

Electrical Design Considerations for Offshore Installations



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Introduction

- This seminar is intended to present a high level view and set a stage for further review of differences and specific requirements of offshore electrical installations
- Discussions of the codes, standards, and regulatory requirements will present our interpretation of present requirements; however, in addition to the expected changes in codes and standards, agreements of jurisdiction between regulatory agencies are also being revised. It is imperative that the authorities have jurisdiction (BSEE &USCG) be contacted early during the design phase to clearly define the regulatory and standard requirements.
- During this seminar, we will concentrate on manned offshore US requirements



What's Different About Offshore?

- Surrounded by sea and hydrocarbons – No place to run
- Logistics difficult
 - Materials by Supply Boat
 - Personnel Transfers by Chopper
 - Escape in Chopper or in Survival Craft/Raft
 - Offshore work costs 5x to 10x what it would onshore
- Expensive real estate
 - Hull costs \$12 for each pound it floats
- Relatively Small Footprint
 - Buildings Cramped
 - Tight Equipment Spacing
 - Material Handling Issues - Studies a Must



What's Different About Offshore?

- Hostile Marine Environment
 - Humid
 - Salty and Corrosive
- Extreme weather conditions
 - Hurricanes and Typhoons - 160 mph wind criteria
- Marine Motions for Floater
 - Pitch and Roll
 - Lateral and Vertical Accelerations
- Emergency Equipment designed for +/- 22.5° pitch and roll



So ... is 22.5° Realistic?



A US Coast Guard helicopter flies by the Thunder Horse platform. Support vessels are also on hand as a joint effort with Coast Guard is under way to rebalance the BP-operated facility in the Gulf of Mexico following Hurricane Dennis.

Picture courtesy: U.S. Coast Guard. Photograph by Petty Officer 3rd Class Robert M. Reed



The Offshore Marine Environment

Environment is the enemy offshore!

- Salty Sea spray, constant humidity, and hot sun.
- Condensing moisture several hours per day - complete electrolytic cell (anode, cathode, metallic path, path for ionization)
- Dissimilar metal galvanic corrosion is exacerbated
 - Aluminum sacrificial (anodic) to mild steel
 - Mild steel sacrificial (anodic) to Stainless Steel
- All equipment breathes (including NEMA 7)



The Offshore Marine Environment (*cont*)

Careful selection of equipment, design and materials for equipment “exposed to the elements” is essential

- Electrical equipment in controlled environment wherever possible.
- Stainless Steel, non-metallic materials (fiberglass, etc) and coated “copper-free” aluminum (<0.4%)
- Severe-service coatings and design (motors, generators, transformers)
- TEFC, TEAAC and TEWAC enclosures
- VPI insulation (motors, generators)
- Space heaters in switchgear, motors, generators, transformer chambers, etc.
- Stainless Steel Hardware
- Stainless Steel valved fins for transformer radiators



The Offshore Marine Environment (*cont*)

Equipment, Design and Material Selection (*cont*)

- IP-56 / NEMA 4X ratings for equipment
- Sealed contacts for equipment located outdoors
- Breather / drains in boxes and enclosures
- Seal welding instead of stitch welding (large generators, motors, stanchions)
- Galvanic isolation of aluminum from “mild” steel
- Standardization of outdoor equipment
 - “robustness”
 - corrosion-resistance
 - risk mitigation against hydrocarbon releases



The Offshore Marine Environment (*cont*)



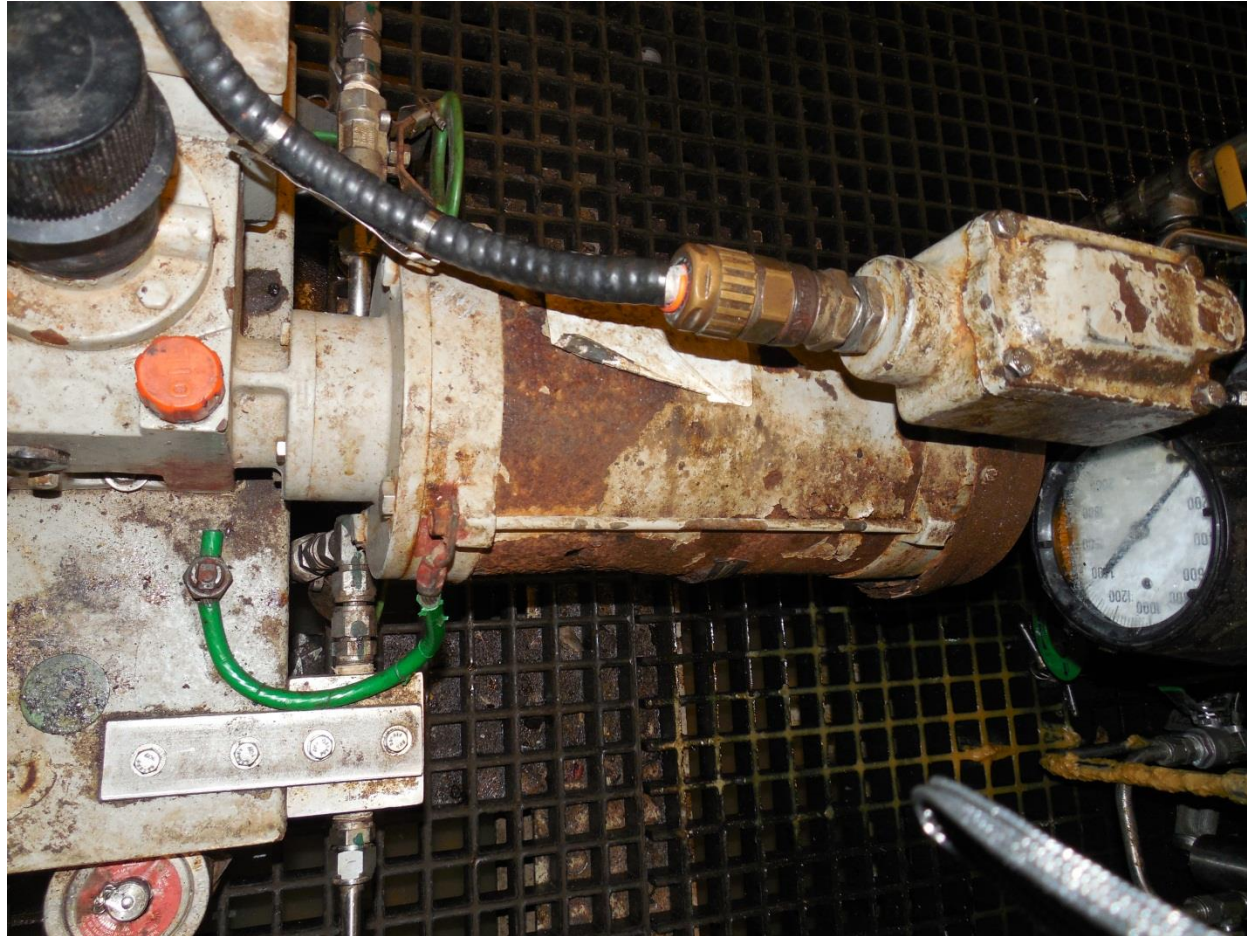
The Offshore Marine Environment (*cont*)



The Offshore Marine Environment (*cont*)



The Offshore Marine Environment (*cont*)



The Offshore Marine Environment (*cont*)



The Offshore Marine Environment (*cont*)



The Offshore Marine Environment (*cont*)



The Offshore Marine Environment (*cont*)



The Offshore Marine Environment (*cont*)



Platform Types

Pics of Jacketed (Fixed), Semisub and SPAR



Codes and Standards

US Waters – Common (Floaters and Fixed)

- BSEE Jurisdiction - CFR 30
 - NFPA 70 – NEC (Chevron uses art. 500 / BP uses art. 505)
 - NFPA70E
 - API RP 14F and 14FZ (Chevron uses 14F / BP uses 14FZ)
[Note: USCG CFR's do not reference 14F/FZ]
 - API RP 500 and 505 (Chevron uses RP 500 / BP uses RP 505)
- Coast Guard Jurisdiction - CFR 46
 - Aids to Navigation – fog signal and obstruction lights per USCG requirements
 - Abandon platform and general alarm system per USCG requirements



Codes and Standards (*cont*)

US Waters – Additional Requirement for “Floaters”

- USCG Letter of Alternate Design “01-13” dated 26 June 2013
(Includes numerous inclusion of IMO standards)
- IEEE Std 45
- Certifying Authority (e.g., DNV, Lloyds, ABS MODU, etc)
[Note: MODU pertains to facilities with and without drilling]
- Joint BSEE/USCG jurisdiction - BSEE Memoranda of Agreement and Understanding with USCG
- EPA requirements for diesel engines (Tier emission ratings)



Codes and Standards (*cont*)

International Waters

- IMO (International Maritime Organization)
 - SOLAS (Safety of Life at Sea)
- IEC Standards (e.g., IEC 61892, IEC 60092, etc.)
- Requirements of “Authority having Jurisdiction”
- Requirements of Certifying or Classing Authority (ABS, Lloyds, DNV, etc)



Certification of Hazardous Area Equipment

Certification of electrical equipment in hazardous areas is subject to requirements of the “Authority having Jurisdiction”

Gulf of Mexico Fixed Facilities

- Equipment on fixed production and drilling facilities fall under the authority of BSEE.
- BSEE Enforces the requirements of API-RP-500/505 and API-RP-14F/14FZ
- API-RP-14F/14FZ enforce the requirements of NFPA-70 (NEC)



Certification of Hazardous Area Equipment (*cont*)

Gulf of Mexico Floating Facilities

- Equipment for Marine systems on floating production facilities fall under the authority of USCG.
 - Certifying agencies (such as ABS) may serve as intermediaries between Owner and USCG and may have additional requirements of their own.
- Equipment for Production/Processing systems on floating and subsea production facilities fall under the authority of BSEE.
- There is overlap of jurisdiction (e.g., switchgear that feeds both services) on facilities.



