and IEC61511 standards. Safety Integrity Level (SIL) is the probability of the safety related system performing the required safety functions under all conditions within the stated period of time. As per IEC 61508, SIL is classified into four levels; SIL 1 to SIL 4, based on the Probability of Failure on Demand (PFD).

Safety integrity level	Low demand mode of operation (Average probability of failure to perform its design function on demand)
4	$\geq 10^{-5}$ to $< 10^{-4}$
3	$\geq 10^{-4}$ to $< 10^{-3}$
2	$\geq 10^{-3}$ to $< 10^{-2}$
1	$\geq 10^{-2}$ to $< 10^{-1}$

Figure- 3: Safety Integrity Level

The PFD indicates the average safety unavailability of the SIF, i.e. the time for which the protection function is not available.

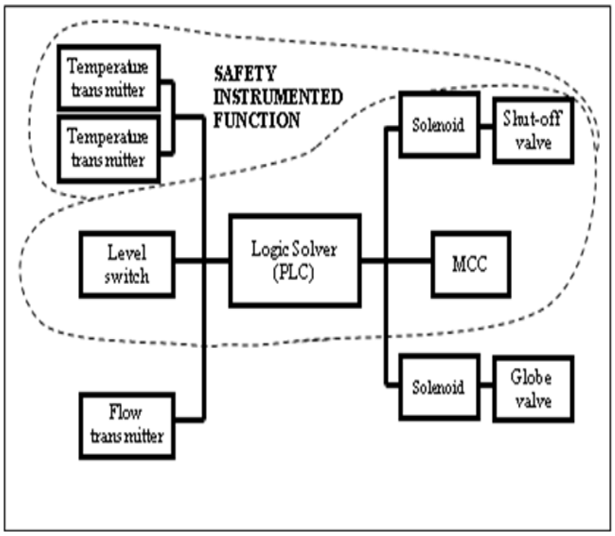

Figure- 4: Safety Instrumented Function

As seen in the figure 4, a SIS shall contain multiple SIF's and each SIF shall have many components. Each SIF will be designed with a SIL level which for process industry ranges from SIL1 to SIL3.

BIRTH OF THE SIL

The activities mentioned in box 1 to box 4 of the figure 1 are often termed as design phase of the SIS.

The most important activity in the design phase of the SIL is 'Hazard and Risk Assessment'. This lays the foundation for establishing the requirements of the SIS. This activity is performed to evaluate the possible hazards and hazardous events associated with the process and the equipment, the sequence of events leading to the hazardous event, the process risk associated with the hazardous event. Based on these, the requirements of risk reduction are identified and the safety functions required to achieve the necessary risk reduction is identified.

The second step of the design phase is to allocate the safety functions to the protection layers. The safety functions which are allocated to be implemented in SIS would then be assessed for the integrity requirements, thereby establishing the required SIL for each SIF; which is being referenced in this paper as the birth of the SIL.

There are various techniques or approach to identify the SIL based on qualitative, quantitative and semi-quantitative methods.

- Safety Layer Matrix – Qualitative method
- Risk Graph – Semi Quantitative method
- Fault Tree Analysis – Quantitative method
- Layers of Protection Analysis (LOPA) – Semi Quantitative method

The steps as referenced in the box 3, further establishes the requirements of the SIS with reference to each SIF and its associated integrity requirements so that the intended functional safety is achieved.

The last step of the design phase is the actual design of the SIS to meet the required 'functional' and 'integrity' requirements.

SCOPE OF THE PAPER

All the phases of the safety lifecycle are not covered in detail as the focus of the paper is the operational phase of the SIS. This paper considers the activities covered by box 6 and box 7 of the figure 1 as operational phase of the SIS.

Also, since the evolution of the functional safety standards; IEC 61508 and IEC 61511, the industry has reached to a good maturity level in the defining of the SIF and its associated SIL. Hence, this paper assumes that the design of the system, its installation, commissioning and validation is foolproof and the intended SIL for the SIF was met by the design.

However, it is very important to note some important design factors. Whether the aspect of maintenance is considered during the SIS design? For example, how one repair does or replaces a faulty trip valve? Is a shut down required or there are alternate provisions necessary? How is it monitored for safe operations during this time?

Another important aspect is SIS has to be designed with proof testing in mind. If this is not done at the specification and design phase, the SIS is very difficult to test. The SIS design should correlate a specific proof test with the proof test coverage assumed for verification of SIL. If not, then the design of the SIS is not foolproof.

SAVE MY SIL

Operation of the SIS with the designed SIL during operational phase depends on the organizational procedures and culture with respect to maintenance and testing. Improper maintenance, deviation of the parameters from the designed SIL would have adverse effect on the SIL, i.e. the process operation would continue with a degraded SIL. A degraded SIL for a given SIF would mean that safety function is unavailable and if at that juncture, if a demand is placed on this SIF, it's likely that a hazardous event would occur against which this SIF was supposed to protect.

Hence it becomes imperative that at all times; the SIL of the SIF is being saved against the degradation. The chapter 16 and 17 of IEC 61511 part 1 and part 2 provides a brief guideline on the 'SIS operation and maintenance' and 'SIS modification' respectively.

The Organizational and Human Factors in the Operation Phase of the Safety Instrumented System factors influencing the SIL are identified and examined for studying its effect on the SIL of the SIF.

DETAILS OF THE STUDY

The figure 5 indicates the various human and organizational factors in operational phase of the SIS which may affect the SIL levels.

First, these parameters are described for understanding what these factors are.

Second, the operational phase activities are determined so that the relation between the human and organizational factors and operational phase activities can be established for verifying if these can affect the SIL of the SIF.

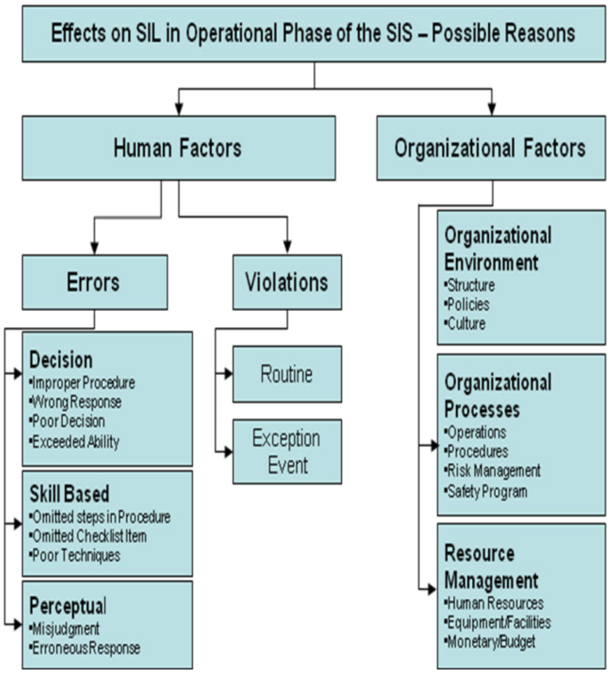

Figure- 5: Human and Organizational Factors

Human Factors

Human factors can be broadly categorized in two categories: errors and violations.

Errors

The errors represent the mental or physical activities of individual that fail to achieve their intended outcome.

→ **Decision Errors**

Decision errors are the errors which represent the conscious and intentional behavior for a given situation, but the plan proves out to be inadequate or inappropriate for the situation. Though the intent of the actions is to achieve the results in compliance to the requirements, the actual outcome is deviation and might lead in to and incident.

→ **Skill Based Errors**

Skill based performance relies on actions by a person based on the skills acquired over time during performing the job and by undergoing specialized training. The leanings are stored in the memory. Skill based errors occur when the person fails to execute the actions which are either well rehearsed actions or known to him as a result of the trainings. So these errors can be classified as execution errors or failure to apply the right skills for the task.

→ **Perceptual Errors**

Perceptual errors relate to the errors which are related to failure to notice important cues or information, or to perceive information critical to decision making. Examples of perceptual errors include failures to recognize dangerous situations, or approaches to dangerous situations; failures to recognize patterns of events that could lead to failures; or a lack of awareness of surroundings, situations or behavior that could led to adverse events.

Violations

Violation represents the willful disregard for the rules and regulation that govern the safe operation.

→ **Routine**

Routine violations are common abrogation of policies, rules or procedures. These tend to be habitual in nature and often overlooked or tolerated by the governing authorities.

→ **Exception Event**

Exceptional violations are isolated departure from the authority and do not necessarily indicates the behavior of the individual.

Organizational Factors

The organization factors directly affect the supervisory practices as well as the conditions and actions of the operators. Many latent failures revolve around the issues related to organizational environment, organizational processes and the management of resources.

Organizational Environment

Organizational environment refers to a broad class of organizational variables that influence work performance. In general, this can be viewed as the working atmosphere within the organization. The organization policies and work culture is also good indicator if the organizational environment.

An organization's policies and culture are also good indicators of its climate. Policies are official guidelines that direct management's decisions about such things as hiring and firing, promotion, retention, raises, sick leave, drugs and alcohol, overtime, accident investigations, and the use of safety equipment.

Culture, on the other hand, refers to the unofficial or unspoken rules, values, attitudes, beliefs, and customs of an organization. Culture is "the way things really get done around here."

Organizational Processes

Organizational processes refers to corporate decisions and rules that govern the everyday activities within an organization, including the establishment and use of standardized operating procedures and formal methods for maintaining checks and balances between the workforce and management.

Resource Management

Resource management encompasses the realm of corporate-level decision making regarding the allocation and maintenance of organizational assets such as human resources (personnel), monetary assets, and equipment/facilities. Generally, corporate decisions about how such resources should be managed center around two distinct objectives – the goal of safety and the goal of on-time, cost effective operations.

OPERATION PHASE ACTIVITIES

It is important to understand the important activities carried out during operational phase. These activities are:

a. Operation
b. Maintenance
c. Proof Testing
d. Modifications

a. Operation

The written procedures should be available which describe the operation of the SIS which includes:

- Bypass and Override management (authorization, security – password protection, recording for audit trail, monitoring and review of overrides, requirements for removal and reset);
- Operating instruction for trips;
- Operating Manual for instructions for response to equipment/component faults including fault alarms. There should be procedural arrangements in place to ensure timely repair so that mean time to repair criteria can be met. This also includes maintaining the necessary spares.

b. Maintenance

The written procedures should be available for SIS maintenance activities which include:

- Maintenance instructions based on the diagnostic information of the SIS;
- Spare parts management (segregation of faulty or non-conforming parts, identification to prevent interchange of similar parts etc.);
- Competence of maintenance personnel;
- Operating restriction during maintenance (Whether to halt operations or running in degraded mode);
- Control of software back-ups and memory media (E/EPROMS, floppy disks, files on hard disks on portable PCs etc.);

- Post maintenance restoration of equipment and proof testing.

For systems where a high diagnostic coverage is claimed, for example high integrity systems, the probability of failure (expressed as failure rate) is critically dependent upon the mean time to repair the faults revealed. For such systems, the repair performance should be monitored and reviewed against the design criteria.

c. Proof Testing

The PFD or the failure rate of a SIS depends upon the frequency of proof testing. The proof test is carried out to detect unrevealed failures of the system and includes necessary maintenance in cases failures are revealed.

The proof test interval should be an order of magnitude less than the mean time between failure of the system and the demand rate.

Proof test procedures should be available which specify the success/failure criteria and detail how the test will be performed safely, including any management arrangements, operating restrictions and competence of personnel.

IEC 61511 has clearly stated that the proof test of the SIS shall be for entire SIS, i.e. the sensor, the logic solver and the final element. Hence while proof testing of the SIF for either the sensing element or final element; it is assumed that the test would include the logic solver. If so, then it is not necessary to separately proof test the logic solver. Proof test of '10 years' is widely applied and accepted value for the logic solvers. However, what these tests should be, diagnostic coverage of these tests and what should be the necessary corrective actions on revealed failure is highly debatable. This is because the logic solvers available in the market place have high level of diagnostic coverage and the diagnostic tests carried continuously. Hence the proof test term is generally referring to the testing of either the sensing element or the final element.

d. Modification

A management of change system for control of any modifications (minor or major) should be in place to ensure that:

- Any unauthorized modifications are prevented;
- Authorized modifications are not ill conceived (appropriate lifecycle phases of IEC61508 are performed);
- Safety verification to confirm that the required safety function and integrity have been maintained;
- Design and implementation is carried out by competent persons

The activities in the operational phase requires a methodic approach to be taken so that the performing these activities doesn't bring in new hazards in to the system which may result in to demand scenario.

The operational phase therefore requires following to be addressed:

Planning – In order to ensure the functional safety is achieved as per the design criteria, planning of the activities to be carried out, its frequency as per the SIL calculations and the resources for carrying out these activities need to be planned. The planning process shall also address the competence requirements and training for personnel to achieve the required skills or to attain the desired competence.

List of activities to be carried out – The activities to be carried out for each SIF shall be listed and documented.

Instructions and procedures to be followed – Step by step instructions for carrying out the activities for each SIF shall be identified. The procedures shall include actions and constraints that should be noted before start of the activity. It should also include the repair methodology for the identified deficiencies during the tests.

Documentation – Documentation for carrying out the activities and noting of results of the maintenance or proof tests. The documentation requirements shall include for example, name of persons performing the test, date, SIF number, results of test, unresolved issues, repair activities performed etc.

Now the human and organizational factors are known and the requirements of operation and proof tests identified, it need to be identified which of these factors affect SIL in the operational phase of safety instrumented systems?

A study of some hypothetical examples has been performed to examine the effect on the SIL due to actions and decisions the operators have taken.

Effect on SIL due to "Bypass Management Procedure"

Bypass

Bypasses are mostly necessary to allow on-line maintenance and proof test, reducing equipment downtime and improving process availability. However, bypasses increase the likelihood of systematic errors (e.g., left in bypass, inappropriate use of bypass). This increased systematic error must be off-set with procedures, administrative controls, and access security provisions.

The below examples demonstrates that though bypass may be necessary, the use of it should be controlled and the process strictly monitored to be operating in the limits. Proper documented procedure for bypass management and management of increased risk due to bypass should be thought off and adhered too.

Human Factors – Errors - Decision Errors

The operation of the gas fired boiler with four burners (A, B, C and D) were facing problems on one of the flame scanner on one burner A. The flame scanner used to pick up the flame signal after 17 seconds in place of 3-5 seconds and the safety logic allowed for 10 seconds before the burner would be put on shutdown or the boiler under shutdown if other burners are not in service. As the procedure till the scanner was replaced with new one, it was decided that the use of the bypass flame scanner for burner A shall be done with the field operator monitoring the flame and feedback to the control room to remove the bypass after the burner lights off.

This puts the SIF unavailable and the SIL degrades to SILa as the operator response can't have the required reliability factor (the maximum PFD which can be claimed is 0.1).

Human Factors – Violations - Routine

The refined petroleum storage depot had decided to go for an early trip after a serious overfill which had resulted in vapor cloud explosion in one of the tanks. This was done by means of Safety Instrumented Function relying on a single level transmitter with level HH set point at 80% of the tank capacity. This was resulting in huge capacity under utilization. But due to strict corporate decision, the depot manager decided to bypass the level transmitter at about 77 to 78% and the control room operator continue to monitor the level until it reached the 95%. At normal flow rates, it used to take around 2 hours to reach to 95% level from the 78%. At this instance, the control room operator used to remove the applied bypass and the inlet trip used to occur. However during increased flow rates, it would take little more than 1 hour to reach the 95%. The operator and the depot manager failed to consider this and this resulted in SIF being unavailable.

This puts the SIF unavailable and the SIL degrades to SILa as the operator response can't have the required reliability factor (the maximum PFD which can be claimed is 0.1).

Organizational Factors - Organizational Processes

a. **Example 1:**

During the pig receiving operations, it was normal to have considerable amount of H2S gas being present. The pig receiving area had sufficient H2S detectors to detect H2S leaks in normal operation, however as an organization procedure, the H2S detectors in this area were bypassed during the pig receiving. Once the pigging operations completed, the bypass used to be removed. However the probability of the detectors remaining in the bypass condition even after the pigging operation is completed is high as there is no mechanism to revert the bypass automatically or in the permit closure procedure.

This results in the SIF being not available (loss of layer of protection) as the activity is operator dependent.

b. **Example 2:**

During the design phase, aggressive test coverage was suggested by operating company stating that there maintenance and testing procedures are robust enough to detect hidden failures.

The below example demonstrates that if the coverage on the valve is changed slightly from 93 to 92, the SIL of the SIF changes from SIL2 to SIL1. This proves proper procedures for maintenance should be in place to ensure the coverage claimed is met; else the SIF is operated with degraded SIL. Use of ExSilentia tool is made for the calculation purpose

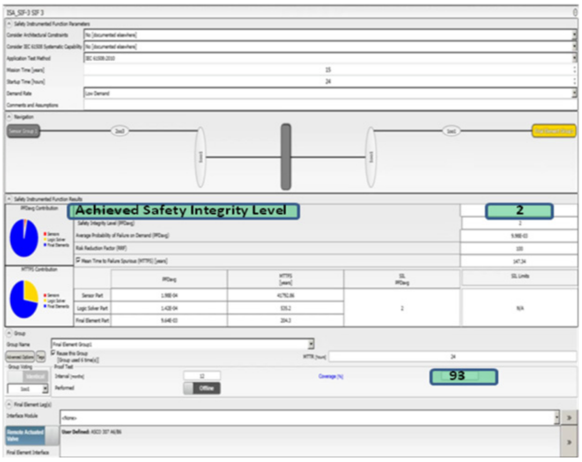

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Figure- 6a: SIL – Proof Test Coverage

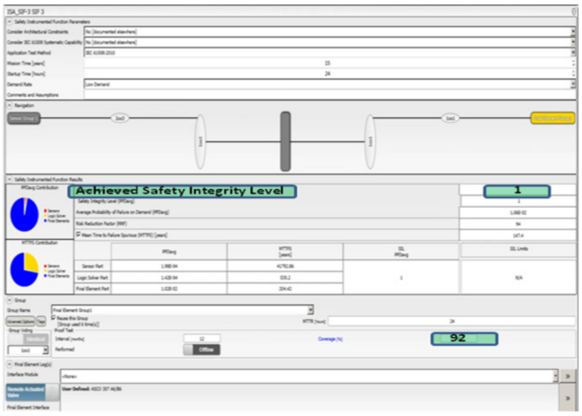

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Figure- 6b: SIL – Proof Test Coverage

Effect on SIL with regards to "Failures and Repair"

When a fault is detected in any of the component of the SIF (sensor, logic solver or actuating device), a decision must be taken to either continue to operate the process or to take the process to a safe state. Continuing to operate requires compensating measures required to be performed by operators. The additional risk is introduced in the process by operating the process with a degraded or disabled SIF which HAZOP has not considered. The failure of the compensating measures during the repair period to take necessary actions within the process safety time if demand is generated can lead to an accident scenario. Also this protective function used to reduce the risk may not be below the owner/operator risk tolerance criteria.

