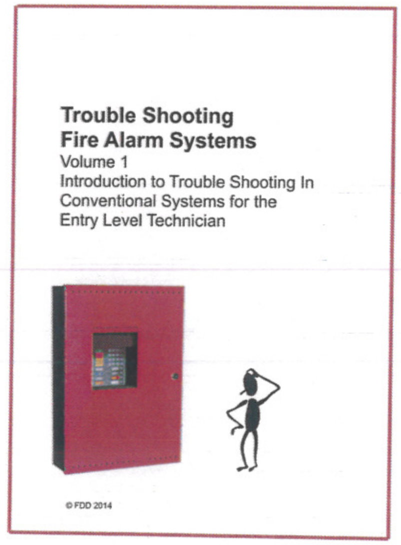
Celsius 232

Fire Detection Devices Information Bulletin

Introduction to Conventional System Troubleshooting



As part of a Fire Protection Technology program at a local college, Fire Detection Devices staff have created the first of three handbooks dealing with fire alarm system troubleshooting. We will include portions of the handbook in this and future editions of Celsius 232. Volume 1 opens with review material, and then proceeds with a discussion of power supply-related trouble, followed by initiating circuit faults including opens, shorts and grounds.

In this edition of Celsius 232, we reprint the forward and first two Parts of the handbook. We look forward to receiving your comments and suggestions as we go along.

Part 1 – Introduction

- **Definition of "Trouble"**

  Trouble is a condition in which the fire alarm system is operating in a degraded mode due to equipment failure, circuit failure, fault condition or operational malfunction.

- **Why is Trouble shooting so important?**

  A trouble condition in a fire alarm system can indicate a problem that could be considered minor, or conversely be of drastic proportions. In some cases, a circuit trouble can worsen over time if allowed to go unchecked. For example a single ground fault can turn into a double ground resulting in the shutdown of a signal circuit or in some cases, cause an alarm condition. A power failure affecting only the FACP could render the system completely powered down and useless if no response is made to the initial power-off trouble signal.

  Even if the system is monitored, a trouble signal could indicate a minor problem or it could be a warning of complete system failure. The station operator has no way of determining the seriousness of the trouble condition

  It follows that *immediate investigation of any trouble signal is vital in order to maintain the highest possible level of life safety.*

- **What code reflects the necessity for trouble shooting**?

  The National Fire Code clearly states that the owner of a building is responsible for ensuring that the fire alarm system remains fully functional as "the failure or malfunctioning of the appliance, device or component would adversely affect fire or life safety".

- **What is the purpose of this book?**

  Fire alarm systems have evolved into extremely complex, communications-based systems. Today's fire alarm control centre is capable of handling fire emergencies by providing reliable detection, signaling and voice instruction. As a result, panic is reduced and building occupants are provided with safe egress from a fire emergency. For many years, prior to the arrival of the computer-based intelligent "addressable" system, a more conventional technology was the basis for fire alarm systems.

  The difference in technologies can perhaps be illustrated as follows: The removal of a smoke detector from its base when connected to a conventional panel mechanically creates an open circuit which means that supervisory current fails, resulting in a trouble condition. When an addressable detector is removed from its base it will not respond to a poll and this communication failure results in a trouble condition.

  In either case, the result is the same i.e. a trouble condition, even though the technologies producing the result are vastly different.
  This book, referred to as Volume 1, will focus on trouble shooting in the conventional environment, and introduce the reader to some basic routines that are used at the panel as well as the field wiring. More complex trouble shooting challenges are discussed in Volume 2, and many panel-specific scenarios, both conventional and addressable make up Volume 3.

The Appendices

It is possible that his book may be used as a resource for a course involving fire alarm technology. In the Appendix section, one will find examples of laboratory report forms that can perhaps be modified for use in a school or other learning centre environment.
The Lab reports presume that a certain quantity and type of fire alarm panels and their related equipment is available.

To this end, some sketches of system layouts are offered as a starting point or at least to offer some food for thought on behalf of the person developing a course that begins with the study of Fire Alarm System basics. These board-mounted systems can serve as inspection training as well as offering trouble shooting challenges that can be easily handled by a junior technician after he or she has read and understood the contents of this book.