Certification of Hazardous Area Equipment (*cont*)

USCG Requirements for Hazardous Areas

- All equipment installed within hazardous areas must have general NRTL (“Nationally Recognized Testing Laboratory”) certification as electrical equipment for the type of application.
- Per NEC, not all Electrical equipment installed within a Division 2 area need be NRTL certified for the specific hazardous area (e.g. junction boxes, cable stuffing glands, motors)
- All electrical equipment installed with a hazardous area that does require hazardous area certification per NEC must have NRTL certification for the specific hazardous area



Certification of Hazardous Area Equipment (*cont*)

USCG Requirements for Hazardous Areas (*cont*)

- The certifying “Nationally Recognized Testing Laboratory” must be acceptable to the “authorities having jurisdiction” for the project.
 - USCG has a web site listing agencies acceptable to them
 - BSEE requires certification to acceptable US standards
- USCG will accept IEC certification in instances so long as it is tested in a laboratory (IECex certification) to an acceptable standard (e.g. IEC 60079-**))
- USCG will NOT accept ATEX certification by itself



Ambient Temperatures

Two Types of Ambient Temperature Ratings

- Withstand Capability of Equipment – maximum temperature within which it will perform its function at its rated capacity
 - Switchgear, MCC's, Motors, Transformers, Instrumentation, Cables, etc.
 - Equipment is selected to perform within a maximum ambient temperature
- Capacity Rating for Equipment Performance – design temperature selected by project upon which to base equipment/system performance where it is proportional to the ambient temperature
 - Gas turbine drivers (Power generation, Pumping, Compression, etc.)
 - Process design



Ambient Temperature for Capacity Ratings

- Generators are inexpensive compared to turbine drivers
- Consideration should be given to oversizing the generator (and switchgear) so that it matches turbine rating throughout the likely operating temperature range, including lower temperatures
 - Can make up production, water injection, etc on cold days
 - Improves motor starting capabilities
 - Must tradeoff with short circuit levels, generator frame size changes, etc.
- When generator is oversized, consider one-line displaying both:
 - Actual rating of generator
 - Capability of generator at ambient design temperature



Withstand Ambient Temperatures

Equipment Standards (to which Equipment is Built)

- NEMA MG-1 / API-541/546 / IEEE-841 consider 40°C ambient as “usual” for Motors and Generators
- IEEE C57.12.** consider 40°C max / 30°C average ambients as “usual” for Transformers

Regulatory Standards (to how Equipment is Applied)

- The authority(s) having jurisdiction set the requirements, Regulatory standards and Recommended Practices that address ambient temperatures in which Equipment is applied
 - NFPA 70 (NEC)
 - USCG Letter 01-13
 - USCG/BSEE Memoranda of Agreement and Understanding
 - API RP 14F/14FZ
 - IEEE 45



Regulatory Impact on Ambient Temperatures

BSEE Requirements (for Production Equipment)

BSEE enforce the requirements of API-RP-14F/14FZ

USCG Requirements (for Marine Systems)

The design basis for Marine related electrical systems are defined in USCG Letter 01-13:

Ambient temperature of **40°C** (104°F) except for the following:

- **50°C** (122°F) for rotating electrical equipment in “Machinery Rooms” and “Weather Decks”
[unless 45°C (113°F) can be shown as a maximum for these spaces]
- **45°C** (113°F) for Cables and other non-rotating electrical equipment for “Machinery Rooms” and “Weather Decks”
- **30°C** (86°F) is permitted in air conditioned spaces (but 40°C is norm) – duplication of HVAC recommended
[Must consider equipment that must operate when HVAC is not available]
- **55°C** (131°F) for all control and instrumentation equipment



Driver Selection Study

HISTORY

- Legacy Shelf Gulf of Mexico Platforms:
 - Incorporates a Few Mechanical Drivers
 - Electrical Power Used for Smaller Drivers and Utilities
 - Little or no formal study – decision was relatively easy
- Gulf of Mexico Deepwater Developments:
 - Designed for Significantly Larger Throughput
 - Incorporates Numerous Larger Drivers
 - More driver configurations to be consider



Driver Selection Study Methodology

- Goal is to determine the economically optimized number of gas turbines vs. large electrical motors on a facility.
- A formal driver study can help to determine this solution based on project economic factors and constraints:
 - Project ROR
 - Field Life
 - Project Price for Oil, Gas, Emissions (Tradeoff low NO_x vs. firing rates)
 - Project estimating factors (hull costs, tons of steel, bulks, etc.)
- Economic decision will heavily depend on “Availability” of options compared – the economic optimum is not inherently obvious
 - All Electric Drivers - Large Power Generation with all Motor Drives
 - Mixes of Drivers - Smaller Power Generation plus Mechanical Drives



Driver Selection Study Methodology (cont)

DEVELOP SELECTION CRITERIA (“METRICS”)

- Select and define the criteria upon which to base selection decisions
 - Life Cycle Costs (NPV)
 - CAPEX and Installed CAPEX
 - OPEX (Fuel Costs/ Maintenance Costs)
 - Environmental Impacts - Production Flaring
- Agree and Rank the criteria with Management (record results)
- Be true - don't waiver from the criteria once agreed



Driver Selection Study Methodology (cont)

DEFINE AND EVALUATE OPTIONS

- Brainstorm Options – then cull all but “Credible Scenarios”
- Gather required data for each “Credible Scenario”
 - Equipment Cost, Weight and Dimensions (CAPEX)
 - Installation Cost Factors for Equipment (INSTALLED CAPEX)
 - **Fuel** and Other Consumables Costs Over Life of Field
 - Maintenance Costs over Life of Field
- Evaluate each scenario against each other and rank according to agreed “Metrics”
- If a “deal killer” arises in the evaluation, go on to the next scenario
- Pick the optimum Scenario and proceed.

Refer to PCIC 2002-15 for more detail on Driver Studies

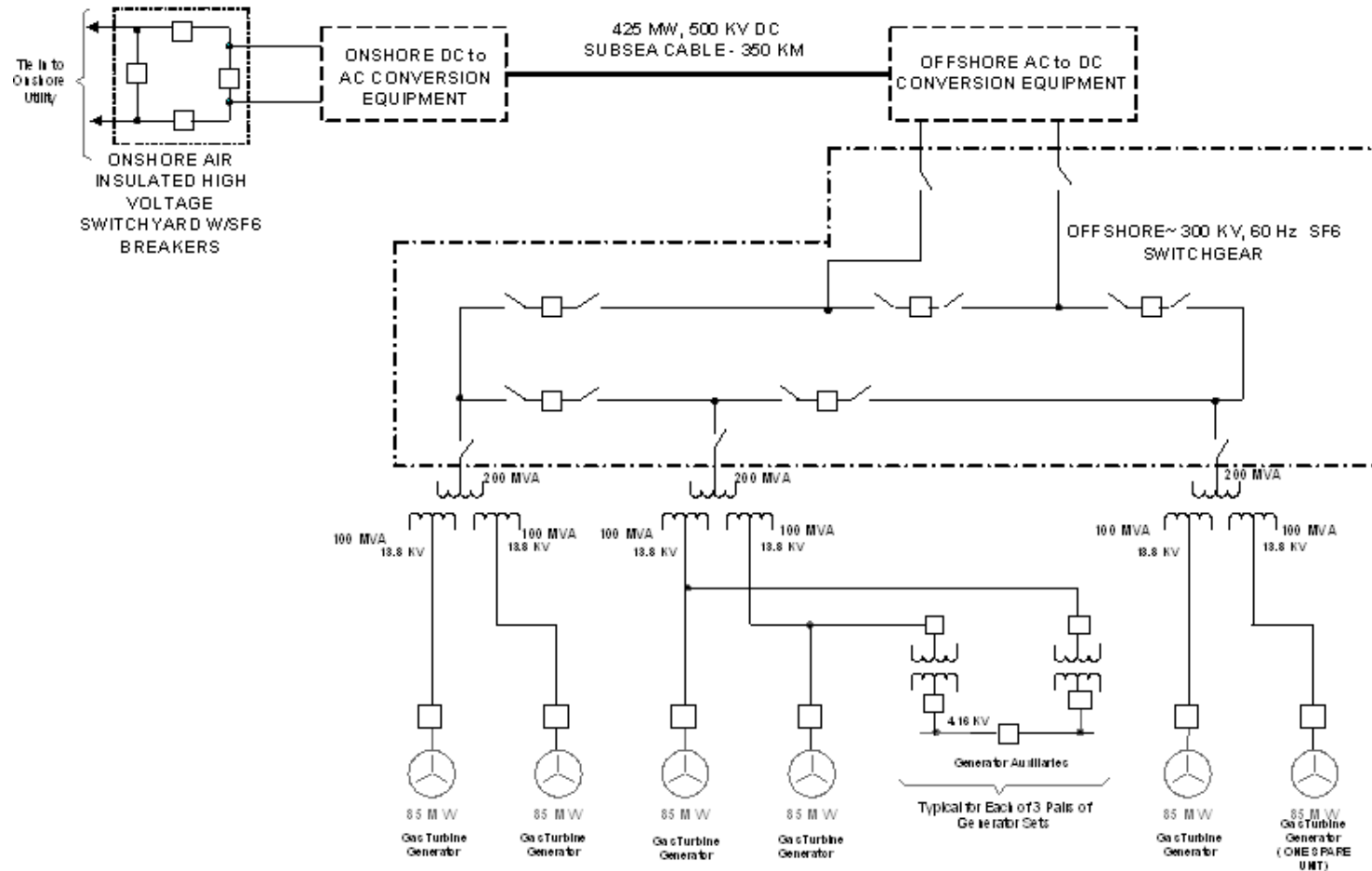


Electrical Power Systems Studies

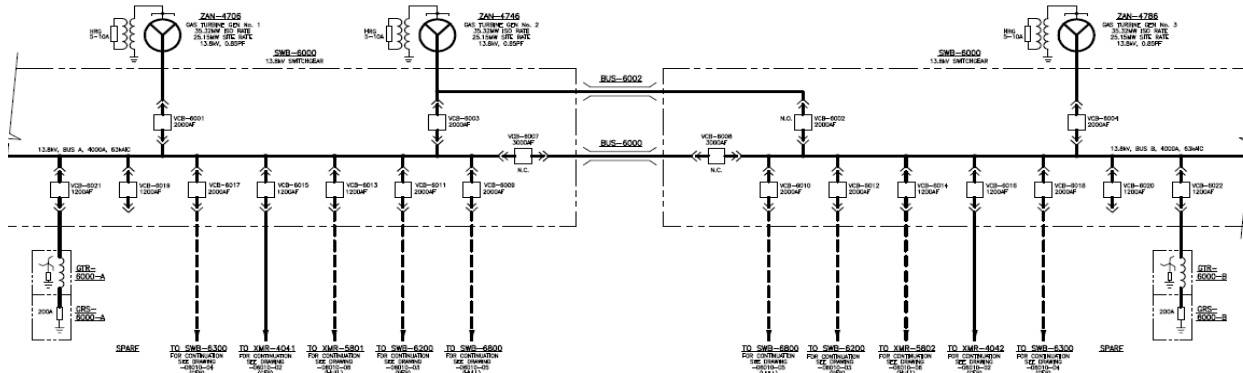
- In addition to load flow, short circuit, motor starting, and protective device coordination studies, dynamic stability studies and often harmonic studies are required
- Subsea power distribution may additionally require electro-magnetic transient analysis for energization and de-energization of subsea systems, including modeling of cable distributed capacitance and individual pole operation of circuit breakers, and more complex motor starting modeling



