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OPTICAL FIBER AND ITS INDUSTRIAL APPLICATIONS

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I. INTRODUCTION

Today's industrial production environment is a digital environment. In industries ranging from power to auto manufacturing to chemicals to food and packaging, manufacturers are rethinking their plant operations and network capabilities. There is increasing use of automation to enable more flexible and efficient production. In addition, the factory floor is becoming more integrated into enterprise-wide business networks converging multiple networks on a single backbone. These conditions, in turn, create new challenges for industrial systems designers and control engineers. One issue of concern is choosing the right communications cabling for the factory communications backbone. The digital factory floor depends on the quality, ruggedness and reliable operations of its communications backbone. If the network is down, and the line isn't running, the operation isn't making money. Engineers need to be certain that their cabling choices can stand up to the rigorous demands of a 24x7 production facility. Copper cabling has been the traditional choice for these industrial applications. However, fiber optic cable is rapidly becoming a viable and proven industrial cabling option, with features and inherent advantages that make fiber a strong candidate for inclusion in industrial solutions.

II. BENEFITS AND DRAWBACKS OF FIBER OPTICS CABLE OVER COPPER CABLE.

Fiber optic technology has a number of benefits for industrial communications:

• ***Long Distance*** Signals can be sent over fiber optic cable for long distances— for example 9 km without the need for intermediate amplifiers.
• ***Ground Isolation*** Since electrical currents do not flow on fiber optic cables, differences in ground potentials between end points do not affect signal transmission. Ground isolation is useful in power plants and switching yards where the differences in ground potentials are high. Grounding systems are not needed for fiber optics.
• ***Lightning Protection-*** Because fiber optic cables do not conduct electricity, signals are not affected by lightning.
• ***Cable Routing-*** Since fiber optic cables do not conduct electricity, they can be placed on the same cable trays as power carrying cables.
• ***Noise Immunity-*** Fiber optic cables are immune to electromagnetic noise from radio stations, motor turn-on surges, welding discharges, electrostatic discharges, florescent lights, cellular devices, hand held operator terminals, wireless security cameras and other Radio Frequency Interference, RFI.
• ***Intrinsic safety-*** In places such as chemical plants and grain silos, the atmosphere is often potentially explosive. Great care has to be taken with electrical wiring and data communications wiring to insure that sparks will not ignite the atmosphere. Signals on fiber optic cable will not cause sparking and are intrinsically safe. ***Small size-*** Fiber optic cables are relatively small. Where cable has to be added to conduits
that are already partially filled with existing cables, the small size cable can be advantageous.
• ***High data carrying capacity-*** Fiber optic cables are able to carry high data rates; for example, 1000 Mbits/second or 1 GBPS. In most industrial applications, however, data is transmitted at 1 to 10 Mbits/second. For these moderate data rates, there is no need for the high data rate capability.
• ***Security-*** Unlike copper cables, fiber optic cables are difficult to tap and to extract part of the signal without disrupting the operation of the fiber optic communications system. Also, fiber optic cables do not radiate electromagnetic signals that can be picked up with sensitive antennas.

Fiber optics is not used everywhere because it also has disadvantages

• ***Costly-*** The fiber optic cable and the electronics in the equipment attached to fiber optic cables are more expensive than compare to copper cable-based communications systems. Moreover, two fibers are needed rather than just one to have two-way communications. The connectors and the equipment needed to install them are more costly than for copper cable. However Fiber Optic cabling cost is trending in the opposite direction from copper and opto-electronics are becoming much more cost effective.

• ***Signal Distribution-*** In copper communications systems, many devices can share the same cable and communicate with each other. In fiber optics this is not practical. Signal transmissions and reception are point-to-point. A central signal distribution device is necessary to interconnect more than two stations.

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• ***More Training-*** Technicians working with fiber optic equipment need more training than copper cable installers.