Part 2 - Getting Started

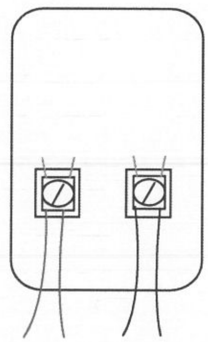
- **Circuit Integrity – Some review**

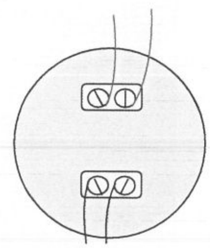
The digital multi-meter (DMM) is the most important tool in troubleshooting. DMM readings of current, resistance and voltage are used to locate circuit opens, shorts and grounds. Logical thinking is essential to troubleshooting and the Boolean Logic approach to locating circuit faults is discussed and demonstrated as part of this Guide.

In general, "circuit integrity" as it applies to a Fire Alarm System contemplates that the circuit will have:

1. Metallic continuity i.e. no opens due to disconnection or breaks
2. No grounds
3. No wire-to-wire shorts

Metallic continuity means that a circuit conductor is continuous from its terminal connection, for example, in the FACP to its final connection point. Along the way, the conductor may be severed, stripped and installed under the terminal of a device. However, it will be re-connected under the same terminal before it leaves the device thus maintaining what we call "metallic continuity". Fire alarm circuits must be designed so that an interruption in the continuity will cause the FACP to go into the Trouble mode, a warning that the system is not fully functional.





In a conventional fire alarm system, this is achieved by passing a small amount of current through the circuit. If the circuit opens, the current stops. The cessation of current flow is detected by the FACP and it is displayed as a Trouble condition.

In the addressable fire alarm system, the interruption, or open will cause the digital communication between the FACP and the devices to cease. The *lack* of response from addressable devices results in a trouble condition the missing device or devices are displayed.

An open-circuit trouble can result from a disconnected wire or a break in an over-stretched conductor. In many cases, it's the connection to a device (detector, bell, horn, speaker) where the open or break occurs. This is usually the result of improper stripping of the insulation resulting in a nick of the copper wire, or the wire could become fractured as it is twisted too tightly under a wire cap (Marrette®). Over tightening of a terminal screw can also result in a wire end fracturing, which may not cause an interruption of the metallic continuity until some time after the installation is complete. Quite often these "opens" are intermittent causing repeated trouble conditions.

Ground-Free Fire alarm circuits must be free of grounds. ULC requires that devices connected to a circuit where a *single* ground has developed, continue to be operable. However should a ground develop on the other conductor of the circuit, the entire circuit will fail as it has effectively become shorted – i.e. the two conductors have become shorted together by simultaneously coming in contact with a steel junction box or conduit. FACP's are designed to sense a current increase to ground by means of a ground-sensing circuit, part of the FACP's power supply section.

In a conventional panel, a ground condition is displayed as "System Trouble" and, in panels of recent manufacture, a yellow LED designated as "Ground" or "Earth" will also be lit. In an initiating circuit, the supervisory current flowing through the circuit will increase only slightly which means that the Trouble LED for that particular Zone will *not* be lit. This means that a ground, unlike an open, is *not shown* as a Zone trouble. The same applies to a single ground on a *signal* circuit.

Note that the `FACP "floats" above earth ground creating a voltage potential between both "+ve" and "–ve" to earth. This allows for ground detection on both sides of the circuit.

Wire-to-wire shorts are probably the most dangerous of circuit troubles. A short means that circuit resistance is reduced to zero which means that voltage disappears. In a signal circuit, a short renders the entire circuit inoperable – a major concern if the building's Fire Alarm system makes use of only one signal circuit.
In an addressable input / output circuit, a short causes all communication to cease – basically a system "crash". This is why the Fault Isolator Module plays such an important role in limiting the effect of a short to one floor zone.
Only on a conventional Initiating circuit (and Sprinkler Supervisory circuit) is a short used to our advantage as devices such as manual stations, heat detectors etc., deliberately place a short across the circuit when they are operated. Although voltage practically disappears in a short circuit condition, the circuit current will increase to the point where the FACP will recognize this as an alarm condition.
Shorts are usually the result of poor installation practices, especially in the stretching of cable around conduit bends resulting in damage to the insulation of the individual conductors. As mentioned above, a wire-to-wire short can be simulated by a double ground condition. A sharp burr in a conduit will easily cut through fire cable insulation and provide a short circuit path between two conductors.