Very Large Offshore System



Determining Number of Prime Power Generator Sets



Steps

1. Develop Electrical Load Tabulations. Prepare lists of minimum, normal, and maximum operating loads, including planned future loads and projected load growth during project detailed design.
2. Evaluate impact of complete shutdown of normal electrical power system. Total blackout of platform in most cases is not acceptable (process upset, well closure, etc). The required minimum number of on line generator sets is determined based on several factors necessary to provide a stable electrical generation system. Typically at least two units must be running with at least one spare (possible exception for water injection).
3. Identify Loads that are acceptable for shedding during an unexpected shutdown of a generator set.



Determining Number of Generator Sets (cont)

4. Evaluate Choices of Turbine Generator Sets .
 - a. Industrial turbine generator sets, aero derivative turbine generator sets, and large frame turbine generator sets can be evaluated, each in a simple cycle, or in rare cases, combined cycle configuration – generally the smaller single shaft gas turbines or the larger two shaft aero derivative turbines are selected.
 - b. Evaluate fuel consumption between choices.
 - c. When choices are available, note that single shaft turbines generally have a greater step load capability than multi-shaft turbines.
5. Determine the ISO ratings and deratings for site conditions for the various size turbine generators to be considered.
6. Identify Unit step load acceptance capability, the ability to add step load within the turbine limits and with a maximum frequency change of approximately 5% - obtain this information from the turbine supplier throughout the loading range of the turbines. USCG/ABS requirements for transient responses can be more onerous for generators supplying marine loads. Caution related to turbine configuration that includes time delay on trip of breaker after turbine trip.



Determining Number of Generator Sets (cont)

7. Determine unit step load rejection capability , within the turbine over speed and combustor flame out limits for the planned fuel mix and the temperature limit loading curves – obtain this information from the turbine supplier.
 - Note: *Turbines should be able to withstand 100% loss of load without tripping turbine on over speed.*
8. Determine effects of dry low Nox combustors on the step load accept and reject limits – obtain this information from the turbine supplier.
 - Note: *Generally, dry low Nox combustors reduce the step load capability of the turbine. The use of dry low Nox combustors on units that may operate in ranges below optimum loading, which is common in “islanded” electrical systems, may produce significantly more CO₂ than that produced when operating near full load. With light loading, the dry low Nox combustors can increase green house gas emissions*

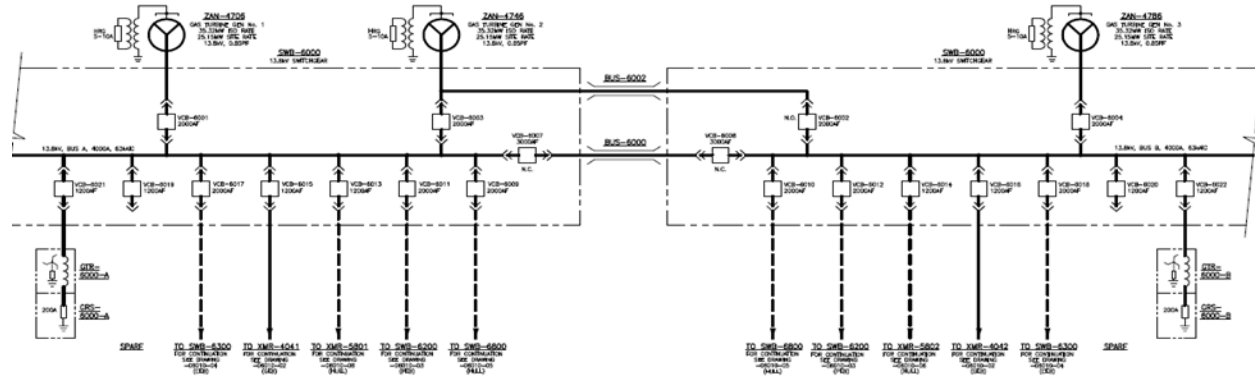


Steps in Determining Number of Generator Sets (cont)

9. Compare spinning reserve margins and step load capability to the step load increase when a turbine generator is unexpectedly shutdown for each configuration option.
- Note: *The spinning reserve and step load capability of the remaining on-line turbine generator sets must be adequate to accept the additional loading of the generator set that has unexpectedly shutdown, minus the load that can be quickly shed.*



Determining Number of Generator Sets (cont)



Example:

Conditions:

- Three aero derivative turbine generator sets running at 60 % of site rating
- Each turbine's step load capability at 60 % loading is 20%
- One of the three turbines receives a trip signal

Result: Each turbine generator can accept additional load of approximately 20 % of its site rating and the remaining load of the tripped unit must be shed, usually within approximately 200 ms, including scan time and logic and breaker operating time.



Determining Number of Generator Sets (cont)

10. Perform Dynamic Stability Studies.

- a. Once generator configuration options are reduced to those with acceptable spinning reserve and step load capability, dynamic system stability studies are performed, initially in the early phase of the project to determine the viability of the various configuration options.
- b. The objective of the stability studies is the verification of the power system stability during various operating scenarios including generator short circuit, shutdown of an online generator unit, and sudden opening of a circuit breaker feeding large loads.



Determining Number of Generator Sets (cont)

- c. The dynamic stability study results define the required quantities of load shed, and the maximum time allowed for load shed to occur to maintain electrical system stability and prevent loss of the entire prime power generation during unexpected shutdown of a turbine generator set.
 - d. The dynamic stability study confirms the minimum number of generator sets that must be running for the various load and load shedding scenarios.
11. Perform RAM (Reliability, Availability, Maintainability) studies to consider planned and unexpected down time, and to determine the required number of spare turbine generator units.



Essential Generation

Three Power Production Modes

- “Normal” Mode (clearly defined)
Facility is performing its design functions. Power supplied by Main Generation.
- “Emergency” Mode (clearly defined by regulatory – req. for floaters only)
Emergency condition exists and the Emergency Generation is providing power.

Specific requirements apply to Emergency Generation and Emergency Loads for facilities under USCG jurisdiction and/or classed by ABS. One restriction is that the Emergency Generation is intended for “emergency” situations only.
- “The Third” Mode (all other cases – not so clearly defined)
The platform is “shut down”, but no emergency condition exists. Main Power Generation nor the Emergency Generator are running. However, either continued habitation or safe evacuation (e.g., hurricane) is desired and electrical power is required.



Essential Generation (cont)

- One person's meat is another person's poison.

There are many ways to label the third mode – “Auxiliary”, “Standby”, and “Essential” can all cause confusion. Here we will label the third mode as “Essential” for the purposes of discussion.

- “Essential” in this case is wider in scope than the USCG/ABS definition. It includes all loads that are deemed “essential” by USCG/ABS as well as all loads essential to continue habitation (or safe evacuation) of the platform.
- Typically an “Essential” Generator(s) is provided on the platform. An alternate is to have provisions to tie in a portable Essential Generator.
- Continued habitation on the platform requires having an Emergency Generator as backup for safe abandonment. The Essential Generator should power all loads on the Emergency bus as well as other loads and the Emergency Generator should be shut down. Hence, the Essential Generator is larger than the Emergency Generator.
- A separate “Hurricane” Generator can be used for periods of abandonment, but often the Essential Generator fills this purpose to reduce the number of engines on the platform.



Essential Generation (cont)

Typical Types of Load to consider for Essential Generation supply are:

- Emergency switchgear loads
- subsea “flow assurance” loads
- Lighting within control and electrical rooms / portion of platform area lighting
- Loads to maintain a level of life support facilities on the platform and within the quarters (i.e. HVAC, lighting, kitchen, potable water, sewage, etc.)
- Limited HVAC and/or pressurization in control, electrical and instrument rooms
- Diesel fuel transfer pumps
- Loads to “blackstart” one main generator set
- Instrument / plant air compressor
- Crane auxiliaries
- Loads needed during temporary evacuation (Hurricane, etc.)



Essential Generation (*cont*)

- The previous list is exhaustive and would require a large Essential Generator.

However, it is highly unlikely they will all be needed at the same time and a smaller generator will usually suffice.

- Following is an approach to determine size required. It is “essential” to include operations and maintenance personnel in this exercise.

