

# Modular Integration of Process Equipment Packages for Oil and Gas Facilities

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**Abstract** - An integrated design approach to a modular process equipment package is discussed. By incorporating the electrical, instrumentation and control equipment on the same platform as the process equipment, a higher level of modular integration is achieved. The benefits include a reduced number of on-site equipment terminations and the ability to pre-commission equipment prior to field installation. The area classification, installation and transit barrier requirements for an integrated modular design approach are reviewed.

**Index Terms** – cable termination, hazardous area classification, modular integration, process building design, cable transit, vapor barrier, cable entry

## I. INTRODUCTION

Prefabricated modular buildings are extensively used for skid packages in both upstream and downstream oil and gas facilities. A typical skid package may incorporate process vessels, compressors, pumps manifolds and other miscellaneous equipment handling flammable materials. The interiors of such buildings are usually classified as hazardous locations in accordance with API RP 500[1], API RP 505[2] or IEC 60079-10-1[3]. Once a process module has been classified, the certification of electrical equipment and the wiring methods are impacted in accordance with the relevant installation codes within the jurisdiction of the installation.

Switchgear, motor control centers and process control equipment are typically designed for installation in a non-hazardous location. This requires that the equipment be located off-skid, usually in a remote building location. The electrical equipment connections are then completed on-site when the skid modules are set in place. This approach requires that the interconnection, commissioning and testing of the systems be performed on-site. This can be both expensive and time consuming depending on the location and project logistics.

What if the process equipment and the protection, instrumentation and control equipment could be installed on the same skid assembly? This would permit the wiring connections to be completed at the fabrication facility and allow the pre-commissioning of process equipment in a controlled environment. It would reduce on-site labor and improve quality by allowing the majority of work to be done in a factory controlled environment. This would ultimately reduce overall installation costs. Is there some way of promoting this design concept?

There are several options with respect to the area classification design, building layout, and the construction methods used to implement the integrated design concept. This paper looks at ways of executing an integrated process package design where both process equipment and electrical, instrumentation and control equipment are installed on a common skid package.

## II. STANDARD MODULAR PROCESS PACKAGE CONCEPT

A typical oil and gas process skid package will incorporate only the process equipment. This is primarily due to the requirement to classify the immediate area surrounding the process equipment for hazardous area classification purposes. Depending on the probability of a release and the level of ventilation available, a process skid may be classified Class I Division 1 or Class I Division 2 using API RP 500 as a basis for design, or Zone 1 or Zone 2 using API RP 505 or IEC 60079-10-1 as a design reference.

Once the process module has been classified as a hazardous location, the electrical and instrumentation equipment must be certified for location. Hazardous location certified equipment is typically more costly and often of limited availability. For this reason, the majority of the electrical and control equipment is located off-skid in a non-hazardous location with only the end device sensors located on the process skid. This results in a large number of wiring interconnections that must be completed in the field. Fig. 1 illustrates a typical design approach to a modular oil and gas process package.

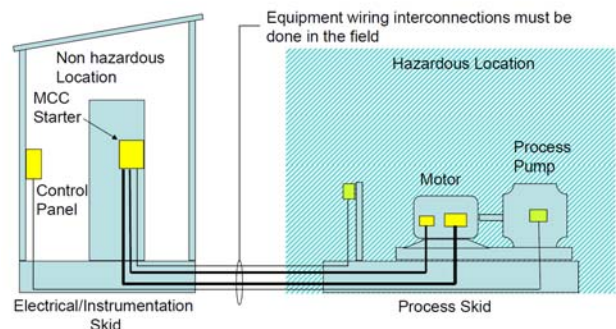


Fig. 1  
Standard Modular Process Skid Design Concept

### III. INTEGRATED MODULAR PROCESS PACKAGE CONCEPT

The integrated modular design package concept incorporates all process, instrument, electrical and control systems on a common skid. To install non-hazardous location certified utility, electrical and control equipment on a process skid handling flammable materials, a “safe” area must be created. The design of the safe area is part of the hazardous area classification design for the skid package. This can be accomplished in one of three ways.