Organizational Factors – Resource Management and Human Factors – Errors - Perceptual

The refined petroleum storage depot has a SIF implemented in the ESD system for protection against overfill (only inlet valve closed and pump stopped only if other loading is not planned and goes into recirculation mode). The operator is trained for this and is aware of this. The tank which is under filling has known problems with closure of valve and the operator is expected to close the manual valve in the line before the high level is attained. The organization decides to operate with faulty resources relying on the operator actions. However during the loading operation, the field operator is not put on standby mode to operate the manual valve. Based on time to reach the overfill level from the pre-alarm, the control room operator is supposed to notify the field operator (who manages other tanks too) to reach in time to perform the closure of manual valve. However due to misjudgment on the flow rate the field operator is notified late resulting in overfill.

This results in the SIF being not available (loss of layer of protection) as the activity is operator dependent.

Organizational Factors

Organizational Processes & Resource Management – It is a known fact that the SIL Verification calculation uses device failure rates, test coverage, mean time to repair (MTTR), and test intervals to ascertain the average probability of failure on demand (PFDAVG). These factors are often played upon and varied during design phase to achieve the necessary SIL.

Due to the tough economical conditions, the company downsizes the maintenance team. This results in to corporate decision to reduce the proof testing activities without verifying the effect on the SIL of the SIF. The below examples are used to verify that if proof test is not carried within specified time, the SIL would get degraded.

a. <u>Example 1:</u>

The below example demonstrates that if the proof testing on the valve is changed from 12 months to 13 months, the SIL of the SIF changes from SIL2 to SIL1. This means, even a delay of one month can cause the degradation of the SIL. Use of ExSilentia tool is made for the calculation purpose.

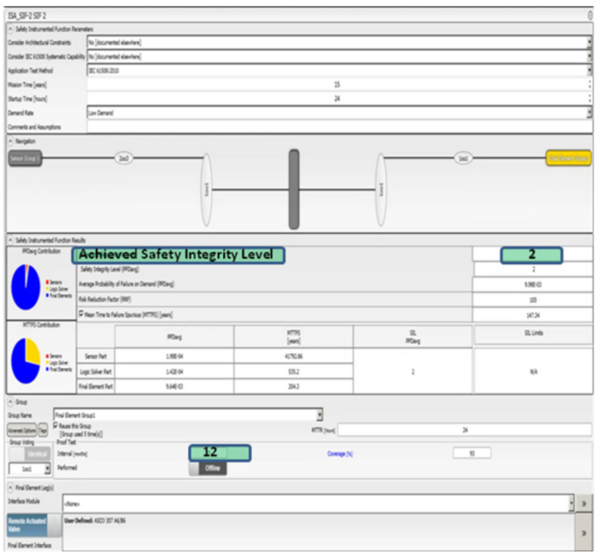

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Figure- 7a: SIL Degradation - Valve

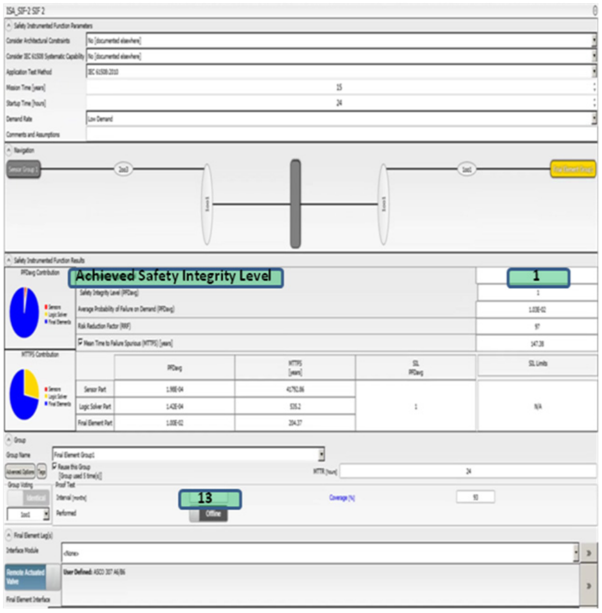

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Figure- 7b: SIL Degradation - Valve

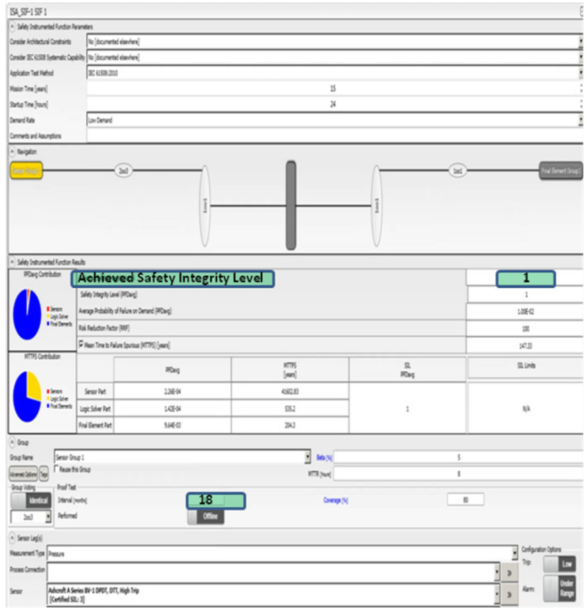

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Figure- 8b: SIL Degradation - Transmitter

b. **Example 2:**

The below example demonstrates that if the proof testing on the transmitter is changed from 12 months to 18 months, the SIL of the SIF changes from SIL2 to SIL1. Use of ExSilentia tool is made for the calculation purpose.

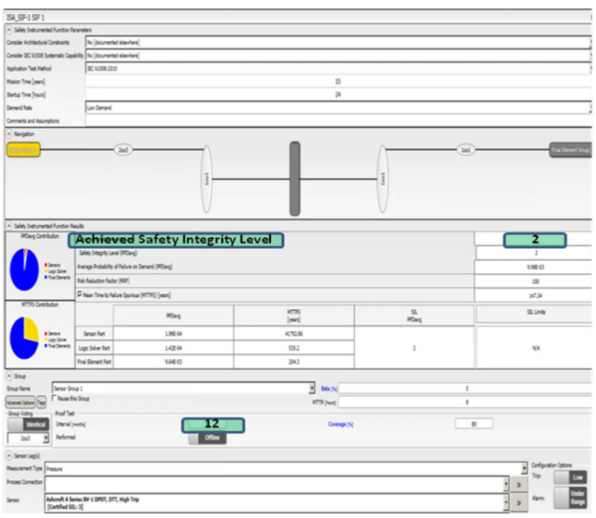

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Figure- 8a: SIL Degradation - Transmitter

The above two examples demonstrates that if the proof testing interval need to be changed, it need to be verified for its affect on the SIL. A decision to operate with more risk than the tolerable risk can prove dangerous.

RESULT OF STUDY AND CONCLUSION

A few situations were studied to observe the effect on the SIL of SIF due to the organizational and human factors during the operational phase of the SIS. It was proved that how the SIL level can be impacted if the operation phase doesn't follow the requirements defined during design phase. These are the situations which any operating company should avoid so that the 'SIL is saved' during the operational phase.

It is seen that during the design, SIL for SIFs is based on an ideal situation in which humans and organizations function optimally (i.e., no deviations in operation methodology and maintain the design of the SIF to meet desired SIL). In real life however, a human and organizational factors influence the SIL for SIF (degrade it) and some time even put a situation where the SIF are not available.

The chapter 16 and 17 of IEC 61511 part 1 and part 2 provides only a brief guideline on the 'SIS operation and maintenance' and 'SIS modification' respectively. However, it is upon the operating company to have robust procedures in place to ensure the management of functional safety during the operation phase.

FURTHER WORK

Further research is required to explore the possibilities of overcoming the human and organization factors during the operational phase by automated methods. Also quantification of possibilities of these human and organizational factors during the design and inclusion in design SIL need to be explored.
This paper intends to draw attention and focus on the requirements of operations and maintenance phase. The IEC 61511 standard itself provides limited guidance on the operation and maintenance phase of the safety lifecycle. Hence it become imperative on the part of the operating company which focused a lot on functional safety requirements during the earlier phases of the safety lifecycle and the invested in the SIS itself, should put up adequate attention towards management of functional safety so that the 'SIL is saved'.

ACRONYMS

SIS	Safety Instrumented System
SIF	Safety Instrumented Function
SIL	Safety Integrity Level

REFERENCES

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[2] IEC, IEC 61511, Functional Safety of Instrumented Systems for the Process Industry Sector.

[3] Guidelines for Safe and Reliable Instrumented protective Systems - Center for Chemical Process Safety.

[4] Reference Reading material from internet (various websites) which was referred for understanding the human factors.

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BIOGRAPHY

Amit is an Instrumentation engineer with 18+ years of professional experience in process industry. He is working with Fluor Daniel India pvt. Ltd. For around two years and previously worked with Honeywell India for around fourteen years. He has extensively worked on

Safety System projects in different roles which involved activities like design and detailed engineering, HAZOP, SIL assignment and verification, Front End Engineering and Design (FEED), commissioning, project cost estimation and consultancy. Apart from India, he has worked on various projects across globe at locations like South Korea, Norway, UK, UAE, Netherlands, USA and Australia.

He is a **TUV Rheinland certified Functional Safety Expert** (TUV Rheinland FS Expert ID: 189/12)

Meghna Bahl is an Instrumentation engineer with 9 years of experience in Oil and Gas industry. She is working with Fluor Daniel India Pvt. Ltd. She has worked on various Feed and detail engineering projects on activities like Cost estimation & feasibility study, HAZOP, P&ID reviews for projects in India, USA, Russia, Qatar, Saudi Arabia.

Unified security and safety communication in areas with explosive atmospheres – a case study.

Authors: Tom-Andre Tarlebø

IECEx/ATEX, IEC 60079, Communication, Ethernet, integration, VoIP, IP, LAN, WAN, critical communication, safety and security, radio, public address, centralization / decentralization, IP extenders.

ABSTRACT

As the world of Ex-equipment slowly-but-surely is converging on a common legislation (IECEx), this is to the benefit of manufacturers and users alike. To a large extent, this means that many of the past barriers (artificial or justified) are lifted and the market becomes globalized and standardized. For the manufacturers this means that although “certify once, sell everywhere” is still Utopia, we are several steps closer. For the owners/users of the equipment, this means more vendors to choose from, which leads to a more competitive marketplace. In addition, a common global certification and legislation means more predictability and safety for the workers, operators and neighbouring industries and population in areas where EX industry is present.

Looking towards the safety and security industry and the technological development in the past 10 years, it is clear that there are even greater gains to be had in the areas of operational efficiency and safety through integration of systems for safety, communication and operation. This is what we will address in this case study.

INTRODUCTION

With over 70 years as a manufacturer of products for safety and security communication (marine, offshore, airports, power-plants, etc) and as a systems integrator we have experienced first-hand how the world of safety and security communication has been and is still transitioning to IP-based systems.

Together with the increased use of Ethernet in industrial applications we see a greater level of integration, both between communication systems, but also towards security- and safety systems.

In this paper we will look at our experiences with one of the most professional operators and owners, and how they structure their integration to achieve better communication, increased safety while reducing OPEX by increasing efficiency, reducing maintenance and service cost as well as through growth. We will describe how IP integration affects the overall system architecture and highlight some of the benefits with regards to flexibility, integration and maintenance.

BACKGROUND

Statoil is the Norwegian national oil company and is one of the top 20 oil-producers in the world. Production figures are about 2 BOE per year, placing STATOIL in the same bracket as BP, Total, Petrobras, ConocoPhilips, ENI and Quatar Petroleum, to mention some.

Stringent regulations:

NORSOK (abr. “Norsk Sokkel” literally “Norwegian Continental Shelf”) is a set of requirements, both technical and operational, for all equipment used in the Norwegian sector of the North Sea, one of the roughest environments for offshore oil and gas extraction on the planet. For these reasons, security and safety of the working force is paramount as is the reliability of the systems and equipment used.

Cost reduction measures:

During the past years, Statoil has focussed heavily on reducing OPEX while maintaining the same level of safety and security. The requirements ask for solutions that offer integration through open standards, remote maintenance and monitoring, as well as maintaining or increasing operational efficiency, safety and redundancy. Further, personnel cost, operating in a high-cost region and in some of the roughest waters on earth where manual labour comes at a premium, is a significant cost driving factor. Increased integration and automation not only improves security and safety, but it also has a direct effect on the OPEX through reduced need of manpower. The observations made in this paper should be seen in this context.

INTEGRATED OPERATIONS

“Integrated operations” embodies the philosophy of integrating production, safety and communication systems to achieve better operational efficiency, improved safety and reduced OPEX. For the sake of this paper, the focus is on the communication part but the principles apply for all parts of the operation.

Utilizing IP technology and MPLS data-networks reduces the need for maintenance and test through self-diagnostics, monitoring and reporting. For offshore installations this is particularly valuable considering the cost of (potentially hazardous) transportation, housing, inconvenience and service of specially trained personnel.

Enhanced monitoring reduces the risk of sudden failure, which could mean plant shut-down and production halt; a costly and most unwelcome situation. By continuously monitoring the health of remote systems, maintenance engineers and system managers can plan replacement and secure components in advance to utilize the maintenance crews most efficiently. Saving a single trip to an offshore installation can mean tens of thousands of dollars per crewmember.

THE NEED FOR COMMUNICATION

Oil and gas installations, as most other industrial installations, have a diverse and mission-specific need for communication. Whether it is direct calls between operators in control-rooms, from control-room operators to service and maintenance crews, drill deck operators or communication between platforms/sites/ships, the requirements for direct communication are as diverse as the solutions applied. In addition there is a need for mass communication in the form of public address- and general alarm systems.

Listed are some of the systems most commonly used to address these requirements:

- Mobile radio systems (UHF/VHF, Analogue/Digital/PRS)
  - Security personnel
  - Service and maintenance crews
  - Vehicle operators
  - Emergency response teams
- Intercom systems (analogue/digital/IP-based)
  - Control-room operators
  - Guard outposts/gates
  - Intra-site control-room communication
  - Crane/machine operators
- Telephone systems (Landline/GSM/Satellite)
  - Out-of-site communication
  - Office communication

- Public Address systems (Analogue/Digital/ IP-based)
  - o Control-room operators
  - o Security systems
- Alarm/evacuation systems
  - o Fire&Gas alarm
  - o Evacuation alarm
  - o Intrusion alarm

In addition most security systems today include video surveillance and access control/personnel registration systems.

COMMON SYSTEMS

Interfacing to the communication systems, there are a range of security systems that are critical to the operation of the facility:

- PAGA system:

The Public Address and General Alarm system is the main form of communication in a critical situation. It is almost always composed of an A- and a B-system, located in different parts of the platform or facility. Speakers are wired to ensure full coverage in the event of either system failing. PAGA systems have traditionally been analogue or digital, but more systems are transitioning to IP with the increased demand for tighter integration, locally or remotely. The PAGA system is fully monitored and will report faults in any piece of central equipment (System controllers, amplifiers), field equipment (access panels, microphone stations), speaker loops (open loop, short circuit or ground fault) or auxiliary equipment (flashing lights/beacons, integrations to other systems).

- F&G system:

The Fire and Gas alarm system detects and fights gas leaks (from EX zones into non-EX zones as well as toxic gas release to air) and fires. It integrates towards the SAS (Safety and Automation System) as well as directly to the PAGA system.

- SAS system:

The Security Automation System is connected to all mission critical systems. It integrates to the process systems (SCADA) as well as to security and communication systems. Should any critical system fail, the SAS is responsible for closing down production in a controlled matter until all critical systems are operational.

- ESD system (Emergency Shut Down): The PAGA is integrated towards the EDS-system. This system powers down non-critical equipment in a shut-down scenario. Typical trigger for the ESD is detection of combustible atmosphere in the clean-air system used for purging the telecom equipment rooms (Ex p). For the communication system this generally means shutting down all non-Ex field equipment or the entire system (in the case of an ESD2 or "Abandon Platform Situation", APS).

- TMS system:

The Telecom Management System monitors all communication equipment. Common protocols are serial interface, and dry contact, but in the last 5 years SNMP is becoming the main channel for monitoring these systems. The TMS allows remote monitoring of the telecom systems, remote diagnostics and general operational statistics which in turn allows for better scheduling of service- and maintenance operations. By using an SNMP-server as the gateway, a near real-time stream of output data can be shared, whilst avoiding the risk of direct intervention (configuration or manipulation) of the system by a malicious party.

- Entertainment system:

All entertainment systems, such as TV, radio, background music, etc shall be muted in the case of a high-priority event, such as an alarm or an emergency announcement. Traditionally this is done over dry contact (relay) connections, but recent development in IP entertainment has enabled a range of new features, such as: Text messages with info about the situation showing on monitors and TVs, display of evacuation map, video playback of emergency procedures, etc. This type of integration augments the safety by giving the operators a better understanding of the situation.

