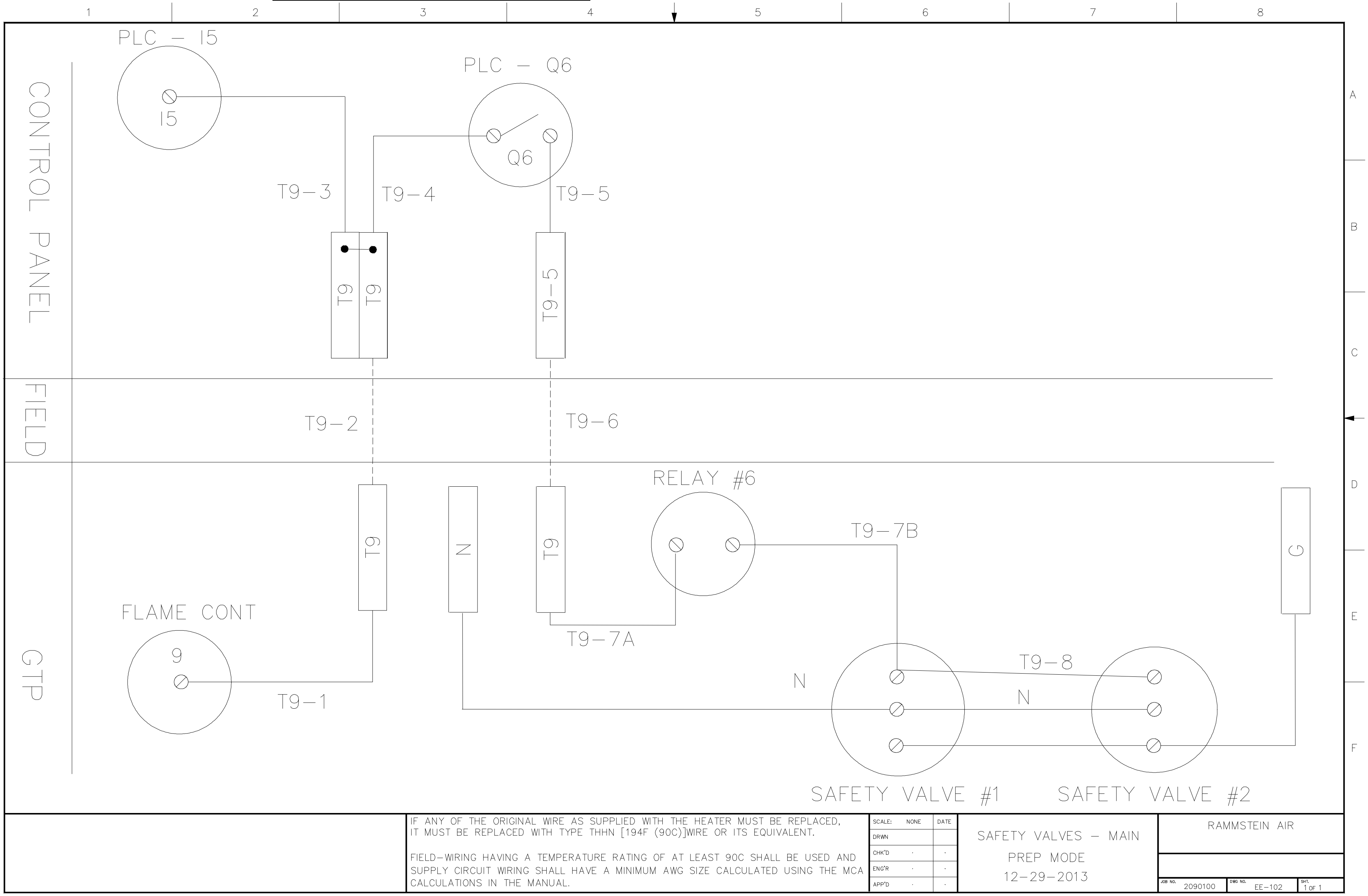
13.2.9 Flame controller pilot solenoid



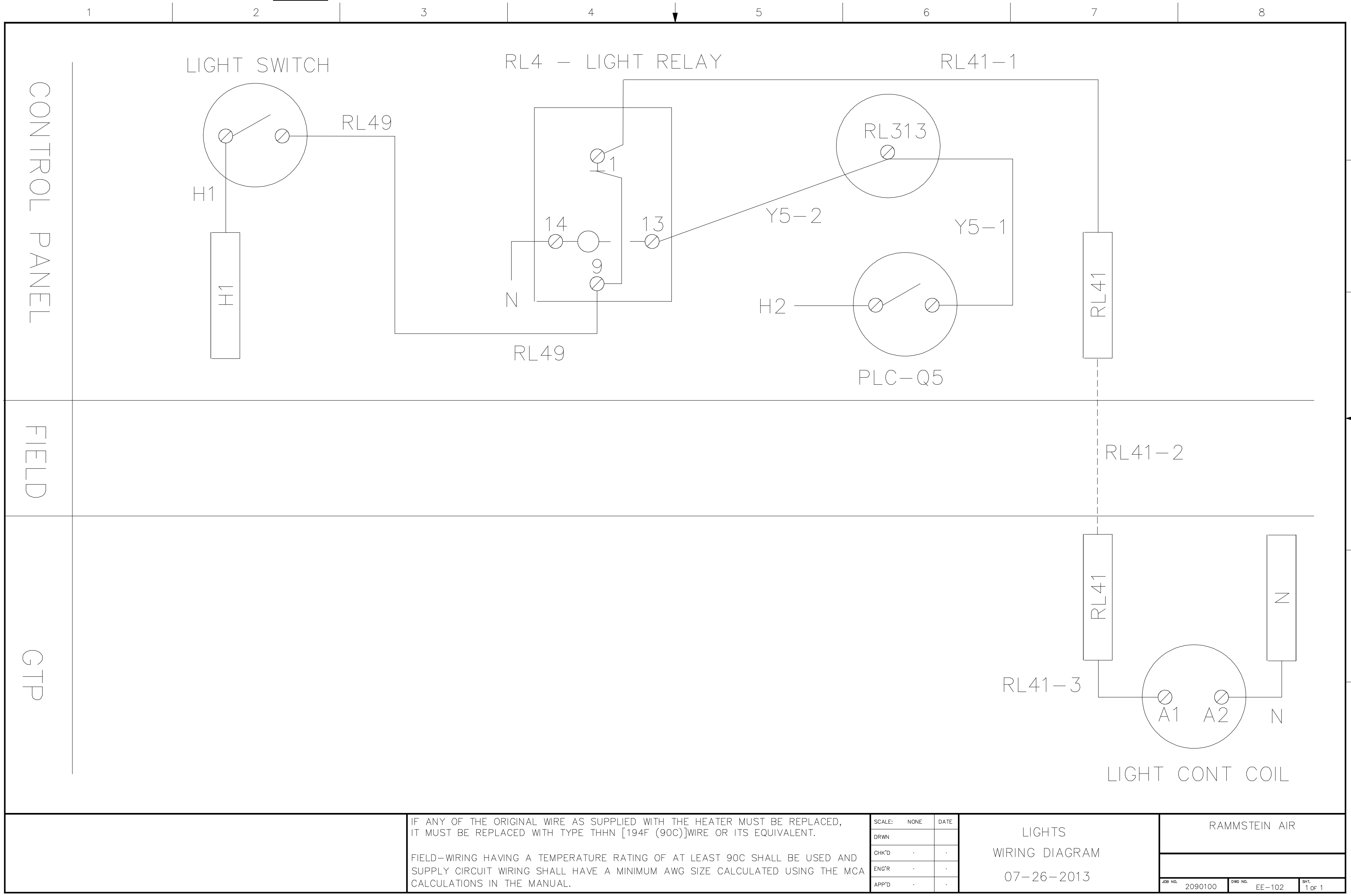
13.2.10 Safety valves -Main – Spray/Bake



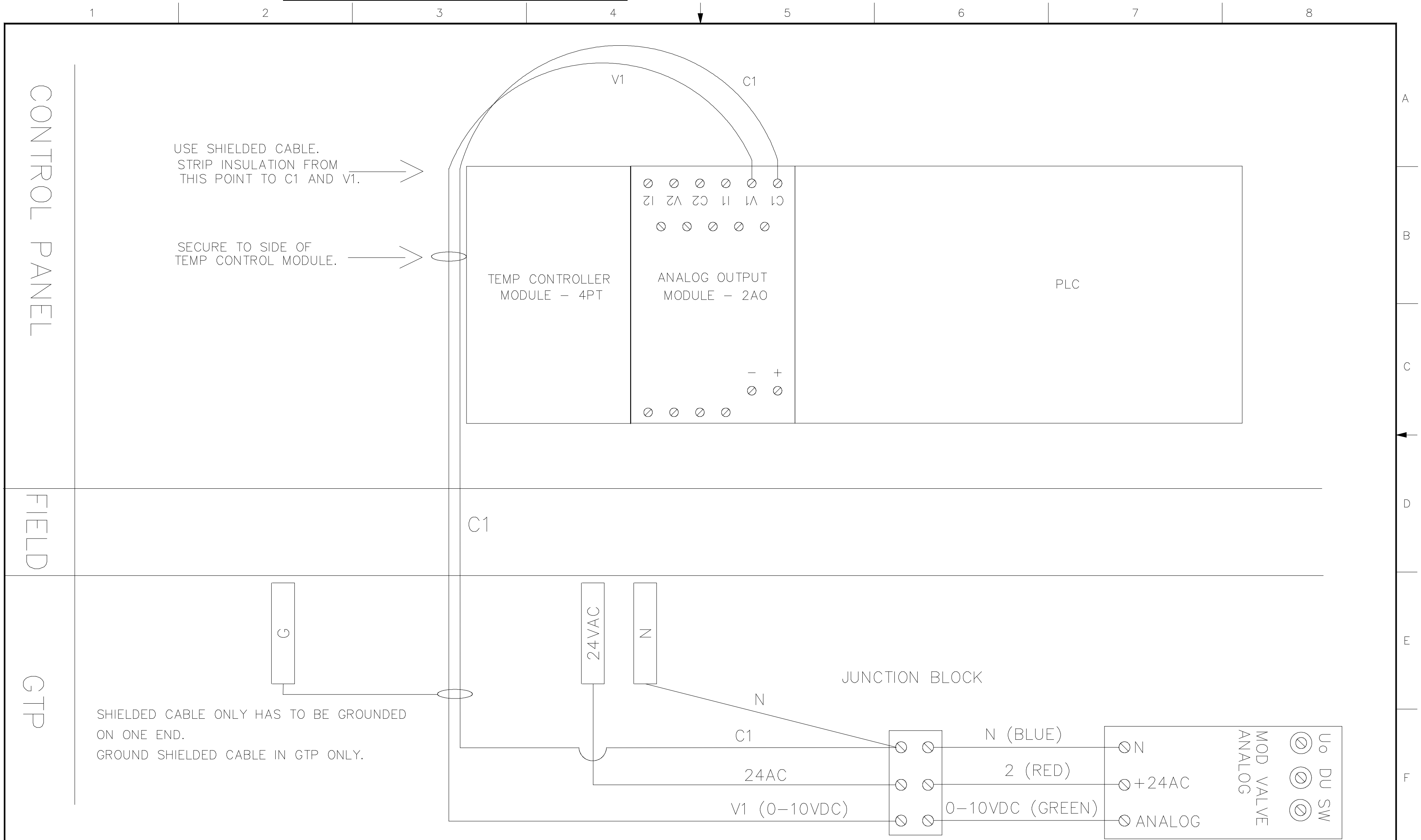
13.2.11 Safety Valves – Main - Prep Mode