1. Physically separate the non-hazardous location from the hazardous location on a common skid.
2. Create a positive pressure zone within the hazardous location to prevent the migration of flammable gas/vapours into the non-hazardous location.
3. Incorporate the use of a physical barrier to segregate the hazardous location from the non-hazardous location.

#### A. Option 1 – Physical Separation

Option 1 separates the hazardous location from the non-hazardous location by distance. A building incorporating the electrical and control equipment is located outside the classified area on a common skid. The distance between the buildings and the process equipment is determined by the extent of area classification design for process equipment. This is a function of the process parameters and vapor density of the flammable materials and the level of ventilation within the immediate area. Fig. 2 illustrates this concept.

The primary disadvantage of using distance as means to separate a hazardous from the non-hazardous location is the size of overall skid package is increased impacting the size and weight of the shipping envelope.

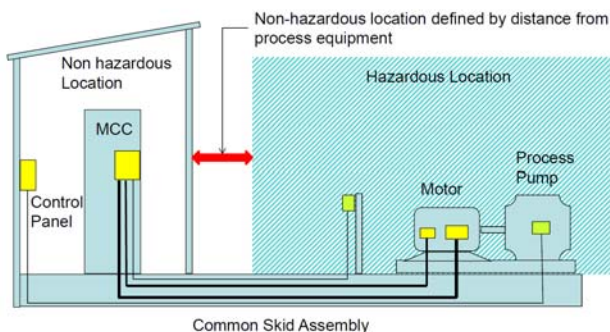


Fig. 2

Option 1 – Integrated Design using Physical Separation

#### B. Option 2 – Pressurized Control Building within a Classified Area

Option 2 involves creating a non-hazardous location within a process unit by using a positive air purge. An enclosed building is pressurized to a value slightly beyond normal ambient pressure to prevent any flammable fugitive emissions from entering the designated non-hazardous location.

The requirements for a pressurized building are defined in IEC 60079-13[4] and Chapter 7 of NFPA 496[5]. The basic requirements for a purged room or building as defined by IEC 60079-13 are as follows:

1. The positive pressure air system must provide 25pa (0.1 inch WC) of pressure with 50% of all outlets opened. The minimum air velocity through an open door is 0.3 m/s. This requirement may require the use of an air lock entry system.
2. The purge system must be monitored by a pressure or flow switch. If flow detection is not possible at the outlet, gas detectors shall be used to ensure that the air within the room is at or below 25 % of the lower flammable limit (LFL).
3. All safety devices, the pressurization system and its controls and the electrical isolation means, system fan and motor shall be suitable for the area external to the room unless located in a non-hazardous area.
4. The purge volume for pressurization and for general artificial ventilation shall be a minimum of 10 room volumes. The purging flow rate is required to be a minimum of 5 air changes per hour.
5. In the event of an interruption to the purge system, a procedure is required to prevent equipment from becoming potential ignition sources.
6. The pressurization system is required to energized independently from the electrical power to the room.
7. The entry of cables, electrical conduits and other penetrations into the room is required to be sealed so that the necessary pressure differential or ventilation integrity can be maintained.
8. Personnel access doors are required to be automatically self-closing, close fitting and designed to close and latch against the normal pressure differential. Restricted access doors are not required to be self-closing.

Depending on if the unclassified room or building is located in a Zone 1 or Zone 2 location, additional requirements will apply. Within a Zone 1 location, a type ‘px’ purge is required. A type ‘px’ purge requires that the source air for the purge system be sourced from a non-hazardous location. In the event of a pressurization system failure, all equipment not certified for a Zone 1 location must be de-energized. The concept is illustrated in Fig. 3.

Within a Zone 2 location, a type ‘pz’ purge is required. Although it is preferable that the purge air for a type ‘pz’ system be sourced from a non-hazardous area the standard does allow air from a Zone 2 classified area to be used as a source of air for the purge system as illustrated in Fig. 4. Under such conditions, the air intake to the room must incorporate combustible gas detection. Gas detection on the air intake system must be configured to shut down the air source if the combustible gas LFL value exceeds

40%. The supply fan and motor, gas detection and all other equipment used for alarming and emergency actions/interlocks are required to be certified components suitable for installation in a Zone 2 location.