- PBX integration:

With the transition to iPBXs in the late 2000s, the integrations offered by analogue PBXs over serial- or contract-interfaces have been expanded by direct integration over IP through protocols like SIP and SNMP. This allows for more advanced reporting and functionality.

- UHF/VHF radio integration:

Traditionally, radio has been integrated as an extension of the PAGA system, enabling operators carrying portable radios to receive the same emergency announcements that are transmitted on the speaker system. With digital radio systems such as DMR or TETRA, additional data such as text messages, geolocation information, distress beacons and operator activity can augment the security of the personnel. One novel application is to use geolocation data to dynamically allocate terminals to a PAGA zone, depending on location. In a critical situation the same system can identify the location of all operators, aiding evacuation and rescue efforts. Text messaging can be used to give silent alarms and convey situational information.

- PRS (personnel registration system):

The PRS is used to keep track of personnel on a facility in the case of an emergency situation. IP-integration allows for automatic announcement of missing personnel, personnel entering restricted areas, etc.

CASE 1: MULTI-PLATFORM OFFSHORE INSTALLATION

This case is for one of the biggest green-field developments in the North Sea this century. The installation consists of four individual platforms, each with a complete security and PAGA system. The platforms are interconnected through elevated walkways, spanning 80 to 120 m each. Each platform can operate as an integrated part of the total system, but also be able to operate as stand-alone systems in an emergency situation. Each system contains a PAGA system with A/B-redundancy, TMS, SAS, F&G, Radio, PBX and PRS integrations.

System overview

The system is constructed using a separate fiber ring for the PAGA system, spanning from platform 1-4 and back to 1. This is the primary redundant link for IP communication between the nodes. Additionally, each node (consisting of the A and B devices for a platform) is connected through a firewall, to the general platform fiber network for integration and reporting. All access panels/microphone stations feature intelligent IP technology, offering fully monitored field equipment as well as advanced functionality such as digital signal processing (noise reduction, echo cancellation, automatic gain control, dynamic range compression). All field equipment not placed in the CCR is Ex certified for Zone 1 operation (gas group IIB minimum).

Monitoring and reporting

During normal operation, fault and error reporting over SNMP is enabled through the TMS system at all times. Note that no remote access or -configuration is normally permitted. The link between the PAGA and the shore-link is normally disconnected and has to be physically reconnected before performing remote upgrade and reconfiguration. This is a security measure to prevent malicious or unintentional tampering with critical functionality.

Temporary phases

As the construction of this multi-platform installation is tiered, not all facilities will be present at production start. Drilling- and riser –platforms will be put into operation before permanent production- and accommodation facilities are present. During this phase, the systems connect though a fiber link to an access panel on a supporting vessel off-platform. Typical installation will be on a flotel (floating hotel) or temporary accommodation unit (typically semi-submersible, TLP or jack-up rig). By using IP-technology and standard networking equipment, ranges of several hundred meters is not a challenge. Expandability is cost efficient, using off-the-shelf networking equipment such as WiFi-links, single- or multi-mode fiber or even satellite communication. Generally redundant fiber network connection is strongly preferred.

Benefits of using IP integration

In this case, the main advantages lie in the reporting and remote monitoring as well as the scalability of IP-based systems. As the development of the field progresses the systems are expanded organically, linking up platforms as they are deployed. All of this is done seamlessly and without reprogramming.

SNMP is used as a rich reporting protocol, offering full system monitoring over IP. A hardened IP network, using firewalls and gateways ensure that security of the system is maintained while enabling both local and remote monitoring. Through the fault and reporting system, every part of the PAGA system is monitored at all times, from central equipment such as power supplies and data switches to system controllers and amplifiers (per channel monitoring). Even field equipment is monitored at all times, including access-panels and microphones (in both EX and non-EX areas), speaker loops and signal devices (such as beacons/flashers). Reporting over SNMP ensures a structured information flow that is easily filtered, sorted and prioritized.

Syslog is used as a supplement in the case of fault and warnings, to assess the fault and find the root cause.

CASE 2: ON-SHORE FACILITY, UPGRADE

This onshore facility is a refinery/storage facility. It contains a loading/unloading terminal, crude oil storage, refinery, distillate storage as well as the world's largest technology centre for carbon dioxide capture and –storage.

System overview

The system is based around a pair of IP audio servers, operating as a redundant system. Further each central contains dual networking and power supply, fed by 2 discrete power sources.

The operations centre features 20 operator positions as well as a situation room for command and control in critical situations. The facility further has a gate manager, a fire department and various offices; cracker, port manager, quay office, oil spill management, readiness crew quarters, etc. The system is based around radio technology, with 42 different channels (frequencies). Each operator can listen in on as many as 6 simultaneous channels and transmit on one of these (selectable).

Critical events

In the event of a critical situation, an alarm is distributed in three stages:

Stage 1):

An automatic voice message is broadcast to the Officer on duty through the radio system as well as to his personal mobile phone. The voice message is repeated until he acknowledges the message through a key-press combination on his phone. Simultaneously the alarm message is played at the fire department and the main gate through wall mounted loud-speaking intercom stations. The officer on duty, usually the fire department manager respectively the gate manager, has to acknowledge the alarm by pressing the call-key. Generally al communication is carried out over radio, as it offers mobility, but the fire dept./gate personnel can also use the intercom for a direct connection to the control centre. At the situation room, the situation panel will show that all units have received and confirmed the alarm message.

Stage 2):

The alarm can be escalated by the officer on duty. The second stage informs all communication operators in the control centre as well as the offices. Some of these operators have an administrative function in this scenario and will be instructed to acknowledge the message by a key-press combination. As each operator checks in, the corresponding indicator is lit on the situation-room panel.

Stage 3):

If the situation group decides that this is a real and overhanging threat to human life or the materiel, they may escalate the situation to level 3. In this scenario the voice message is transmitted to all radio frequencies simultaneously, notifying all personnel about the current situation. Most of the communication is carried out over radio (internally on the plant) and through telephony (emergency services).

Benefits of IP integration

Without IP integration it would be very costly and difficult to distribute 42 different radio channels with dynamic channel selection to dispatch officers and the remote offices, 30 in total.

Programmed features such as status indication, acknowledgement of alarms, and multiple functions (situationally dependent) per device would also be unfeasible without intelligent devices and a flexible and programmable audio server.

The biggest change from the previous system was, however, better monitoring. All radio bases/ repeaters are integrated through monitored IP-gateways which not only support audio in/ out but also control inputs and -outputs. In this case all fault relays on legacy equipment are connected as input to the system, vastly improving the overall monitoring of the critical components in the system. As well as offering a centralized fault and error management system, accessible over the network (through SNMP or Syslog).

Functionally, the operators' work stations offer a more streamlined workflow, as the operator can dynamically choose which radio channels to listen to, as the situation demands. As all stations are identical, reassigning personnel to other tasks only requires training in the procedures of the task, as the equipment is already familiar to the operator.

Financially, this integration allowed the reuse of all existing radio equipment but with the added safety-, security- and operational benefits of IP integration and a programmable and flexible audio server.

SUCCESS FACTORS FOR INTEGRATED OPERATIONS

In order to successfully implement integrated operations, achieving improved operational efficiency and reducing operational expenses there are several factors that should be observed. Key factors are interoperability between systems and future-proof and cost-effective deployment. In our experience, these are the most important factors to consider:

Open- and commonly accepted standards

Integration through industry specific, or better yet, open and common standards as well as common interfaces is the key to achieving supplier independence, ease of maintenance as well as minimizing risk of obsolescence. Relying on proprietary APIs, protocols or interfaces increases the risk of obsolescence and vendor tie-in and should be avoided if possible.

Flexible platforms of integration

The platforms on which one chooses to integrate the means of communication should be flexible in terms of scalability, integration paths and technology, ensuring that the system offers sufficient integration for legacy systems as well as scalability for future expansion and integration.

Use of standardized infrastructure

Utilising standard infrastructure ensures compatibility of equipment (replacement, expansion) and gives the owner freedom of choice with regards to equipment providers. This must be assessed in the context of the regional regulations and legislation, particularly when working with radio communication.

Compatibility with systems already in use with support functions

Whether it is a Platform Supply Vessel or the local fire brigade, a system which integrates seamlessly to the communication employed by the support functions is a factor to improve communication, reduce response time and increase safety. It can not be expected that supporting services replace their equipment and/or change methods to cater to the technology choices made by the industry. Rather this consideration should be made by the owner/operator in light of local requirements and circumstances.

ABOUT THE AUTHOR

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Mr Tarlebø holds a Master's Degree (M.Tech) in Industrial Design Engineering from the Norwegian University of Science and Technology. Former Senior Product Designer and Product Manager for intercom devices, Mr Tarlebø is experienced with regards to the requirements and expectations of the industry as well as trending technologies. His focus as a Commercial Product Manager by profession and Designer/Engineer by education is the total user experience and the benefits to the users and operators as much as regulatory demands. Today he holds the position of Commercial Product Manager for the segments Oil&Gas and Industrial at Zenitel. Zenitel has more than 70 years of experience in the critical communication industry and nearly 10 years' experience in IP-based systems.

Safety of Natural Gas Pipelines. New Alternatives via Tunable Diode Laser based analyzers

Energy Scenario in India

India's energy requirement is primarily met by coal today. As per Petroleum & Natural Gas Regulatory Board (PNGRB), gas contributes about 11% in the primary energy mix today which is expected to go upto 20% by year 2025.

Power & Fertilizer industries contribute to major demand for Natural gas and is as high as 60%. A substantial portion of this comes from LNG imports at terminals, subsequent depressurization processes and feeding into the national pipeline grids.

Currently there exists about 13000 kms of Natural Gas pipelines in India.

Predominantly they are operated by the national carrier GAIL and some by other operators like Reliance & GSPL

This network of pipeline is expected to double in the next 10 years.

Since most of these Natural gas pipelines are cross country and run through habitable areas, protection of these pipelines is extremely important.

There have been many accidents related to natural gas pipelines across the world. But one of most significant one which brought about changes in the way corrosion is inspected and standards are formed include a accident at El Paso in USA

On Saturday, August 19, 2000, a 30-inch-diameter natural gas transmission pipeline operated by El Paso Natural Gas Company, New Mexico ruptured. The released gas ignited and burned for 55 minutes. Twelve people were killed with extensive damage to property

Investigations revealed Chlorides, Dissolved O2, CO2 (Carbonic acid), and H2S present in pipeline all contributed to corrosion. All this led to low pH and rupture

With appropriate changes in API standards proper monitoring & inspections of moisture & H2S in Natural Gas were recommended.

More recently 15 people were killed and 18 injured when a massive blaze raged through a village in Andhra Pradesh's East Godavari district following a blast in an apparently leaking gas pipeline.

All these and other tragedies reinforce the absolute need to monitor parameters to prevent corrosion in pipelines.

All natural gas contains H2O (moisture)which is measured & controlled in natural gas pipelines at production and gathering sites, custody transfer points, compression stations, storage facilities and in the distribution markets. **Moisture measurement** is critical for gas companies to meet quality specifications and to protect pipelines from corrosion. Typical Measurement Ranges are 0-50, 0-100, 0-200, 0-500 ppmv

Similarly **H2S** is naturally occurring in oil and gas reservoirs. Produced gas containing high levels of H2S requires treatment to avoid corrosion problems.Typical Measurement Ranges are
0-10, 0-20, 0-50, 0-100, 0-500 ppmv

Control of these two parameters can prevent accelerated corrosion and Hydrate formations which are typical causes of pipeline rupture.

Historically various technologies have been used to measure both these parameters. These include Lead Acetate tape for H_2S, P_2O_5 & AL_2O_3 for Moisture.

Traditional Technologies

The traditional gas analyzer technologies has been consistently grappling with reliable measurement of low concentration gases. Various principles including IR, UV & VIS for Hetro atomic molecules, Lead Acetate tape for H_2S, P_2O_5 & AL_2O_3 for Moisture have been used. The most common challenges and problems faced by companies & users include

1) High maintenance
2) Frequent recalibration
3) Aircon shelters / rooms
4) Accuracy issues with interfering gases
5) Wear & tear with moving parts
6) Consumables including carrier gas

The end result being either the measurements are faulty or the equipment are sunsequently abandoned because they don't work and are extremely difficult to maintain.

New TDL / TDLAS Technology

TDL absorption spectroscopy (TDLAS) is a high-resolution technique that enables the measurement of specific gases with precision while avoiding interferences that are common with traditional infrared analyzers. This technology was developed by NASA & Jet Propulsion Laboratory for its Mar's Polar Orbiter Project in 1999. The key characteristics of the designed sensor were Reliabilty, Robustness, Accuracy & Response Time looking at the remote standalone operation on the Martian soil and the "first time only time" principle.

Tunable Diode Laser (TDL) technology is proved to be exceptionally reliable for measuring trace gas components like H_2O, H_2S, CO, NH_3 & C_2H_2. This technique was perfected by SpectraSensors Inc. a spin-off of the NASA Caltech Jet Propulsion Laboratory in Pasadena California. The TDLAS technology available includes Extractive, Cross pipe – tube & In-Situ.

Fig.1 – A Dual Channel TDLAS

The TDLAS technology complements the present day analyzer technologies for measurement of low range concentration gases in critical, harsh environments especially in the Natural Gas Processing, Transportation, Petrochemicals, Refineries, LNG & Specialty Gas industries

Advantage of TDLAS Analysers

1) Extremely Reliable measurements of low concentration. Intrinsically stable drift free lasers.
2) Robustness of technology to work in extreme environments
3) Accuracy
4) Fast Response

The advantages of TDLAS technology includes extremely stable measurements. The corrosive gases do not come in contact with the source, detectors enabling very little maintenance and virtually eliminating requirement of recalibration.

Fig.2 – Field installation of TDLAS

How does it work?

As the light passes through the gas sample, energy is absorbed, reducing the amount of light arriving at the detector. The SS-Series analyzers use long lasting and resilient Tunable Diode Lasers that emit near-infrared light. The robustness of Diode Lasers is proven in many consumer and commercial applications such as CD players and fiber optic communications. The length of the laser beam affects the sensor's sensitivity and hence some companies offer the dual-pass optical path in most applications (or a greater number of passes for some applications).

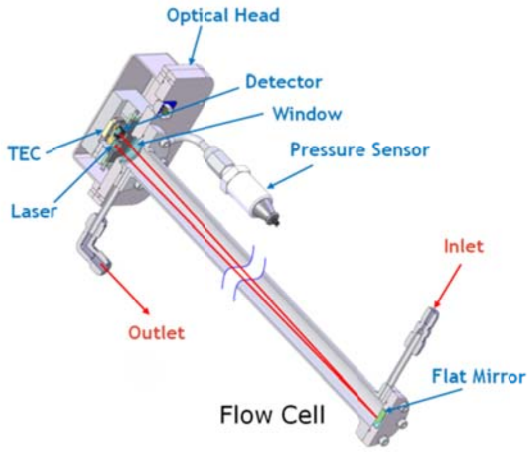


Fig.3 - A Typical Sample cell with source & detector

Primary Areas of Applications

1) Natural Gas and Gas Processing including Pipelines – H2O, H2S, CO2
2) Refining & Petrochemicals – H2O, H2S, CO2, NH3, C2H2
3) LNG – H2O, CO2
4) Specialty & Bulk gases
5) Metrology & Climate Research

Currently more then 6500 installations use this TDLAS technology, predominantly in the Natural gas industry.

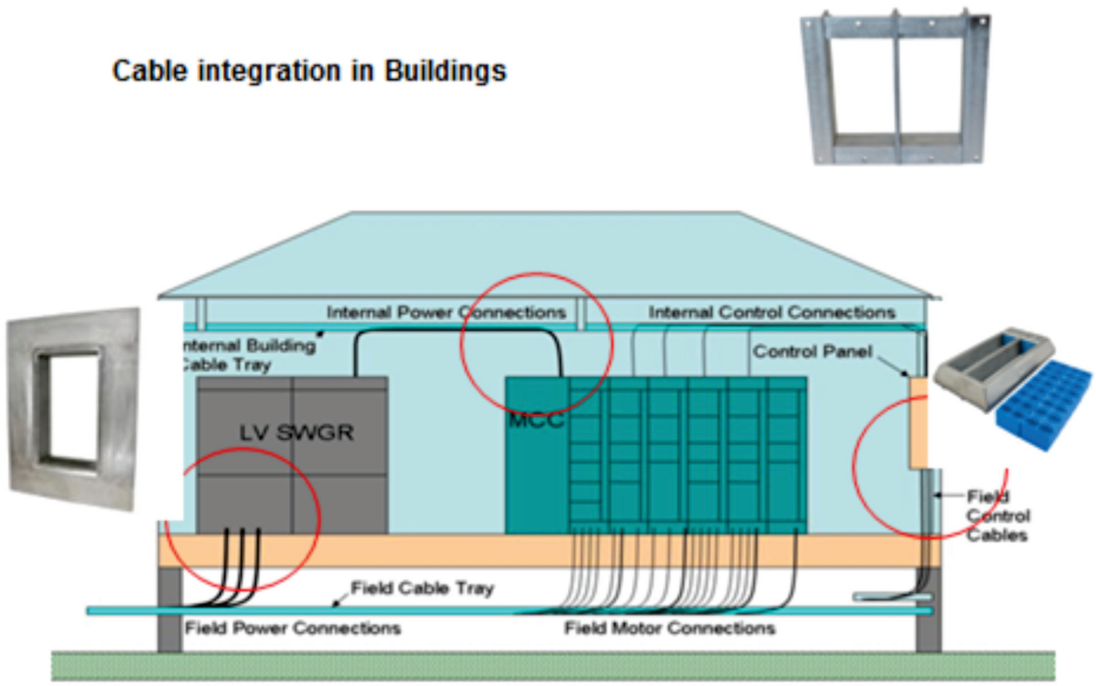
Photos Courtesy – SpectraSensors Inc
Contact: hemal.desai@in.endress.com

(Hemal Desai is graduate in Instrumentation Engineering and has over 24 years of experience in process control & automation business. Currently he heads the Marketing Group at Endress+Hauser India Pvt ltd.)