13.2.12 Lights

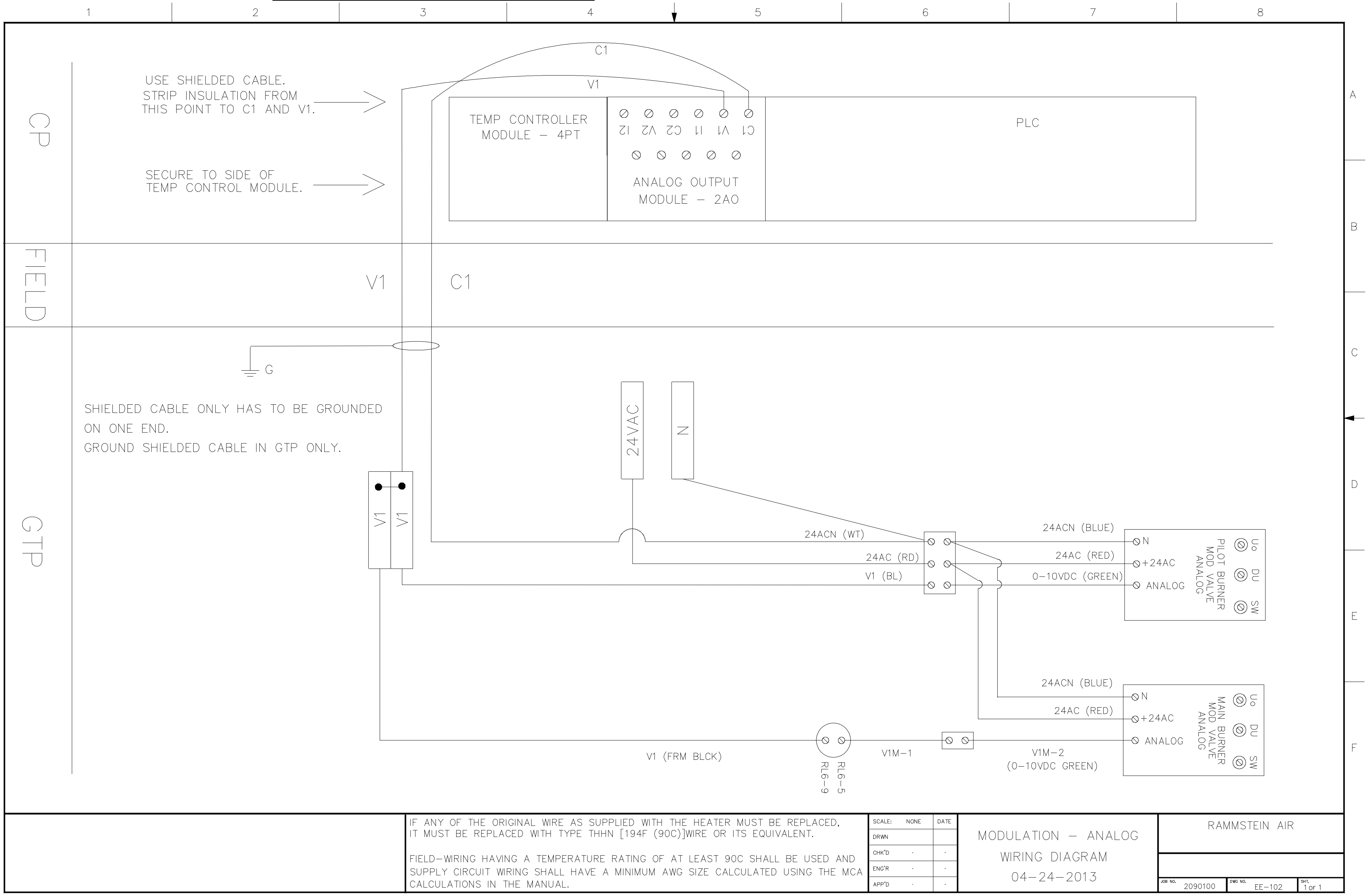


13.2.13 Modulation – analog – Spray /Bake

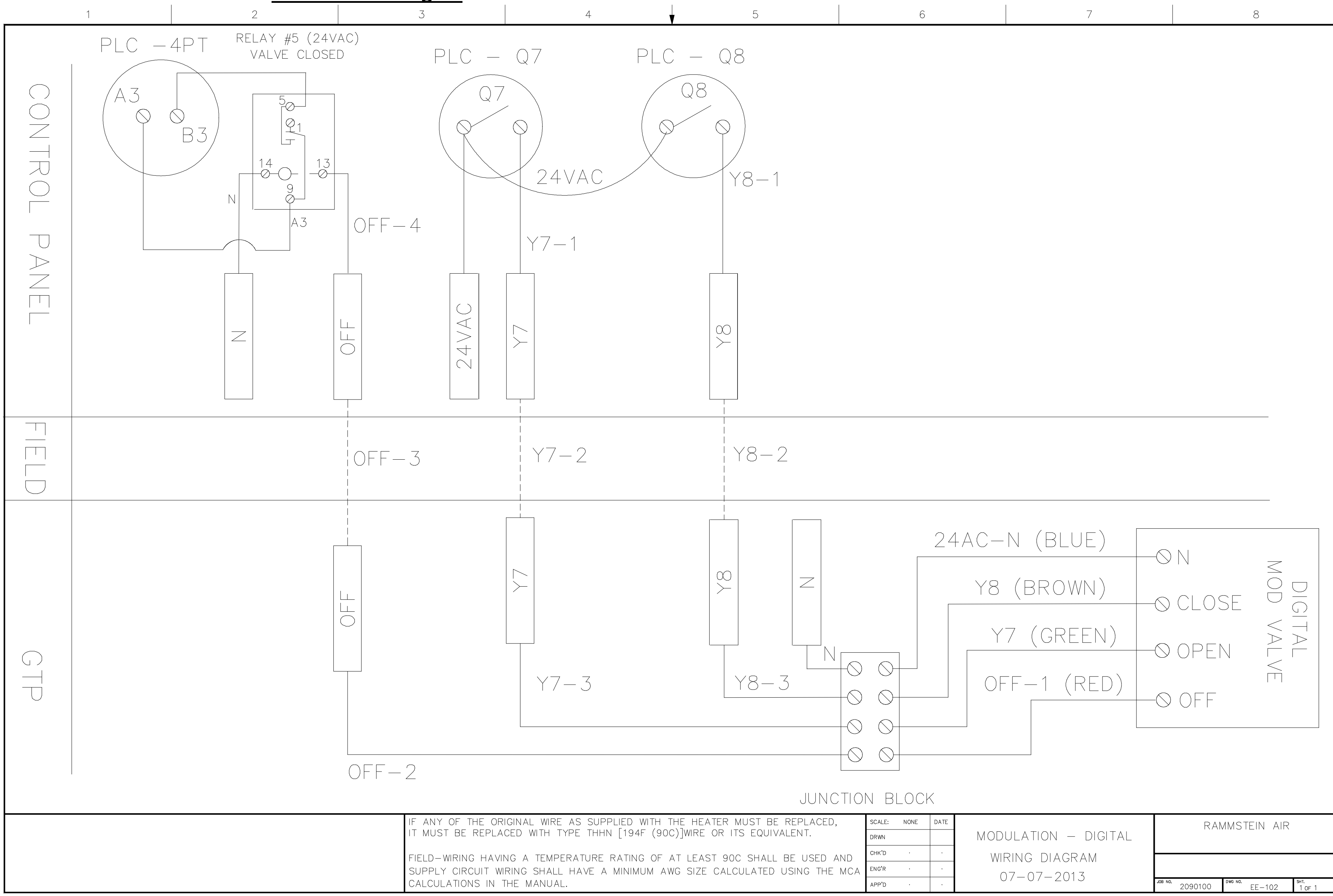


IF ANY OF THE ORIGINAL WIRE AS SUPPLIED WITH THE HEATER MUST BE REPLACED, IT MUST BE REPLACED WITH TYPE THHN [194F (90C)]WIRE OR ITS EQUIVALENT. FIELD–WIRING HAVING A TEMPERATURE RATING OF AT LEAST 90C SHALL BE USED AND SUPPLY CIRCUIT WIRING SHALL HAVE A MINIMUM AWG SIZE CALCULATED USING THE MCA CALCULATIONS IN THE MANUAL.	SCALE: NONE DRWN CHK'D - ENG'R - APP'D -	MODULATION – ANALOG WIRING DIAGRAM 04–24–2013	RAMMSTEIN AIR JOB NO. 2090100 DWG NO. EE–102 SHT. 1 OF 1

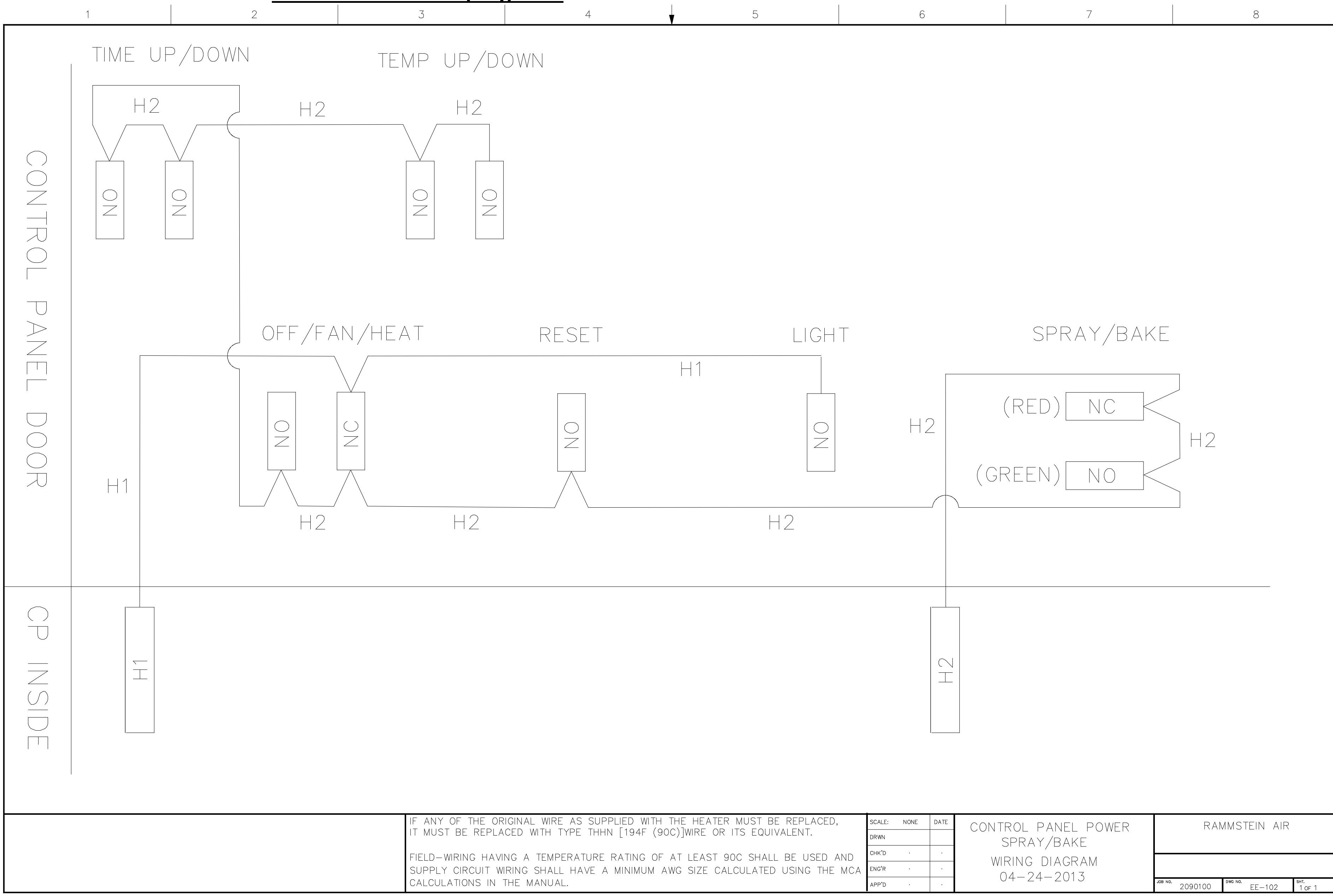
13.2.14 Modulation – analog – Prep Mode



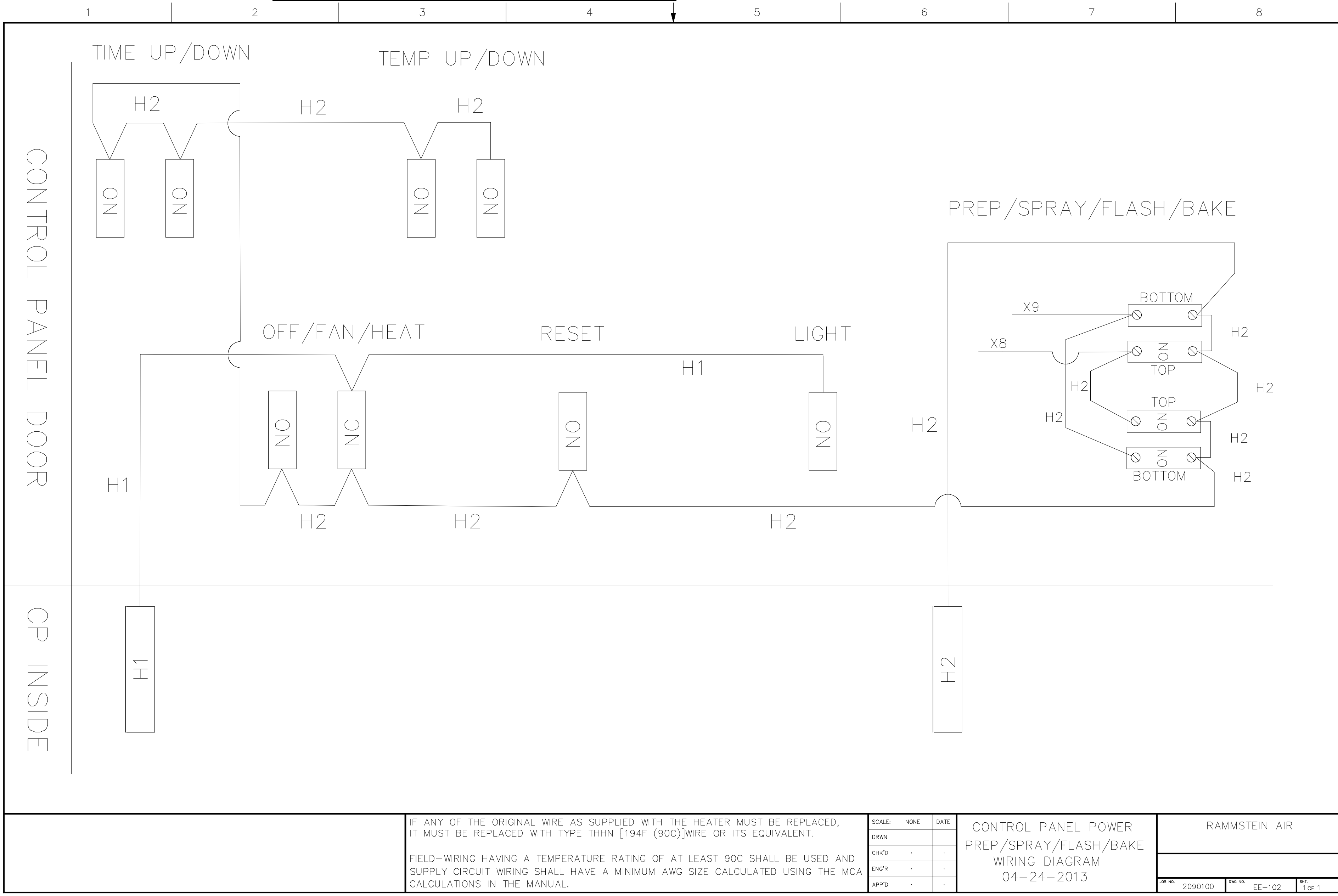
13.2.15 Modulation – digital



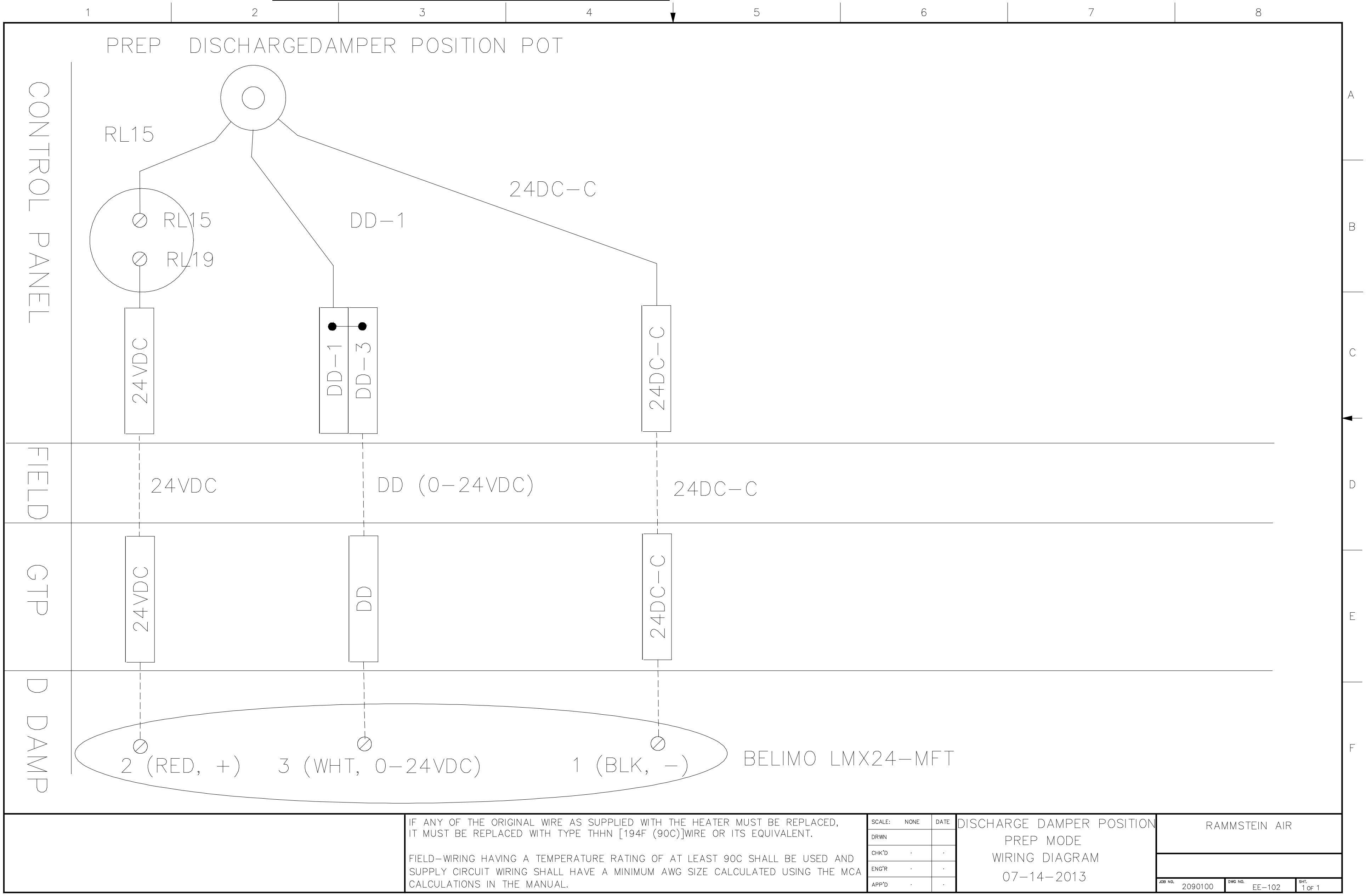
13.2.16 Power for CP door: Spray/Bake



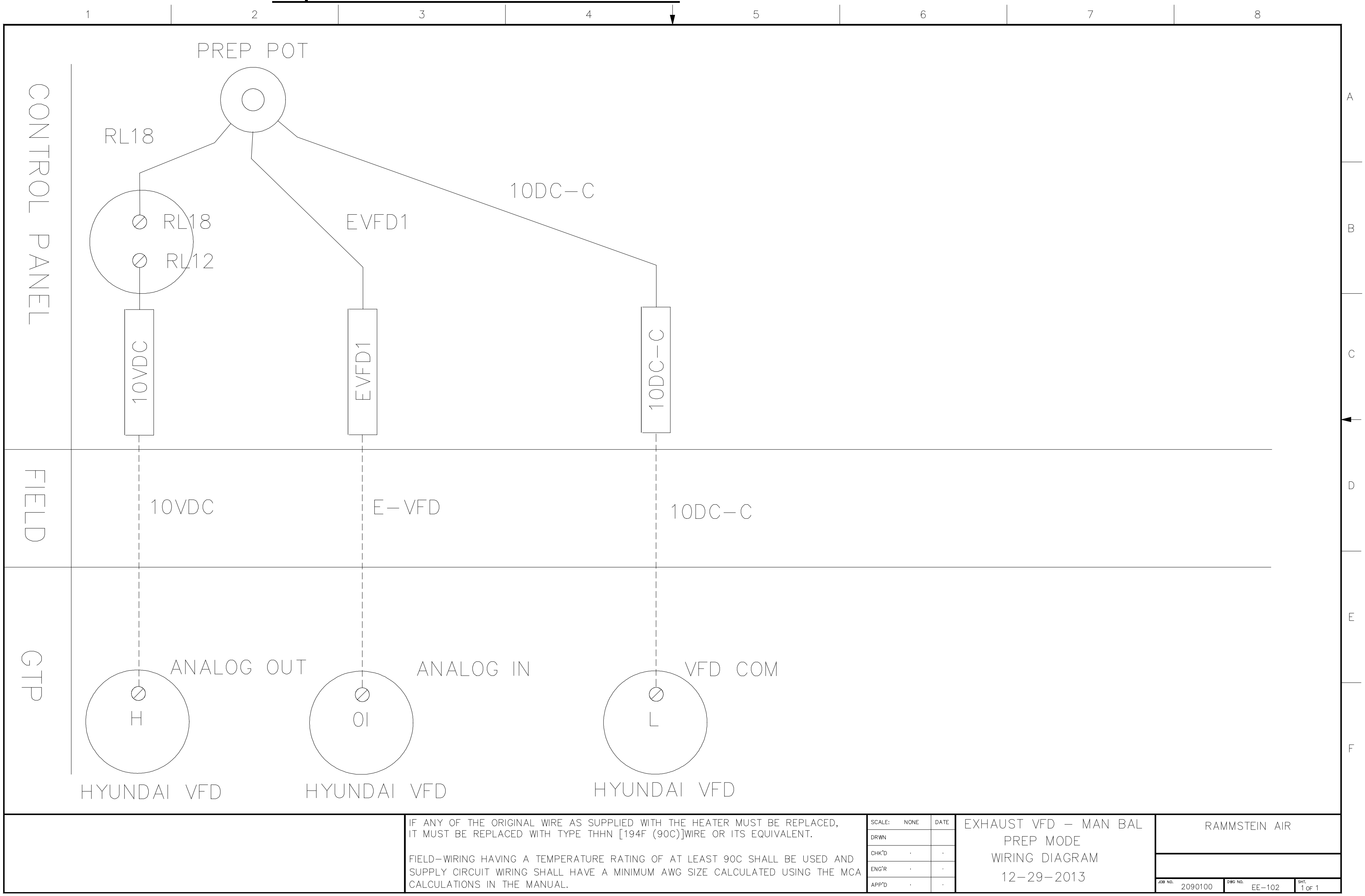
13.2.17 Power for CP door: Prep/Spray/Flash/Bake