Upon failure of a type 'pz' purge system, power to the room may be maintained for a limited duration. If the pressurization system is not restored following this limited duration period, power to the room is de-energized to all equipment within the room not certified for a Zone 2 location.

The purged building option is often used when the non-hazardous building or room is surrounded on all sides by a hazardous location. This is often the case where the non-hazardous location resides within the classified boundaries of a large refinery or petrochemical complex.

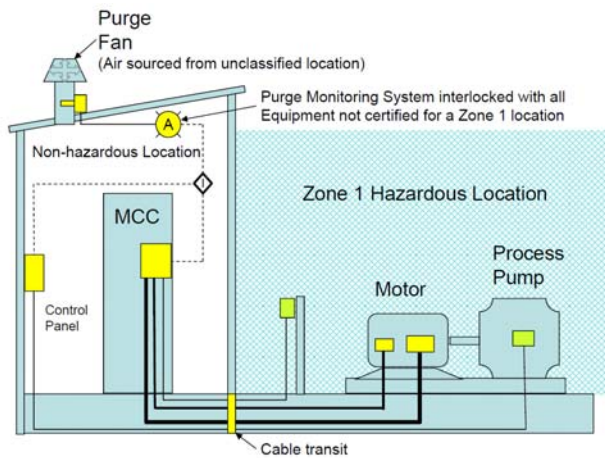


Fig. 3  
Option 2 – Pressurized Building within a Zone 1 Classified Location

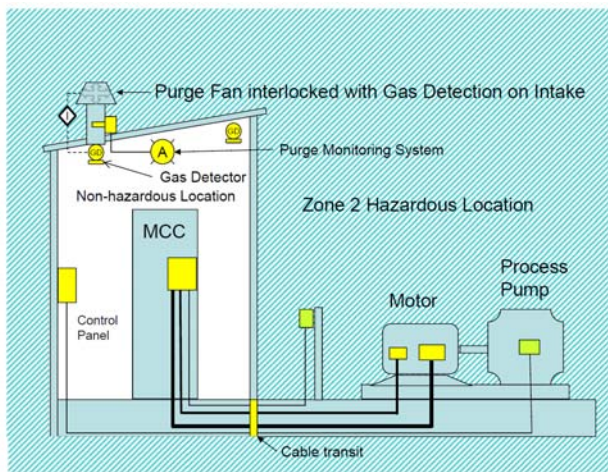


Fig. 4  
Pressurized Building Using Air Sourced from a Zone 2 Hazardous Location

A non-hazardous room or building may be installed adjacent to a classified area provided a suitable barrier is placed between the hazardous location and the non-hazardous location. Fig. 5 illustrates the use of a physical barrier in the context of an integrated skid module.

IEC 60079-10-1 discusses the use of “physical barriers” to limit the extent of a zone. The document does not describe what a physical barrier should be and how it should be constructed. It is generally accepted that in the context of a modularized process skid, the “physical barrier” must be constructed to prevent the migration of flammable gas/vapours from a hazardous location to a non-hazardous location under normal ambient pressure conditions.

Section 6 of API RP 500 and API RP 505 describe in more detail the design of a physical barrier used for such purposes. The “vapor barrier” as it is termed in the API documents must meet the following performance criteria:

*“a wall or other obstruction that will limit the passage of gas or vapor at atmospheric pressure, thus preventing the accumulation of vapor-air or gas-air mixtures in concentrations above 25% of their lower flammable (explosive) limit, LFL (LEL)”*[1]

One simple way of achieving this performance objective is to specify construction materials and installation methods that conform to the definition of “air-tight” or “air barrier” as referenced in the national building codes and standards. The following design criteria is based on standard building code requirements for air barriers and will meet or exceed the API performance specification for a “vapor barrier” in the context of an area classification design:

- 1) Materials: materials used for an air barrier system shall have an air permeance not to exceed 0.02 L/s.m<sup>2</sup> @ 75 Pa.
- 2) Assemblies of materials and components: shall have an air permeance not to exceed 0.2 L/s.m<sup>2</sup> @ 75 Pa.
- 3) The entire building: The air leakage of the entire building shall not exceed 2.0 L/s.m<sup>2</sup> @ 75 Pa.