1. Identify likely scenarios of activities (along with manning and hoteling levels) likely to occur when Main Generation is not available. Examples are:

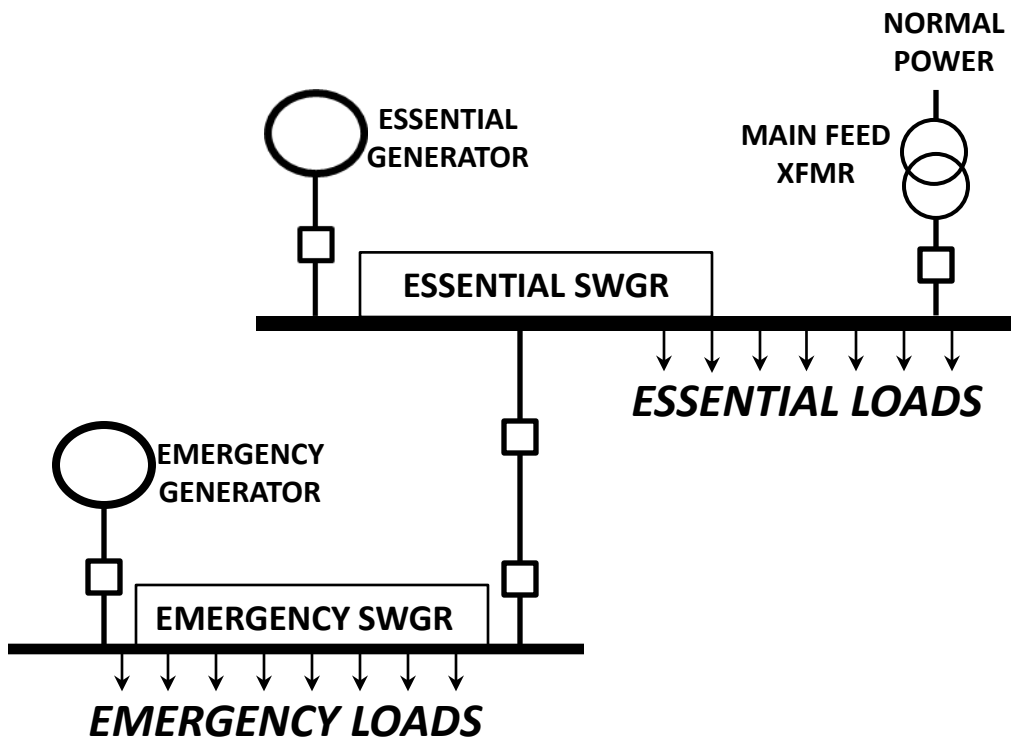
- During platform shutdown from an ESD
- Subsea flow assurance
- Continued “long-term” habitation with no production (and no main generation)
- Black start of one Main Gen-set

2. Determine the amount of load associated with each scenario. The worst case scenario determines the sizing requirement for the Essential Generator.



Essential Generation (cont)

A typical configuration



NOTES

1. Emergency Generator and Swgr sized in accordance with USCG/ABS requirements.
2. “Essential” loads connected to “Essential Swgr”
3. “Main Feed Xfmr” supplies power to the Essential and Emergency busses when Main Power is available. This transformer (and the Essential Switchgear) must be sized to run all Essential and Emergency loads during “Normal” operations
4. When Main Power and Emergency Generator are offline, Essential Generator feeds power to both the Essential and Emergency busses.
5. The Essential Generator need only be sized for the worst case scenario in the previous exercise; it will be undersized as compared to the Main Feed Xfmr.

Refer to PCIC 2011-17 for more detail on Essential Generation



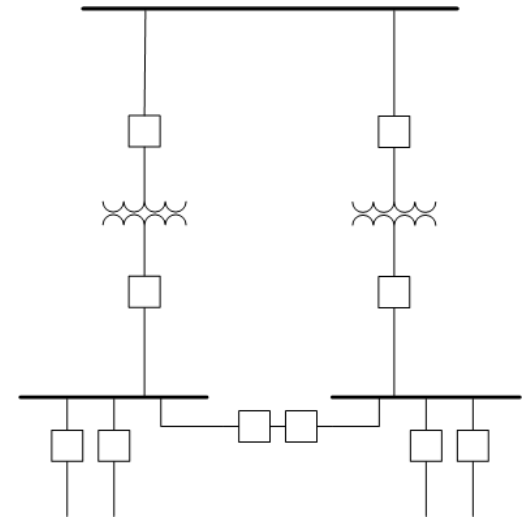
Generation and Distribution Voltages

- For most mid size to large offshore systems, generator output voltage varies from 4.16 kV to 13.8 kV – due to ampacity and short circuit limitations of the switchgear. Larger systems may require use of individual step up transformers and greater main bus voltage rating
- Operation of two separate generation systems to avoid individual generator step up transformers is generally not recommended due to loss of stability, reliability, and availability
- Medium Voltage Switchgear Limitations
 - Ampacity: Generally switchgear is sized with breaker ratings up to 3000 amperes (4000 ampere breaker with fan cooling is an option, but not generally used because of the breaker fan reliability concerns)
 - Short circuit: Generally short circuit ratings are limited to 63 kA (current limiting protectors can be considered, but not encouraged, war stories abound, and selectivity on phase to phase faults is compromised)



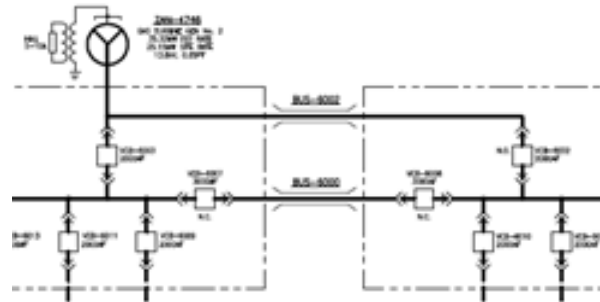
Distribution Considerations

- Secondary selective supply to lower voltages is standard design practice, with the recommended transformers sized to allow loss or maintenance of one transformer without a requiring a load reduction:
 - When secondary tie breakers are normally open, each transformer is sized so that its base rating without fans at a 55 degree C rise is adequate for the load on that side of the tie breaker(s) with extra capacity for future loads and for design growth during the project
 - and the 65 degree C rating of each transformer (with fans if installed) is adequate to supply the full operating load on both sides of the tie breaker(s) plus load growth



Distribution Considerations (cont)

- Double tie breakers: Some operators use double tie breakers on generator busses and medium voltage switchgear to allow complete isolation of the tie breaker cubicle for maintenance



- Use of synch check relays and breaker interlocks must be installed to prevent inadvertent synchronizing of out of synch sources when tie breakers or feeder breakers are closed
- Connection of one or more generators to both sides of generator bus tie breakers to allow greater flexibility for maintenance, by installing two generator breakers



Distribution Considerations (cont)

- Design margins: Generator configuration and switchgear and motor control equipment layouts are usually determined early in the project, and adequate design load growth during the project (30% is not uncommon for low voltage loads) plus future spare capacity must be included in the early sizing
- Low inrush induction motors: Though primarily developed for use offshore, industry has not had good experiences with them – larger enclosure sizes, often operation at higher temperatures, high vibration, early life motor failure
- Reverse vars: Large capacitors on front end of adjustable speed drives, harmonic filters, and capacitance of long step outs can cause reverse var flow to generators and possible shutdown on loss of excitation
- Due to corrosion and maintenance considerations, install distribution equipment indoors and require packaged equipment vendors to allow use of indoor MCC's for motor starters
- Motor Starting



Switchgear and Motor Control

- Key Design Considerations
 - IP22 Enclosure (NEMA 2)
 - >12.5mm object
 - Dripping water when tilted 15 degrees
 - Drip shields
 - Insulated handrails
 - Rubber matting “deck coverings” at front and rear of equipment
 - HRGs must have visual and audible alarm



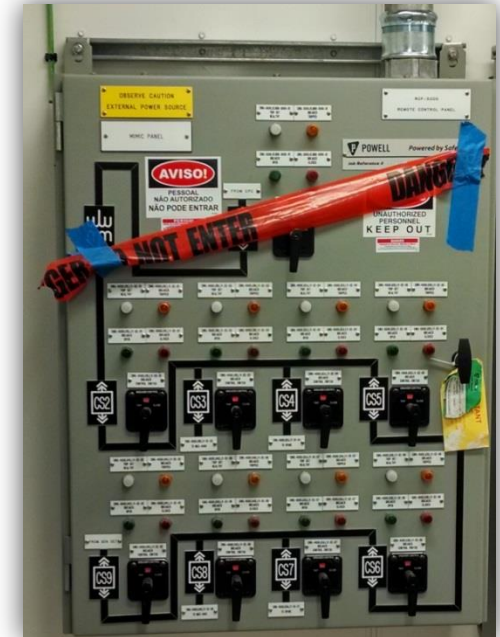
Switchgear and Motor Control

- Arc Resistant Equipment
 - Vent into room
 - Building exterior is hazardous area
 - High overhead volume of space
 - Must coordinate with cable tray and HVAC duct
 - Vent Exterior to Building
 - Building exterior is unclassified
 - Fire damper required at wall penetration
 - Must coordination of vent duct with cable tray and HVAC duct
 - Rarely implemented
 - Caution: IEC 62771-200 allows equipment in such a way that the maximum earth current is less than 100A.
 - LV: Still need to maintain coordination between SWGR and MCCs.



Switchgear & Motor Control

- Other Possible Safety Options
 - Keep your people away from the switchgear
 - Remote Operation of Circuit Breakers
 - Remote Breaker Racking
 - Maintenance Switch



Power Transformers

Transformers on floating structures require specification of Tilt, Pitch, & Roll. Typical offshore practices for application of Power Transformers (i.e., >100 kVA) are:

Outdoors – Use Liquid Immersed

- Transformer internals protected from environment by liquid
- Reduces load on HVAC inside the buildings
- Recommend less flammable and environmentally friendly fluids (preferably that will not support combustion)
- Recommend stainless steel radiators, instruments, and junction boxes
- Cooling fans are a headache – when they are used, specify corrosion resistant materials and a weekly fan exerciser circuit.

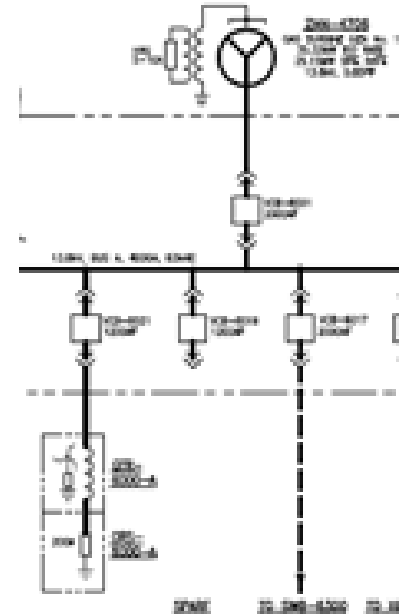
Indoors – Use Less Flammable Liquid Filled or Dry Type – always check authorities having jurisdiction – USCG has some specific requirements for dry type

- Reduce risk of indoor fire and spills
- On larger dry type, can get water cooled units to reduce load on HVAC , though failures have occurred on transformers with cooling tubes integral to windings



Power System Grounding

- When allowed by authorities having jurisdiction, the following is recommended:
 - Hybrid grounding of medium voltage generator buses (low resistance zig-zag on buses, and high resistance on generator neutrals)
 - Low resistance grounding on other medium voltage buses
 - High resistance grounding on low voltage buses above 277 volts
- Note: USCG and certifying agencies have restrictions on system grounding on Floating Production Storage and Offloading (FPSO) vessels) and these regulations must be investigated



- 46 CFR Subchapter J 111.05-21
 - Ground detectors at panel boards

- (a) Electric propulsion system;
- (b) Ship's service power system;
- (c) Lighting system; and
- (d) Power or lighting distribution system that is isolated from the ship's service power and lighting system by transformers, motor generator sets, or other devices.