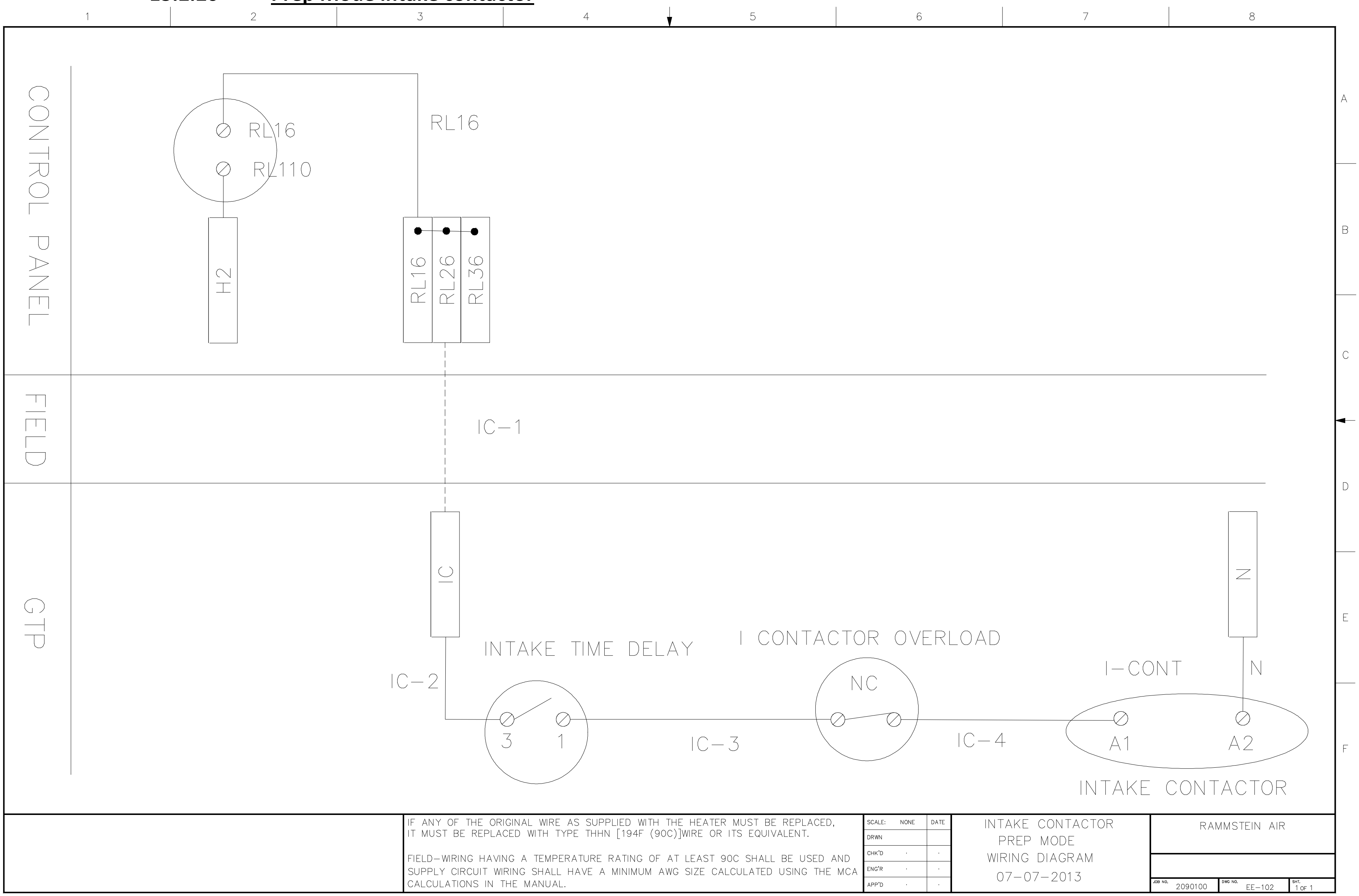
13.2.18 Prep Mode discharge damper position pot



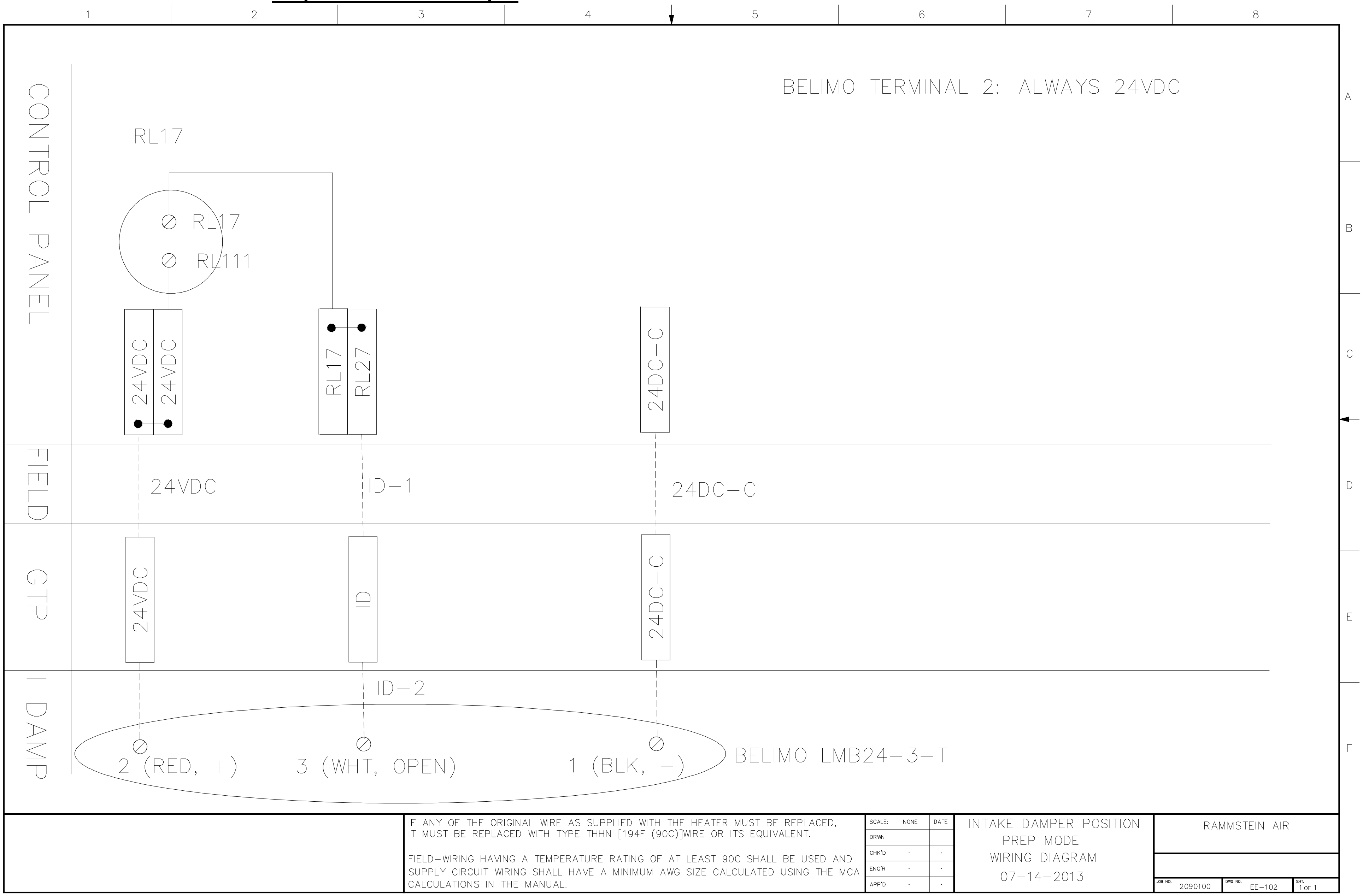
13.2.19 Prep Mode exhausts VFD – Manual balance