The primary advantage of using a vapor-tight barrier to segregate an unclassified area is the simplicity of design. There are no elaborate HVAC or interlocking schemes required to maintain the integrity of the non-hazardous area. All that is required is that the integrity of the vapor-tight barrier be maintained and no positive pressure differentials exist between the hazardous and the non-hazardous locations.

C. Option 3 – Physical barriers as a means of segregation

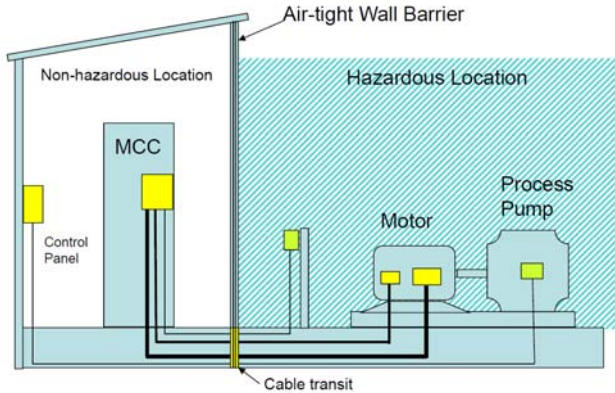


Fig. 5

Option 3 –Building Incorporating a Physical Barrier for Segregation from a Hazardous Location

#### IV. PIPING AND CABLE TRANSIT BARRIERS

A transit barrier can be an important element of an integrated module design. It facilitates the penetration of piping, conduits and cables through walls or floors which may have certification requirements to be fireproof, vapor-tight or designed to maintain a pressurized environment. A transit barrier must be capable of being installed in a variety of wall constructions, must be equal to the fire rating of the constructed wall, must allow a variety of conduits and cable connections of various configurations to pass through, and allow for future changes and modifications.

Transit barriers through walls and floors vary widely in materials and installations. Materials such as cement, compounds, steel gland plates and some foam type sealants may be considered as suitable vapor-tight barriers. However, within the construction of modular and/or skid-based units, these traditional solutions are often not effective or area efficient. In modular and/or skid-based unit construction, a mechanical transit barrier, which allows opening and closing the system throughout the life of the unit has significant benefits.

Most often, these mechanical transit barriers allow multiple cable and/or pipes to transit the wall or floor through a single opening, with each cable secured within a rubber-based block and the entire transit window is mechanically compressed to create a gas-tight, water-tight barrier. Fig. 6 illustrates the use of a transit barrier in integrated modular application.



Fig. 6

Cable Transit Used as Vapor Tight Wall Barrier

The combination of a steel-framed window, rubber or silicon-based cable or pipe blocks and a mechanical compression wedge ensures the integrity of the industrial-strength vapor barrier wall or floor and minimizes the loss of pressure in a purged location. Cable and pipes are easily installed and can be opened or closed repeatedly as required to install new cable and pipe penetrations. This allows the flexibility of changes in the future without compromising the integrity of the segregation method used.

#### V. CONCLUSION

There are several advantages to integrating process, electrical and instrumentation equipment on a common skid package. It allows the wiring connections to be completed in a controlled fabrication environment, facilitates the pre-commissioning of instrumentation and control equipment prior to shipment to site, reduces on-site labor and reduces overall installation costs.

There are several ways to integrate the process and the electrical and instrumentation equipment. The, instrumentation and electrical equipment may be enclosed in separate building on a common skid. Unclassified equipment may be protected using a pressurized building enclosure or segregated using a physical barrier.

The building envelope penetrations require careful consideration. They must facilitate the installation of piping and cables and must maintain the structural and fire integrity of the wall, the physical barrier or pressurized building requirements and allow for future expansion. A mechanical transit barrier design meets these requirements and incorporates innovations to reduce installation costs and facilitate future expansion.

#### X. REFERENCES

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## H. VITA

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