• ***More Care-*** Fiber optics is very susceptible to mishandling and dirt. Workers dealing with fiber optics have to use extreme care not to damage or degrade the performance of the fiber optic communications system.

III. FIBER OPTIC TECHNOLOGY AND TERMINOLOGY

A fiber optic communications system is composed of three types of parts (as shown in figure) the ***Transmitter***, the fiber ***Medium*** (cable) and the ***Receiver***. The transmitters and receivers are located inside the computers, robots, controllers, or other devices that need to send or receive data. These end devices are called ***Stations***. The Repeater is a station. Signals are transmitted over a fiber optic cable in only one direction. This is called ***Simplex*** communication. Generally, two-way communication is needed between stations so that two of each of the basic components is needed. The two-way communication is called ***Duplex***. The Repeater requires duplex communications.

The transmitter is made up of a light emitter and the electronics that modulate the light to send information. The emitter is generally a ***Light Emitting Diode, LED***.

The medium is the fiber optic cable and the associated connectors, splices. etc. that carry the light from the transmitter to the receiver.

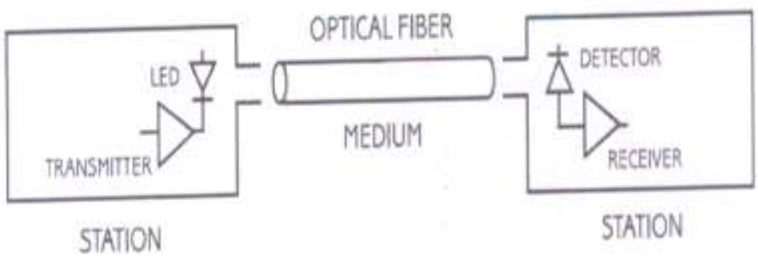

Figure 1 - Fiber optic system components

The receiver is a light detector that turns the received light signals back to electrical signals and an amplifier that conditions the signal for use in the station. The detector is a light detecting diode (Photo Diode or Photo Transistor).

IV. SIGNAL MEASUREMENT

The strength of the optical signal is measured in two types of units: ***micro-Watts***, **µ*W***; and ***dBm***. These two measurements are related by the equation:

$$\mathbf{dBm = 10 \log \frac{Signal\ \mu W}{1000}}$$

For the signal levels applicable to fiber optics, the relationship is shown in the table below:

dBm	µW
+3	2000
0	1000
-3	500
-6	250

The above values are absolute signal levels. Relative signal strengths, used to compare two signals, are described in ***dB*** (deci-Bell). If the power of signal A in µW is twice that of another signal B, then signal A is 3 dB more than signal B. As the table shows, when a signal in W is twice as large as another it is 3 dBm more: when a signal in µW is half as much as another signal, it is 3 dBm less.

V. FIBER OPTIC CABLE CHARACTERISTICS

As light travels through fiber, it is ***attenuated***; it gets smaller. Attenuation is stated in dB per unit length. For example, if a 2 km long fiber cable has an attenuation of 4 dB/km and light entered the cable at -17 dBm, the light leaves the cable at:

-17 dBm -(2 km x 4 dB/km) = -25 dBm

Another property of the fiber optic cable is that light signals traveling in the fiber become distorted. The longer the cable, the more distorted the signal gets. A way to quantify this distortion is by stating a ***bandwidth-distance product***. For example, if the cable has a bandwidth-distance product of 300 MHz km then the fiber can transmit a 300 MHz

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signal over 1 km or a 150 MHz signal over 2 km, etc. (150 MHz x 2 km = 300 MHz km).