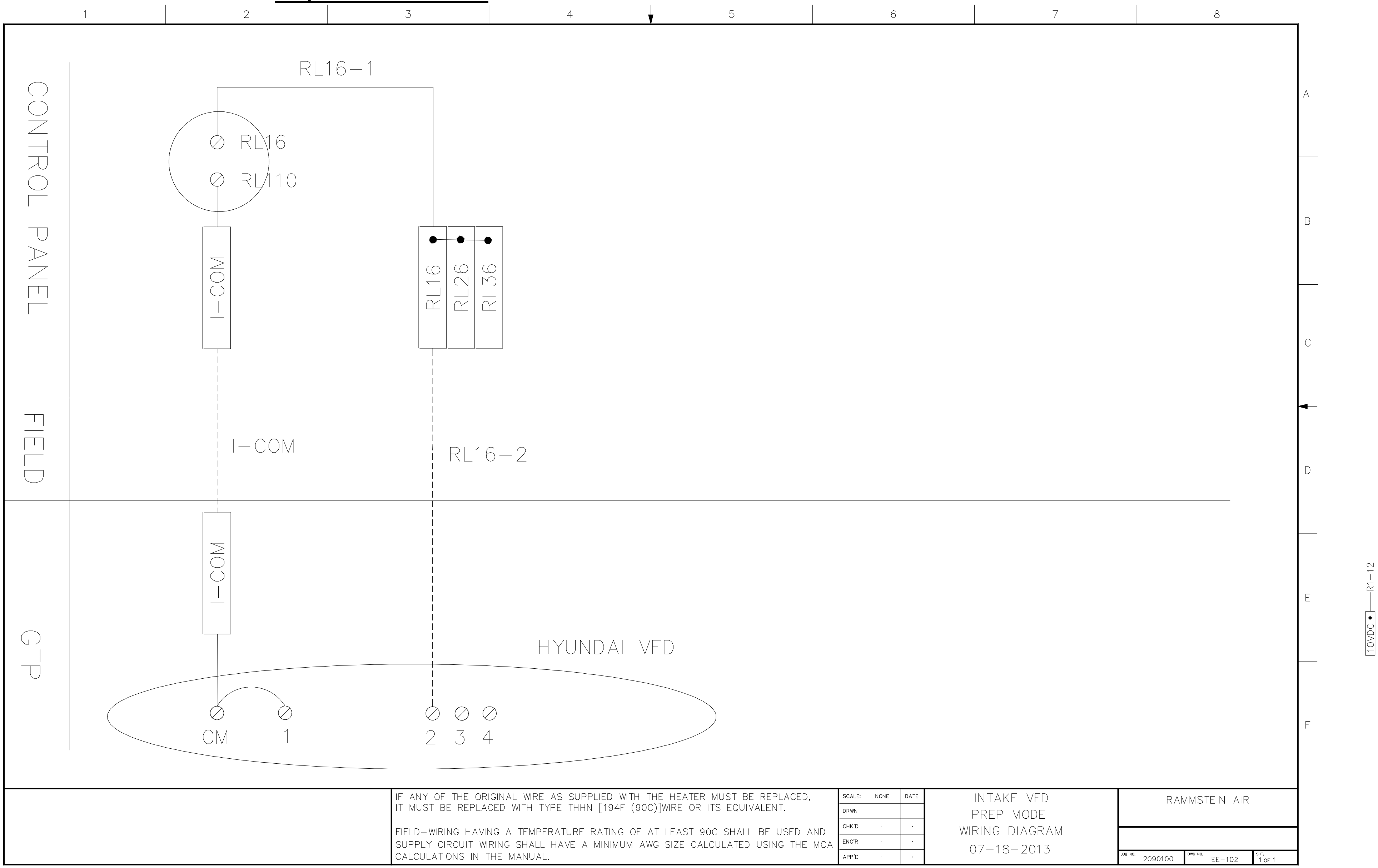
13.2.20 Prep Mode intake contactor



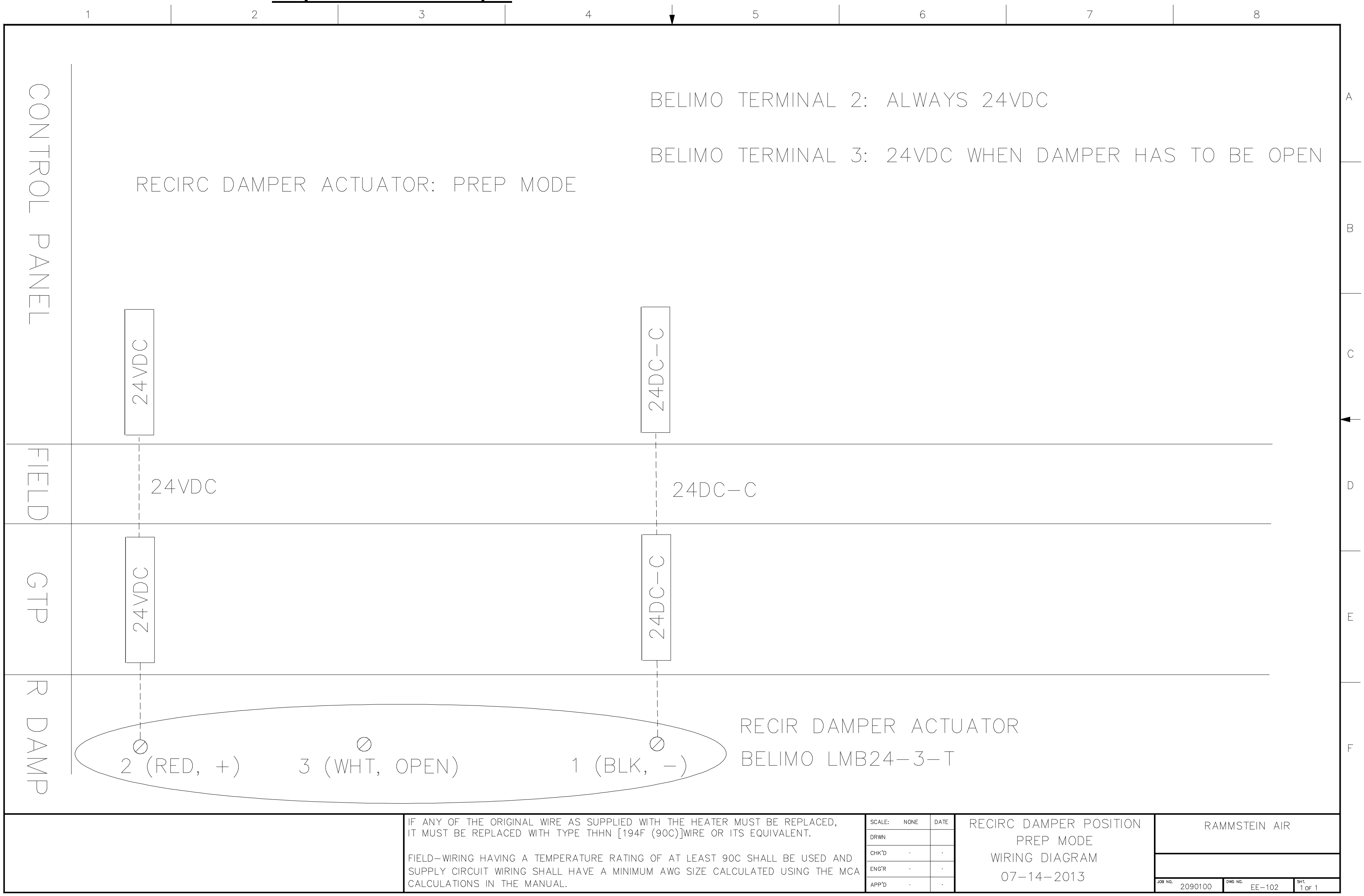
13.2.21 Prep Mode intake damper



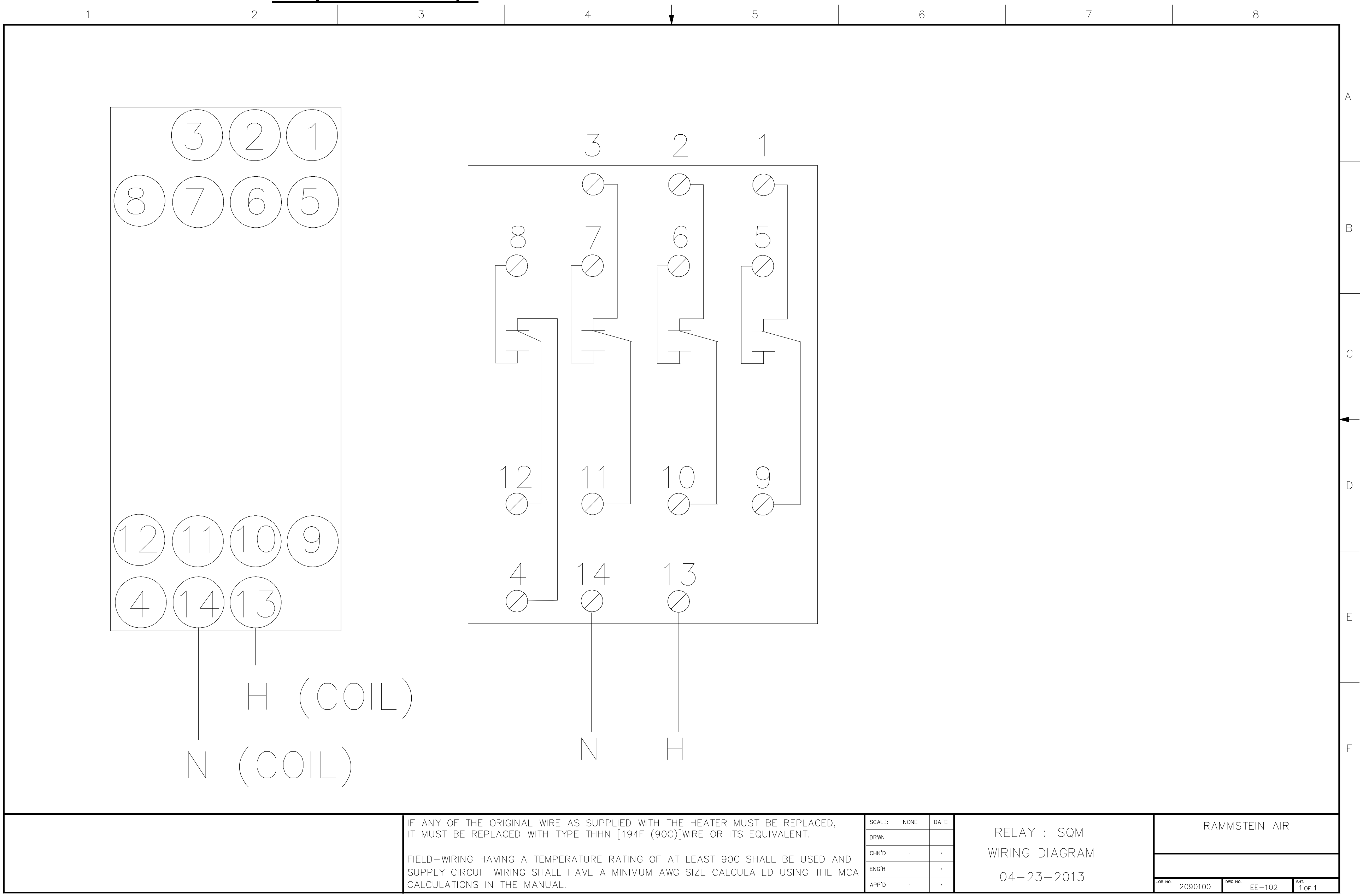
13.2.22 Prep Mode intake VFD



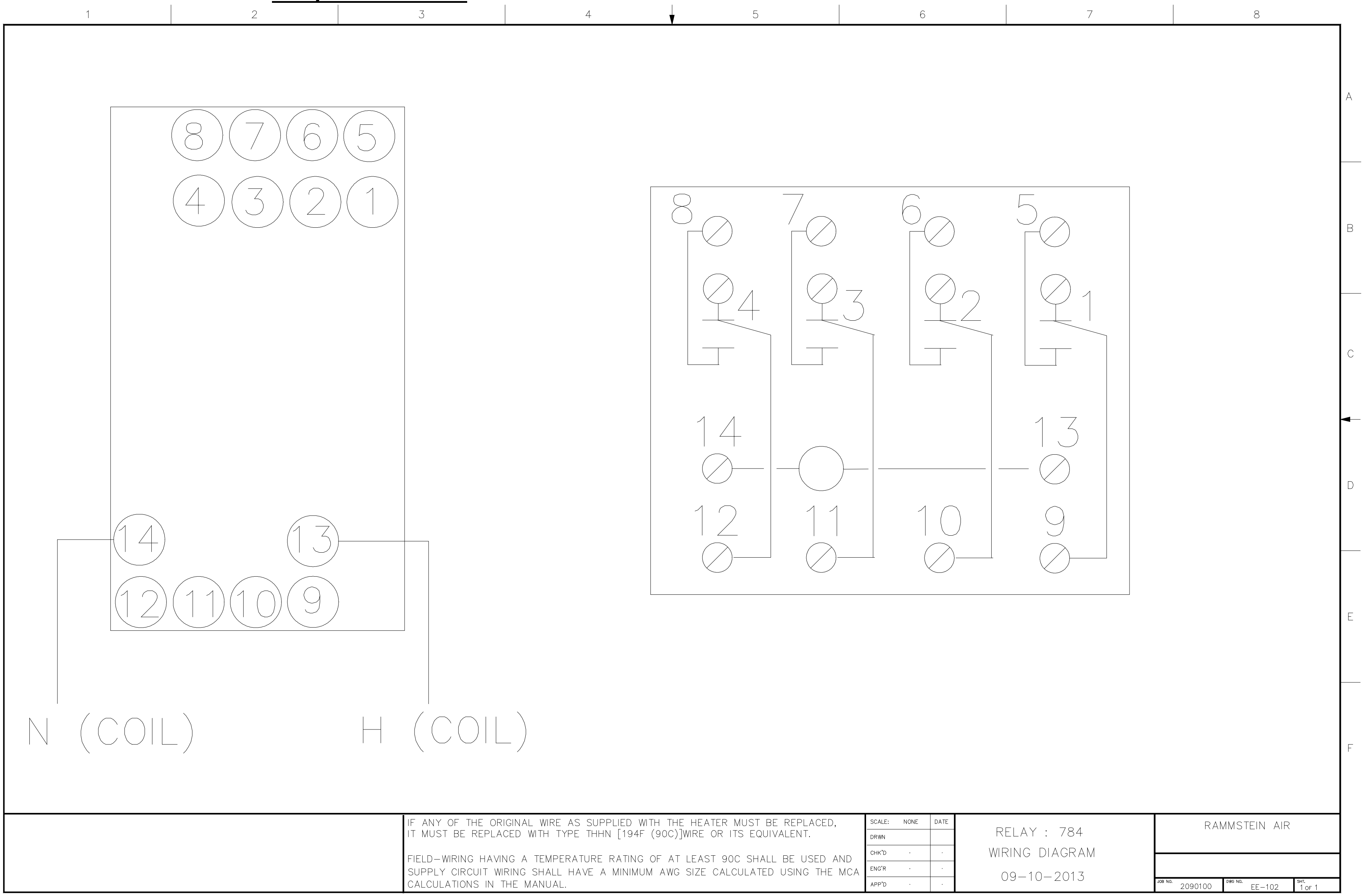
13.2.23 Prep Mode recirc damper



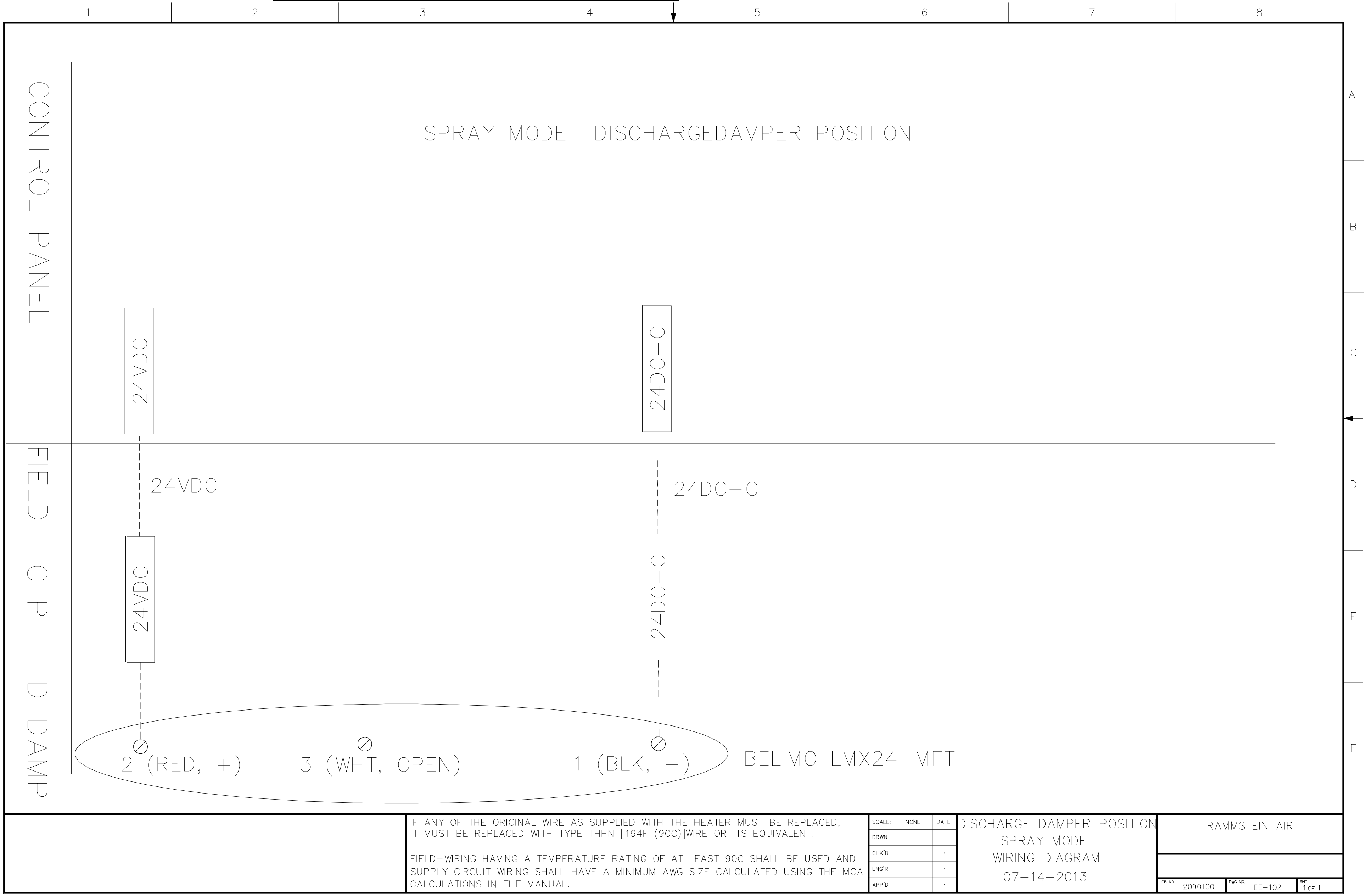
13.2.24 Relay Terminals: SQM