- **How do we know a system is in Trouble?**

1) Audibly
   A FACP will turn on its trouble audible device, usually a piezo or a buzzer that is silenced by pressing a button or switch designated as "Panel Silence", "Trouble Silence" etc.
   Note: This audible is also associated with the activation of a sprinkler supervisory switch, accompanied by the turning on of a LED designated as "Supervisory".

2) Visually
   Regardless of the type or location of a trouble condition, a yellow LED designated as "System Trouble" or "Common Trouble" will be lit. Another yellow LED will offer more specific information such as "battery", or "signal", or "zone #" or "ground", etc.

3) Notification of a trouble condition may come from a Signal Receiving Centre or a call from the building owner or property manager.

- **What can the customer tell us?**

  A good technician will get as much information as possible from the customer. This could be the building superintendent, or custodian – somebody who spends a lot of time in the building and is somewhat familiar with what goes on in the building on a daily basis. Information such as:
  - Have there been any contractors working in the building in the past week or two? If so, what were they doing and in what part of the building were they working ?
  - Exactly when did the trouble condition (or false alarm) occur?
  - Have there been any complaints of leaks of any kind?

  Listen for clues such as:
  - " This always happens a couple of days after it rains".
  - " The phone company was in a while ago and some cable guys were working on the 4th floor."
  - " The pool area has always been a problem for the alarm system".

- **Where Will Trouble Develop?**

  Power supply – both primary and emergency power. The FACP has two sources of power. Failure of either power connection to the panel will cause a trouble condition.

  Input circuits – in conventional systems, input circuits are referred to as either initiating or supervisory, the former meaning circuits connecting manual stations and automatic detectors, the latter referring to sprinkler supervisory switches.

  Output Circuits – typically are signal circuits including speakers, ancillary circuits (relays) .

  Device failure – In conventional systems, the electrical failure of a device will **not** cause a Trouble condition, as long as the **integrity of the circuit is not affected**. This means that a fracture in the coil winding of a bell, the disconnection of the blocking capacitor in a speaker, the corrosion of a switch in a manual station, the failure of a photo-receptor in a smoke detector – can render the device inoperable yet *not* cause a trouble condition. These deficiencies are only caught during a regular, periodic inspection. Some devices can create a trouble signal on their own, and these are primarily addressable analogue devices that report their individual condition with respect to accumulated dirt or environmental changes. Any of these devices that are given an address that is not part of the programmed data base of the host FACP, will make themselves known by generating a trouble condition, and displaying a message on the Liquid Crystal Display such as "non-configured device".

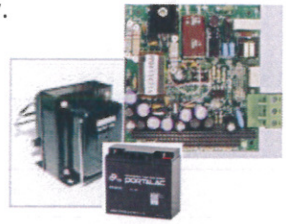
  In the case of the Beam Detector, full blockage of the photo-receiver portion will result in the device creating a Trouble condition – a warning that it has been rendered inoperable.

Intentional (Disable or Bypass) – In either conventional or addressable systems (and especially the latter), the technician may wish to bypass certain building systems such as Elevator Recall, Fan Shut Down etc., so that that these building systems will continue to run normally while the fire alarm system is being tested. These building systems are referred to as ancillary functions that are controlled by the fire alarm panel. All ancillary functions that have been bypassed during a fire alarm inspection must be returned to normal status when the inspection is complete. For this reason, the panel will go into the trouble mode as soon as the first bypass is engaged. It serves as a reminder to remove the bypass in order to restore the panel to normal.