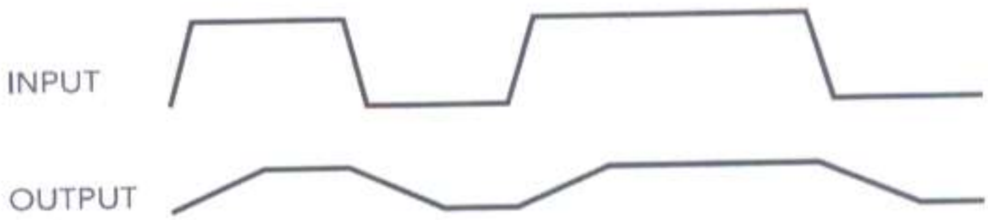

Figure 2 - Distortion

The bandwidth required depends on the rate at which the data is sent, how the data is encoded for transmission, and on the rise and fall times of the optical signal. Suppose that data is sent at 5 Mbits/second and that the transmitted data is encoded so that there are as many as four signal periods for each bit of data. The signal rise and fall times generally must be no more than 20% of the width of the shortest period. In this example, the signal periods are 50 ns wide so that the rise and fall times should be about 10 ns.

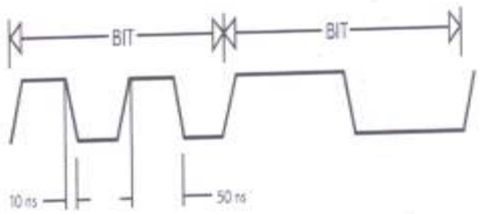

Figure 3 | Signal rise and fall times

The needed bandwidth of the transmission system that will carry such signals is given by

$$\mathbf{BW} = \frac{\mathbf{0.35}}{\textbf{Rise time or fall time}}$$

In this 5 Mbit/second example, the required bandwidth is at least

$$\mathbf{BW} = \frac{\mathbf{0.35}}{\mathbf{10\ ns}} = \mathbf{35\ MHz}$$

If a fiber optic cable is to carry this signal for 2 km, then the cable's bandwidth distance rating should be at least

2 km x 35 MHz = 70 MHz km

There are many different types of fiber optic cables available that have different attenuation and bandwidth characteristics. A cable with two fibers in it is shown below.

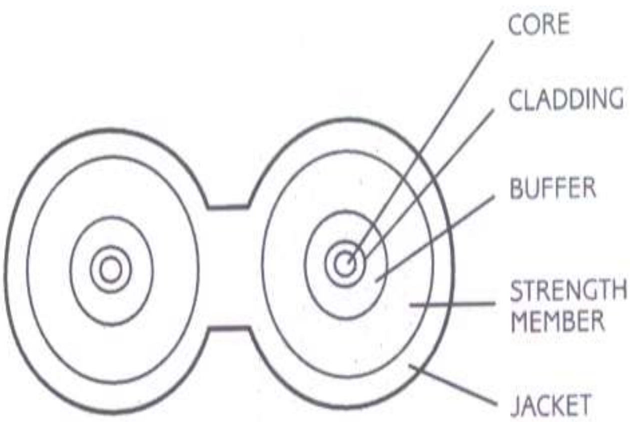

Figure 4 - Two-fiber cable with tight buffer

The major classification of cable is its light carrying fiber physical size. ***Core*** diameter is the center part of the cable that carries the light; the ***Cladding*** diameter is the part that confines the light to the core. Both are made of high purity glass. The measurement of the diameter of the fiber is in ***microns***, millionths of a meter, also called ***micro-meters***, or abbreviated as µ***m***. A representative listing of popular fiber sizes is given below. The size of the fiber is often written as the core size/cladding size. The 62.5/125 fiber is pervasive in North America the 50/125 fiber is popular in Japan and Europe and the 100/140 fiber is frequently used by IBM.

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Core µm	Cladding µm	Attn. (dB/Km) (850nm)	BW-dist (MHz-Km)	Relative light launched (dBm)
50	125	4	400	-17.3
62.5	125	4	160	-13.5
100	140	5	100	-8.0

The fiber sizes listed above are ***multi-mode*** fibers. The light traveling in multimode fiber can take multiple paths through the fiber. There are also ***single-mode*** fibers where the light takes one path through the fiber. Single mode fibers are used for very high data rate applications because the signal distortion is low. The core diameter in single mode fibers is about 6µm. Single mode fibers are more expensive, require a laser as an emitter, and require a great deal more care and expertise than multi-mode fibers.