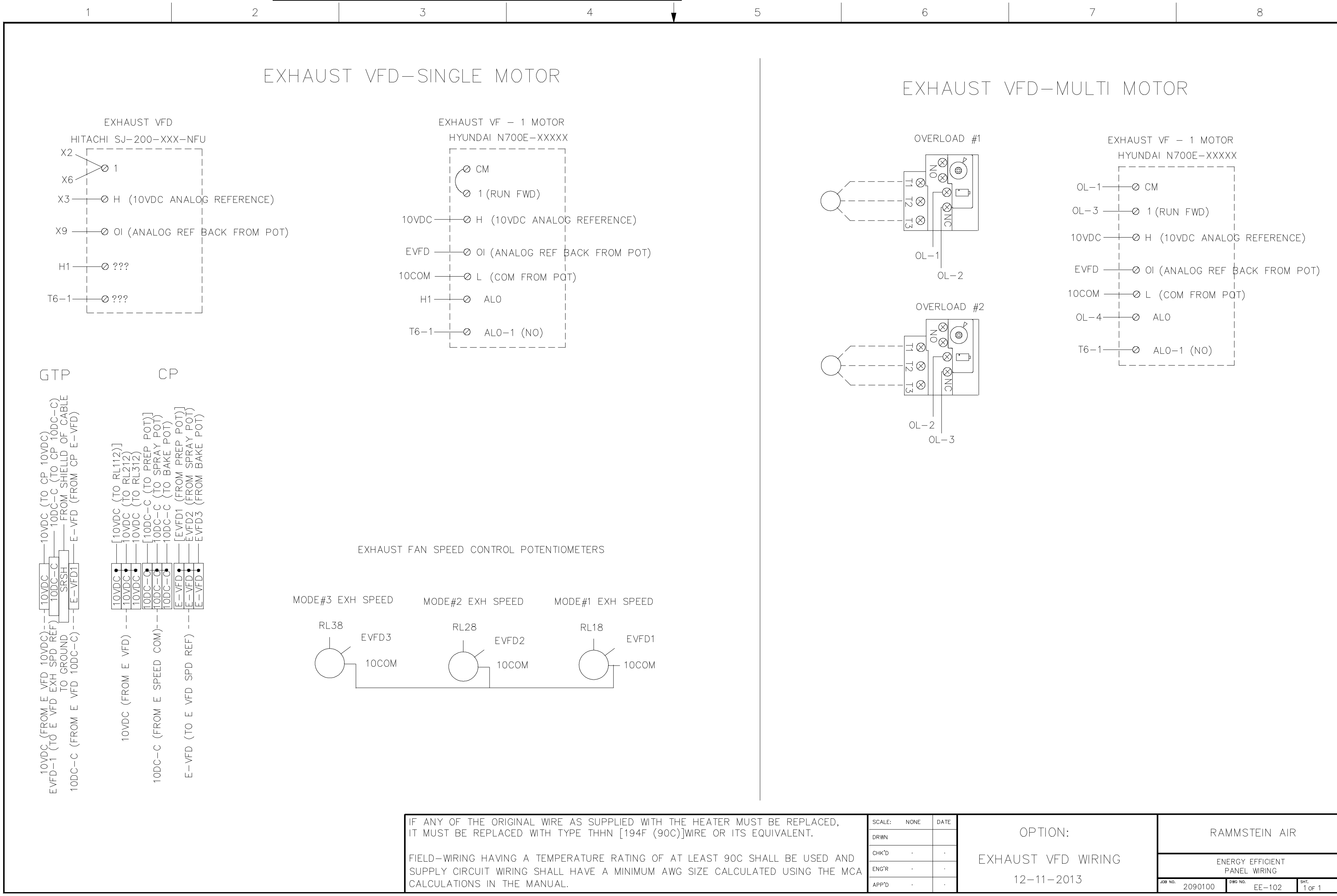
13.2.25 Relay Terminals: 784



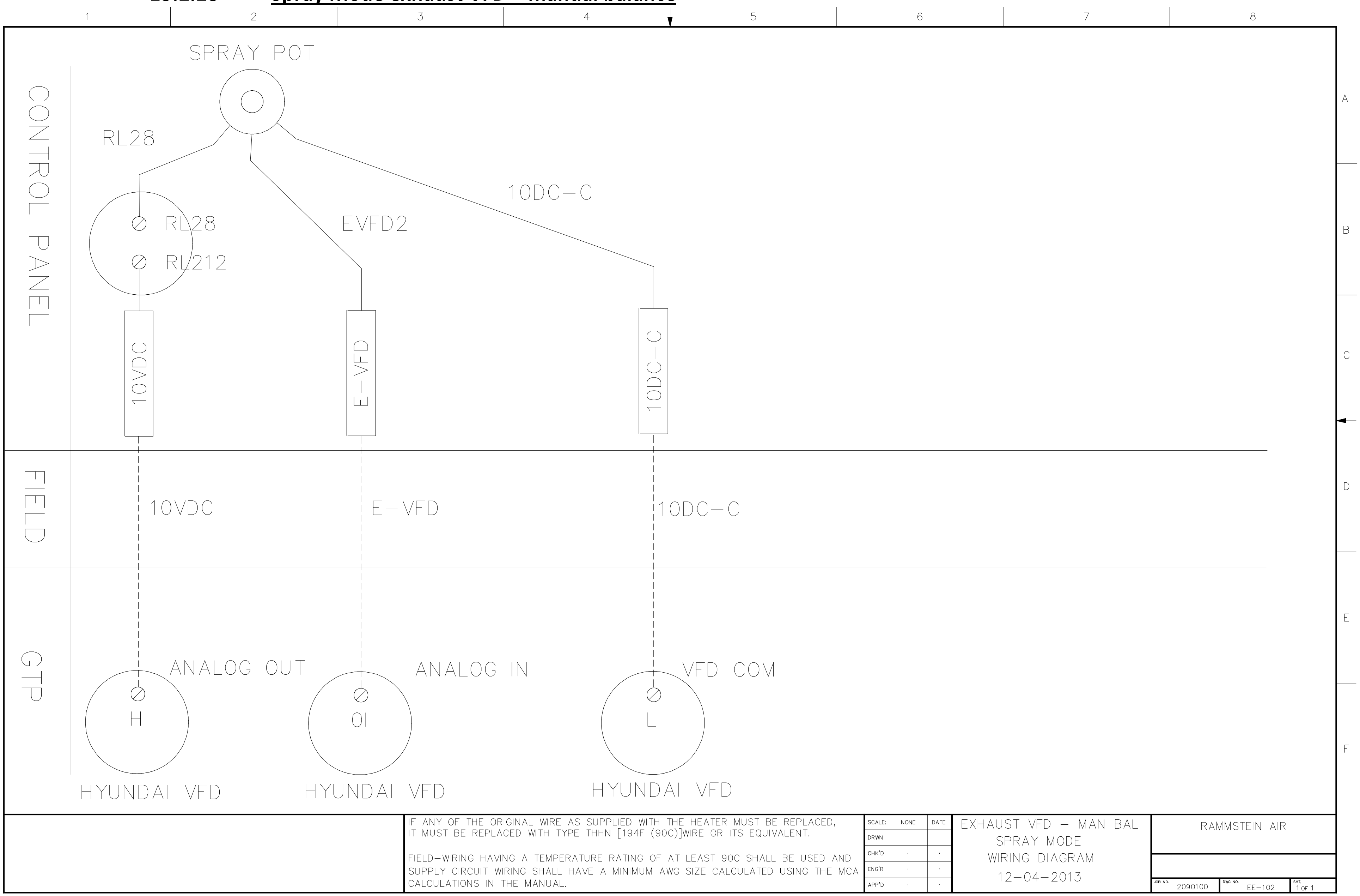
13.2.26 Spray Mode discharge damper position pot



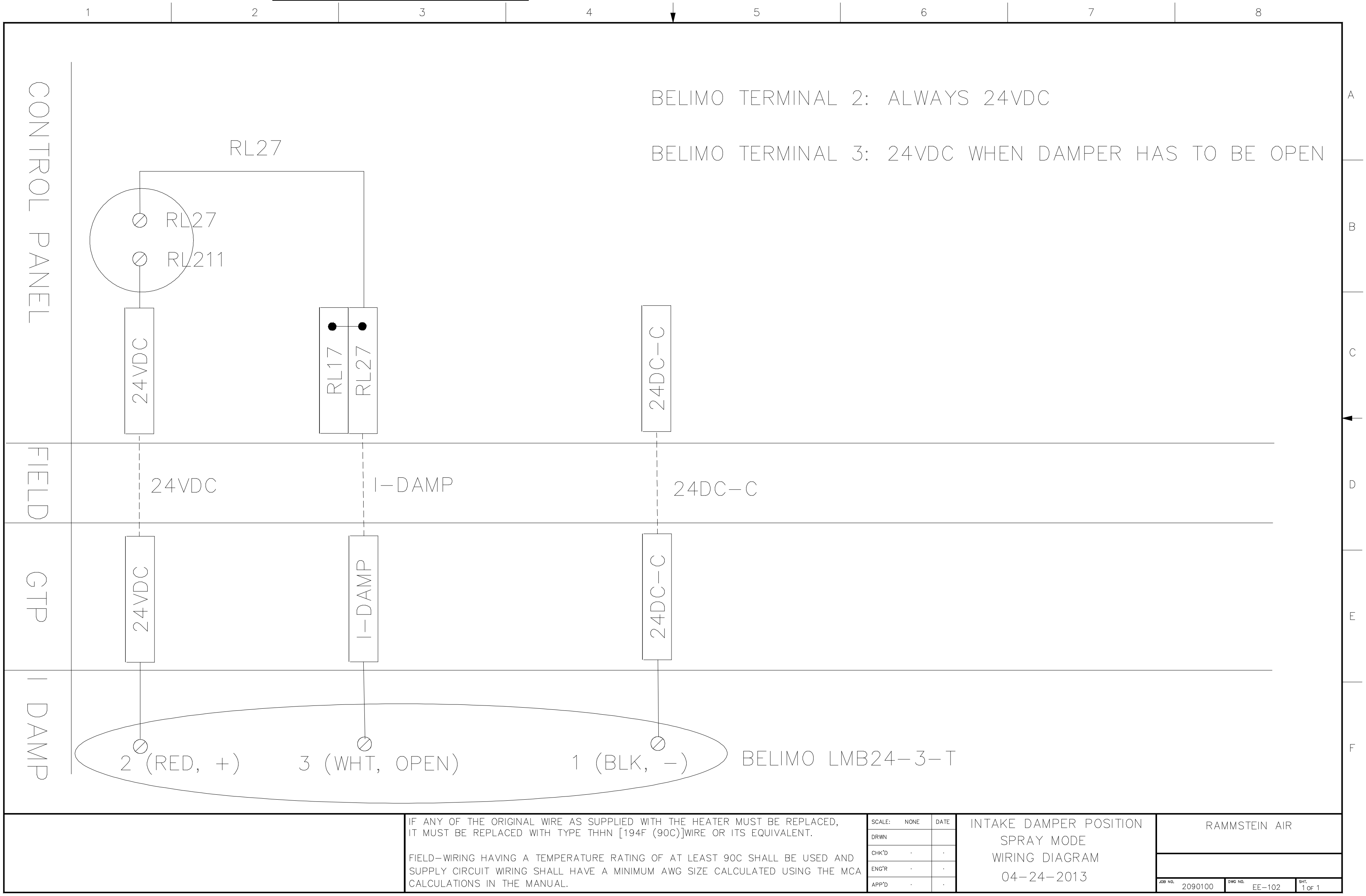
13.2.27 Exhaust VFD wiring – 1 or 2 exhaust motors



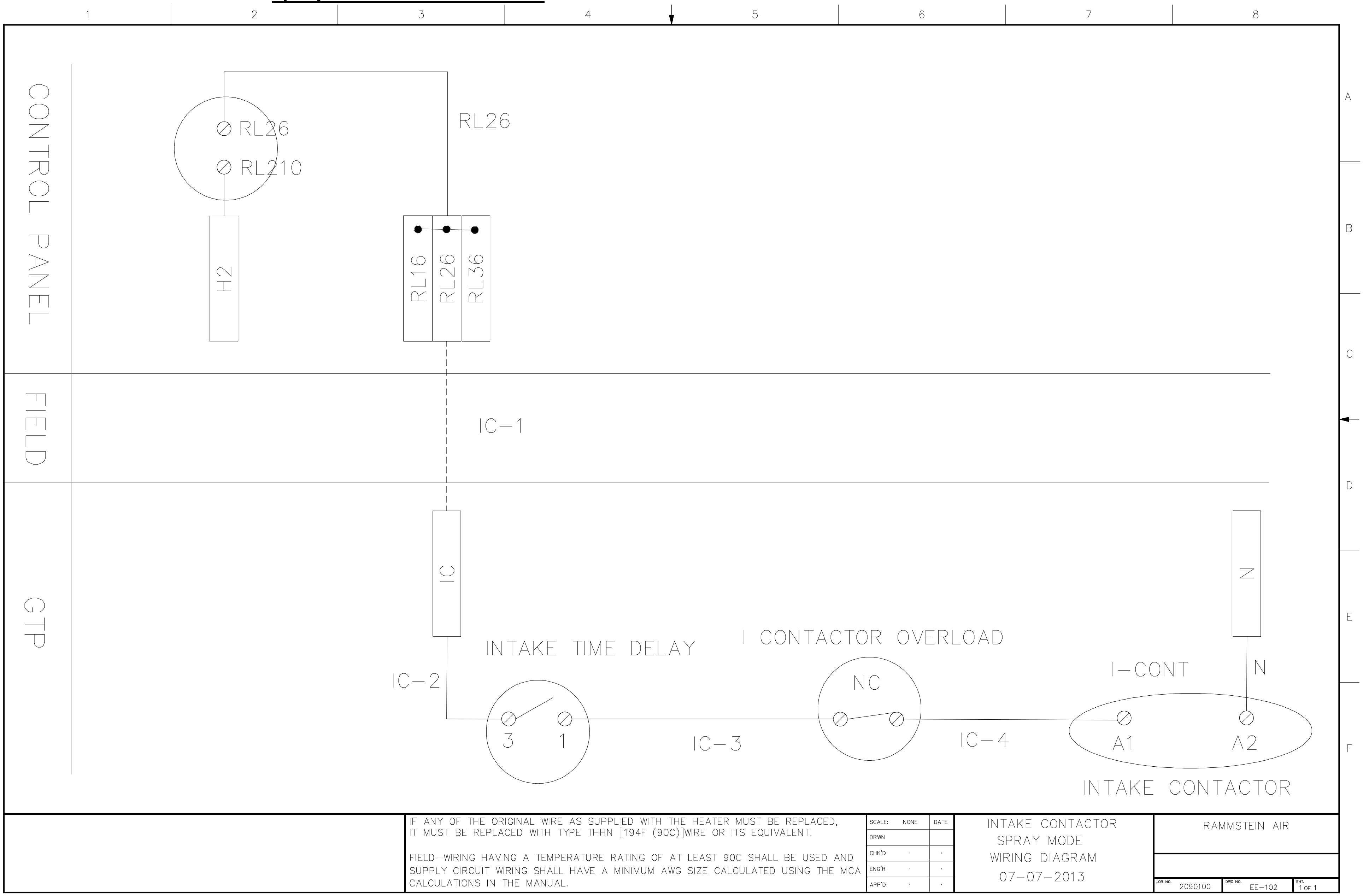
13.2.28 Spray Mode exhaust VFD – manual balance