Integration of Modular Cable sealing System

Allen Gibson – Global Manager Process Industries, Roxtec Group
Naresh Kumar – Manager Process Industries, Roxtec India Pvt. Ltd.

What is Modular cable sealing – The Cable sealing technology seals where cable/pipe passes from one chamber to another from the wall/floor penetrations, cabinets or panels etc. to provide them fire/water/gas tightness to provide safety and ensure operational reliability?



In terms of Industrial reference standards:- *Modular Cable transit device is an entry device, intended for one or more cables, with a seal made up of one or more separate elastomeric modules or parts of modules (modular internal seal), which are compressed together when the device is assembled and mounted as intended(As per IEC 60079-0 chapter 3.7.5).*

Why we require: - To ensure safety of Man, Material and machine alongwith meeting the industry safety parameters as below: -

1. Blast-rated wall (As per OISD standard 163)
2. Fire Tightness (As per standard ISO834 &EI120)
3. Grounding (earthing) to ensure electrical safety and EMC
4. Vapor Barrier / Smoke and Gas tightness
5. Water and dust tightness (Ingress Protection IEC 60529:2001)
6. Reduce partial discharge & increase operational reliability from external & internal environment factors.
7. Faster installation and easy maintenance to reduce man-hours and increase uptime

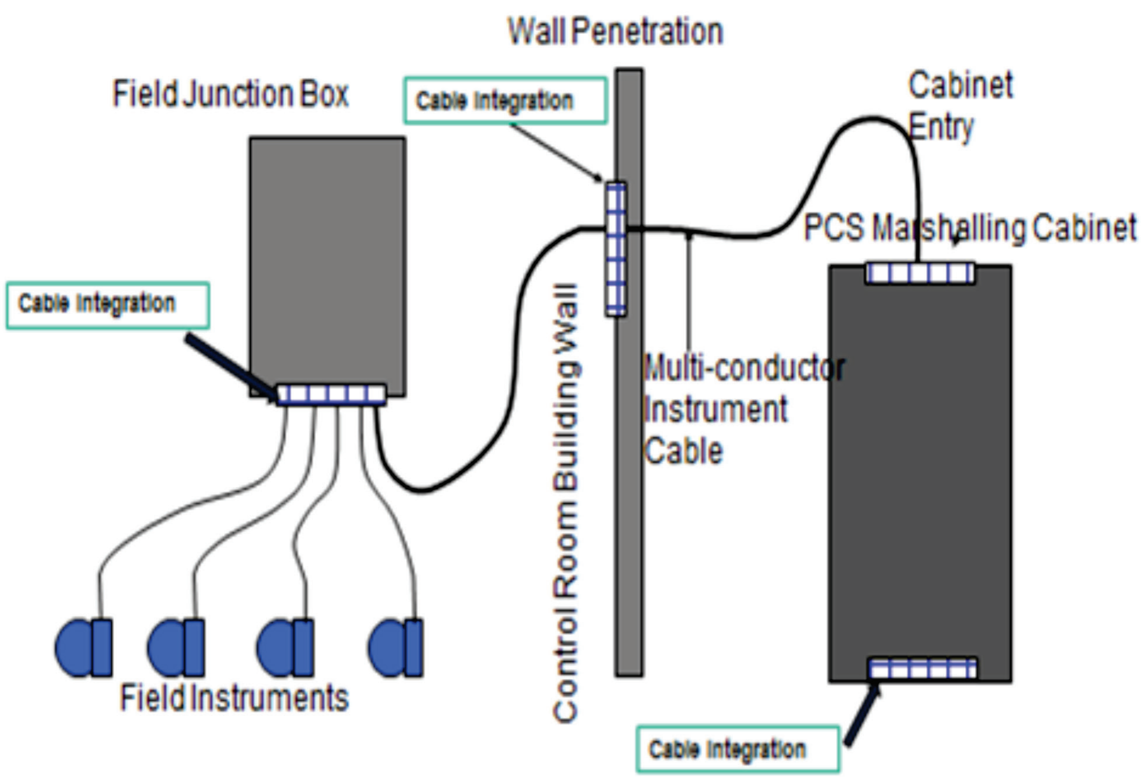
1. OISD-163

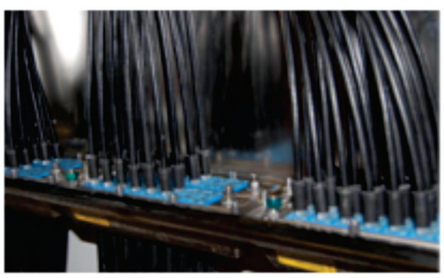
OISD-163 which primarily focuses on blast or explosion protection into control buildingswith minimum blast pressure of 3 psi.

2. CONCEPT OF MODULAR CABLE ENTRY SEALING

Targeting simplicity, flexibility in cable OD, interchangeability of blocks, segregation of cables for electrical and control safety, reliability and easy installation. Modular cable sealing system has created unified cable integration into buildings, panels, JBs and cabinets. While conventional sealing known with different names like sealant, glands and fire wool etc.

Cable integration in control Room,Panels and JBs and kiosks as per IEC 60529:2001 and OISD 163





Certifications:

1. Third Party certification for blast proof protection from DNV
2. Passive fire protection from UL, FM and ASTM
3. Third Party certification forGas tightness (2.5 Barpressure) from DNV
4. Third Party certification for Water tightness (4.0 Bar pressure) from DNV
5. Third Party certification for thermal cycling, contamination, vibration and shock absorption from DERA
6. Low smoke index test from LNE Paris
7. Rodents protection test from Huntingdon Life sciences Ltd.
8. Ageing test from SP Technical Research Institute, Sweden
9. IP-66/67 test from SP Technical Research Institute, Sweden

Note: all certifications are valid with 100% blocks filled with cables for space optimization.

IEC 60079-0

Edition 6.0 2011-06

INTERNATIONAL STANDARD

3.7.5

cable transit device

an entry device, intended for one or more cables, with a seal made up of one or more separate elastomeric modules or parts of modules (modular internal seal), which are compressed together when the device is assembled and mounted as intended.

NOTE Cable transit devices can also serve as Ex blanking Elements when the elastomeric modules provided allow for this function.

- Cable transit devices are recognized and approved for use according to IEC 60079-0
- MCT devices used in **electrical equipment** within hazardous locations **MUST** be properly certified and labeled

Why whitepaper – This paper focuses on introducing multi-cable transits to electrical, instrumentation and civil design teams working with onshore oil, gas, petrochemical and heavy industrial facilities, reviewing the critical components for design and installation, relevant international standards for use of multi-cable transits and providing a recommended work process for proper designs of the transits. The paper also informs how humidity effects in these expensive utilities reduce their life cycles due to internal and external environmental conditions, Partial discharge etc.

Topic covers anddemonstrates improved safety and improved projectdelivery when modular cable sealing systems are included into owner and EPC design scopes. Various international standards for cable transit devices and common safety demands are presented, including the use of cable transit devices for vapor-tight barriers,blast-rated structures, fire walls, pressurized buildings, and simple ingress protectionagainst environmental elements.

Incorporating such technology into owner-level andengineering-level design standards, is demonstrated to provide project savingsthat include reducing project man-hours, detail design time, and reduced fieldmaintenance time. Proper multi-cable transit design and installations are also shown toincrease project safety and operational uptime.

About The Authors:

Allen Gibson graduated from Oklahoma State University with a BScBA. Since 1990, he has worked for international oil and gas companies in both technical and commercial roles, and served as President / CEO of a US-based LPG company. He is a member of the International Society of Automation, IEEE Industrial Applications Society and a member of the PCIC Europe Executive Committee and serves as Chairman for the PCIC Middle East Local Committee. Since 2007 he has worked for Roxtec Group and serves as the Global Manager for Process Industries. Allen may be contacted by email: agibson.project@gmail.com.

Naresh Kumar presently working with Roxtec India as Manager-Process Industry. He has 15 years' experience at different roles in different industry. Mainly he worked in oil and gas industry.His areas of specialization include sealing technology in industry, electrical safety, utility etc. He has Post Graduate Diploma in Management from IIMM Pune.He may be contacted by email: roxtecnaresh@gmail.com

Selection of Switching Interface – A Need for Reliable Control Systems

Ashish Manchanda, Andrea Sabbatelli

ABSTRACT

The Control Cabinets in Process Automation are incomplete without Interposing Switching Components which are required to drive critical higher load outputs and / or provide input isolation for the Digital signals.

Many relay users takes a standard product for all applications and more often they are not able to keep a track of the Relays that had failed prematurely, or the quantity they have replaced. The worse situation is when happily all the relays are replaced during the annual plant shutdown. This happens when designer of the control system is unaware of the Electrical life cycle of the relay which is an important parameter necessary for optimum utilization of the relay components. It could be that a same relay works for all applications, but for a limited time period. Because every application is different, so is the type of the relay.

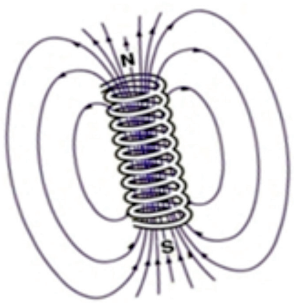
With the advancements in technology and the multiple options now available in Relays, which if considered at the time of detailed engineering, can not only help in increasing reliability, reducing the cabinet footprint, remove wiring errors, save space but also optimize costs directly as well as indirectly by reducing downtime.

Many internal and external factors influence the performance of relay. Based on the application one must carefully analyze all these parameters and select an appropriate relay as its failure is immediately reflected on the process. An overview through this paper on the relatively lesser known domains in the selection criteria of Relays will enhance the confidence of the engineers to design a reliable control system.

Key Words: Relay,Contacts, Electrical Life, Reliability

1. INTRODUCTION

An Electro Mechanical Relay is a considered to be constituted of two primary components connected together- An Electromagnetic Coil and a Switch/Poles.The coil changes the switch from one state to another when a rated voltage is applied to it. This operation seems to be so simple but the question is- Is it really so simple or we should give it a second thought...



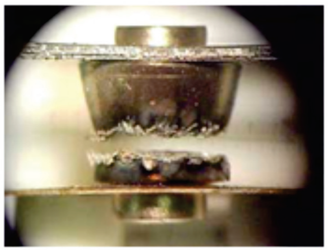
Many relay users takes a standard product for all applications and more often than not they're perfectly happy even if the relay performs for an inconsistent time period which may be shorter than the complete life cycle of the relay. Or they do not mind replacing the entire bunch of Relays in the Plant / Machinery during the annual shutdown. This is due to the fact that they never examine the important parameters necessary for optimum utilization of these switching interfaces. It could be that a same relay works for all applications for a limited time period but as every application is different, so is the relay.

2. FACTORS AFFECTING PERFORMANCE OF RELAY

Many internal and external factors influence the performance of relay, they can be broadly classified into the following different types:-

Each of these factors is important. Based on the application one must carefully analyze all these parameters and select an appropriate relay as its failure is immediately reflected on the control system reliability.

2.1 Contact Material



The contact material has the major influence on the relay performance typically when it is compelled to be used under high current, continuous operation and connected load. The correct contact material is like the correct tires for a race car, Rally tires on a F1 car are not so good. The same is true for relays; the wrong material will have a big effect on its performance. If a wrong contact material is selected for an application, it can destroy the contact due to material vaporization thus considerably reducing the service life of the relay. See Picture 1

Picture-1: Relay Contacts showing theeffects of severe over current due to wrong selection of contact material.

There is no universal contact which covers all applications. The selection depends on various factors like type of load, level of load, type of voltage supply, frequency of switching etc. Many different contact materials are used today for relays and their use is depending on their properties. For example if one has the knowledge of the inrush current of the load also apart from the nominal load current, then going for the right kind of contact material can easily be selected. A few commonly used contact material and their applications are shared as below:

2.1.1 AgNi (Silver Nickel):-

It is a good standard contact for most relay applications.Has high wearing resistance, which implies that over a long period of use the contact resistance does not increase. It has Medium resistanceto welding with the ratio of Rated Current Vs Inrush Current handling capability of approximately 1:2. Used normally for Resistive and slightly inductive loads.

2.1.2 AgCdO (Silver Cadmium Oxide):-

It has high wear resistance and welding resistance when used with high AC loads. Used normally for Inductive and motor loads.

2.1.3 AgSnO2 (Silver Tin Oxide):-

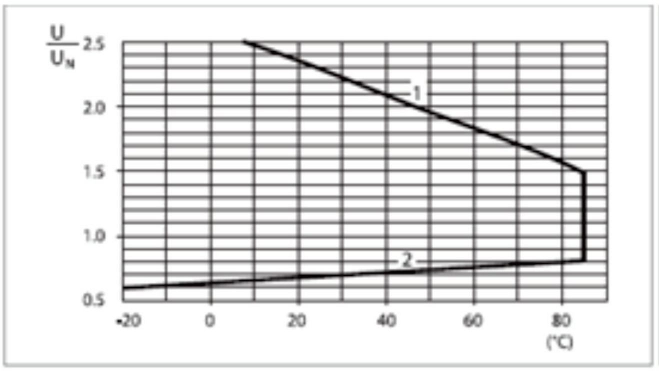
It has excellent resistance to welding and is best suited for lamps and capacitive load. It has a very high ratio of rated Vs inrush current of 1:5. Wear resistance is however lower as contact resistance usually increases after repeated switching.

2.1.4 AgNi + Au (Silver Nickel Gold Plated):-

It has a gold plating over AgNi of 5µm thickness and is used in applications involving small and middle load range 50mW (5V/2mA up to 1.5W/24V), where gold plating erodes very little. If the switching current is in higher, then the gold plating evaporates.Hence with small loads, Gold Plated Relays are used as their contact resistance is lower and more consistent compared to other materials. However, the gold plating is useful only when the load current is not more than 500 mA usually. In some cases where the need is to protect the contacts against rough industrial environment instead of hard gold plating, a gold flashing of 0.2µm is done to allow protection of contacts during storing. But gold flashing is not a substitute for gold plating.

2.2. Coil Requirement

Every coil has its own target voltage and working range, right relay for right application depends purely on the operating range of the coil. The relay might work correctly over the working range as specified by the manufacturer but proper attention needs to be paid for selecting the coil.



1 - Max. permitted coil voltage.
2 - Min. pick-up voltage with coil at ambient temperature.

Picture 2 - The graph in Picture 2 shows a typical DC Coil operating range v ambient temperature.

A user should give emphasis to the minimum pick-up voltage and the maximum permitted coil voltage with respect to the ambient temperature. In some circuit's leakage current or Transient EMF might have enough voltage to keep some coils energized even after the control voltage is removed, therefore not releasing the coils in the intended way. Different manufacturers specifies different coil voltage ranges, usually a 24V DC relay has a working range of 0.80 to 1.1 times the nominal voltage U_N.

Also, important to understand is that in the Electro Mechanical Relay coil there is an Operating Time and Release Time, which is to be considered for control circuits where time critical actions are to be performed. For example if during an error in the process a relay has to disconnect a circuit within 10 ms then Release Time of the coil must be lower than 10 ms. Similarly if the Relay has to actuate a tripping mechanism within a specified time then the Operating Time of the relay coil plus the bounce time of the contact (a mechanical contact while making, bounces for some time before the contact is finally permanently settled under the effect of the coil's electromagnetic force) put together has to be lower than min required time for tripping.

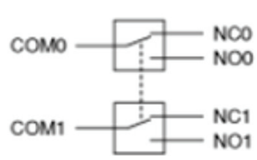
There are occurrences where due to the Electro Magnetic Interferences within the operating zone, stray currents/voltages influence the coils behavior. In such cases it is important to consider relays Leakage Current Suppression and EMI filter components within the relay. These circuits can be inbuilt inside a relay or can be added later, on site.

2.3 Contact Requirement

Relays are classified by their number of poles and number of throws. The pole of a relay is the terminal common to every path. Each position that the pole can connect to is called a throw. A relay can be made of n poles and m throws. For example, a single-pole single-throw relay (SPST) has one pole and one throw, as illustrated in the Picture 3.

A single-pole double-throw (SPDT) relay has one pole and two throws: A double-pole double-throw (DPDT) relay has two poles, each with two simultaneously controlled throws as illustrated in the following Picture 4 and Picture 5:

Picture 4- Line Diagram for SPDT



Picture 5- Line Diagram for DPDT

Relays are then classified into forms. Relay forms are categorized by the number of poles and throws as well as the default position of the relay. Three common relay forms are.

Form A - Form A relays are SPST with a default state of normally open.

Form B- Form B relays are SPST with a default state of normally closed.

Form C - Form C relays are SPDT and break the connection with one throw before making contact with the other (break-before-make). Please see the Picture 6 Below.

Picture 6 – Shows a Form C/SPDT Contact type

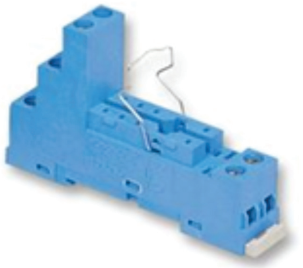
As relays come in different configuration, thus several points of concerns arises in choosing the number of contacts required for the application. The question remains “How many Poles (Contact sets) does the user requires for the application?” Relays typically come in 1,2,3,4 poles and less main stream relays comes with more than 4 poles. For a single loop control application normally SPDT contacts are used, whereas for contact multiplication applications or for operating a three phase load, a 3 or a 4 pole relays are used.

Many a times it is seen that out of a concern on the reliability, users select a DPDT relay even though the application demands SPDT. A feeling of keeping a spare contact option is quite natural in the users, but it is of not much benefit since it requires twice the space, higher energy consuming coils (as it has to actuate a greater coil EMF), extra direct cost of the relay and sometimes an extra indirect cost of increasing the number of control cabinets. The benefit of keeping a spare contact is easily superseded by the plug ability option of a spare relay, which can be replaced much faster than the time required for changing the wiring of an additional spare contact.