The amount of optical signal put into the fiber depends on the amount of signal put out by the emitter and the reception characteristics of the fiber. One of the main factors in the amount of power launched into the fiber is the size of the fiber core. The larger the core, the more signal power is launched. As shown in the table above, for a given emitter, the difference between a 50 µm core and a 100 µm core cable is 9.3 dB. This suggests that a large core fiber should be used. The extra light, however, should be considered against the greater attenuation and the lower bandwidth-distance rating of the larger fiber.

VI. APPLICATIONS

Figure 5 - Fiber Optic Cable

Fiber optic technology has caught the imagination of many people. The ability to shine a light through a small glass fiber over considerable distances has been utilized for diverse applications.

• Long distance telephone lines use fiber optics. Signals for many conversations can be carried over a single fiber without amplifiers. The largest volume of fiber optics cable has been used for telephony. As most of the long distance telephone trunks were completed, an over-capacity of fiber optic cable manufacturing resulted.

Fiber optic cables are being used in Local Area Networks, LANs. Fiber optics is said to have a very high data carrying capacity and low cost. Both parts of this statement are true. High quality glass fiber optic cable can carry a large amount of data and plastic fiber optic cable is inexpensive.

In Captive Power Plant of NALCO multimode fiber optic cable is being used since 1999 for office LAN where the backbone speed is 155 MBPS with 500 user capability. The network is used for multimedia communication (Data, Voice & Image). Our ERP (Enterprise Resource Planning) package is operating on the same backbone interfacing HR, Finance, Materials, Production, Maintenance, Marketing functions. NALCO is planning to upgrade the Network backbone to 10GBPS speed using single mode fiber optic cable along with fast Ethernet network servers & switches.

• An anti-tank missile uses fiber optic cable for flight control. Signals on fiber optic cables cannot be jammed.

• Fiber optics is widely used in Medical Science equipment eg; endoscopy is used for diagnosing gastrointestinal condition for internal bleeding, ulcer etc. In case of Laparoscopy surgery light source, camera, LASER operating instruments uses fiber optic. High-energy laser pulses through the fiber is used to perform internal surgery, cosmetic surgery etc.

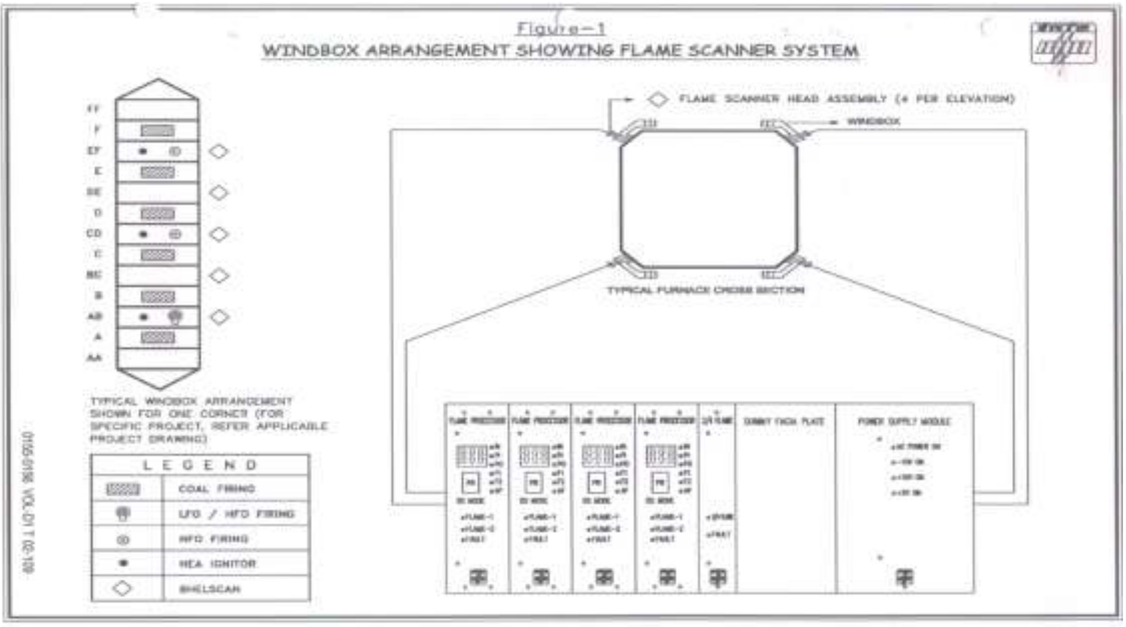
• Fiber optic is used as the sensing element. In Power Plant the Boiler Flame is sensed using fiber optic cable as described in details.