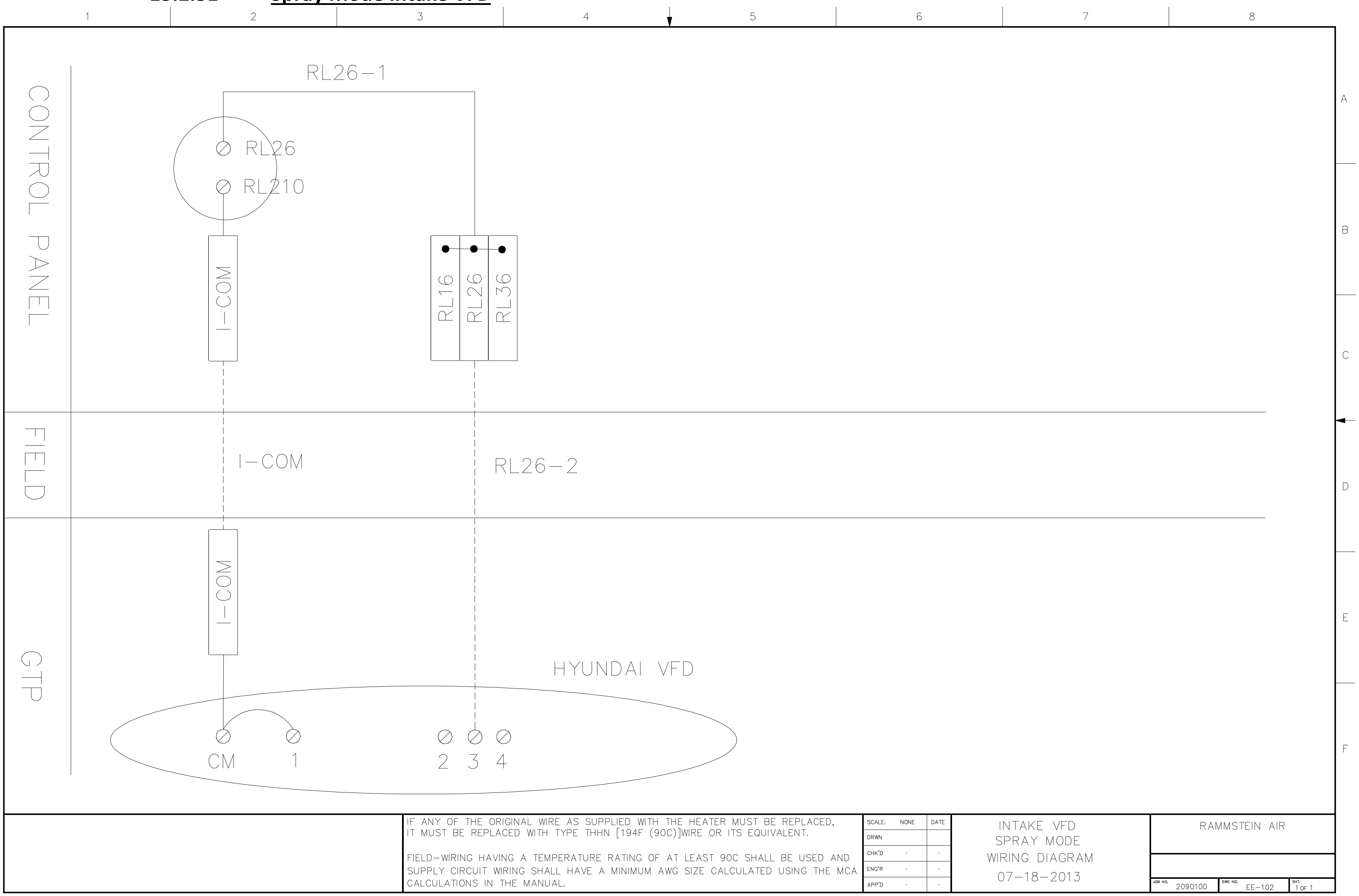
13.2.29 Spray Mode intake damper



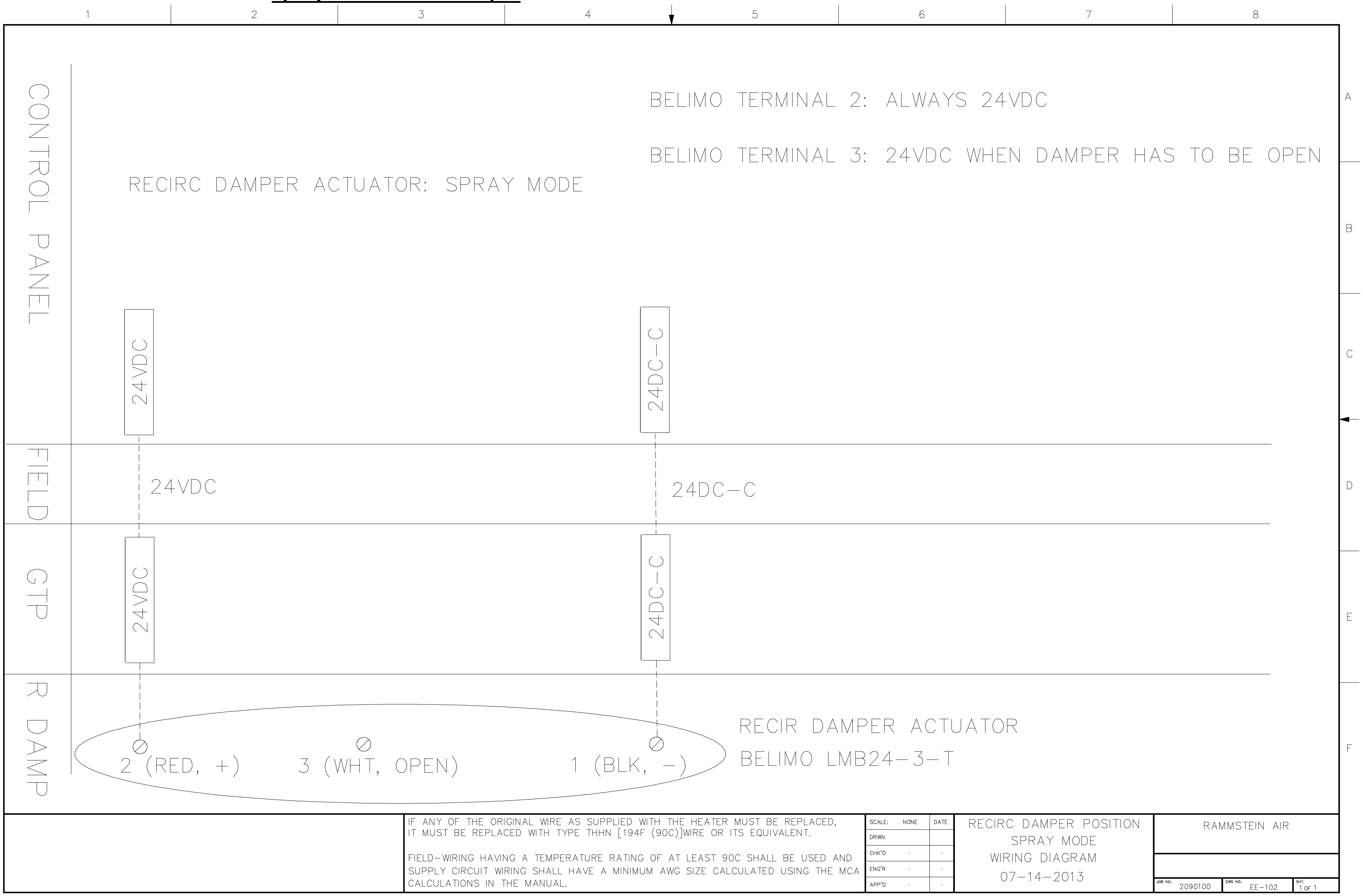
13.2.30 Spray Mode intake contactor



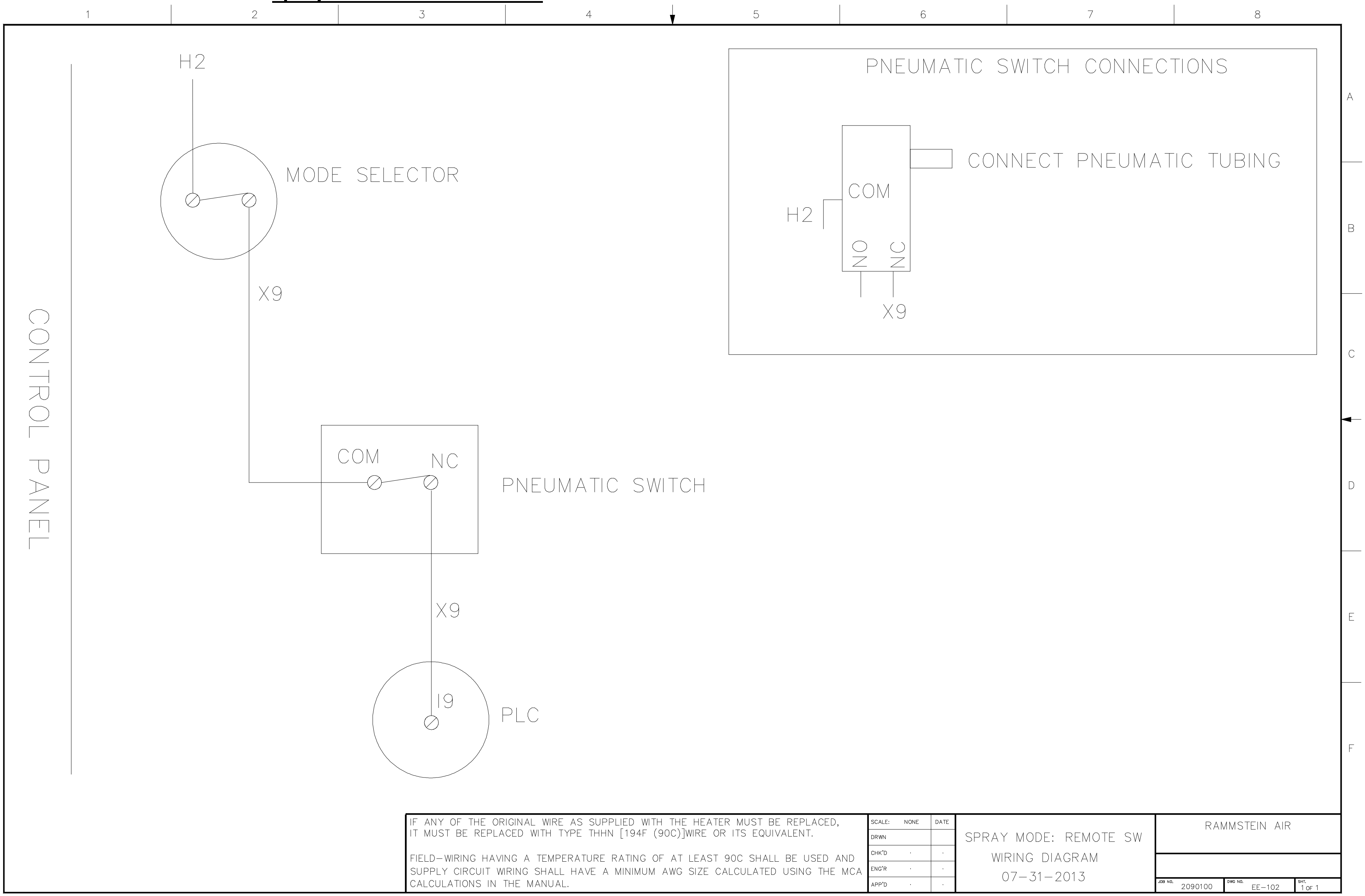
13.2.31 Spray Mode intake VFD



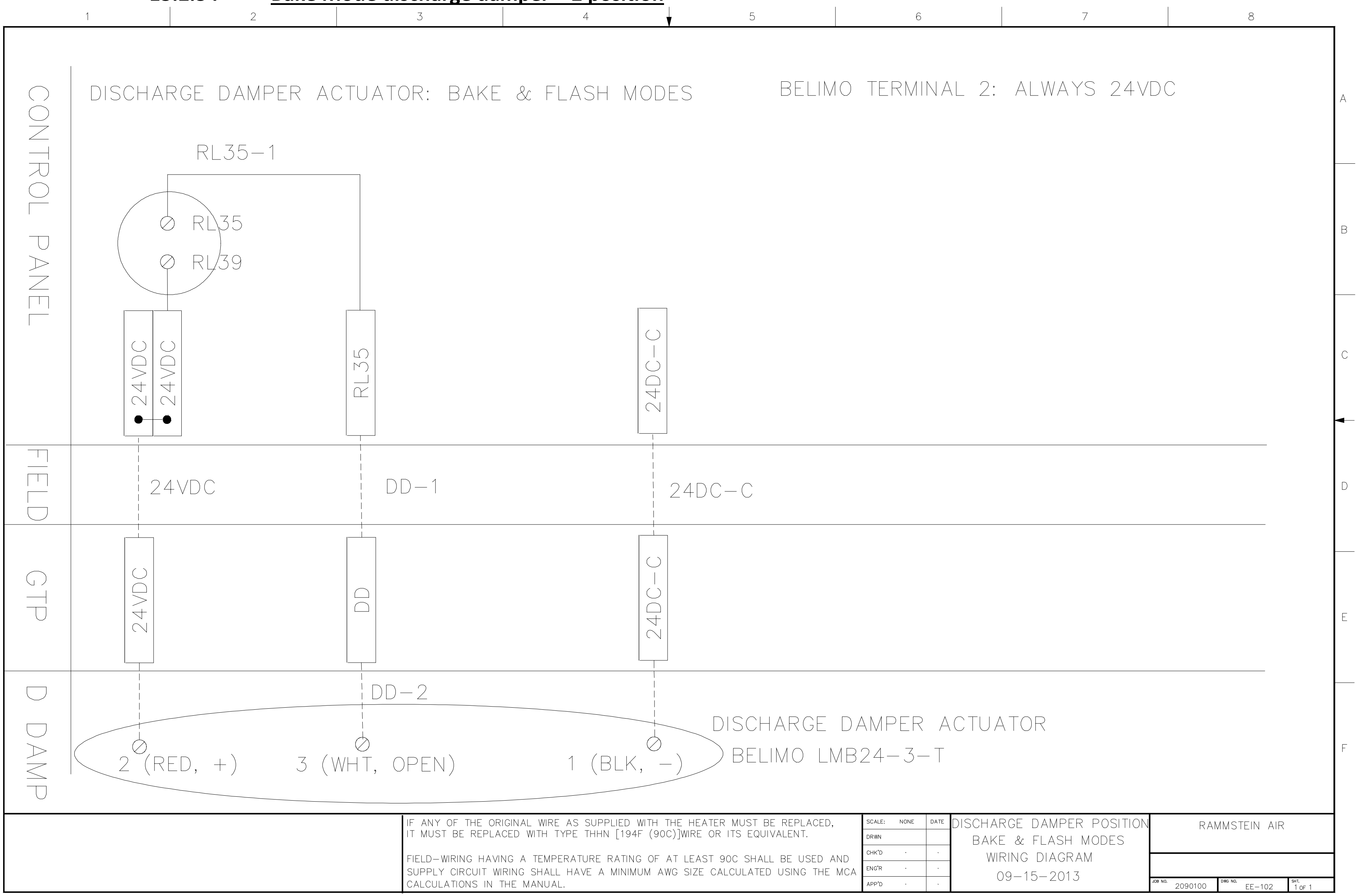
13.2.32 Spray Mode recirc damper



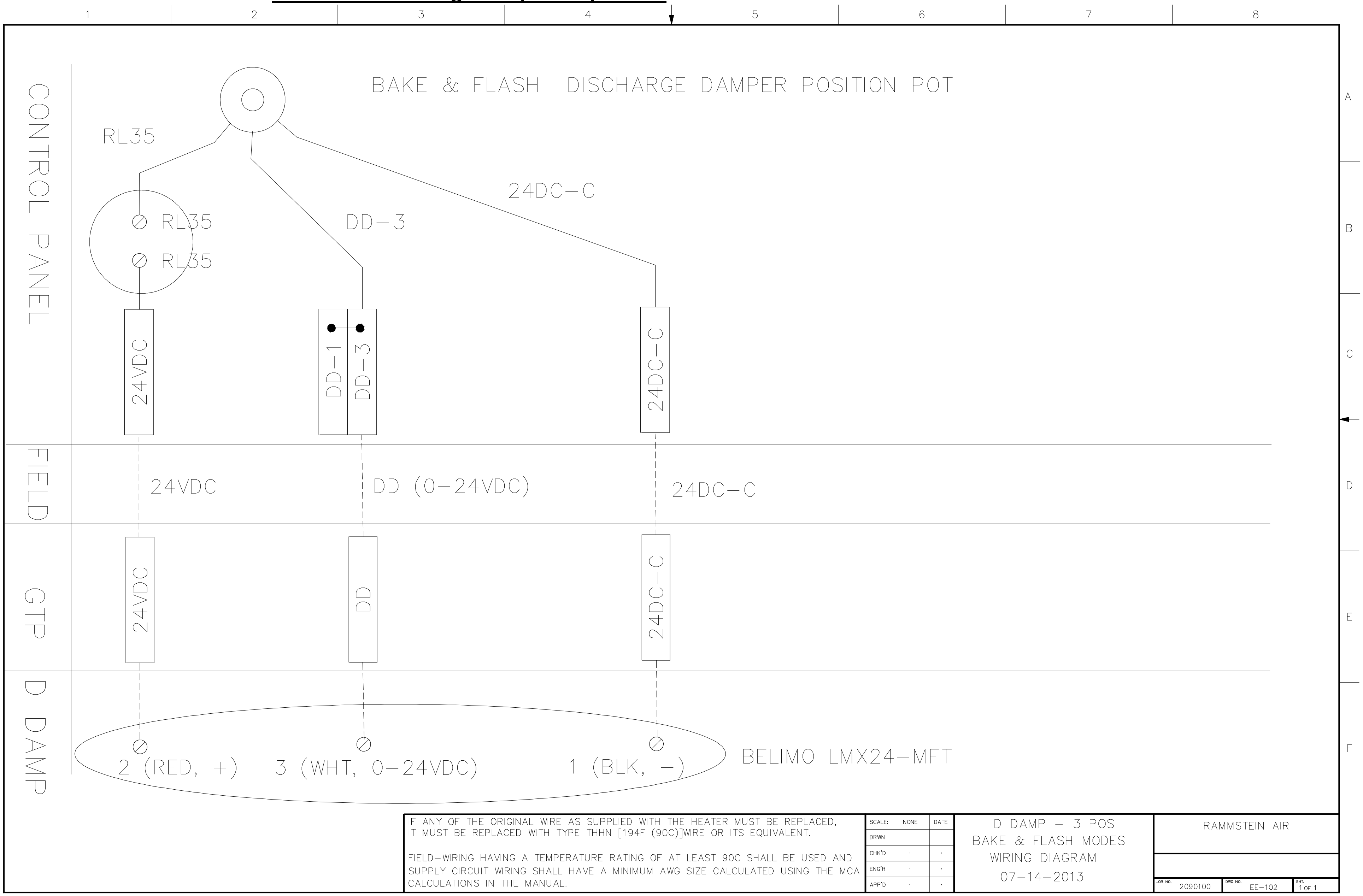
13.2.33 Spray Mode – remote switch



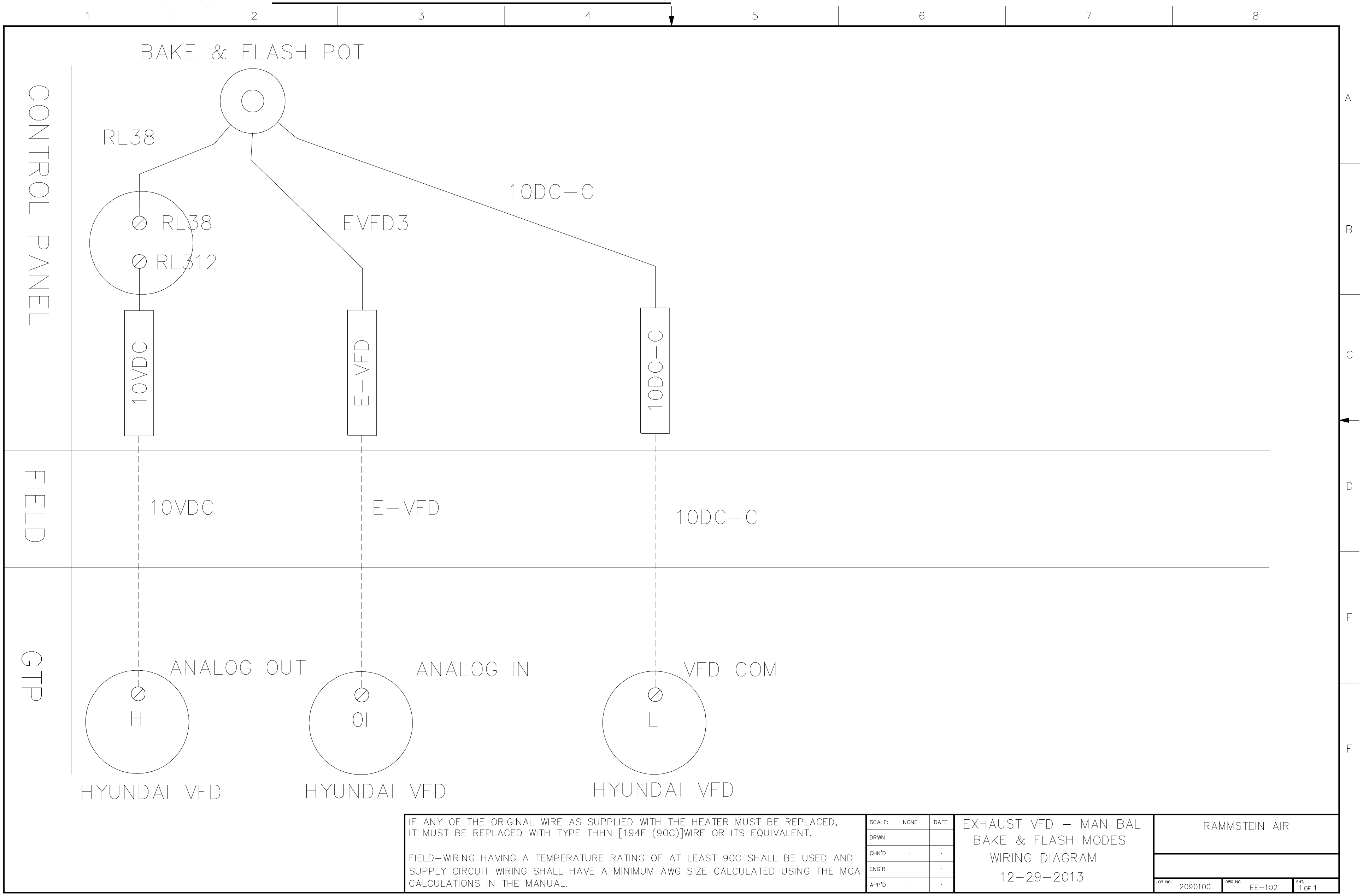
13.2.34 Bake Mode discharge damper – 2 position