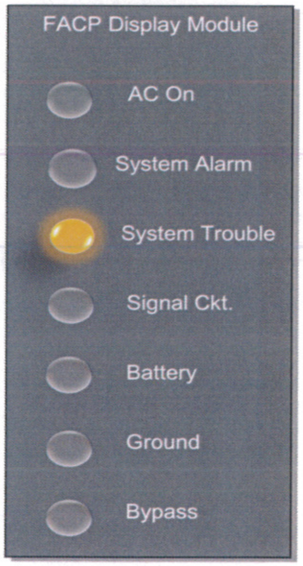
The following sections will look at each one of these issues in greater detail.

Part 3 – A close look at the Power Supply as a Trouble Source

As in any system, the power supply must be fully functional in order for the system to survive. In a fire alarm control panel (referred to as the FACP), the power supply provides power to the initiating circuits, the signal circuits including tone generators and amplifiers, ancillary circuits and other outputs that control building systems related to the occupant life safety. Somewhat unique to fire alarm system, the power supply must also maintain the rechargeable batteries at their peak efficiency with respect to their amp hour capacity. For this reason, the power supply is designed to be very reliable and well protected against power fluctuations and static discharge.



A Trouble signal related to the power supply may be an indication of:



1) Failure of main (primary) power

This will be indicated by the FACP in three ways:

- extinguishing the "AC On" LED,
- turning on the "System Trouble" LED
- and turning on the panel trouble audible.

Note: *If the FACP is monitored by a private agency or the fire department, a trouble message will be transmitted, however the message will not specify the trouble as being AC fail.*

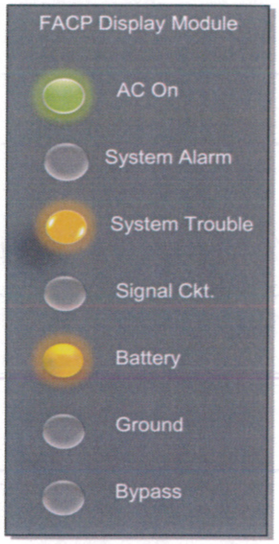
Primary power failure can affect a building, a city block or blanket half a continent. The most dangerous scenario is the failure of the FACP's local breaker which interrupts the power to the FACP only, in which case no other electrical or lighting circuit is affected and all seems normal, save for the fact that the FACP is in the trouble mode, sounding its trouble audible and perhaps transmitting a trouble signal to the monitoring station. If the trouble receives no response from the building management, then eventually the emergency power supply, i.e. the standby battery bank, will be diminished resulting in complete failure of the fire alarm system.

It is unlikely that the FACP can cause a typical 15 amp breaker to fail. Even large fire alarm system controls rarely require more than a few amps to operate normally. Quite often, however, the feed from the breaker to the panel has branch circuits serving outlets etc., a practice that is not acceptable to the electrical code. Appliances plugged into an outlet can over-current the circuit causing the breaker to operate and disconnect primary power to the FACP.

Technicians are aware that what might look like a mains failure (no green LED, only one yellow System Trouble LED lit), might be an indication that the power supply itself has failed and that there is no issue with the primary power source. A quick check of the primary and secondary side of the power supply transformer will confirm the presence of AC and that the transformer

is functioning normally. The power supply itself has rectification and regulation circuits that can fail for a variety of reasons.
The only recourse in this case is to replace the entire power supply "module" after which the technician is obliged carry out circuit load tests, especially relating to the emergency power charging circuit and the condition of the batteries.

As stated earlier, FACP power supplies are of a robust design, and component failure should not be considered as a mere inconvenience but thoroughly investigated. Heat sinks that are extremely hot, discoloured components, scorched areas on a power supply printed circuit board are indications that the power supply is being over-currented and susceptible to failure.

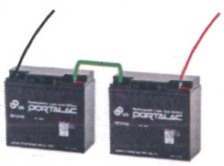


2) **Failure of emergency power -** This will be indicated by the FACP in three ways:

- turning on the yellow "System Trouble" LED
- turning on the yellow "battery" Led
- turning on the panel trouble audible.