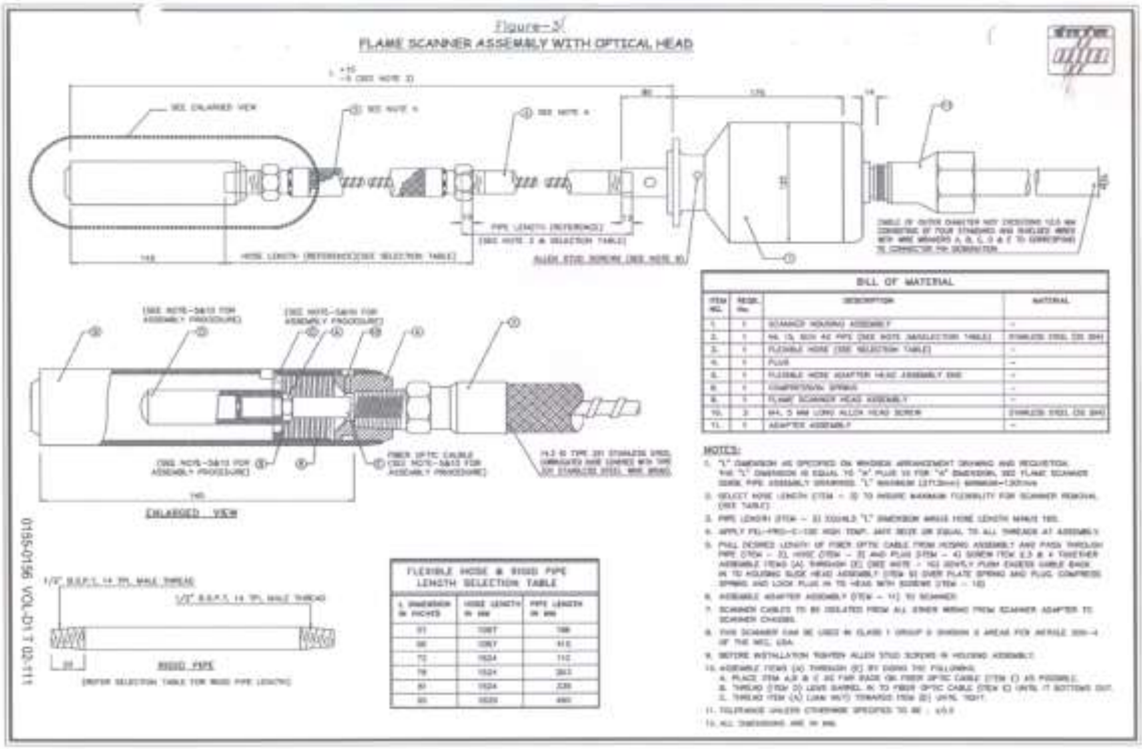
Boiler Flame Sensing System

The Flame Sensing System is designed to detect flame from two different sources using one scanner head. It will discriminate between an individual oil gun flame and a background fireball (coal) flame. It discriminates between the two flames by sensing the characteristics (frequencies and intensity levels) of the visible light they emit.