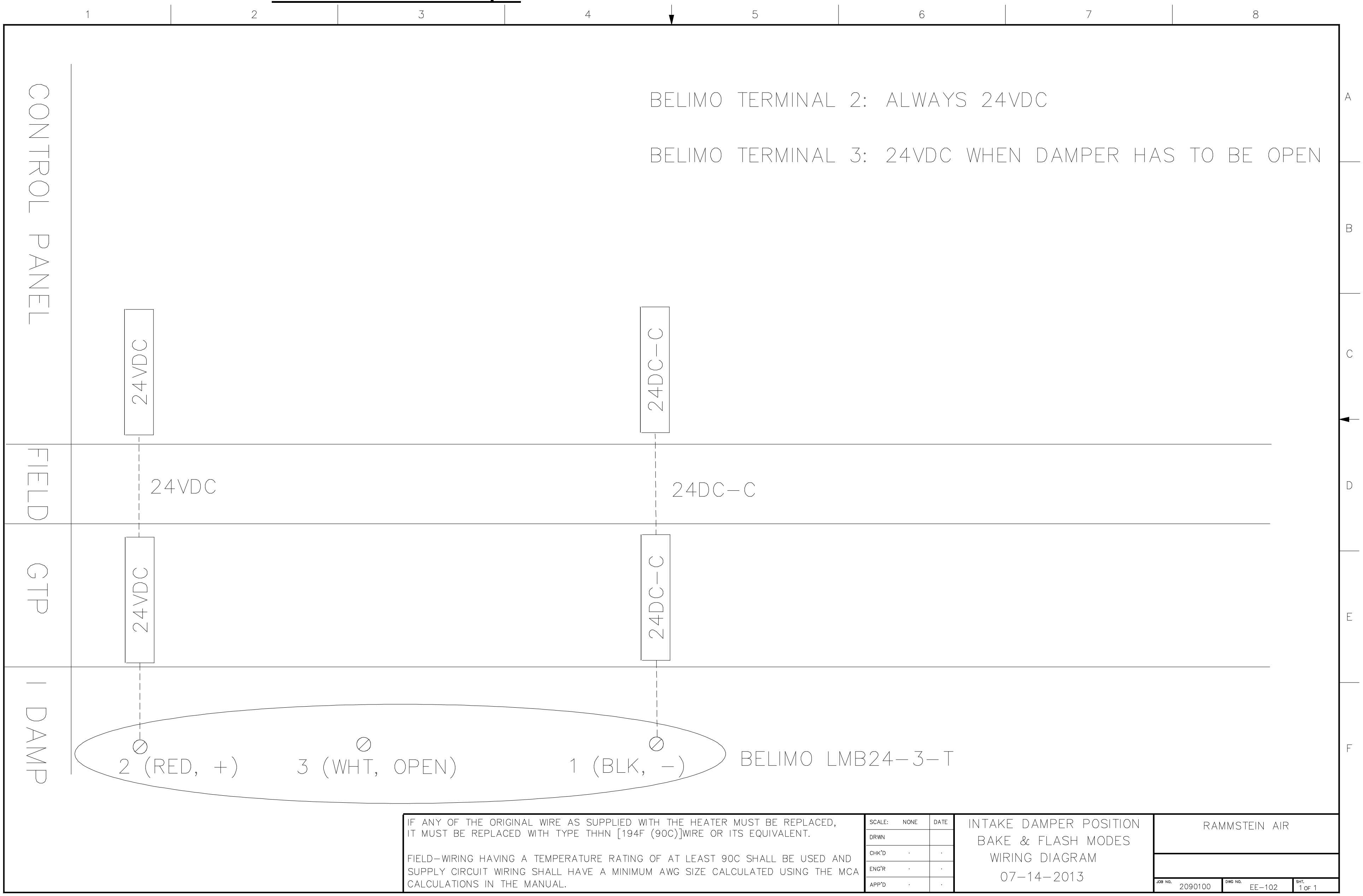
13.2.35 Bake Mode discharge damper – 3 position



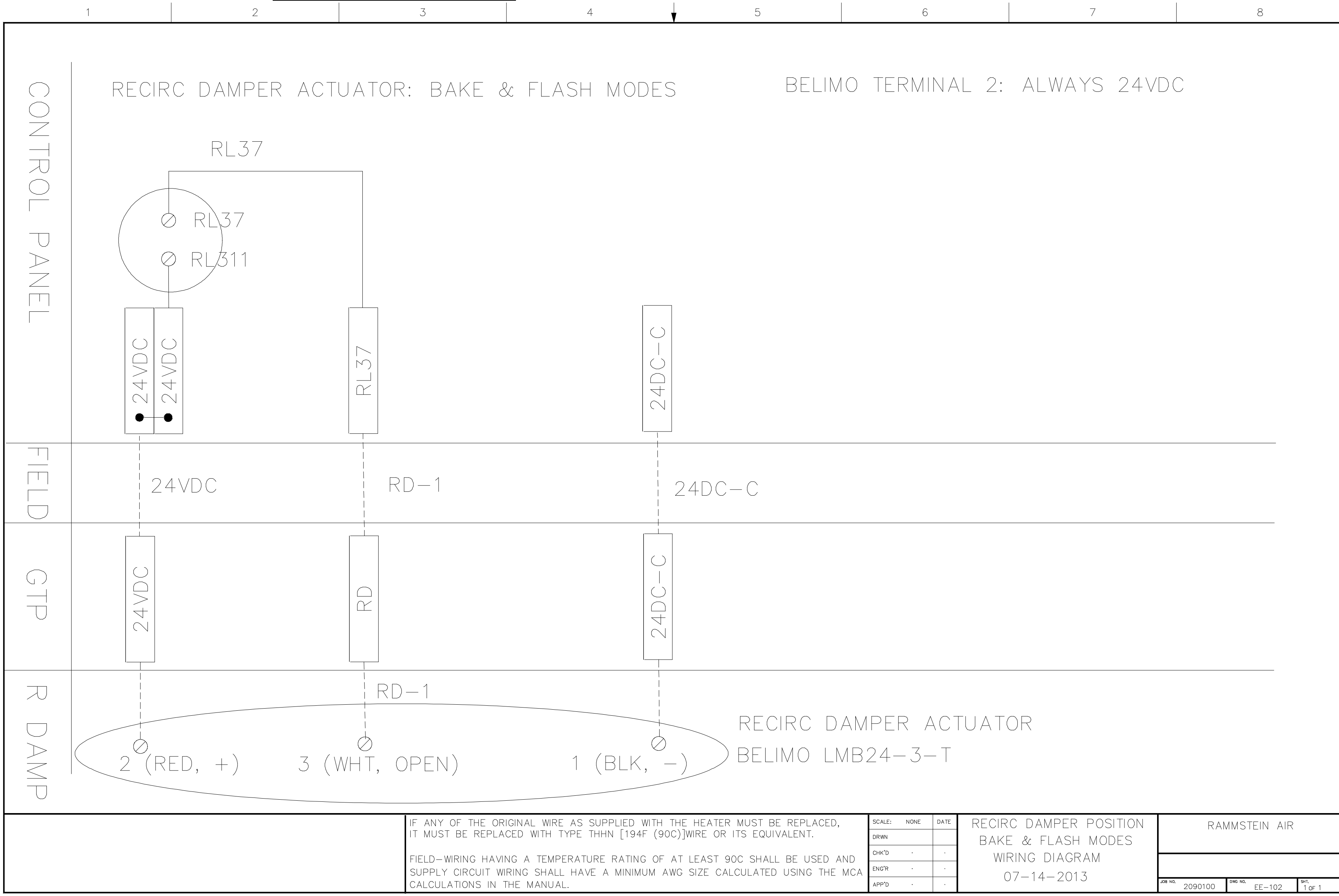
13.2.36 Bake Mode exhaust VFD – manual balance