EQUIPMENT GROUNDING OFFSHORE

- All around is convenient “Mother Earth” – a steel structure
[Note: Historically, marine vessels WERE bonded directly to earth as the sole grounding connection. It was difficult to find many marine cables with a separate grounding conductor.]
- Even though this structure is frequently used for direct equipment bonding, it alone it does not satisfy the requirements of NFPA 70 Arts. 110.54(B) and 250.118. *
[Note: Many foreign structures not bound by NFPA 70, and use direct equipment bonding to the structure as the sole ground]
- Due to the corrosive environment outdoors, grounding connections outdoors must be protected to maintain the integrity of the ground bond. Particular care must be used for thermally welded connections.

** Refer to IEEE Paper “Some Fundamentals of Equipment-Grounding Circuit Design” by R.H. Kaufman, Nov 1954*

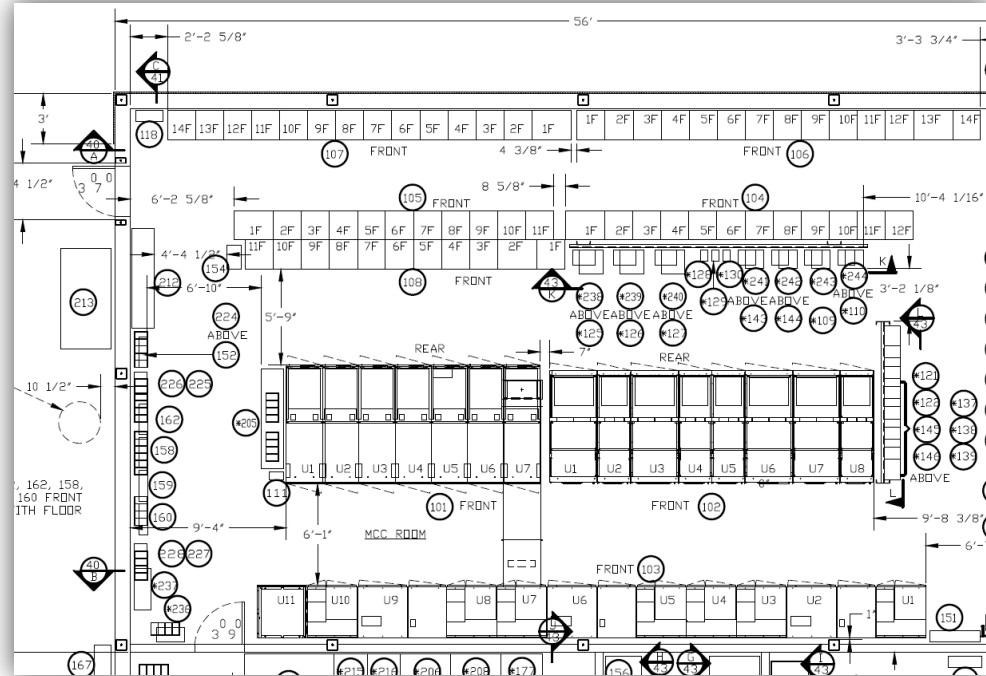


Electrical Buildings



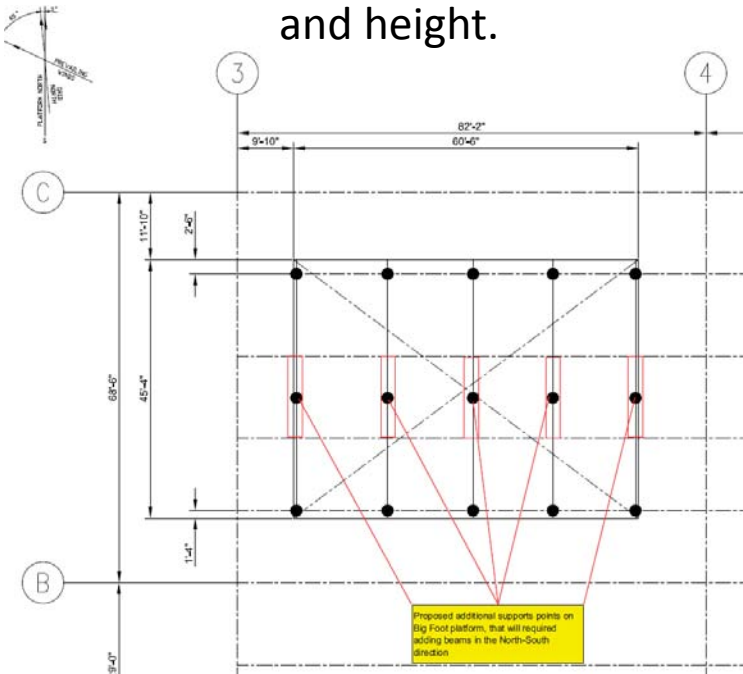
Building Layout Considerations

- Identify Maximum Building Envelop as Early as Possible
- Topsides Constraints
- Equipment Footprint
 - Include Spares/spaces
 - Reserve space for wall mounted equipment
 - Block out space for through deck cable penetrations
- Wall Thickness
 - Impacts equipment clearances and personnel egress
- Interior Height
 - Room to coordinate all overhead systems
 - Cable Tray
 - HVAC Duct
 - Bus Duct
 - Arc Plenums
- Maintenance Considerations
 - Stairs, Ladders, Walkways
 - Material Handling



Building Construction

- Structural Design and Analysis
 - Software Driven
 - Load Cases: In Place, Lift, Transportation
 - Interior columns and multiple support points can reduce structure weight and height.



W24 x 104



1 ft height and 156 lbs per foot savings

W36 x 260



Building Construction

- Blast Resistant Designs

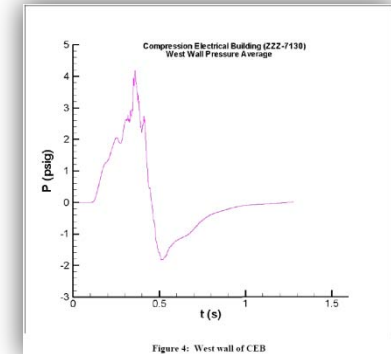
- Purpose:

- To protect people from the effects of a vapor cloud explosion.

- Definitions:

- Blast wave

- Pressure pulse rapidly reaches peak pressure
 - Exponentially decaying overpressure
 - Suction phase



- Free field overpressure (P_o) or incident overpressure

- Overpressure realized as the blast travels along the structure.

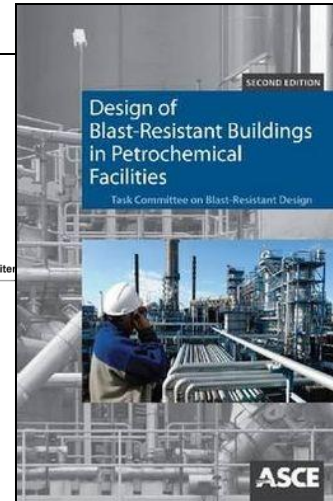
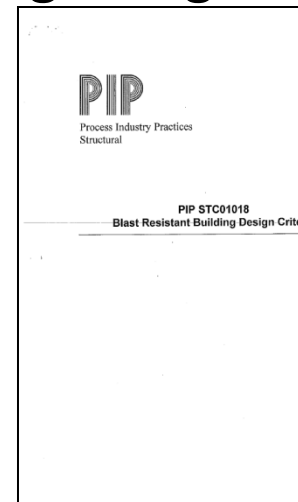
- Reflected Pressure (P_r)

- Pressure of the blast wave as it impacts the wall nearest to the blast source.



Building Construction

- Blast Resistant Designs
 - Typical references:
 - ASCE – Design of Blast Resistant Buildings in Petrochemical Facilities, 2010
 - PIP STC01018 Blast Resistant Building Design Criteria
 - API 752, 753

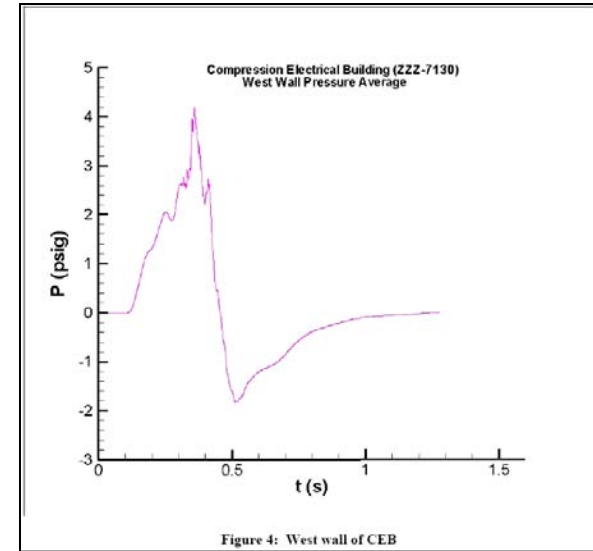


Building Construction

- Blast Resistant Designs

- Design Criteria:

- Pressure (psi)
 - 14.5psi – 1bar
 - Time (ms)
 - Impulse (psi-ms)
 - Area under the blast curve
 - Response Criteria

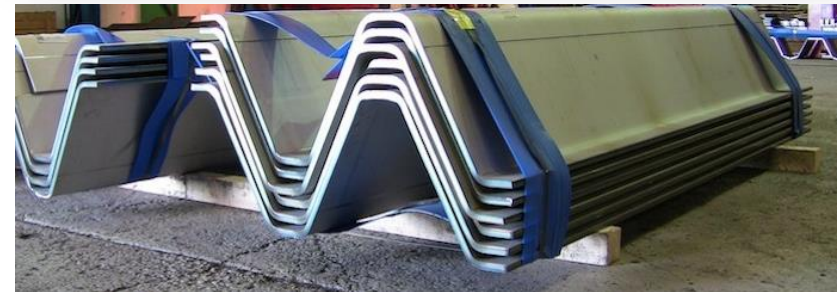


- Low: Localized damage. Building can be used. Repairs may be required to restore integrity of structural envelope
 - Medium: Widespread damage. Building cannot be used until repaired. Total cost of repairs could be significant depending on the damage.
 - High: Structure is severely damaged and additional loading from subsequent blast or environmental conditions may cause collapse. Cost of repairs could approach the replacement cost of the building.