The system consists of four scanners located in guide pipes at each corner of the furnace the electronic chassis is mounted remotely in an instrument rack with other unit control components as shown is figure-1

The scanner assembly (Figure 3) is comprised of a scanner head assembly which contains a lens for observing the flame, and a fiber optic cable. The fiber optic cable is contained within a fixable hose and an adjoining rigid pipe. The rigid pipe connects to the scanner housing.





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The fiber optic cable transfers the visible light, emitted by flame and observed by the lens, to the scanner housing, which contains the electronic components the properties of the fiber optic cable allow the “flame” signal to be transferred to the scanner housing assembly without distorting the flame signal characteristics. The lens and fiber optic cable are located on the “fire side” of the wind box.
At the scanner housing assembly, the flame signal impinges on a photodiode. The photodiode converts the visible light (flame) signal to an equivalent electrical signal. This electrical signal is conditioned by amplifiers in the scanner housing assembly and generates an equivalent “current” signal to be transferred to the remotely located card rack assembly.
In the scanner housing electronic circuitry, the flame signal is processed in such a manner that two limits are established. One limit establishes an “intense” flame signal and the other limit establishes a” no flame “(no visible light) signal. The “no flame“ signal is also referred to as the “dark furnace” condition.

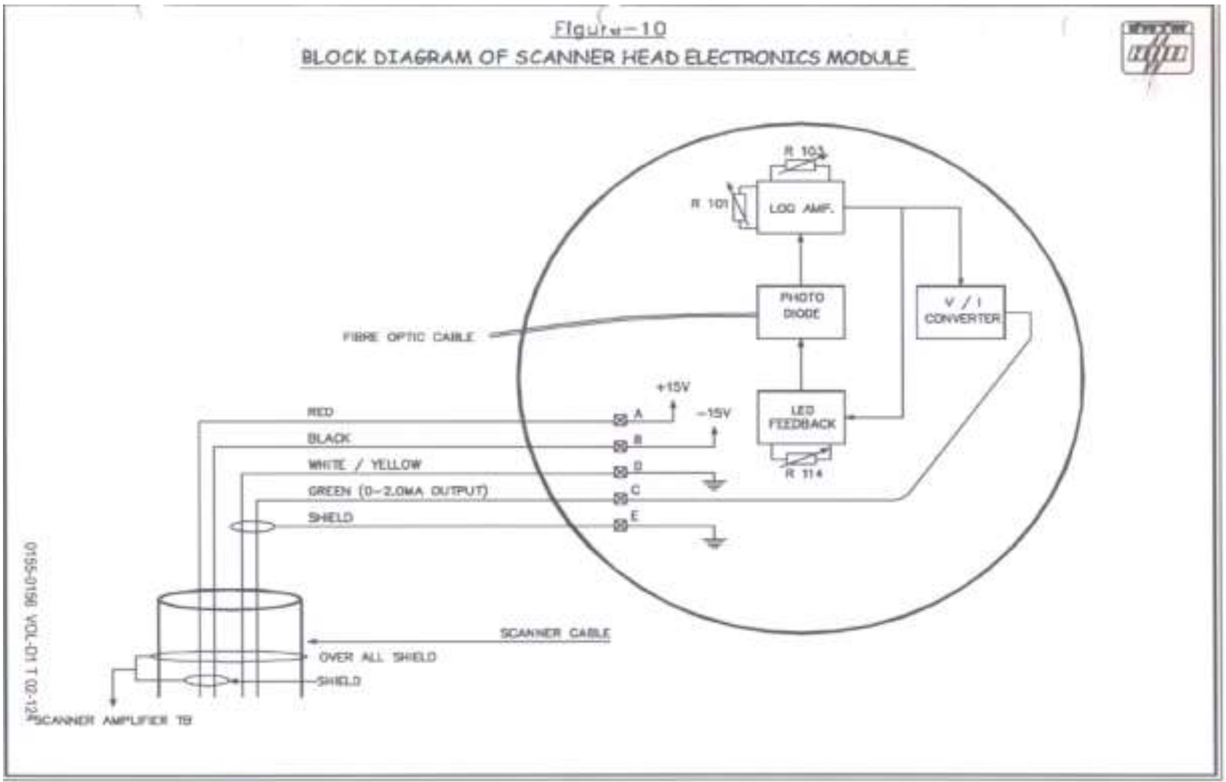

Figure-10
BLOCK DIAGRAM OF SCANNER HEAD ELECTRONICS MODULE

A shielded four (4) conductor cable (up to maximum 200 mtr. length) receives power from the card rack assembly and sends the current (flame) signal to the card rack assembly for conditioning. The card rack assembly contains electronics circuitry which separates the ‘current’ (flame) signal into its “frequency” & “intensity” components.

The intensity component is processed by the electronic circuitry on the intensity and fault detection card. If the intensity component of the incoming flame signal falls outside the high and low acceptability limits set by the card electronics, the fault light at the associated scanner channel (1, 2, 3 or 4) will glow. This indicates a malfunction in the scanner housing electronics, photodiode or the associated circuits in the card rack assembly. When a fault exists at any scanner channel, the card rack fault alarm light will also come on.

When the intensity signal is within its limits, above the drop-out or pull-in levels, the channel intensity light comes on and the flame meter indicated the flame signal’s intensity component.