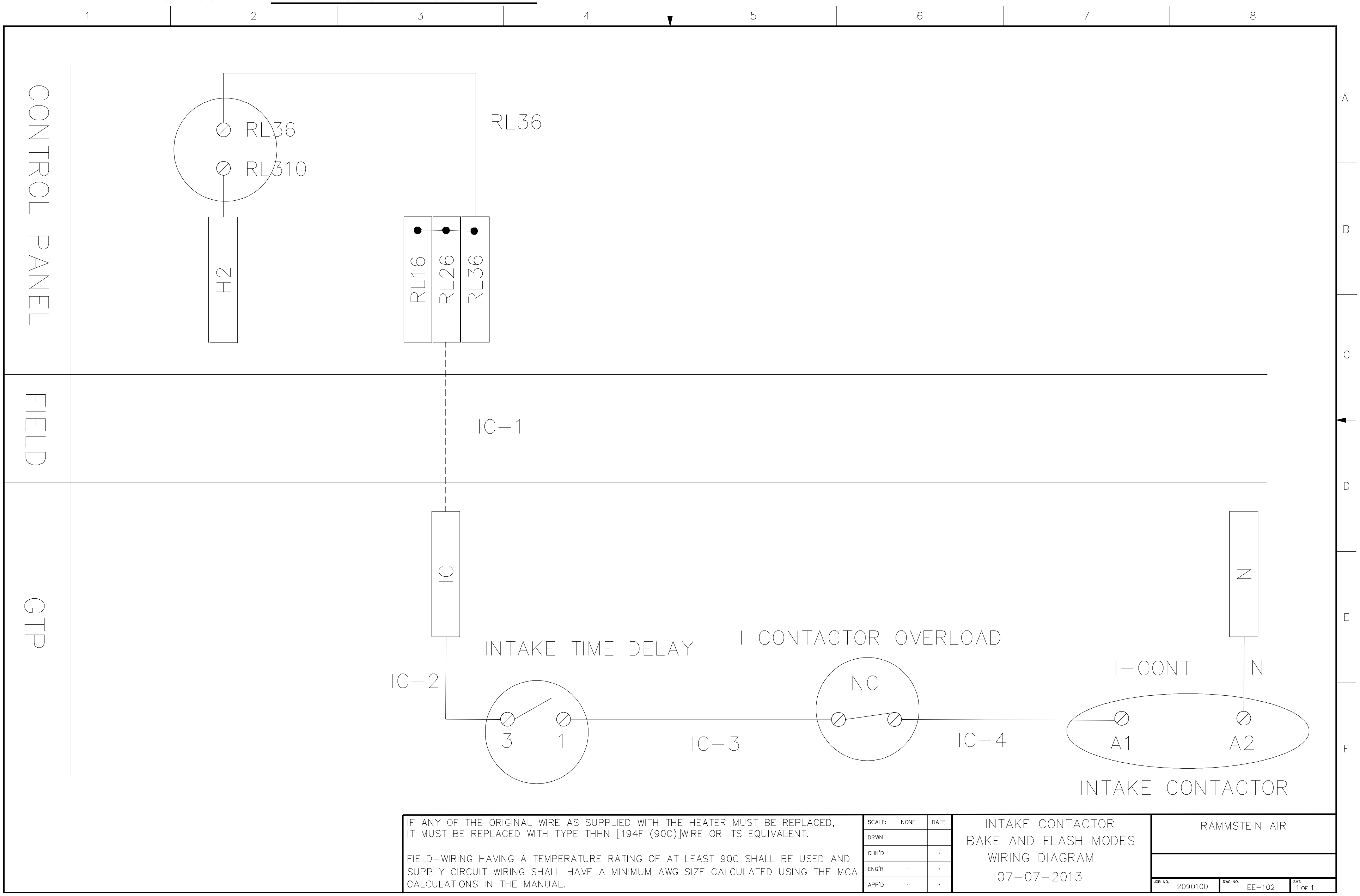
13.2.37 Bake Mode intake damper



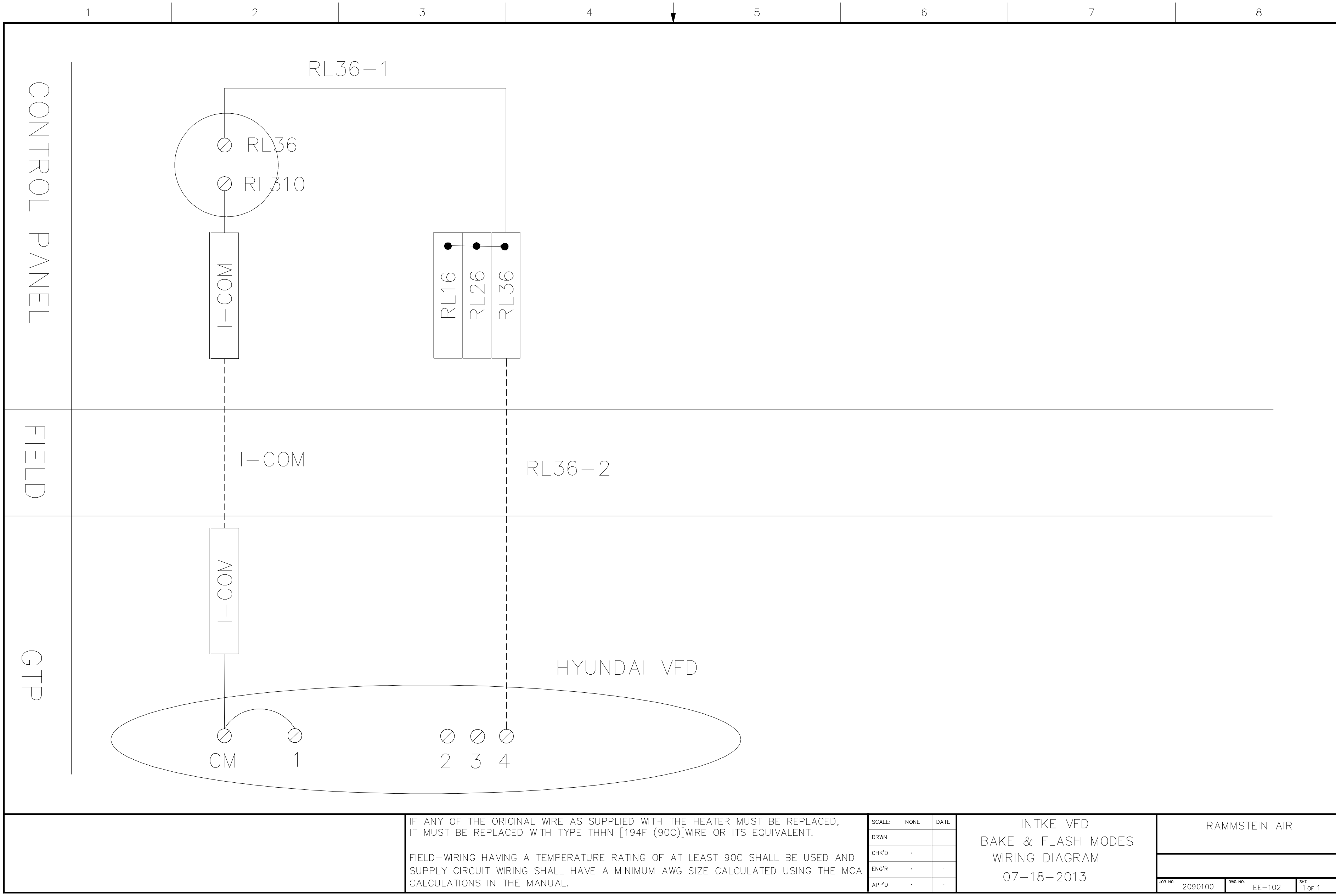
13.2.38 Bake Mode recirc damper



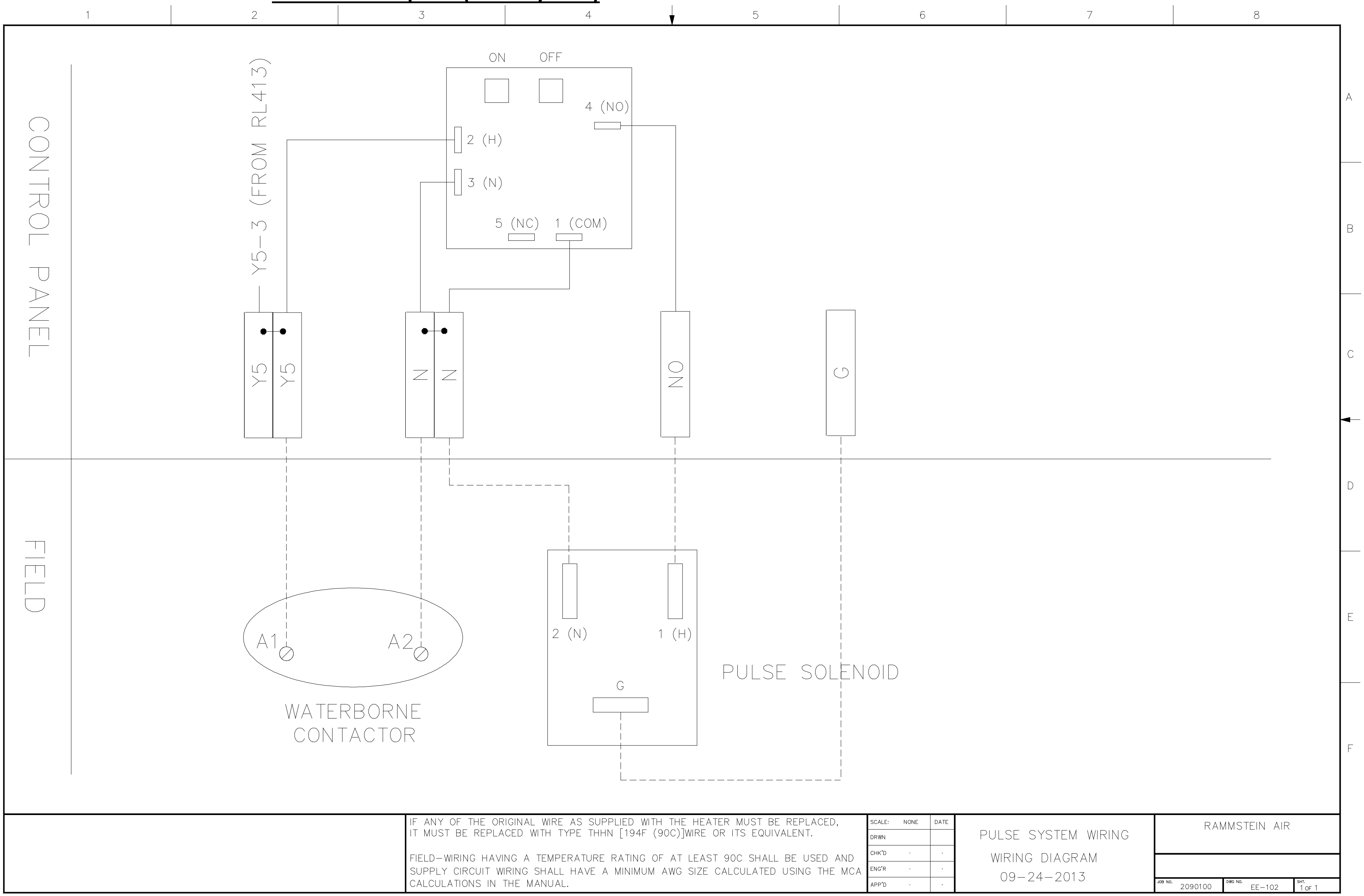
13.2.39 Bake Mode intake contactor



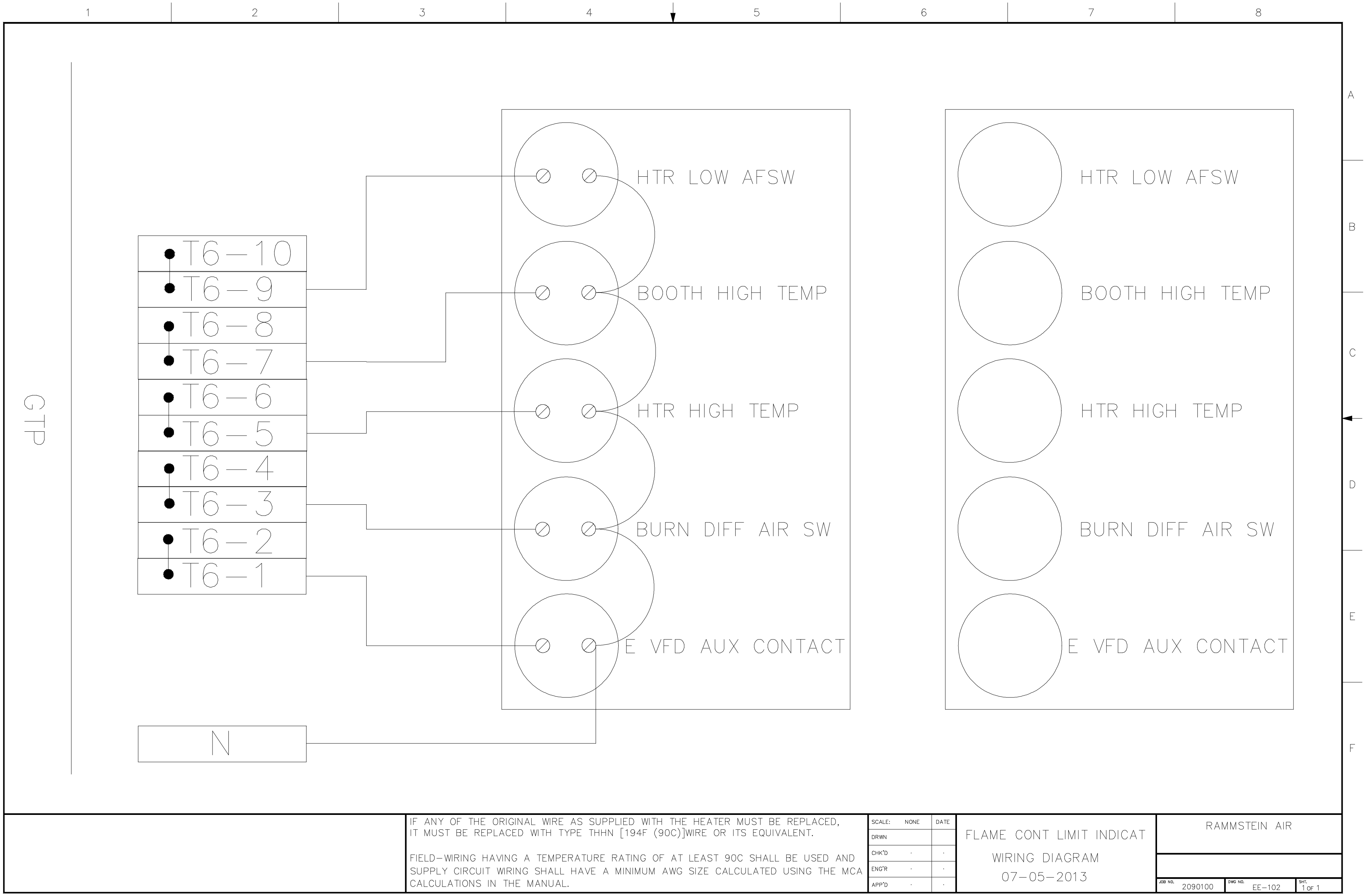
13.2.40 Bake Mode intake VFD



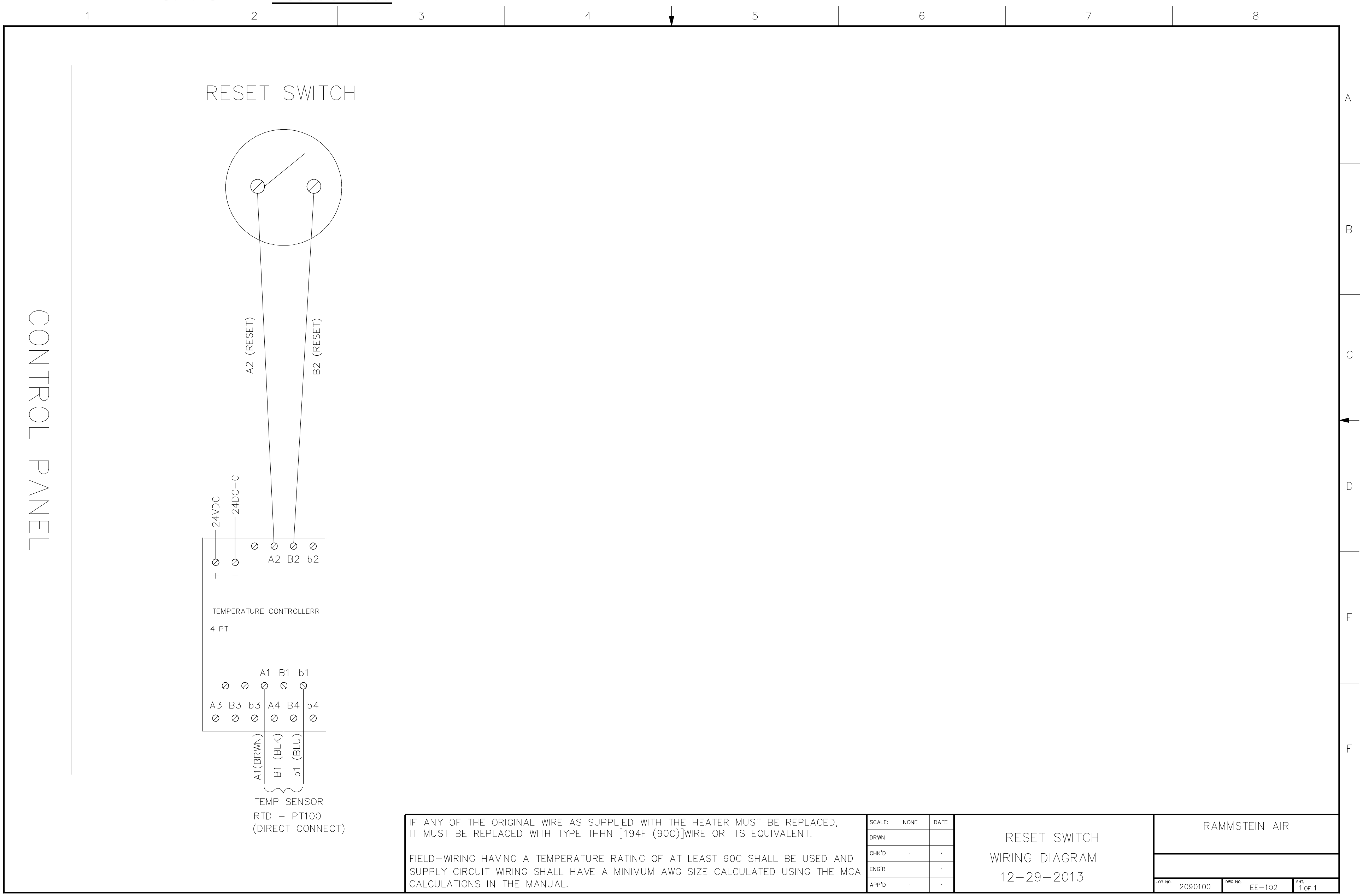
13.2.41 Waterborne Option (Pulse System)



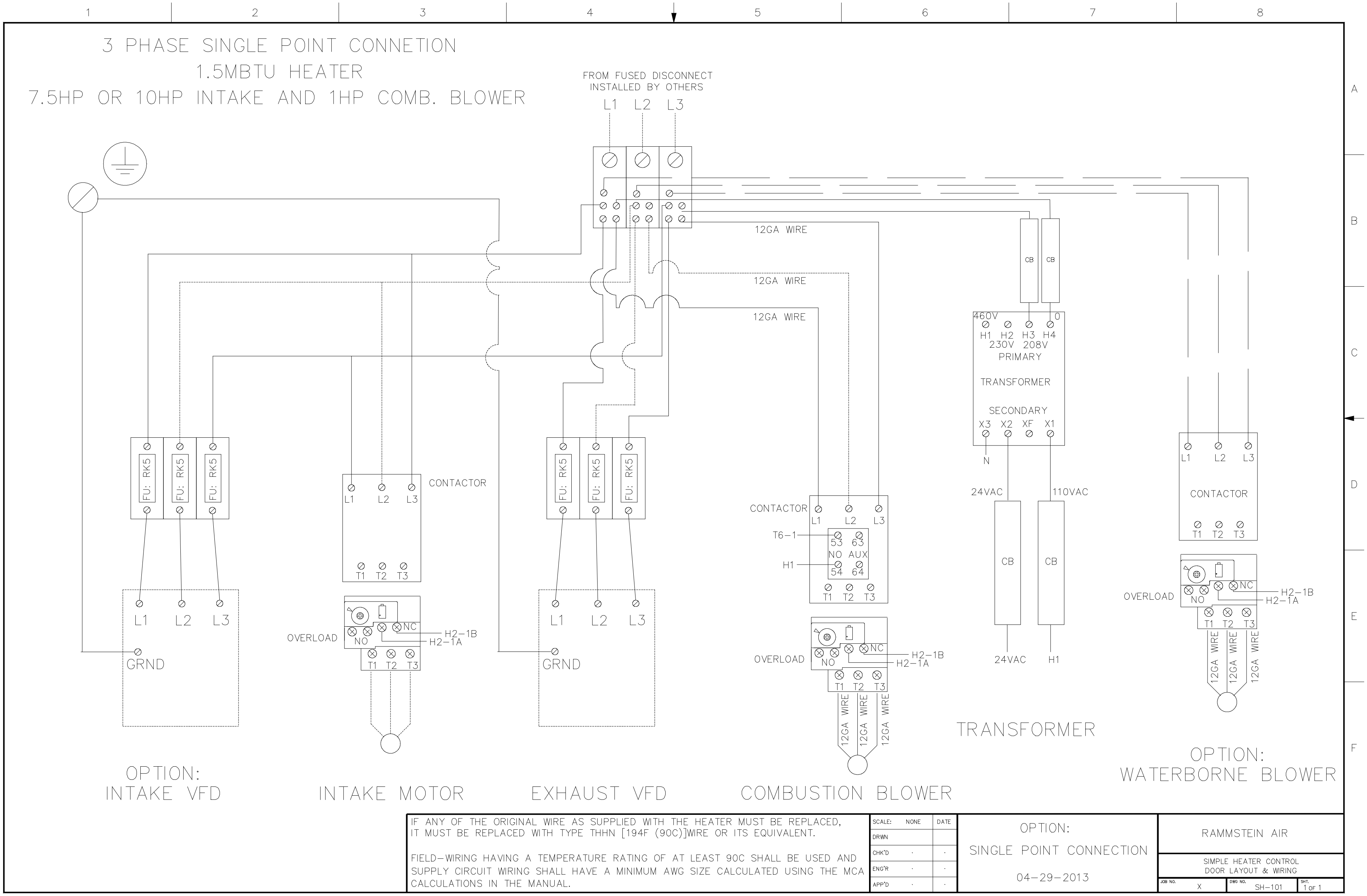
13.2.42 Flame Controller Limits Indicator Lights



13.2.43 Reset Switch



13.2.44 Single Point Connection



14 Demonstration kits

1. Practice panel
2. Standard CP for PLC related exercises
    - Programming chip
    - Programming cable
3. Take Prep/Spray CP for temp controller related exercises
    - Temp sensor
4. VFDs
5. Relay bases
    I. 2 pole
    II. 4 pole
6. Blower with blast gate and pressure gauge:
    i. Measure air flow and amps while changing static pressure on fan
7. 30" round duct
    i. Measure spray booth ventilation rate
8. Pneumatic switch kit

15 Supplies

Tables/chairs
Dry eraser board
Extension cords
Power strips

Note pads
Pens
Water
Paper towel

Extra multi meter
Gas pressure gauge
Air flow meter

Sensocon velocity pressure sensor
3.5mm screw drivers
Laptop
Gas pressure taps
Jumpers for AFSW testing
Umbilical tester
Flame controller and base

Non contact thermometer
Temperature data logger

NEC book
NFPA33
NFPA86
ANSI z83.25
Temp controller manual
Copies of Training manual
Copies of Installation Manual
VFD manual WWE: small and large
VFD manual Hyundai: small and large

16 Customer to bring

Multi meter
Screw drivers