Note: *If the FACP is monitored by a private agency or the fire department, a trouble message will be transmitted, however the message will not specify the trouble as being battery fail.*

The emergency power supply consists of battery power, usually with two 12 Volt re-chargeable batteries connected in series. When standby power requirements are large, the batteries can be a series-parallel arrangement as shown here:



2 batteries in Series

Two fully charged 12 Volt batteries (approximately 13.6 Volts each) connected in series will deliver approximately 27 Volts. The batteries shown here each have a capacity of 18 Amp/Hour referred to as "Ah". The power capability of a battery pack connected in this way can be described as " 27 Volts @ 18 Ah".

4 batteries in series -parallel

When more emergency power time is required, batteries can be connected in parallel. In this configuration, the Ah capacity of the batteries add together (i.e. 36 Ah). Terminal voltage of the set remains at 13.6 Volts. When two sets of batteries in parallel are connected in series, the overall output capability of the battery pack is 27Volts @ 36Ah. This series/parallel arrangement is not recommended due to its complexity, however it will be found in some larger systems.

The FACP senses the presence of the batteries by means of the charge current sent to them by the power supply. Any interruption of the wired connections to the batteries or any interconnecting jumper or in-line fuse will result in a trouble condition described above, as current level will drop to zero.

The gel-type battery that is widely used in fire alarm panels do <u>not</u> show their internal condition and charge level as would the liquid lead-acid, glass case battery with gravity beads. Regular testing for sufficient Ah capacity with load test meters is the only way to determine that battery integrity is acceptable.

Over time, the gel material can dry out resulting in continuing reduction in charge current to the point where it is so low that the panel considers the battery connection to be interrupted. A trouble condition is therefore created, however visual inspection of the batteries will not reveal any wiring fault or outward sign that the batteries have failed internally. This "drying out" process can happen relatively quickly, perhaps a short time after the batteries have been tested and accepted in, say, an Annual Inspection. Date coding is therefore especially important when looking at the gel-type battery. It is generally accepted that after 5 years of normal life in a FACP, the battery bank should be considered due for replacement.

A more dangerous condition develops if excessive corrosion builds op on the plates in two or more cells such that they make contact with each other, producing a short circuit condition within the battery. This will result in an excessively high rate of charging current that can, if not limited or fused, damage the charging circuit. In this case a trouble condition may or may not be displayed by the FACP, however excessive heat emanating from the power supply area, the transformer and heat sinks as well as swelling of a battery will obviously indicate a serious over-current condition.