Building Construction

- Blast Resistant Designs
 - Construction Strategies
 - Stiffened Wall
 - Crimped Plate Wall
 - Pre-Fab Blast Wall



Building Construction

- Fire Ratings
 - Three Types of Marine Fire Ratings
 - A / H / J
 - Fire Test Reference Number
 - First alpha character denotes the Class of Fire
 - A = “A” class fire
 - Second is a number which denotes the length of time able to insulate against the fire (normally in 15 minute blocks).
 - A-60 = “A” class fire, Insulation for 60 minutes



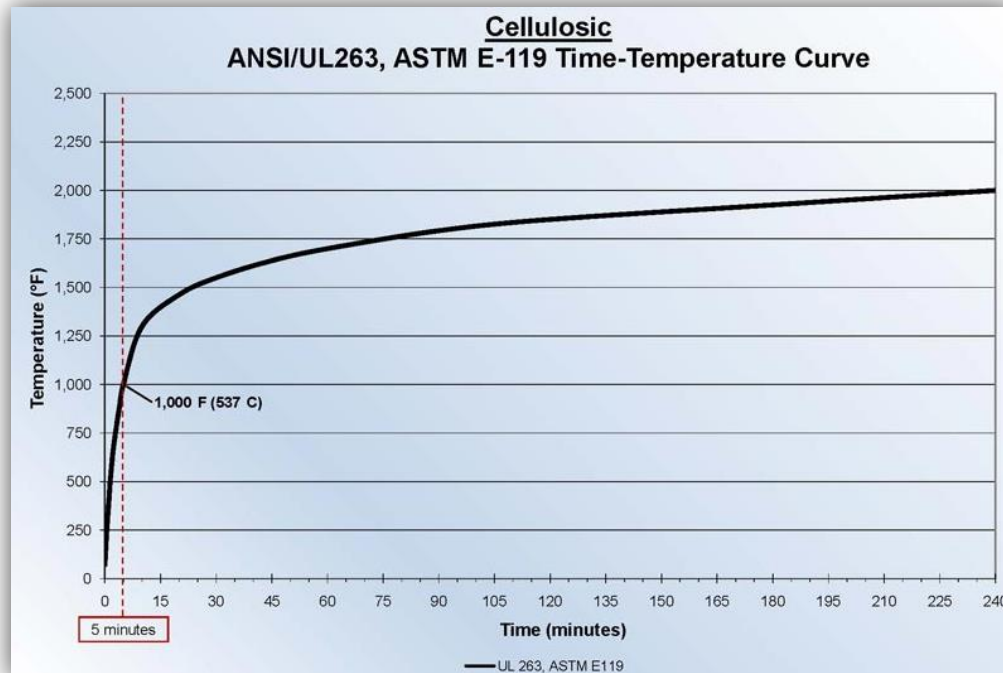
A Class Fire Rating

- Sometimes known as “standard”
- Simulates cellulosic fire (paper, wood, cloth, etc)
- ASTM E-119 Standard Test Methods for Fire Tests of Building Construction and Materials
 - Gradual Temperature Rise
 - Criteria
 - Integrity
 - No passage of smoke or flames and maintain structural integrity for one hour.
 - Insulation
 - Average temperature on non-exposed side not to exceed a rise of 250 degrees F within time limits specified.



A Class Fire Rating

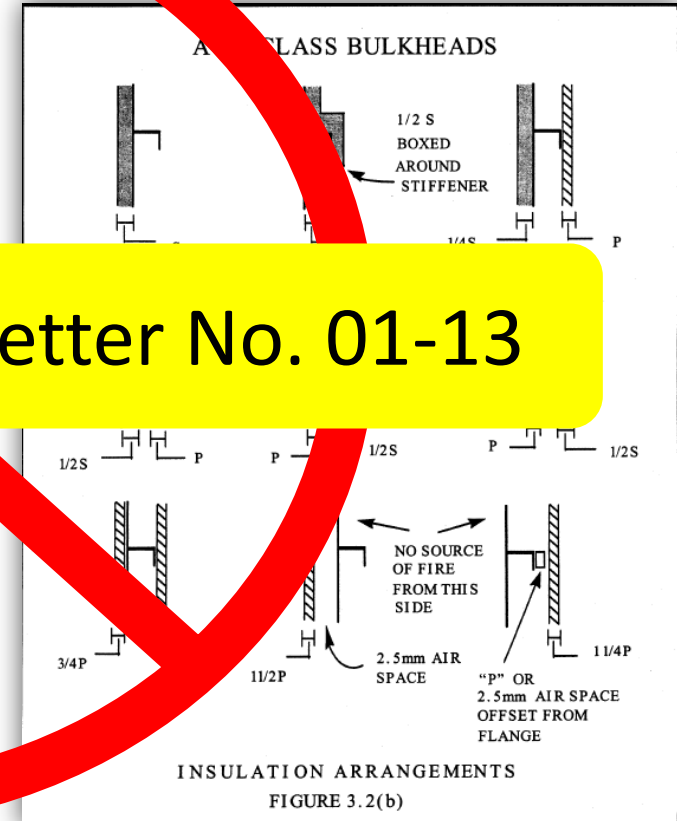
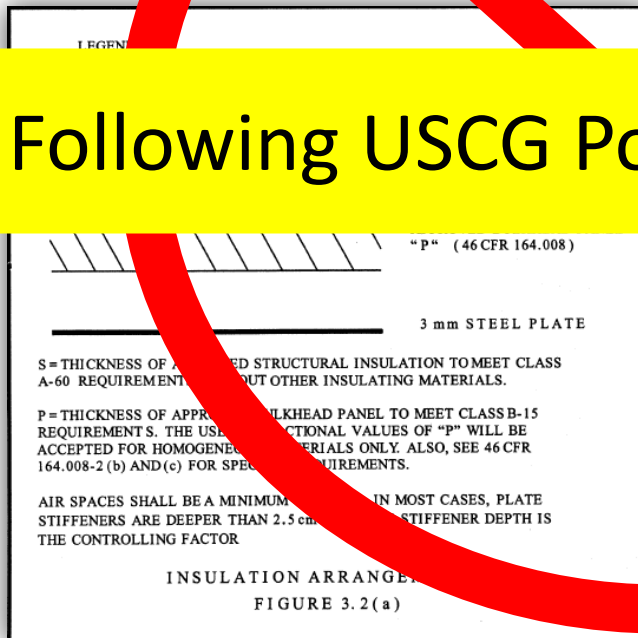
Designation	Integrity	Insulation
A-60	1 Hour	60 Min.
A-30	1 Hour	30 Min.
A-15	1 Hour	15 Min.
A-0	1 Hour	0 Min.



A Class Fire Rating

- NVIC 9-97
 - Serves as the prescriptive standard for construction of A Class bulkheads and decks.

If Following USCG Policy Letter No. 01-13



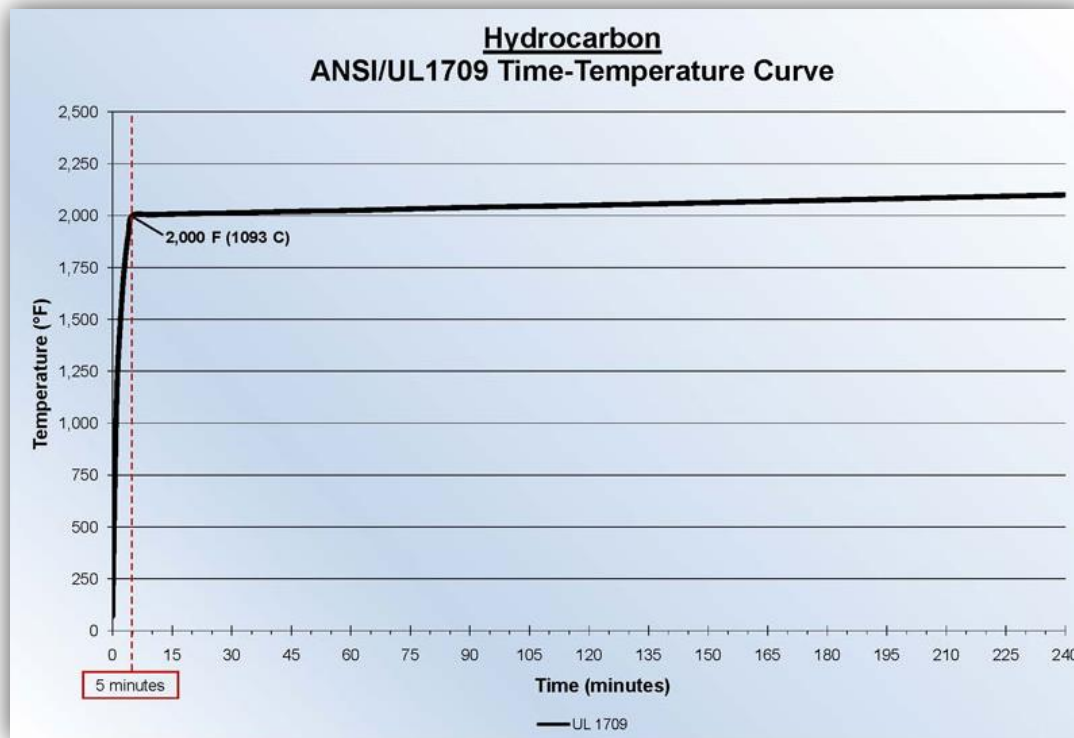
H Class Fire Rating

- Simulates fire in process area (gas, petroleum, etc)
- UL-1709 High Rise Test Hydrocarbon Fire Curve
 - Rapid Temperature Rise
 - Criteria
 - Integrity
 - No passage of smoke or flames and maintain structural integrity for two hours.
 - Insulation
 - Average temperature on non-exposed side not to exceed a rise of 250 degrees F within time limits specified.