As per the latest standards, now the forcibly guided contacts (mechanically linked) are being used in the Electro Mechanical relays being used in Safety applications of Control System i.e. Emergency Stop etc, wherein a NO contact

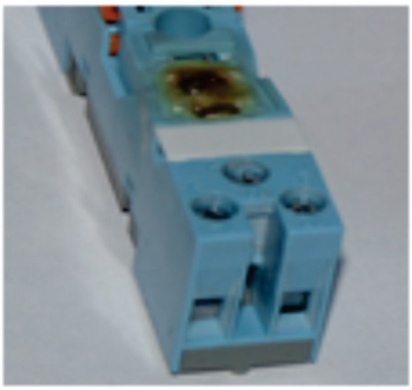
2.4 Socket/ Base

This is one of the most important and usually the mostly ignored part of a relay used in a control system. The users must keep in mind that the relay can get only as good as its Base or Socket. The best of the relays will under-perform if the mating socket is not optimized with respect to the relay. (See the Picture 7 below of a typical DIN Rail Mountable Socket for a DPDT Relay)



The important bit is quality of materials and plating’s in the base, the plastics need to withstand the heat generated from the contacts both in the relay, and the contact made between the terminal pins of the relay and the relay socket. Also, the metal clamps in the socket needs to have enough elasticity as well as force to maintain its proper pressure on the relay terminals. Usually this is where improperly designed sockets fail and let down the control system as the clamps in the base open up with heat and fails to return to its original position, and this reduce the pressure, and increasing heat, until a failure occurs.

In all cases the relays and the bases/sockets should be made by the same manufacturer as per the specific matingrequirements and considerations. The socket clamps should be of non-ferrous metal composition to prevent rusting. Also all the plug-in Pins of a relay should be of the dimension.



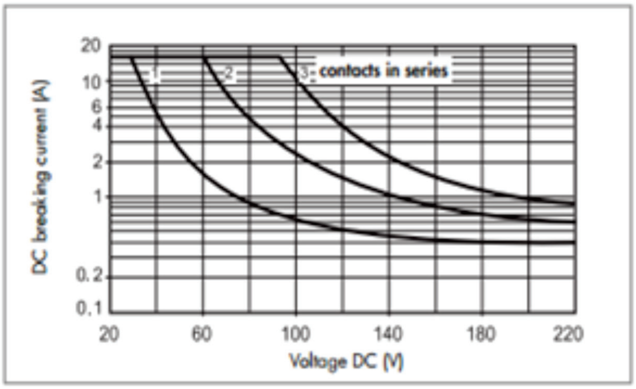
The secret to a good electrical connection is the result of Area x Pressure. If a connection between the clamps of the socket is made up with too little pressure, moisture and air will penetrate the joining point of clamp and relay terminals and promote corrosion which raises contact resistance and increases heating which can accelerate corrosion and further deteriorate the contact force leading to failures in socket (See Picture 8).

2.5 Type of Load

It is important to select the parameters of relay in accordance with the type of load connected. Loads can be of different types example- Resistive, Inductive, Capacitive, Lamp Load, Motor Load etc. Some loads like Motor and Inductive loads have high inrush current and can damage the contacts of relay if not selected properly.

For both small AC and DC load especially for control applications, the arc produced during changeover of contacts is less. A basic differentiation between the large AC and DC Loads is that AC loads are to be carefully handled with respect to the making of the contacts as they have usually higher inrush currents, whereas while switching DC currents it is the breaking of the contacts that has to be considered more critically. Unlike switching of large AC loads, DC loads, due to non availability of Zero Crossing to extinguish the arc automatically, can only switch relatively a much smaller DC load.

In industrial applications demanding switching high DC loads, a user has an option to connect two contacts in Series to increase the switching capacity. (As shown in the Picture 9 Below)



Another important consideration on the load is the type of AC & DC Load classification. This is based on the utilization category. For Example, if the Relay is selected for a resistive or slightly inductive DC load i.e. according to DC 1 load category, the same relay will not suffice for DC 13 types of load which are usually the category for highly inductive electromagnetic devices like Solenoid, Contactors etc, unless a freewheeling diode is connected across the contact.

Table 1 below depicts the overview of the Load Classification with Application Examples:			
Load Classification	**Supply Type**	**Common Applications**	**Switching with relay**
AC1	AC single-phase AC three-phase	Resistive or slightly Inductive AC loads.	Work within the relay data given generally
AC3	AC single-phase AC three-phase	Starting and stopping of Squirrel cage motors. Reversing direction data of rotation only after motor has stopped. Three-phase: Motor reversal is onlypermitted if there is aguaranteed break of50ms betweenenergisation in onedirection andenergisation in theother. Single-phase: Provision of 300ms“dead break” timewhen neither relaycontacts are closed-during which timethe capacitor discharges harmlesslythrough the motorwindings.	For single-phase the standard relay data is sufficient. For three phase load, the relay manufacturer must give the data
AC4	AC three-phase	Starting, Stopping and Reversing relays direction ofSquirrel cagemotors. Jogging(Inching). Regenerative braking (Plugging).	Not possible using Since, when reversing a phase of Squirrel cage connection a severe arcing will occur
AC14	AC single-phase	Control of small electromagnetic loads (<72 VA) power contactors, magnetic solenoid valves and electromagnets.	**Assume a peak inrush current of approx. 6-times rated current, keep this within the specified** “Maximum peak current” for the relay.
AC15	AC single-phase	Control of small electromagnetic loads (>72 VA) power contactors, magnetic solenoid valves and electromagnets.	**Assume a peak inrush current of approx. 10-times rated current, and keep this within the specified “Maximum peak current” for the relay.**

DC1	DC	Resistive loads or slightly inductive DC loads. Switching voltage at the same current can be doubled by wiring **2 contacts in series.**	Work within relay data normally provided by the manufacturer
DC13	**DC**	Control of electromagnetic loads, power contactors, magnetic solenoid valves and electromagnets.	**This assumes no inrush current, although the switch off over-voltage can be up to 15 times the rated voltage. An approximation of the relay rating on a DC inductive loadwith 40 ms L/R can be made using 50 % of the DC1 rating. If a freewheeling diode is wired in parallel to the load, it can be considered the same value as DC1.**

2.6 Insulation

The main functions of a relay is toconnect and disconnect different electric circuits, and usually, to maintaina high level of electrical separation between different circuits. It is therefore necessary to consider the level of isolation appropriate tothe application and the task to be performed - and to relate this to therelay's specification. The user needs to check whether the insulation levels of the relay in use is in accordance with their application needs, or alternatively whether they are tested in accordance with the IEC 61810-1 standards. The right way to ensure the required insulation values is to check the same between the following three points:

a) The Coil and the Contacts

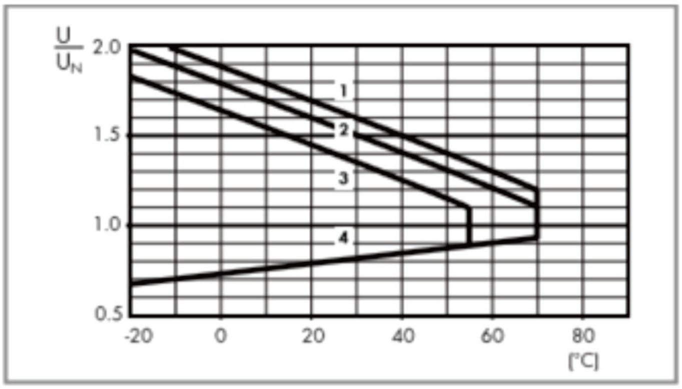
b) The adjacent Contacts (if the relay is of 2 Pole or more)

c) The Open Contacts

2.7 Temperature and Climatic Conditions

Temperature plays one of the most important roles in defining the reliability and the service life of a relay. The relay exposed to harsh ambient temperatures would lead it to work unreliably. While designing the control system it is therefore necessary to take temperature as the main criteria.Some of the important parameters of a relay that get affected due to higher working temperatures are:

2.7.1 COIL: A typical Coil Voltage variation graph with respect to temperature is shown in Picture 10. Here, we can see that if the temperature inside the control cabinet is higher the lesser is the flexibility in the working voltage range of the relay coil.



DC coil operating range v ambient temperature

1 - Max. permitted coil voltage at nominal load (DC coil).
2 - Max. permitted coil voltage at nominal load (AC/DC coils U ≤ 60 V).
3 - Max. permitted coil voltage at nominal load (AC/DC coils U > 60 V).
4 - Min pick-up voltage with coil at ambient temperature.

2.7.2 CONTACT LIFE: The Electrical Life is to be tested in accordance with the IEC 61810 standards at the maximum temperature point of the operating range mentioned by the manufacturer. However, flexibility is allowed for the relay manufacturers to specify the Electrical Life at a lower temperature. However, at higher temperatures the value of the no of electrical switching cycles surely degrades. Therefore, it is important for the designers to match the operating temperature of the relays with that of the ambient temperature of the application. Typically in the control system where the control room environment is not conditioned, it is always advisable to select a relay that has a minimum 10 Deg C higher operating temperature rating with respect to the ambient as a factor of safety measure for reliable operations.

2.7.3 RELAY HOUSING: The Relay has a few thermoplastic/thermosetting plastic parts for holding the Coil, holding the Contacts, socketsand in most of the cases the complete housing/enclosure also. The thermal stability therefore of these insulating parts of the relay is of great significance. As per the thermal classification the maximum temperature withstand capability of the insulating material can be identified as per Table 2 below:

Thermal classification	Maximum temperature
Class - Y	90 °C
Class - A	105 °C
Class - E	120 °C
Class - B	130 °C
Class - F	155 °C
Class - H	180 °C

For a relay, the base holding the metallic relay pins gets heated up due to the high current, the increased contact wear, the socket and pin contact resistance and also the ambient heat. If all these conditions summed up together cross the temperature limit of the base material, then the relay pins tend to lose their proper position. Hence it is better to consider insulation material with H Class rating for applications with higher temperature.

2.7.4 The other climatic conditions of dust, moisture, gases etc can be handled by selecting a correct type of RT rating of the relay. The brief overview of the same is as per the below Table 3.

Table 3: Environmental protection: according to EN 61810-1. The RT categories describe the degree of sealing of the relay case

Environmental Protection Category	Relay Type	Protection
RT 0	Unenclosed relay	Relay not provided with a protective case.
RT I	**Dust protected relay**	Relay provided with a case, which protects its mechanism from dust.
RT II	**Flux proof relay**	Relay capable of being automatically soldered without allowing the migration of solder fluxes beyond the intended.
RT III	Wash tight relay	Relay capable of being automatically soldered and subsequently undergoing a washingprocess to remove flux residues withoutallowing the ingress of flux or washing solvents.
	Special Applications	
RT IV	Sealed relay	Relay provided with a case which has noventing to the outside atmosphere.
RT V	Hermetically sealed relay	Sealed relay having an enhanced level of sealing.

2.8 Type of Mounting

Today depending on the application type, a user has different options for mounting the relay. The most common being the PCB version. These types of relays can directly be soldered on a PCB or plugged into a PCB soldered socket.

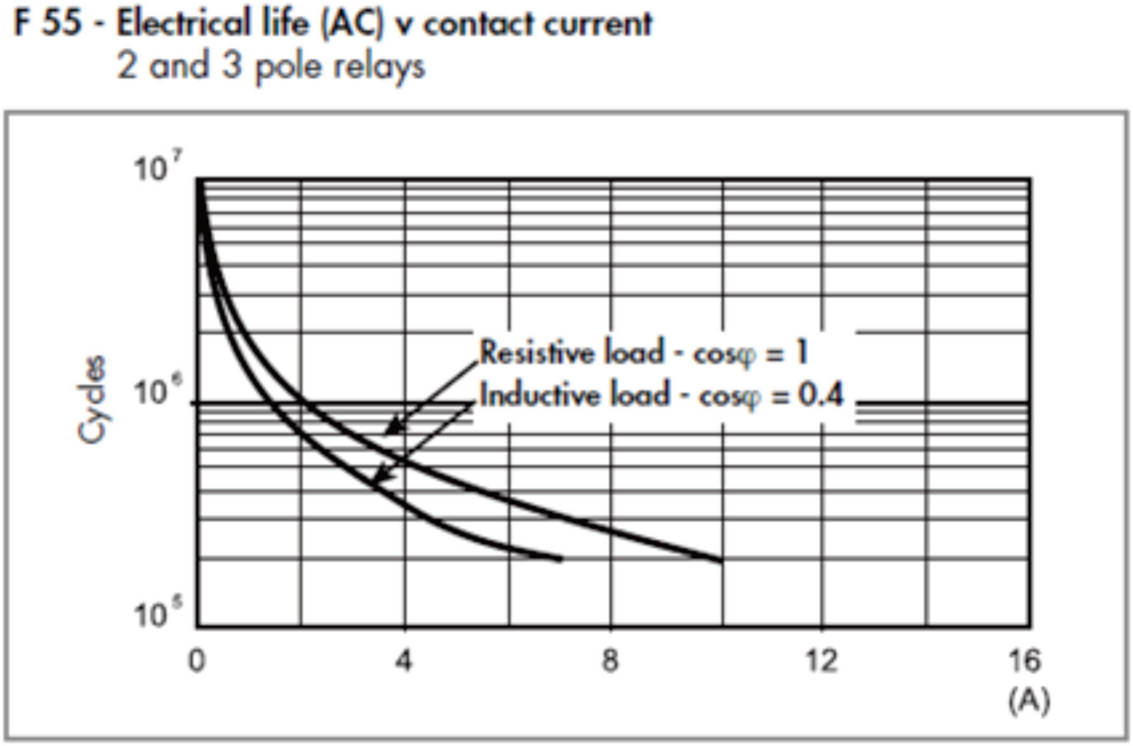
In industries however DIN Rail Socket/Base mounted relays are preferred because of their modularity and ability to mount on DIN rails with screw or spring loaded terminations on the socket.

Also another option is to use a relay with feed through socket which is mounted on the control panel's body by giving a cut-out in the sheet metal. In such a case the wiring connected with the feed through socket is done by either lugs or soldering.This is normally used if there is no space for DIN Rail available in the cabinet.

Fourth type of mounting is Flange mounting, which isnormallyused for relays with very high current rating i.e. 20 Amp and above where plug ability is difficult to attain. The Flange mounting gives a very good advantage to the user to easily mount the relay on a DIN Rail or on the panel body and use common lugs to make the wired connections.

2.9 Electrical Life Time

A relay should typically have an electrical service life in at-least a few hundred-thousands of switching cycles tested at the rated load current and at the ambient temperature of the application,so as to efficiently work for a higher life span. The Electrical endurance test is performed on each contact load and each contact material as specified by the manufacturer.Unless otherwise explicitly stated by the manufacturer, this test is carried out at the upper limit of the ambient temperature



Picture 11

range, and the relay coil shall be energized with rated current and voltage. The contacts are monitored to detect break and/or make malfunctions as well as unintended welding of contacts.

The reliability of a relay is best defined in terms of the number of cycles it can operate while meeting its specifications before it fails. MCTF (mean cycles to failure) values for a relay are useful to get a reliability prediction, it is not necessary to test the relays until they all fail. The life test can be suspended after a certain proportion of relays have failed – generally the test should be run until at least 10% have failed. This indicates the B10 statistical value for the purposes of reliability calculations. And, this value could be used to calculate an approximation to the related MCTF figure. Where, Failure, in this case, refers to the contact "wear-out" mechanism that occurs after a number of switching cycles are achieved.

For Example – Please find below An Electrical life chart for a relay: here One Million Electrical Switching Cycles at 2 A of Resistive AC Load at the contact is shown as per Picture 11.

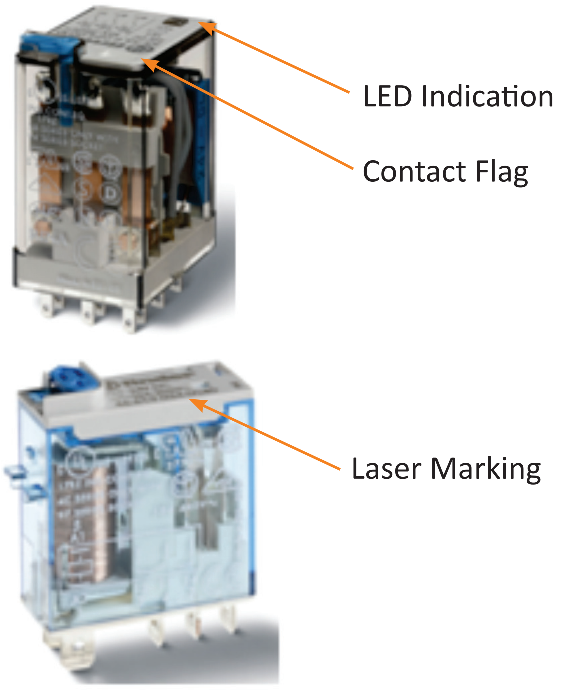
Picture 11 - The "Electrical Life Vscontact current" chart indicates the life expectancy for a resistive load as well as an inductive load for different values of contact current. Life, or number of cycles, from these charts can be taken as Predicting life expectancy

2.10 Service Factor

Since a relay is considered as a non-repairable component, there is always need for easy diagnostics, speedy replacement and upgradability with respect to adopting the unpredictable environmental conditions.

There is now technology available where the Industrial relays can easily be upgraded without changing any wiring. This kind of flexibility is required when the site conditions where the relays are installed are showing some random problems of Surges, Electro Magnetic Interferences (EMI), induced voltages etc. This is possible by simply plugging-in varistor modules for surge protection, filter modules for EMI protection, diode modules for inductive kick-back protection etc.