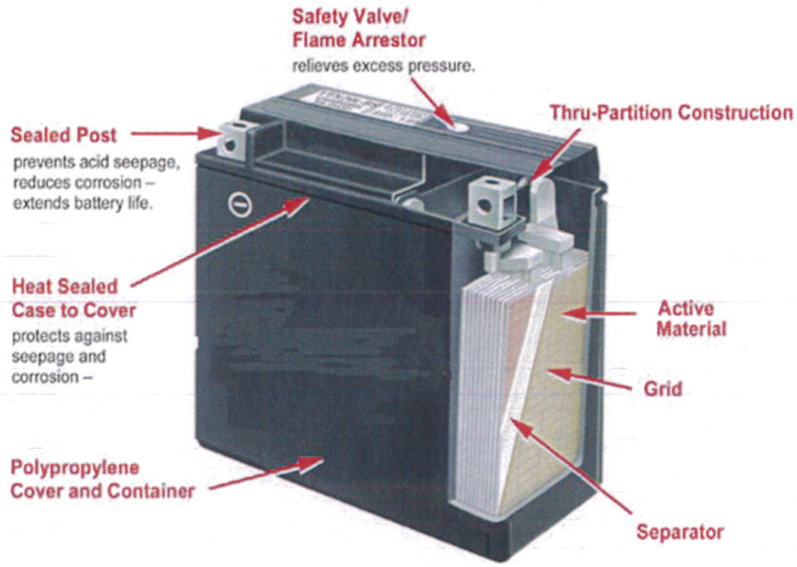


Photo courtesy Peak Technologies

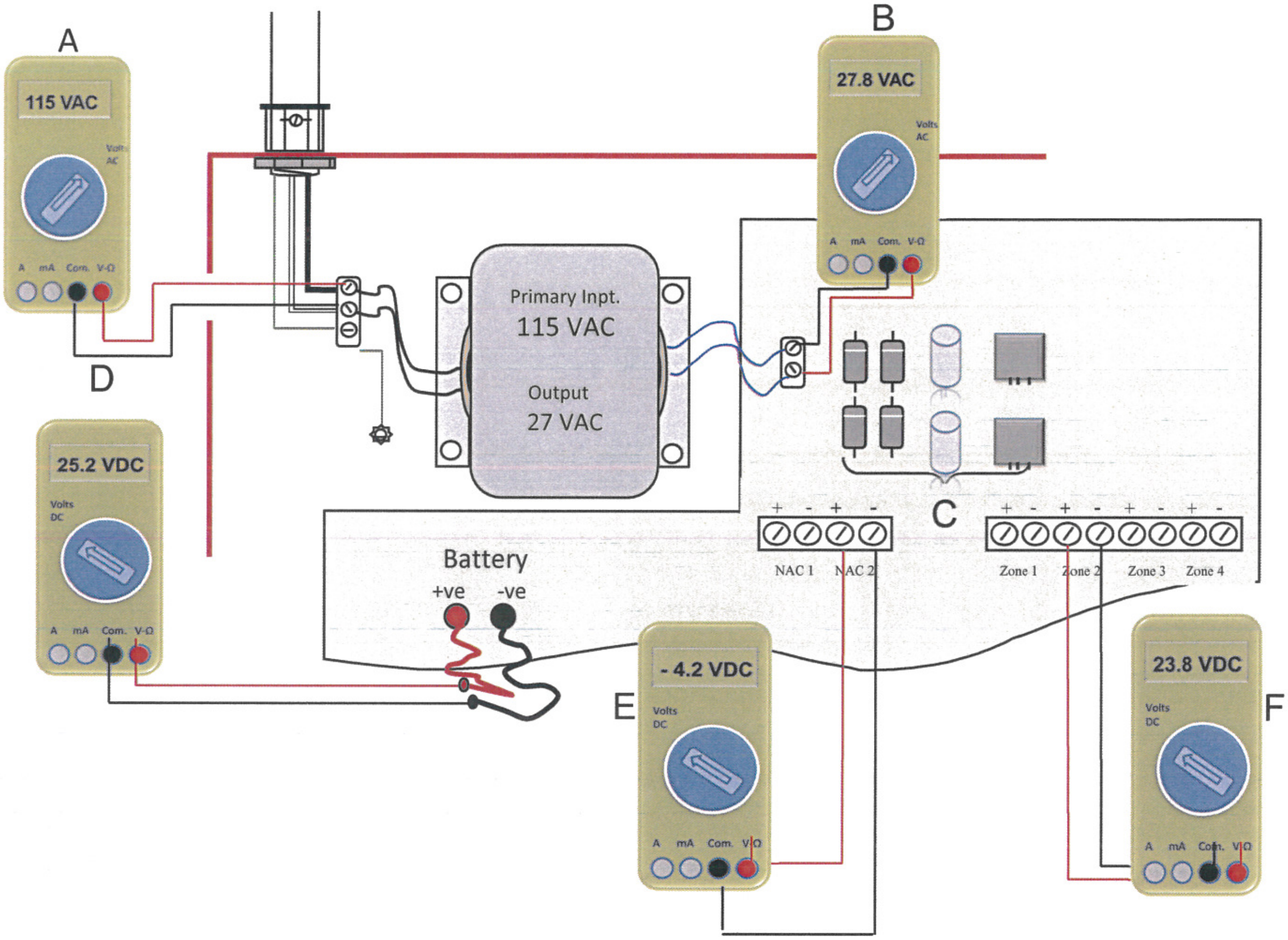
In most panels, a charge current that becomes excessively high will trigger a trouble condition, perhaps because a fuse has blown, or the charging circuit has reached its current limit.

3) Component Failure within the power supply module – a difficult problem

The failure of a component in the power supply module can occur without any outward sign. To make matters worse, trouble conditions attributed to input circuits or signal circuits could actually be caused by problems within the power supply module. An intermittent failure of a voltage regulator for example, can result in voltage fluctuations resulting in alarm or trouble conditions. Similarly, failure of the power supply's filtering ability will adversely affect speaker output.