H Class Fire Rating

Designation	Integrity	Insulation
H-120	2 Hour	120 Min.
H-60	2 Hour	60 Min.
H-0	2 Hour	0 Min.



H Class Fire Rating

- Construction Strategies
 - Insulation
 - Coatings
- Products are type tested
- Installation must be per manufacturer's type test certificate

INTERNATIONAL PAINT LTD.

STONEYGATE LANE
FELLING
TYNE AND WEAR
NE100JY
United Kingdom
Telephone: +44 191 402 2648
Fax: +44 191 495 2003

MA Certificate No. 09-NC1700163-X

Product: Coating, Intumescent

Model: Chartek 7

Intended Service:

Insulation for Steel Bulkheads.

Description:

Insulation to provide fire integrity to Steel Bulkheads.

Ratings:


Bulkhead provides fire integrity as detailed below with minimum Chartek 7 application thickness.

H-0 Bulkhead: 6.5 mm

H-60 Bulkhead: 10.0 mm

H-120 Bulkhead: 14.0 mm

as demonstrated by testing as per IMO Resolution A.517(13) with Hydrocarbon Curve.

 **ABS**
FOUNDED 1862

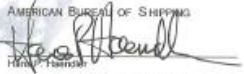
CERTIFICATE NUMBER: 01-HS551270B-4-PDA
DATE: 14 July 2010
ABS TECHNICAL OFFICE
Houston Materials

CERTIFICATE OF DESIGN ASSESSMENT

This is to Certify that a representative of this Bureau did, at the request of
INTERNATIONAL PAINT LTD. - TYNE AND WEAR

assess design plans and data for the below listed product. This assessment is a representation by the Bureau as to the degree of compliance the design exhibits with applicable sections of the Rules. This assessment does not waive unit certification or classification procedures required by ABS Rules for products to be installed in ABS classed vessels or facilities. This certificate, by itself, does not reflect that the product is Type Approved. The scope and limitations of this assessment are detailed on the pages attached to this certificate. It will remain valid as noted below or until the Rules or specifications used in the assessment are revised (whichever occurs first).

PRODUCT: Coating, Intumescent
MODEL: Chartek 7
ABS RULE: 2010 Steel Vessels Rules 1-1-4/7.7, 2020 Guide for Building and Classing Facilities on Offshore Installations 3-8/9, 4-6/6
OTHER STANDARD: IMO Resolution A.517(13) with hydrocarbon curve (A.517(13) expired 31 December 2003); Fire Test Reports Omega Plant 15510-100281, Omega Plant 15510-100282, Omega Plant 15510-100285, VITEC Report Revision 1.0, dated 28 February 2005 entitled Application of Topcoats and Primers with Chartek 7.


HENRY J. FAIRBANK
Engineering Type Approval Co-ordinator

NOTE: This certificate is evidence of compliance with one or more of the Rules, Codes, Standards or other criteria of ABS or a statutory national or international standard. It is issued solely for the use of ABS, its members, its clients or other authorized entities. Any significant changes to the design or construction of the vessel or facility must be made in the certificate and the certificate will be void. This certificate is governed by the terms and conditions as contained in ABS Rules 1-1-4/7.7 and 2020 Guide for Building and Classing Facilities on Offshore Installations 3-8/9, 4-6/6.

NOTED 010



H Class Fire Rating

- Effect of USCG Policy Letter No. 01-13

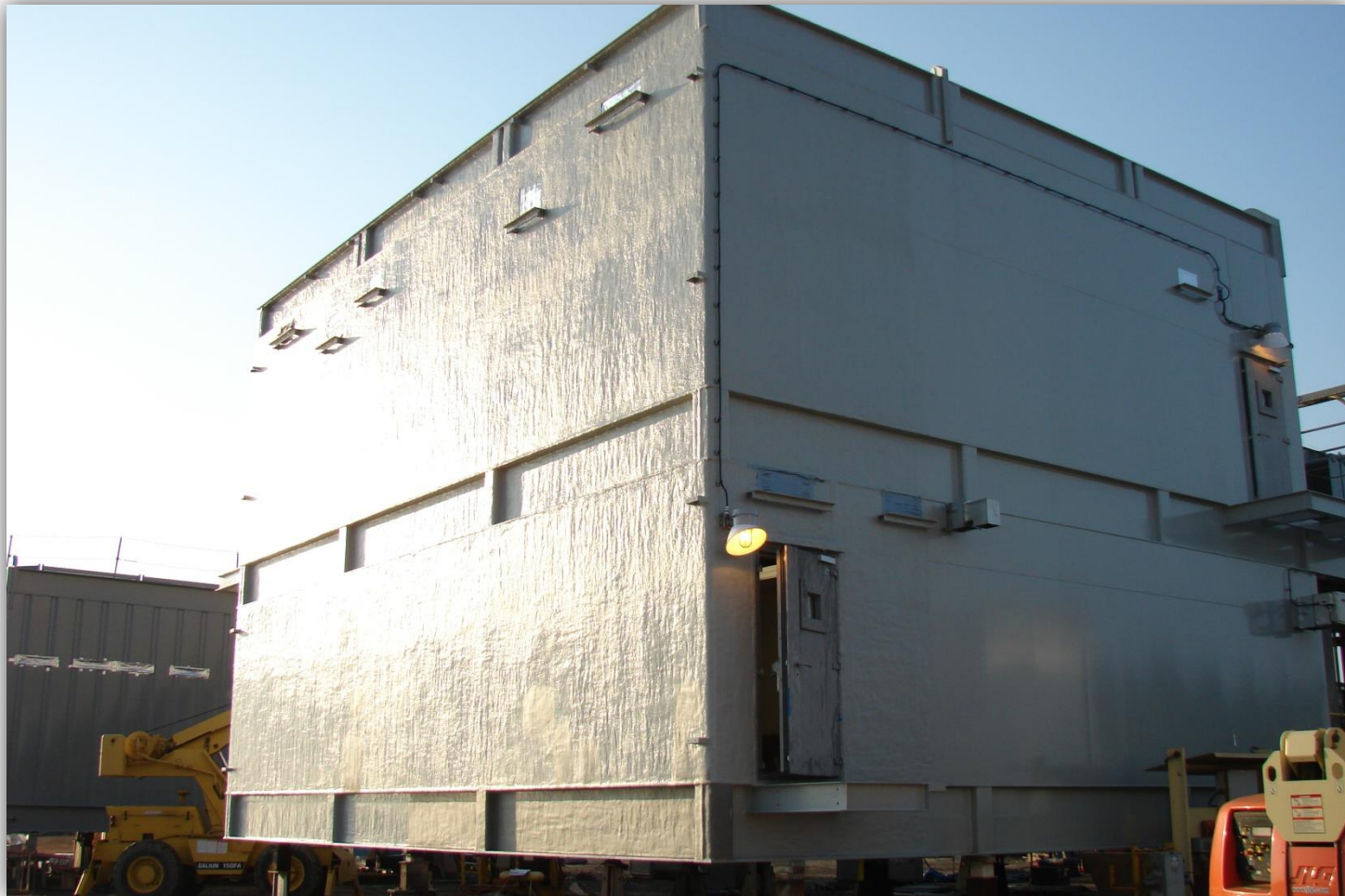
(40) Exterior boundaries of all normally occupied deckhouses or temporarily installed modular buildings that are normally occupied, including overhanging decks that face process areas, wellheads, produced oil storage tanks and similar hydrocarbon hazards must meet minimum H-60 rating standards, and extend on the sides of any such structures for a minimum distance of 10 feet. H-60 test methods must be in accordance with:

- (a) Reference (gg), test method C, Tests of Fire-Containment Capability or Walls; or
- (b) Annex 1, Part 3 of reference (hh), using the H-class time-temperature curve, where the furnace temperature reaches 815°C after 3 minutes, 1010°C after 5 minutes, and is maintained between 1010°C and 1180°C for the duration of the test.

Any Doors, MCTs, HVAC Penetrations, etc. must that fall within this boundary must also be H-60 rated

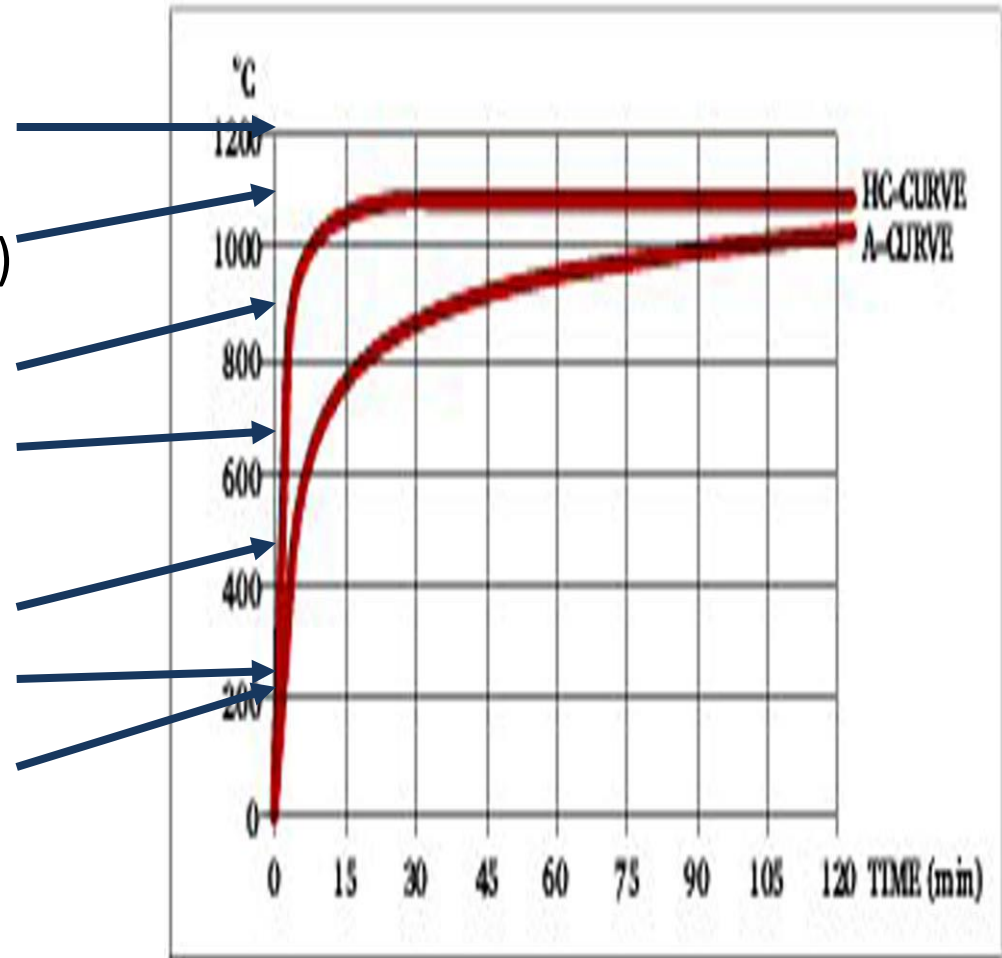


H Class Fire Rating



What The Temperature Means

- F14 Tomcat- 4" from exhaust (2192°F/1200 °C)
- Softening of High Carbon Content Steel (2109°F/1154°C)
- Molten Rock/Lava (1652°F/900°C)
- Melting of Aluminum (1220°F/660 °C)
- Temp of Venus (873°F/467 °C)
- Very Hot Oven (464°F/240 °C)
- Paper Ignites (451°F/233°C)