The frequency component is processed by frequency detection cards. The type of flame established will provide a frequency spectrum. The card rack contains two frequency detection cards for each scanner channel. One proves the fireball (FB) flame frequency and the second proves the flame frequency of its associated oil gun (discriminating-DISC). Each frequency detection card a frequency generator which must be adjusted to match the frequency of the flame (FB or DISC) being observed. When the frequency match is made the associated yellow TRIM light will go off or flash occasionally and the associated FREQUINCY light will come on. This indicates that an active (above the selected frequency) fossil fuel flame is present a frequency

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permit logic signal is then established on each card. If the associated intensity permit light is on and the channel fault light is off, the FLAME-FB and /or the FLAME-DISC light will come on. When at least two of the four FLAME-FB lights come on, the system 2/4 FLAME light will also come on. If less than two scanner channels sense fireball (FB) flame the system will indicate no flame. The outputs of the system and the individual scanner channels are represented by the positioning of sets of from C contacts (break before make). **These contacts are usually wired into the furnace safety control system so that a no flame signal from the scanner system will initiate a unit master fuel trip.** The system contains a self-checking feature which actuates a fault alarm (contact closure) and a FAULT ALARM light on the associated printed circuit board assembly. It is illuminated when the intensity component of the flame signal (oil gun and fireball) of any scanner falls out of preset limits.

Biography

"**Er. Santosh Kumar Acharya** is Presently working as DGM (Control & Instrumentation) in Project department of CPP, NALCO.. He had Joined NALCO in November'1984 as first batch Graduate Engineer Trainee (GET) and working since then in its Captive Power Plant at different capacity. He was involved in erection & commissioning of Unit #1 to 6 (6x120MW) Power Plant initially & subsequently maintained the control & Instrumentation area of these Units. He had also worked for one year (1983-84) at National Radio & Electronics Company (NELCO), Mumbai as System Engineer in their Industrial Systems Division manufacturing Control Systems for AC/DC drives & UPS.
He had done his B.Tech in Electrical Engineering from NIT Warangal, in 1981 and done his M.Tech in Electrical Engineering from IIT Madras in 1983.
He is a man having 28 years of experience in Power Plant Process, Maintenance of C&I area and Project Planning, Monitoring & Execution