The natural tendency is to examine the field circuitry when the problem actually stems from within the power supply.

The following sketch shows the basic components of the power supply module as well as typical supply voltages for the emergency power supply (batteries) , the initiating and signal circuits. Digital multi-meters are added to show typical voltage readings



Meter A shows that the primary voltage source is present. This will be supplied directly from an electrical panel, protected by a separate breaker switch. In many instances the primary input of the FACP's step-down transformer share the same termination points as the Line (black) and Neutral (white)wires delivering the 115 VAC. The electrical ground wire (green) provides a water pipe ground reference for the FACP enclosure.

Meter B is displaying the voltage at the secondary winding of the transformer. This is a typical reading and will vary one or two volts from panel to panel.

Section C indicates that this secondary voltage is rectified, filtered and regulated with the end result being an operating voltage level of (typically) 25-26 VDC . Test points are usually provided to ensure that the operating voltage level is correct and that the power supply components are fully functional as they rectify, filter and regulate as intended.

If there is no easy way to read the operating voltage on the power supply module itself, then check the supply voltages that are *provided* by the power supply module, as follows:

Meter D is taking a measurement of the charging voltage for the batteries. To charge a 24 volt battery pack (two 12 volt batteries in series), a charging level above 24 volts is required. The sketch (previous page), show that the batteries have been disconnected and a voltage reading is taken across the panel connection. The charging voltage could be as high as 26 or 27 volts. The charging voltage and current supplied to the emergency power supply is carefully regulated by the power supply module. An off-normal reading of this charging voltage (either very high or very low) is a definite indication that the power supply module is not functioning properly. A reading of the charging current should show charging current in the milliamp range if the batteries are fully charged. The health of the batteries themselves can cause a trouble condition, as discussed in (2) above.

Meter E is taking a supply voltage reading on one of the two available signal circuits. It is a negative reading which is expected, because in the alarm state the panel will reverse the polarity on these terminals and increase the voltage level to approximately 24 VDC, the operating voltage for most bells, horns and strobes. In this case the manufacturer has selected a lower level of supervisory voltage and so this reading may appear to be suspect, i.e. perhaps indicating that there is a problem with the power supply module. Checking the manufacturer's technical data for this particular panel would show that the non-alarm voltage reading of approximately 4 VDC (read as -4 VDC) on a signal circuit is normal.

Meter F is taking a supply voltage reading on one of the four input circuits, also referred to as the initiating circuits. These circuits are described as Class B (2-wire) and have an end-of-line (EOL) resistor across the end of, the circuit. The EOL regulates the supervisory current flowing through the circuit at a level determined by the manufacturer and will vary slightly from panel to panel. These circuits have a supply voltage of 20-24 VDC, which is used to power electronic sensors such as smoke detectors. Conventional initiating devices can place a short (manual stations, heat detectors, waterflow switches), or a resistive short (smoke detector) across the circuit when in activated. This causes the circuit current to increase well above the supervisory current level. It is this current increase that puts the panel into alarm. By the same token, a decrease in circuit current resulting from a wire break or disconnection will cause the panel to go into trouble mode.

So what are the chances that the power supply portion of the alarm system will cause a trouble condition?

Regrettably, a power supply malfunction can mislead the technician by manifesting itself as a battery failure, a "swinging" or intermittent open circuit, a series of false alarms, and so on. And again, regrettably, careful analysis of the power supply is usually the last resort. In many instances, the replacement of the power supply portion resolves one or more issues that cause undue system problems.

As an entry level technician, you now know what meter readings are expected, however the examples given here are generic, and actual readings prescribed by the panel manufacturer must be sought. If nothing else, these readings can be considered to be the panel's "vital signs" and are a product of a myriad of components that make up the power supply module. Power supplies are considered to be robust in design but a static discharge (e.g. lightning), moisture, corrosion to name a few, can cause the failure of any one component. That failure may not be catastrophic and it may not be immediately obvious. It is the careful analysis of your meter readings that will point to the problem as a power supply issue.

Watch for the next installment,

Part 4 – Trouble Conditions on Input Circuits