The Service factors are also to be considered when there is a need to diagnose a fault in the relay and also the ease with which they relay can be replaced in an existing control system. It is very important to have indication for both - the Coil Actuation as well as the Contact Latching, so that the user can identify the nature of the fault. See Picture 12



Picture 12 – Shows the technology of relays with Dual Diagnostics

After the fault is diagnosed, the user needs an easy identification of the key technical parameters of the relay, so that the correct replacement can be ensured without looking at extensive documentation. For this purpose, it is important that the technical parameters are Laser printed on the relay, as the ink printing normally wipes out over a period of time. See Picture 13

Picture 13 – Shows the Marking on the relays which are important for service

3. CONCLUSION

The reliability of relay plays an important role in the availability of control system. For each application therefore the best relay shall be chosen based on different technical parameters. With the advancements in technology and the multiple options now available in these Relays, the need of the hour is for optimization of the selection parameters. This kind of design elevation if considered at the time of detailed engineering can help in:

- increasing reliability of Control System,
- saving space by reducing the cabinet footprint,
- reduce the wiring errors,
- estimate electrical life and do preventive maintenance judiciously
- enhance diagnostics, thereby reducing downtime
- Preventing additional heat generation inside the cabinet, thereby saving energy.

REFRENCES

1) EN61810-1ed3:2010-12–Electromechanical elementary relays: Part 1 General requirements
2) EN61810-2ed2:2012-04–Electromechanical elementary relays: Part 2 Reliability
3) National Instruments – White Paper on Relay Forms – www.ni.com
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CONTROL ROOM SOLUTIONS

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Introduction:

Lets define what exactly a control room is. Control room can be defined in the following versions

control room is functionally a diagnostic center of the plant

control room is the heart of the plant

control room is the drawing room of the plant

Its overall an EXPERIENCE that is being taken care of when it comes to design of control room and here comes the module that governs- THE HUMAN scale and the process defined as HFE (Human Factor Engineering). When three experiences that of operator, owner and visitor combined together derived is a solution which is ergonomically comfortable and functional efficient at the same time.

Why a control room calls for special design requirements? It's a 24x7 mission critical/control functions control and monitoring space. A small mishap can be a cause of a great concern in the operations of the plant.

Aspects of design:

Location of control room building with

respect to the plant

Location of control room in the building
Functionality defining the no of operators
HFE incorporating ergonomics, viewing angles, lux levels, dynamic lighting, HVAC, fire & safety, traffic patterns, furniture design and overall aesthetics

Location of the building depends on the overall plant layout and definition of the primary source of information to the operator. And this defines the nature/form of building (normal/blast proof, windows/ blank walls, remote/plant vicinity)

Location of the control room in the building depends on the functionality and safety concerns in the building. It should facilitate the operators with easy egress in case of emergency and should allow a hassle free environment equipped with suitable paraphernalia and facilities in the vicinity. Its recommended that the control room should avoid canteen and noise creating areas in the vicinity.

Functionality and occupancy of the Control is derived out of a workshop with the stake holders of the project ie the end users, automation contractors and the consultants involved. The task analysis of the each operator , corresponding console and relation to video wall defines the space and the matrix, thereby giving form and boundaries to the space. For example a convex console would be suitable if the video wall is smaller than the overall console length and if vice-versa its concave, the first row of operators see the bottom of the video wall the second row sees the middle and the third row sees the top.
These factors govern the layout and general arrangement of the CCR

Human Factor Engineering

HFE is the process of integrating human capabilities in the design of products, work places or work systems (plant/facility) resulting in the effective, safe & healthy functioning of human beings, thereby improving operational & maintenance tasks.

This DEP shall be used as a design tool/checklist in the definition phase to ensure that HFE considerations are laid down in the design package.

Good design means that account is taken of "human factors". In other words, operator tasks are matched to what a human being can and cannot do, and this is taken into account, for example, in the layout and furnishing of control rooms, the presentation of information and the design of controls.

The Human performance is greatly affected by the User Interface design & the integrity of management information systems & physical location of equipment. Integration of ergonomics with the traditional approach enables the designers to define an integrated and compatible set of technical and organizational criteria. The methodology extends the consideration of required functionality from the human perspective to provide an error tolerance design that informs the user of situations they are in.

If HFE forms an integral element right from the start of a new construction project, an important contribution can be made to safe, efficient and comfortable control of plants, without raising their life-cycle costs.

Control room building

Workflows
Requirements/ inputs of all the stakeholders need to be incorporated at the concept stage for effective design. Workflow shall be divided in to the following major groups.

Physical infrastructure
Integrated Control & safety System
Process Operation Units
Production Management Systems

Location & Structure

The control room location is determined by non- HFE factors such as safety, wind direction, desired free space around the building, potential for expansion, emergency response and the number of plants that are to be controlled from the control room.

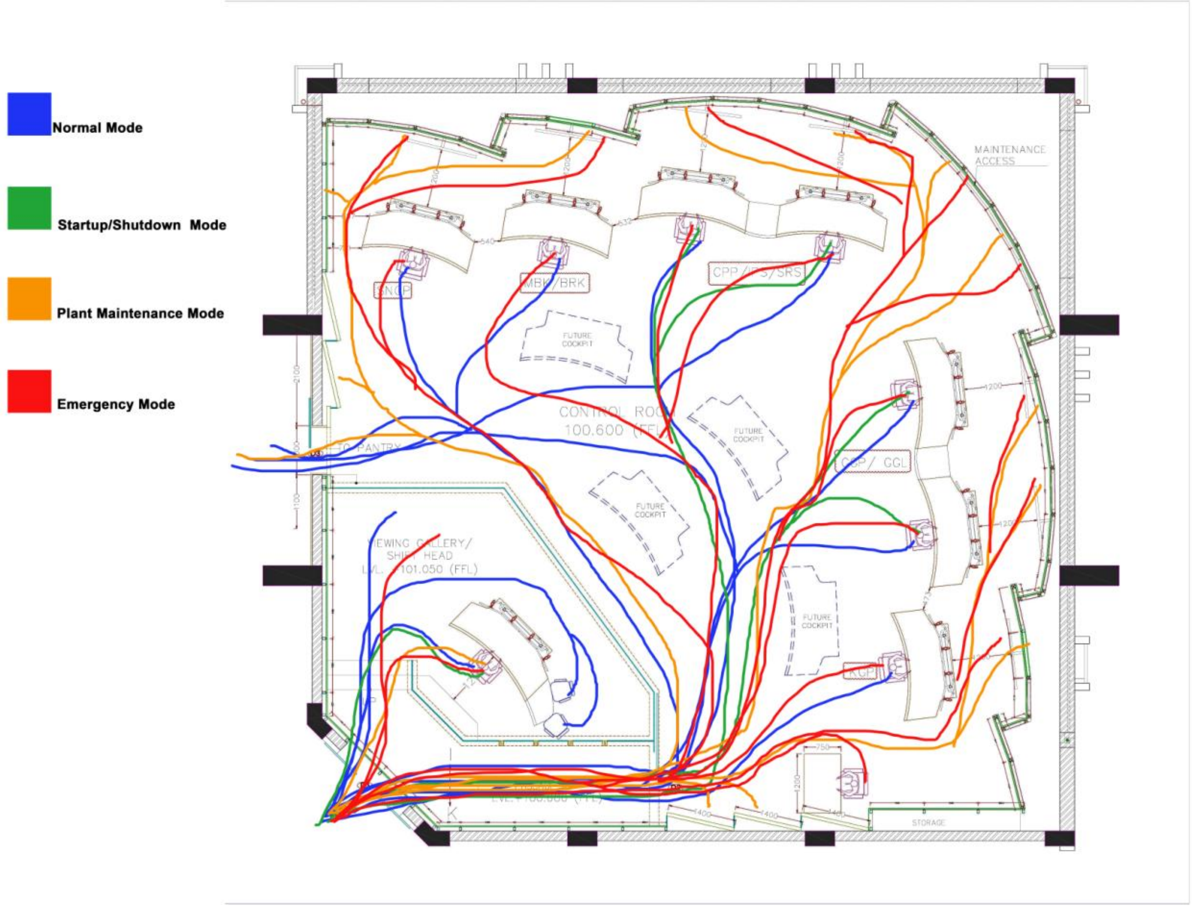
Generic points regarding structure design include:

- The structure should be suitable to withstand possible major hazards.
- It should be able to maintain plant control in emergencies
- It should have emergency exit at vantage points for safe evacuation, in case of emergency.
- With respect to building access, account should be taken of equipment as well as all personnel. In practice, this means that it shall be possible to transport equipment easily through the building. Free passageways of at least 1200 mm should be provided.
- Other personnel and visitors should enter the control building not via the plant entrance, but via a separate entrance (main entrance) and the central corridor.

Floor Space Engineering

The space allocation for control room is determined by:

- Space needed for the console configuration.
- Space for peripherals and other workplaces
- Space for large overview displays, if required
- Space for tiles
- Number of operators.
- Space for meetings
- Space for all support functions
- Space for administrative work, checking of drawings (‘manual table’), small meetings, etc.
- Space for utilities, administrative staff, false floored areas, visitors viewing areas to be allocated based on specific requirement of the control room.



Traffic Patterns in Different Modes (For Example)

Control Area

Control Section

Control area location should be such that there is minimum disruption to operators. The shift supervisor's room should be located in the immediate vicinity of the control room to facilitate the necessary functional and social contacts. The shift supervisor's room should not be accessible solely via the control room because the associated comings and goings would disturb the operator's concentration. Conference rooms should be provided in the control rooms for meeting, trainings etc.

Console Configuration

- Account shall be taken of future expansion when determining the console configuration.
- The configuration of the plant layout consoles in the control room shall conform with the course of the process, from left to right. This is particularly important for the alarm displays.
- The consoles should be grouped functionally for each part of.
- Consoles shall be located so that there are no annoying reflections on the screen (the lighting plan should therefore always be drawn up after the console layout has been determined).

- Arrangement of the consoles next to one another, or at right-angles to one another in a U- shape or in a C-shape is dependent on the number of operators manning the console section and the functioning relationship between the various parts of the process Each of these arrangements has its specific pros & cons
- Dual screens one above the other should not be used, as ergonomic studies have shown this arrangements to cause neck problems due constant straining of the head.
- The maximum number of actively used screens that an operator can physically operate in an upset situation is four next to one another(e.g. includes overview, detail and alarm annunciation screens). Screens for F&G & CCTV applications shall be provided adjacent to these screens. These factors, in conjunction with the number of operators needed in the control room, shall determine the console configuration.
- Console configuration should consider provision of equipment for all other systems communication devices such as PA system telephone as well as PC's for other applications such as laboratory systems administrative use and advanced process applications.
- Console design shall ensure provision of stress-free work surface, optimum equipment placement for reach and view distances and sufficient leg clearance as per ergonomic norms.

Environment factors and furnishing

HVAC

- HVAC system shall be chilled water based, with N+1 redundancy.
- Chiller plant shall be segregated from control center area such that any refrigerant leakage will not cause disturbance to the operations.
- Dual AHU room, each able to sustain the entire control load, shall be provided. AHU & ducting shall be designed with acoustic insulation to limit NC levels below 30db. If large screen displays are provided, care should be taken to maintain uniform temperatures on both sides of the screens
- Precision AC units shall be used for DCS & IT equipment halls. These shall have false floor with the volume below false floor being used as supply air plenum

Recommendation as per Annex A, A.2, ISO 11064-6:2005(E):

- Temperature: 20°C to 24°C
- Relative Humidity: 30% to 70%
- Mean Air Velocity: Less than 0.15 m/sec

Lights

It is preferable that the control room is not provided with windows and outside view. Due to the 24/7 nature of work environment, panel officers productivity may get affected as they view change from day to night & vice versa.
The Control Room, with video wall, high ceiling & large numbers of monitors, demands well designed lighting to ensure desired ambient light without inducing glare on monitors or video wall. Light intensity of the video wall plays an important role in the legibility of displayed text , necessitating careful selection of light fittings. Lighting in the Main Control Room shall be carefully designed to suit the specific layout of equipment with dimming facilities. Lighting level inside the control room shall be 500 lux.

In CCR areas where greater focus is wanted to highlight the display of items such as signage, artwork, or simply for visual interest, specific lighting may be used such as down lighter and as required to achieve

appropriate lux.
Creating visual interest, however still requires direct lighting fixtures such as LED and CFL can provide ascent lighting with lower power consumption. Level of illumination for CCR usually ranges from 200 to 700 lux on the horizontal plane.

In summary, CCRs shall be designed with lighting that is :-

- CRI>=80
- Glare Index (UGR) = 19
- Lux Level = Approx. 500 lx (Average Lux for whole CCR area)
- High frequency control gear for avoiding flicker.
- Dynamic Lighting can be use for better ergonomics
- (Light Color Temperature : 2400 K to 6500 K, Dimmable : 10% to 100%)

Acoustics

Recommendation as per **Annex A, A.5/A.6, ISO 11064-6:2005(E)**

- Ambient Noise: Less than 45 dB.
- Ceiling in Control Room: Acoustic Perforated Metal Grid False Ceiling
- Ceiling in Air Lock Room: Paint Finish
- Wall Paneling in Control Room and Air Lock Room: Insulated Sandwich Aluminum Panel
- Flooring in Control Room: Raised Flooring System consisting of metal pedestal base and head assemblies and inter-locking stringers with 600mm square panels having 1.5mm plastic lamination finish
- Flooring in Air Lock Room: 300mm x 300mm x 3mm Vinyl Tile

Technical Specification for Acoustic Environment

- Acceptable noise level: Less than 45 dB
- Surface reflectance of floor finish: 0.2 to 0.3
- Surface reflectance of wall finish: 0.5 to 0.6
- Surface reflectance of glazed area: 0.5 to 0.6
- Surface reflectance of ceiling: Minimum 0.8

Cable Routing & Access

Recommendations as per **Annex A, A.2, ISO 11064-2:2000(E)** and **Annex A, A.2, ISO 11064-6:2005(E):**

- There should be suitable temperature and illumination level for maintenance purpose.
- It has access for initial installation and future maintenance activities.
- Conduits/Cables Should not overlapping each other.
- Wires in each conduit reflected in conduit schedule are as per standards.

Material & Color

- When choosing the materials, account shall be taken of their acoustic properties (e.g. density of rubber), light (disturbing reflections) and temperature (old to the touch).
- When selecting floor covering, account shall be taken of ease of moving office chairs past the consoles, ease of cleaning.
- Control room shall have wear resistant, acoustic floor tiles with non- reflective finish.
- Fairly inconspicuous color should be chosen, particularly for the large

area (walls ceiling, etc.)

- The ceilings should be light-colored, the walls somewhat tinted, and the floor dark colored.

Overview Graphics

Overview Visualization

- Mission critical control rooms are increasingly being equipped with common overview visualization integrated with all control and automation systems. The main aim of this system is
- Situation awareness for operations groups and all stakeholders.
- Augmenting ability for quick handling of plant upsetsMotivation to operations groups.
- A single, titled large screen display shall be designed to be shared amongst plants/ process interdependent with each other. The displays on large screen shall be in addition to the operators display screens on consoles for DCS, F& G & CCTV systems and shall not duplicate the graphics on the console process control terminals.
- Provision of large screen display enhances collaboration in work environment and makes it possible for all stakeholders to view the same information simultaneously.
- There are two major HFE design factors for development of overview visualization:
- large Screen Display Design & Creation of Overview Graphics Data.

Large Screen Display Design-Ergonomics

Layout

- Layout design should consider the position of the operators during their work. The fact of placing the operator in front of the screen and behind a desk imposes a vertical position of the screen, which leads to a perfect view of the wall. The vertical position of the screens, the operators and the wall, its width and height determine the view angles of the operators.
- Rotation angel of the in vertical position It concerns the angle of the eventual rotation of the neck, in order to have a central view of the wall. How higher and nearer the wall is, how more important the vertical movements of the neck are. . The angle of rotation has to be evaluated for every operator. It depends on the observed point and of the place of observation.
- Rotation angle of the neck in horizontal position. It concerns the angle of the rotation of the neck to have a good view in the horizontal direction. The more the screen is wide & near, the more the horizontal movements of the neck are important.
- These criteria have to be respected in order to minimize the number of internal problems
- & headaches, which both cause unsatisfactory work and absenteeism. The comfort of utilization integrates the visual comfort and the physical stress:
- The visual comfort consists of a number of dimensions.
- Accessibility & visibility of the support
- Readability of the represented objects

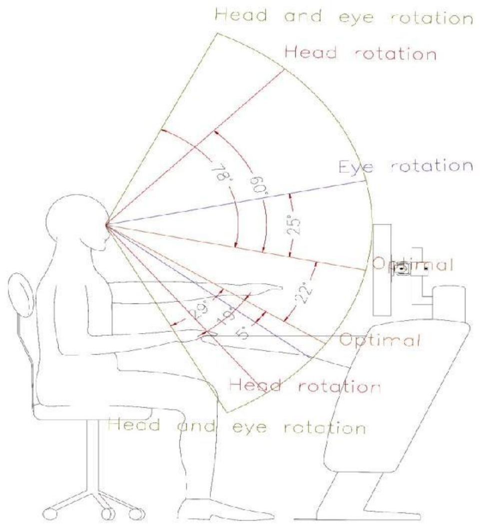
- Density of the displayed information and its structure
- Visual accommodation
- Perception of the colors
- Quality of the images, in terms of stability, physical resolution and distortion
- he physical stress for work
- The dynamic stress, related to a physical, dynamic effort (including a movement)
- The static stress, related to a physical, static effort (without physical movement)

Calculating Projected Image Size

Recommendations for projected image size are as follows:

Presentation Content	Nearest Viewer	Principal viewer	Furthest Viewer
Critical (spreadsheets command centre, Engineering workgroup, etc).	1.33X image height	3X image height	4X image height
General (training, presentation graphics etc).	2X image height	4X image height (if critical)	6X image height
Entertainment (video content)	2X image Height	NOT APPLICABLE	8X image

Optimum Viewing Angle for Human Eye



Uniformity

To make the display wall, consisting of multiple projection modules, look like a single display, uniformity shall be ensured both mechanical and optical design features.

- The gap between projection modules shall be maximum 3 mm so as to avoid black lines or mullions between the modules.
- Individual projection modules will have brightness uniformity and color uniformity that surpasses that of consumer grade display by an order of magnitude in order to make these modules match able
- The inter-cube uniformity of the projection modules shall be matched continuously by feedback mechanisms, algorithms and optical dimming in white, black grey and color over time. The central point of intelligence comparing projection module setting should collect all data and send out changes to settings if required.

Luminance levels

Based upon ergonomics, luminance levels of task areas should be within limitations so as to avoid excessive eye fatigue. Task areas are defined as areas that are to be viewed, while performing the subtasks in order to perform a certain task. These tasks are typical looking at workstation monitors, paper, and the display wall on-axis and off-axis. In order to ensure optimal task performance:

- The luminance level of the display wall will be similar to the luminance level of the other task area.
- In general, large luminance differences will be avoided. Luminance level are not too low and not to high.
- Luminance levels will also be in line with the overall luminance level of the surroundings (walls, ceilings, etc.)
- The average brightness of the display wall throughout the life of the lamp shall be 100 cd/m².

Readability & Contrast

The readability is determined by the on-screen contrast. The on function of the following parameters:

- Projector contrast,
- Screen reflection,
- Ambient lighting and direction,
- Luminance level (a function of viewing angle)
- Sharpness of the pixels.

Safety

Smoke Detectors

In general photoelectric type smoke detector shall be used.

The spacing of smoke detectors shall be in accordance with the guidelines stipulated by NFPA 72 or BS EN 54-7.

Photoelectric Type Detectors shall comprise of Transmitter and Receiver in common unit. The Transmitter shall project a modulated infra red beam to the Receiver where it is analyzed. The presence of smoke in the path will reduce the strength of the received signal.

As a minimum, smoke detectors shall be placed in the frequent location with respect to all enclosed room with CCR

Gaseous Agents

Generally requirements for gaseous fire fighting systems are covered by ISO 13702. Gaseous fire fighting systems shall also comply with the following requirements:

- Gaseous agents not harmful to humans are preferred. If noxious and poisonous gaseous systems (e.g. CO2) are used, it shall only be used for locked off rooms.
- The room where the gaseous agent is released shall be sufficiently tight to maintain the prescribed concentration for the pre-determined time period of minimum 10 min;
- The gas bottles shall be located outside of the protected room.

Conclusion

This Ergonomic Study is done as per ISO 11064 "Ergonomic Design of Control Centres". As our proposed design for CCR is preliminary, thus ergonomic report is based upon input information and our proposed preliminary design.

References

- ISO 7731, Ergonomics — Danger signals for public and work areas — Auditory danger signals
- ISO 7779, Acoustics — Measurement of airborne noise emitted by information technology and telecommunications equipment
- ISO/CIE 8995, Lighting of indoor work places
- ISO 9241-6, Ergonomic requirements for office work with visual display terminals (VDTs) — Part 6: Guidance on the work environment
- ISO 13731, Ergonomics of the thermal environment — Vocabulary and symbols
- IEC 60651, Sound level meters — Electromagnetic and electrostatic compatibility and test procedures
- ISO 6385, Ergonomic principles in the design of work system
- EN 614-1, Safety of machinery-Ergonomic Design Principles
- ISO 7250, Basic Human body measurement of technological design
- ISO 11064 - Part1, Principles for the design of control centers
- ISO 11064 - Part 2, Principles for the arrangement of control suites
- ISO 11064 - Part 3: Control room layout
- ISO 11064 - Part 4: Layout and dimensions of workstations
- ISO 11064 - Part 5, Displays and Controls
- ISO 11064 - Part 6: Environmental requirements for control centres
- ISO 11064 - Part 7: Principles for the evaluation of control centres

Biography

Mr. Sunil S Ladha was born in Udaipur, India in the year 1973. He Graduated from Pillai Collage of Architecture Mumbai in 1997.
Practicing from last 17 years as an architect and HFE & Ergonomic consultant for control rooms Design with experience of 150 control room designs in various sectors in India & abroad.

Karandikar Laboratories Pvt. Ltd.

Explosion Protection and Evaluation of Equipment used in Hazardous (explosive) areas.

By: Ajit Karandikar & Ravi Paranjpe – KARANDIKAR LABORATORIES Pvt. Ltd.

Karandikar Laboratories is an IECEx and NABL accredited test laboratory engaged in evaluation and testing of Electrical Equipment which is intended to be used in areas that are potentially explosive. As a test laboratory we are often asked by equipment manufacturers as to how to ensure that their product will meet the design requirements for hazardous / explosive area applications. It is observed that most product designers do not have a very clear understanding of – what the different explosion protection concepts are and how these concepts ensure protection against explosion.

The objective of this article is to bring about amongst product designers, a better understanding of –

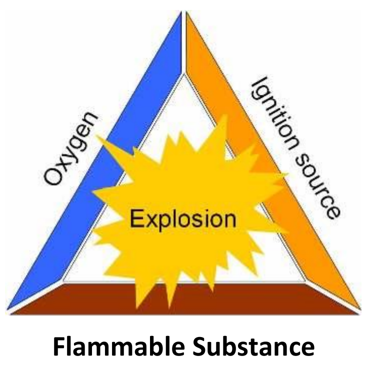
- What are these potentially hazardous areas
- Which type of protection concept should be chosen for the product they are designing and
- Which are the applicable standards to which the product should be designed and manufactured.

What are these potentially hazardous areas?

Hazardous Area, as the name suggests, is obviously an area that has a potential hazard present in it. However, it must be noted that for the context of this article, the only hazard that we will be talking about, is the hazard arising from 'Explosion'. The standards have defined a hazardous area as – ***an area in which an explosive atmosphere is present, or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.***

When we talk of explosive atmospheres we mean only those atmospheres that are made up of flammable gases, vapours, combustible dust, fibres or flyings which, after ignition, permits self-sustaining propagation.

It is necessary to understand that „Explosion" is basically a form of „Combustion". This tells us that for any atmosphere to be explosive we must also have, a source of Oxygen (air) present along with the flammable substance. You would have heard of the „Explosion Triangle" which is made up of three essential ingredients – Flammable substance, Oxygen and a source of Ignition. In the



Explosion Triangle

absence of any one of these there would be no explosion. It is also necessary to understand here, that just the presence of these three ingredients together is not enough reason for an explosion to occur. These three ingredients must be present in the right quantities and accordingly, for each flammable substance mixture in air (Oxygen) the right proportions or limits are established. The limits within which the flammable substance + air mixture is explosive is called its „Explosive Limits‟. All flammable gases have a „Lower Explosive Limit‟ (LEL) and an „Upper Explosive Limit‟ (UEL). Only when the flammable gas + air mixture is within these lower and upper explosive limits it is considered to be an explosive atmosphere.

Now, in a hazardous area an explosive atmosphere could be present but it may not be present to the same extent or with the same frequency or probability throughout the hazardous area. In view of this, every hazardous area is classified into Zones based on the frequency of the occurrence of an explosive atmosphere and also on the duration of an explosive being present.

The standard definitions and nomenclatures of zones for gases and dusts is as given in the table below

Zones		Broad Definitions of Zones
Gases	Dusts	
0	20	Explosive atmospheres are present continuously or for long periods or frequently
1	21	Explosive atmospheres are likely to occur in normal operation occasionally
2	22	Explosive atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

TYPES OF PROTECTION – ELECTRICAL EQUIPMENT

There are nine types of protection currently recognised for electrical equipment, all of which are supported by the "General Requirements" given in IS/IEC 60079-0. This standard contains requirements that apply to more than one type of protection. The requirements given in this standard include - limitations of light metals, Temperature control, aging effects on non-metallic materials (for example UV exposure and medium term exposure at high humidity and high temperature), minimising electrostatic sparking from highly insulated parts and limitation of RF output from communications equipment. Each of the types of protection is also designated by a letter which is included in the marking of the equipment in the way specified in IS/IEC 60079-0.

The principles underlying the specific type of protections are all based on the Explosion Triangle which gives us the equation:

Flammable substance + Oxygen + Ignition = EXPLOSION

In the above equation if we remove or eliminate any one ingredient or factor from the RHS then it will never result in an explosion. Hence the equipment is designed in such a manner that we should achieve at least one of the following…

- Avoid creating an explosive atmosphere i.e there is no Flammable substance
- Avoid igniting an explosive atmosphere i.e there is no source of Ignition

And if we cannot achieve the above two options and if an explosion is inevitable then…

- Allow an explosion to occur but ensure that it does so safely

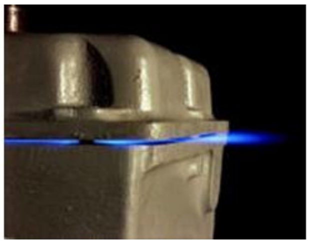
Let us see how this works in each of the specific protection concepts given below:

TYPE OF PROTECTION "FLAMEPROOF"
Ex d – IS/IEC 60079-1

The concept is simple – it works on the principle that - we cannot avoid the flammable atmosphere and neither can we avoid the source of ignition so we work towards the third option i.e. allow an explosion to happen but ensure that the explosion does not come out of the equipment and ignite the external explosive atmosphere.

In this Flameproof Protection concept we put the electrical equipment (i.e. the source of ignition) that needs to be protected in a strong enclosure that is capable of withstanding an internal explosion without bursting or without allowing the escaping hot gasses to ignite an external explosive atmosphere. Because of the simplicity of the concept, this protection concept is one of the most widely used.

The design characteristics of the Flameproof enclosure need to allow for **SAFE VENTING** of the internal explosion hence great care needs to be taken to ensure adequate strength of the enclosure and proper flamepath lengths and gaps. While, the internal components that are placed inside the flameproof enclosure can be normal industrial items (i.e. uncertified items), care needs to be taken regarding the positioning of these items as, the internal geometry can dramatically change the explosion pressures developed. This therefore, compromises the ability of the enclosure to withstand the internal explosion. A particularly inappropriate arrangement of the contents can more than double the explosion pressure. A number of manufacturers sell empty enclosures with component certification. These certified components can be used for placing of other items inside it but will then need to be evaluated and tested again by a certification body before the final equipment is deemed as certified. Additionally, there are specific limitations on batteries which might vent hydrogen and/or oxygen into the enclosure and create even higher pressures.



Component manufacturers can supply component certified items such as pushbutton actuators and indicator lamps that penetrate the walls of the enclosure.

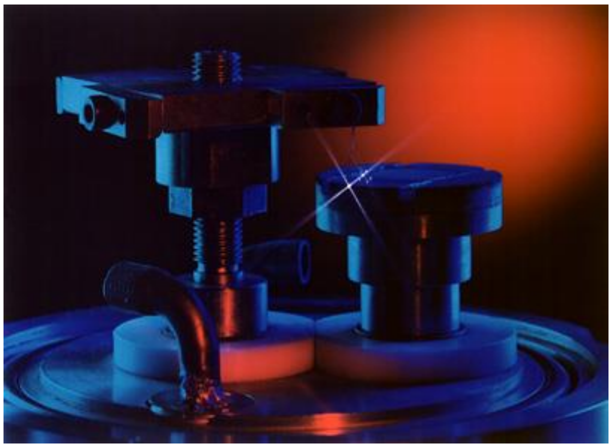
Component certified flameproof switch blocks are readily available for inclusion within enclosures of other types of protection where sparking contacts would otherwise not be acceptable. Although most flameproof equipment is built in a metal enclosure, some smaller items can be made from plastic materials but additional tests are required to ensure that "flame erosion" will not defeat the protection.

The testing regime for flameproof equipment mainly includes, impact test, actual explosion test with hazardous gases, hydro overpressure test and test for non-transmission of internal ignition.

TYPE OF PROTECTION "INTRINSIC SAFETY"
Ex i – IS/IEC 60079-11

The Intrinsically Safe protection concept works on the principle – eliminate the source of Ignition. If there is no source of ignition then there cannot be any explosion. Does this mean that intrinsically safe equipment does not spark at all? No, there could be sparking but the energy in the spark is so low that it is incapable of igniting any flammable substance.

In contrast to flameproof, an intrinsically safe item of equipment will have to be studied at the component level on the circuit board to ensure, that any possible sparking due to faults on the board, is at an energy level below the Minimum Ignition Energy of the explosive atmosphere for which the equipment is designed. It is assumed



Spark Test Apparatus

that the gas has access to all components and that any ignition will lead to a full explosion.

Energy is controlled by voltage and current limitation, and by protection of energy storage components such as inductors, capacitors and batteries. Complex circuits may have to be broken down into component parts, with energy limitation applied separately to each part in order to have a design that is safe but is still capable of carrying out its designed function. Temperature of individual components is controlled and some components are specifically derated as "safety components". Typical circuits will operate at design voltages of 24 volts or less and consume no more than 1.3 watts of power. A detailed analysis of both the schematic circuit and its physical layout are required and it is common for circuit boards to require modification after the first analysis.

Unlike the other types of protection, unless battery powered, intrinsically safe equipment requires to be supplied from the "safe" area by a suitably limited power supply. This is often referred to as a "barrier" as its function is to prevent excessive energy getting to the intrinsically safe circuit. Barrier design can be simple or complex, depending on the exact function, and there are a number of manufacturers who specialise in designing and selling barriers for specific purposes.

TYPE OF PROTECTION "INCREASED SAFETY" Ex e – IS/IEC 60079-7

The Increased Safety protection concept works on completely eliminating the source of Ignition from the equipment. Increased Safety can only be applied to equipment which has controlled temperatures and a total absence of any sparking in normal operation. Thus the standard can be applied to an induction motor but not to a commutator motor.

Luminaires and junction boxes are also commonly designed to meet the requirements of the standard.

Typical design requirements include: especially secure terminals that won‟t come loose under conditions of vibration; enhanced electrical segregation; thermal de-rating of insulating materials, as well as many specific requirements for particular types of equipment. Most equipment is housed in a strong dust and water resistant (IP 54) enclosure, to prevent the outside environment contaminating the equipment, but which neither keeps the gas out nor will withstand an internal explosion.

TYPE OF PROTECTION "ENCAPSULATION" Ex m – IS/IEC 60079-18

This protection concept is based on the principle of – keeping the flammable substance away from the source of ignition. By encapsulating the equipment in potting compound, the explosive atmosphere is kept away from the electric circuits. Some attention has to be given to potential faults in the circuit and most

often the simplest way is to include in-built thermal fuses in series with the supply lines that will permanently disconnect the equipment if there is a fault. There are many requirements on the potting compound and the distances through it, both to the outside surface and between parts of the circuit.

TYPE OF PROTECTION "PRESSURISATION"
Ex p – IS/IEC 60079-2

This protection concept works on the principle of removal of the flammable substance. This type of protection is unique in that it relies on keeping the external explosive atmosphere from getting into the protected equipment. The equipment is pressurised or continuously purged with air from a safe area or an inert gas and it is ensured that the pressure inside the equipment is always higher that the external atmospheric pressure. This ensures that the external explosive atmosphere is never able to enter the equipment and cone in contact with the sources of ignition inside the equipment. Therefore the equipment must be accompanied by a suitable control device that supervises the "purging" part of the cycle and will shut the equipment down if the pressurisation source fails. The source may be a local supply of "instrument air" or a bottle of an inert gas, such as nitrogen.

For large equipment, a significant amount of the purging medium is required to clear out any explosive atmosphere before the equipment can be switched on. This time delay (usually between 5 and 30 minutes but sometimes longer) can mean that pressurisation is not viable for equipment that must be started quickly. The cost of the controller and the requirement to supply the purging/ pressurisation medium mean that this type of protection is not favoured for smaller equipment where other types of protection can be applied. Specialist control panels (particularly those requiring a gas line to be passed through them) and large electric motors are among the favoured applications.

Normally sparking equipment is easily accommodated in this type of protection, as sparking will cease immediately when the equipment is de-energised. However, equipment with hot surfaces may be a problem as one has to ensure that the hot surface has cooled to a temperature below the auto ignition temperature of the surrounding explosive gas which might get in if the pressurisation fails. Thus the internal, rather than the external, temperature is usually taken as the limiting factor.

TYPE OF PROTECTION "NON-SPARKING"
Ex n – IS/IEC 60079-15

Non-Sparking protection concept as the name suggests is based on the principle of removing the source of Ignition in normal operation. This protection concept can be considered as a lighter version of the Increased Safety protection concept as its evaluation considers mostly normal working. Hence this protection concept is allowed to be used only in zone 2 wherein the probability of explosive substances being present is very little.

Currently the Increased Safety Standard is being revised to incorporate Ex nA equipment, with the designation Ex ec. The one section of the standard unique in principle to Ex n is "Restricted Breathing". Here the equipment may, within specific limitations, have some sparking and some hot surfaces, but the enclosure is sufficiently well sealed that in the time an explosive gas atmosphere may be present in Zone 2, insufficient quantities of it can breathe / penetrate into the enclosure to create an explosion. This equipment is marked as Ex nR. "Enclosed Break" (Ex nD) is a form of "Flameproof Lite" and will be transferred to the Flameproof standard as Ex dc.

"PROTECTION BY ENCLOSURE FOR EXPLOSIVE DUST ATMOSPHERES"
Ex t – IS/IEC 60079-31

This concept of protection against explosions of dust atmospheres again uses the principle of keeping the explosive dust atmosphere out of the enclosure. Unlike gas, combustible dust can be considered as not being able to enter an enclosure if adequate level of Ingress Protection is provided. This standard tabulates different degrees of Ingress Protection and different ways of considering temperature based on the Zone of hazard

There are other protection concepts like Oil Filled (Exo), Powder filled (Exq) however these do not find much application in the industry today.

CERTIFICATION STANDARDS

The good news is that now India has now harmonised most of the standards pertaining to equipment used in hazardous areas. The International Electrotechnical Commission has published the IEC 60079 series of standards and India has adopted these and re-published them as Indian standards prefixed as IS/IEC 60079. The publishing of these standards however, have not kept pace with the publishing of the international IEC series and in most cases, we are still using around 1 to 2 earlier editions. The European (EN) standards are also harmonised with the IEC standards and these in most cases identical to the latest IEC standards versions.

The table below gives the current standards that are applicable to the different certification schemes like IECEx, ATEX and Indian:

Standard No.	Current IECEx Standard	Current ATEX Standard	Current Indian Standard
60079-0	IEC 60079-0: 2011	EN 60079-0:2012	IS/IEC 60079-0:2007
60079-1	IEC 60079-1: 2014	EN 60079-1:2007	IS/IEC 60079-1:2007
60079-2	IEC 60079-2: 2014	EN 60079-2:2007	IS/IEC 60079-2:2007
60079-5	IEC 60079-5: 2007	EN 60079-5:2007	IS/IEC 60079-5:2007
60079-6	IEC 60079-6: 2007	EN 60079-6:2007	IS/IEC 60079-6:2007
60079-7	IEC 60079-7: 2007	EN 60079-7:2007	IS/IEC 60079-7:2007
60079-11	IEC 60079-11: 2011	EN 60079-11:2012	IS/IEC 60079-11:2006
60079-15	IEC 60079-15: 2010	EN 60079-15:2010	IS/IEC 60079-15:2005
60079-18	IEC 60079-18: 2009	EN 60079-18:2009	IS/IEC 60079-18:2009
60079-19	IEC 60079-19: 2010	EN 60079-19:2012	IS/IEC 60079-19:2006
60079-25	IEC 60079-25: 2010	EN 60079-25:2010	IS/IEC 60079-25:2003
60079-31	IEC 60079-31: 2013	EN 60079-31:2009	IS/IEC 60079-31:2008

Measure Ultra-Low Emissions Accurately and Reliably with Extractive CEMS Using Nafion-Based Sample Conditioning Systems

Sanjeev Rai, Perma Pure India
Jeffrey Li, Perma Pure China
Eugene Bohensky, Perma Pure USA

Abstract

This paper presents the suitability of Nafion-based sample conditioning systems for low-level pollutant gas measurement with extractive CEMS. Flue Gas Desulphurization (FGD) and Selective Catalytic Reduction (SCR) can reduce flue gas SOx and NOx content, respectively, by more than 90%. These lower levels require analysers that measure the SOx and NOx pollutants in concentrations less than 50 ppm. In the extractive cooler-based sample conditioning system, a percentage of analytes are lost due to their solubility in the small quantities of liquid water always present in such systems. This renders them unsuitable for low-level measurement of soluble analytes. Nafion-based dryers remove moisture in vapor phase, thus reducing the loss of soluble analytes as no liquid water is normally present in these systems. In this paper, real world experience with Nafion-based sample conditioning systems is presented that demonstrates their ability to preserve the analyte levels in emissions and process monitoring gas samples and allow highly accurate results over a long service life. This experience provides power plants and refineries the confidence to deploy superior systems that both improve measurement accuracy and analyzer reliability (by preventing liquid water from entering the analyser).

Table of Contents

Introduction

In order to keep pace with the world's ever-growing energy demand, new power plants, new refineries, and expansion projects at such facilities are very common in emerging economies like India and China. These new and expanded plants are adding to the ever-increasing air pollution, forcing the regulatory bodies to establish stricter emissions limits and, in turn, pushing analyzer companies to develop equipment capable of making accurate measurements of these lowered levels. In India, the Central Pollution Control Board has made it mandatory to install Continuous Emission Monitoring Systems and send the online data to state pollution boards. The new regulatory norms establish the need to have reliable and accurate CEMS which work with minimal maintenance so as not to burden the plants' staff with additional tasks.

The current CEMS industry in developing nations like India is in evolution stage with no single dominating technology. Gas sample conditioning systems are the most important component in the extractive CEMS and they are most often ignored by the specifier. Common techniques are dilution, extractive sampling and in-situ measurement of pollutant gases. Traditionally, condensing technology for removal of moisture from extracted sample gas had been dominating the market, mainly due to its low cost relative to expensive in-situ equipment. Condensing systems face several persistent problems due to the need for dust removal, inability to handle high moisture levels, and reduced performance at high ambient temperatures, resulting in a high maintenance load, high failure rate, and inaccurate measurement due to moisture interference inside the analyzer.

Test methods (*EPA test methods 6C -SO_2, 7E -NOx and EN 14791:2005 – SO_2, EN 14792:2006 – NOx)* for measurement of these pollutants typically require the removal of moisture since water vapor interferes with a range of commonly used analyzer techniques - UV absorbance, chemiluminesence and non-dispersive infrared (NDIR). Low-quality gas conditioning systems that use condensation-based thermoelectric (Peltier) coolers or compressor coolers for moisture removal have been popular due to their low price and ability to effectively condition gas samples with high pollutant levels in limited situations. However, in real world applications all cooler-based systems have significant challenges conditioning gases containing SO_2 because SO_2 has a high water solubility and there will always be a small quantity of liquid water trapped in the bottom of the heat exchanger (impinger) in which the sample gas is cooled. The loss of even small amounts of SO_2 from the sample can lead to misleadingly low SO_2 readings being reported to state regulators. Government inspectors testing the accuracy of the plants' reporting may issue citations or impose fines if the reported pollutant levels do not match what is actually being emitted from the stack.

Efforts to improve the accuracy of measuring SO_2 using injection of H_3PO_4 have also been made but this technique is extremely complex and expensive to use on a long-term basis. The injection of H_3PO_4 into the heated sample using a peristaltic pump upstream of the cooler helps saturate the condensate and reduces the amount of SO_2 removed, but compared with Nafion conditioning systems, the H_3PO_4 injection technique is far less consistent in getting accurate results and is a more costly process to manage and run.

Accurate measurement of all pollutants is increasingly becoming a global responsibility. Accurate measurement allows operators to better manage their pollution control systems, ultimately leading to the reduction of SOx and NOx emissions and a higher overall quality-of-life for the global population. Accurate measurement can only be achieved through effective, consistent gas sample conditioning.

CEMS Operating Conditions Challenging for Condensing Coolers

There are three main issues facing users of condensing coolers in their Sample Conditioning Systems.

1) **The Solubility Problem**

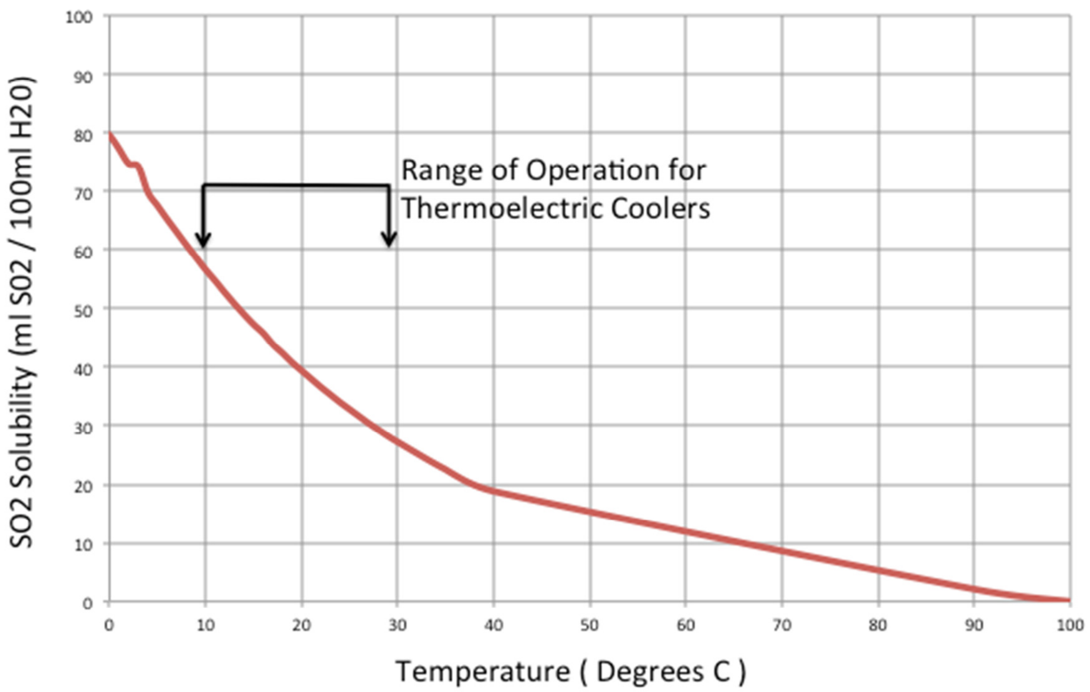


Figure 1:SO2 Solubility in Water

As seen in the chart, SO_2 is extremely soluble in water at lower temperatures. Most chillers / coolers are designed to have an outlet temperature of 4C, and thus lose high levels of SO_2 in the 4C water at the base of the heat exchanger. In reality, most condensation systems are undersized for the task at hand as a way to reduce cost, resulting in an outlet temperature typically in the 10C-30C range. While slightly less soluble at these temperatures, large amounts of SO_2 are still lost[i]. In practice, measurements below 50 ppm are simply not practical with this technology. To get around this problem, methods have been developed to continuously inject an amount of phosphoric acid into the cooler condensate to keep the acidity high. Although this improves accuracy somewhat on the low end of the scale, such systems have proven difficult to operate. Additionally, other gases that have high water solubility like HCl are also almost impossible to measure using condensing coolers since all of the HCl will be removed with water[ii].

Although hot-sample analyzers have been used to overcome this problem, keeping the gas sample hot until after it is analyzed tends to be very expensive and is often plagued with reliability issues. As monitoring requirements have become more stringent, requiring measurements in the 0-100ppm range, it has become increasingly difficult to get accurate measurement using condensing coolers. Unfortunately the error in the measurements tends to make them lower than their actual values, and the dirty secret is these lower measurements make compliance easier, to the detriment of the environment.

2) Known Issues Affecting Cooler Reliability

In complex combustion processes, which burn fuels containing sulfur, sulfur dioxide is produced. Oxygen levels present in the stack result in a sulfur trioxide level that is about 10% of the sulfur dioxide level. Sulfur trioxide when cooled reacts readily with water to form sulfuric acid. Sulfur dioxide can also form sulfuric acid in a two-step process in the presence of nitrogen oxide, oxygen and water. This implies that even if NOx levels are high enough, sulfuric acid may be formed.[iii]

$$2SO_2 + O_2 \rightarrow 2SO_3$$

$$SO_3 + H_2O \rightarrow H_2SO_4$$

$$NO_2 + SO_2 + H_2O \rightarrow H_2SO_4 + NO$$

At elevated temperatures, sulfuric acid is present only as vapor but as the gas is cooled below the *acid dew point*, tiny droplets of sulfuric acid are formed which cause damage to analyzer components and lead to corrosion or clogging of the system. Since acid dew points are typically below 150C, sulfuric acid is not removed by filters in stack probes operating at 180C-190C. It frequently condenses in the metal heat exchangers of cooler-based systems, causing immediate and severe corrosion damage to the cooler, and often, to the analyzer itself.

Sulfuric acid in the gaseous form does not usually cause any problems but when it condenses to form acid mists at ambient temperature, damage to the system is almost certain. The total dew point of a gas sample containing water and sulfuric acid can be calculated using the following equation[iv]:

$$1000 / TDP = 2.276 - 0.0294 \ln(PH2O) - 0.0858 \ln(PH2SO4) + 0.06062 \ln(PH2O) \ln(PH2SO4)$$

Where TDP = dew point temperature in degrees Kelvin
P = partial pressure in mm Hg

Although the equation is tedious to use, it does show that water content and acid both contribute to the total gas dew point. Just lowering the water content may not always be enough to prevent the formation of acid mists and lowering the concentration of sulfuric acid along with the water is often required.

Coolers have difficulty in removing very fine acid mists because the short time spent by the sample going through the cool zone of the system is not enough to remove sulfuric acid. This leads to reliability problems with the sample lines, coolers and critical analyzer components. The acid has been known to corrode the internal components of the cooler, affecting its performance and destroying the sensitive sensor elements of the analyzer.

Standard coolers are used for flue gases generated from combustion processes. Where coal is the fuel the flue gas generally contains 10-12% water and up to 22% when natural gas is the fuel. If the flue gas is processed through a wet scrubber system to reduce particulates it will have a much higher water content of 40-60% or more. This goes well beyond the capacity of standard coolers as the peristaltic drain pumps cannot remove the condensed water quickly enough to prevent carryover into the analyzer.

3) Limited operating range

A common issue faced by thermoelectric coolers is that they are only able to operate in ambient conditions up to 40C (103F) and are not able to withstand more severe (hot, humid) conditions found in many applications. This can often mean additional air conditioning is required for the system - or in cases where the temperature is consistently around 40C - cooler performance is significantly affected. Outlet dew point typically rises 1C for each 1C rise in ambient temperature above 40C. For example, a properly-sized cooler will reduce the sample temperature to 4C if ambient temperature is 40C or less. If ambient temperature rises to 50C (a 10C increase) then the cooler output will also rise by 10C to 14C. This may be enough to cause condensation issues in other areas of the system.

About Nafion-based Gas Conditioning Systems

Nafion-based gas conditioning systems utilize a gas sample dryer made from Nafion tubing to selectively remove moisture from the sample gas. Nafion is a copolymer of Teflon and sulfonic acid, and is highly resistant to chemical attack while selectively permeating water through the membrane. Nafion removes water by absorption as water-of-hydration. This absorption occurs as a First Order Kinetic reaction, so equilibrium is reached very quickly (typically with in milliseconds). Because this is a specific chemical reaction with water, the process is very selective and gases being dried or processed are usually entirely unaffected[v]

Gas conditioning systems utilizing this dryer technology have been developed specifically for the harsh operating conditions found in CEMS applications. Such systems have now been produced for nearly 40 years, and a few have remained in continuous service for over twenty years. During this time much experience has been collected and refinements have been made to improve reliability of our conditioning system designs. Now systems control sample temperature, remove excess water and particulates, and produce a cool, clean, and dry sample for the analyzer.

Figure 2:GASS 6080 Conditioning System

Figure 2: GASS 6080 Appearance

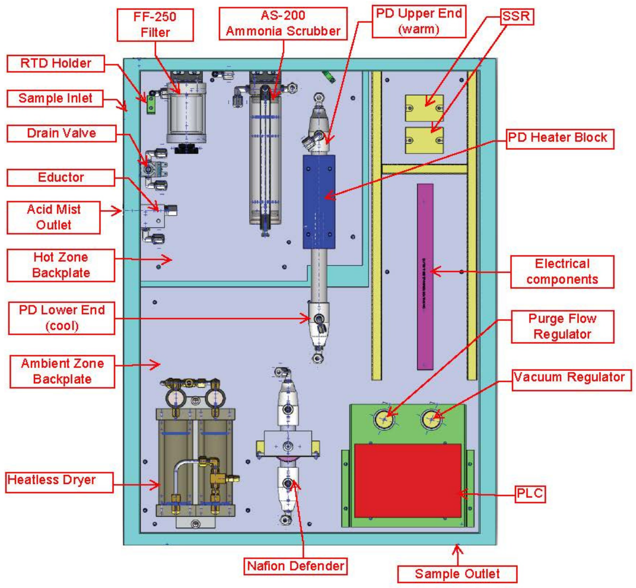


Figure 3: GASS 6080 Components

There are two temperature control zones within the GASS-6080's sealed NEMA-4X enclosure. The first temperature zone (see Figure 3, hot zone) is maintained at 90 ~ 95 ℃, to make sure the flue gas condensation does not occur in this area. The Nafion in the first zone is maintained at temperature of ~95C. As the sample travels through the dryer it loses more than 50% of the moisture. In the second temperature control area, as the sample gas continues to flow through the dryer, additional moisture is removed and the dew point of the flue gas after the Nafion dryer typically reduced to ~ -5 ℃. In certain cases, systems can be designed with an outlet dew point of -20C or lower to better meet process monitoring needs, GASS-6080 systems can be installed directly on to the stack, the closer to the sample take-out point the better so as to avoid any condensation in malfunctioning or poorly maintained heated sample lines. After the flue gas is extracted from the stack, residual dust is immediately removed prior to the dehumidification process. Since the moisture is removed at the stack heated pipelines are not required to transport the sample from the sample point (probe) to the analyzer shelter at ground level. The only utilities needed are 220V power supply (for heaters and PLC) and 0.6 ~ 0.8MPa no oil, no particulate matter compressed air for the system used to produce instrument air.

Technology Innovation Review GASS -6080

- Problems caused by precipitation of the condensate are solved since moisture removal occurs in the vapor phase
- Problems caused by the SO_3 mist are solved by using 0.1 micron coalescing filter to capture condensing sulfuric acid without removing other analytes of interest
- SO_2 measurement accuracy is greatly enhanced by removing the moisture in vapor phase thus minimizing the SO_2 dissolution issue.
- Real-time dew point monitoring of the sample gas leaving the GASS-6080 system assures that the analyzer can be protected from condensation in upset conditions

A major advantage of these systems is the ability to mount them on the stack via a common pipe flange to allow the sample to be conditioned immediately. End users have experienced both savings in installation costs by reducing the length of heated sample lines, and lower running costs as the quick response during analytical calibrations saves the expensive calibration gas.

Experimental Validation of System Performance

In order to prove the basic performance claim of Nafion gas sample conditioning, a comparison was conducted of the performance of condensing coolers and dryers based on Nafion's permeation properties to verify the difference in performance in a laboratory setting. [vi]

The concentration of SO_2 of several test gas mixtures was measured after treatment by the two sample conditioning systems to determine the amount of SO_2 lost during the conditioning process. SO_2 was quantitatively spiked into hot, wet gas streams to achieve wet basis concentrations of approximately 20, 50, and 100ppm at moisture concentrations of 0%, 15%, and 30%. The gases were then treated by each sample conditioning system and the concentration of SO_2 of the dried gas was measured using an ultraviolet analyzer and a FTIR spectrometer.

The experiments conclusively proved that under each condition, Nafion-based dryers performed better than the thermoelectric cooler in terms of the transport of SO_2, particularly at higher moisture levels. Results from the experiments are shown below:[vii]