J Class Fire Rating (Jet Fire)

- Erosion Test
- Fire with Velocity
- Continuously Fed Fuel Source
 - Duration - Up to 60 minutes
 - Maximum Temp -1030 °C
 - Gas Line Pressure- 4.7 Bar
 - Gas Flow Rate - 0.3KG/Sec
 - Nozzle Pressure - 2.4 Bar
 - Nozzle Velocity - 260M/Sec
 - Nozzle Size -17.8mm Diameter
 - Gas Usage -1171KG/Propane
- Construction Strategies
 - Stainless Steel Material
 - Coatings



Fire Rating Classification of Space

- ABS rules provide definitions of spaces and guides for fire ratings.
 - Both ABS and USCG recognize H Class Fire ratings
 - Neither ABS nor USCG have testing criteria for or recognize J Class Fire Ratings

TABLE 3a
Fire Integrity of Bulkheads Separating Adjacent Spaces/Areas

Spaces	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Control Stations including Central Process Control Rooms	(1) A-0	A-0	A-60	A-0	A-15	A-60	A-15	H-60 (d)	A-60	A-60	*	A-0
Corridors	(2)	C	B-0	B-0 A-0 (b)	B-0	A-60	A-0	H-60 (d)	A-0	A-0	*	B-0
Accommodation Spaces	(3)		C	B-0 A-0 (b)	B-0	A-60	A-0	H-60 (d)	A-0	A-0	*	C
Stairways	(4)			B-0 A-0 (b)	B-0 A-0 (b)	A-60	A-0	H-60 (d)	A-0	A-0 *	*	B-0 A-0 (b)
Service Spaces (low risk)	(5)				C	A-60	A-0	H-60 (d)	A-0	A-0	*	B-0
Machinery Spaces of Category A	(6)					* (a)	A-0 (a)	H-60 (d)	A-60	A-60	*	A-0
Other Machinery Spaces	(7)						A-0 (a)(c)	H-0 (d)	A-0	A-0	*	A-0
Process Areas, Storage Tank Areas, Wellhead/manifold Areas	(8)	(Symmetrical)						----	H-60 (d)	H-60 (d)	*	H-60 (d)
Hazardous Areas	(9)							----	A-0	*	A-0	
Service Spaces (high risk)	(10)									A-0 (c)	*	A-0
Open Decks	(11)										----	*
Sanitary and Similar Spaces	(12)											C

Please see the notes under 3-8/ Table 3b for further interpretations.



HVAC Design

- Types of Systems

- Direct Expansion (DX) - refrigerant is in the evaporator coil.
- Chilled Water - refrigerant stays in a common chiller and pipe water to discrete AHUs.
- Variable Air Volume (VAV) - energy efficiency strategy.
- Constant Air Velocity with Reheat (CAVR). Excellent dehumidification performance. Not energy efficient.

- Design Considerations

- 316 Stainless Steel Construction, saltwater grade aluminum as alternate.
- Copper fin coils due to corrosion. Aluminum will eventually turn into aluminum chloride....'salt'.
- Redundancy: 2 x 100% (preferred) or 3 x 50% (complicates duct work)
- Gas detection at air intake
- Smoke detection at return register
- 50 degree C rated motors
- Space issues...taller and higher pressure of AHU fan to help reduce unit footprint.
- Control cabinet space provision
- HVAC Shutdown & Fire Damper Indication Stations at doors.



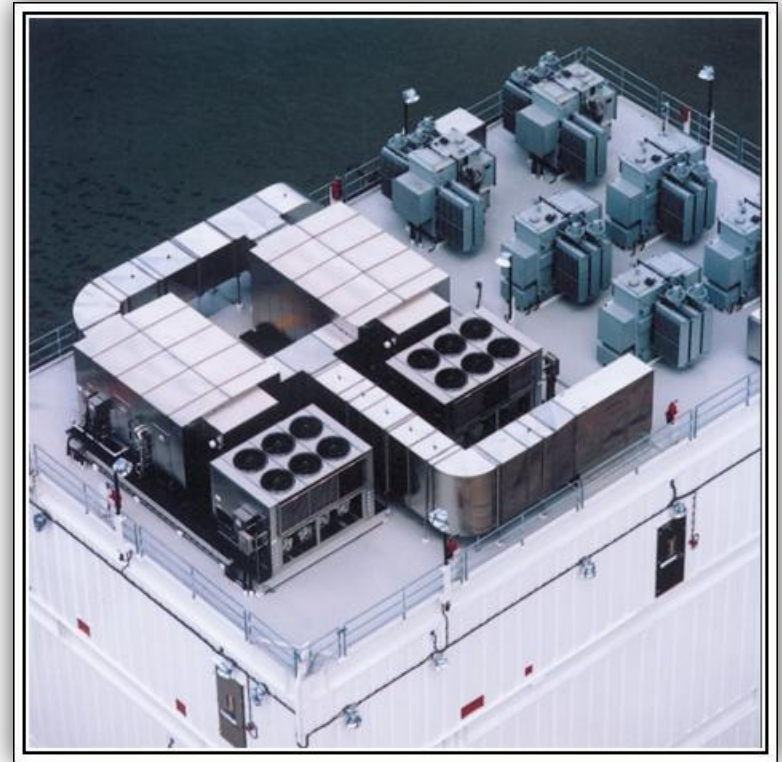
HVAC Pressurization

- Required if module is in a classified area
 - Module is often designed for CI 1 Div 2 area even if outside the vapor cloud area, but this should be specified by the end user
- NFPA 496
 - 60 ft per min airflow out of any opening (i.e. doorway) or 0.1 inches of water
 - Pressurization panel needs to be purged, NEMA 7, or located in an alternate safe area.



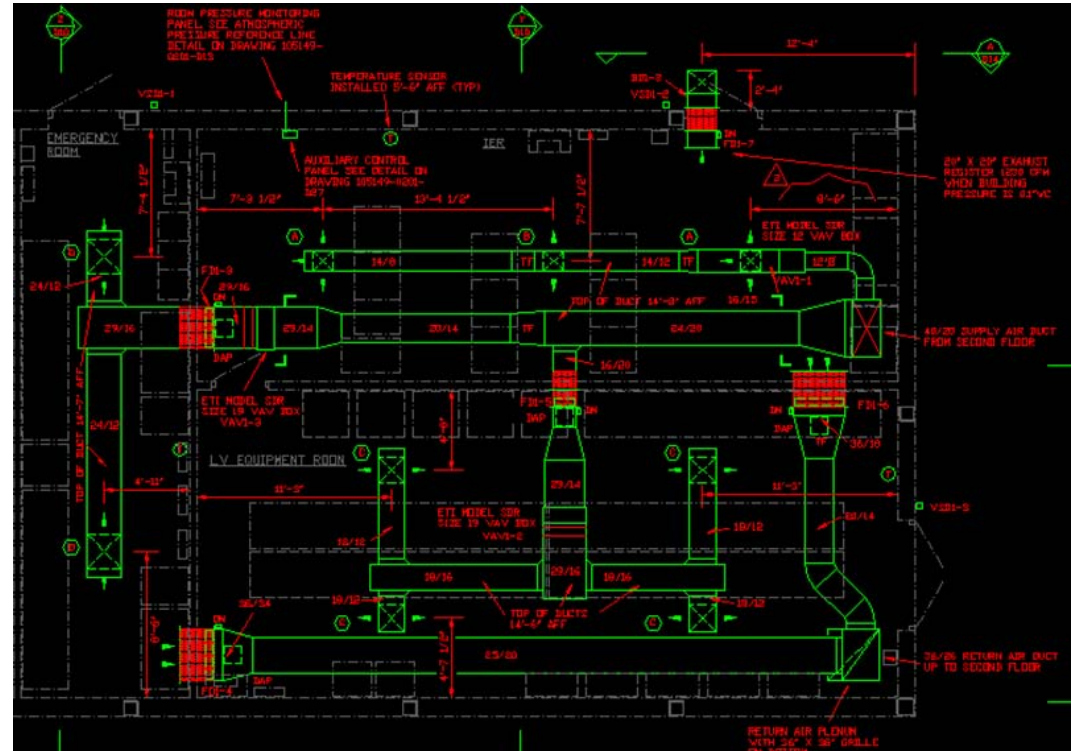
HVAC Pressurization

- Types of Pressurization under NFPA 496:
 - “X” Purge: C1 D1 to Non-Hazardous
 - For equipment only safe to operate in an unclassified area.
 - Power must be cut immediately when positive pressure system fails.
 - “Y” Purge: C1 D1 to C1 D2
 - No Fresh Air Available
 - “Z” Purge: C1 D2 to Non-Hazardous
 - Most Common
 - Recommended that equipment be de-energized as soon as possible after positive pressure system failure is detected.
 - Fresh air intake location dependent upon hazardous area boundaries



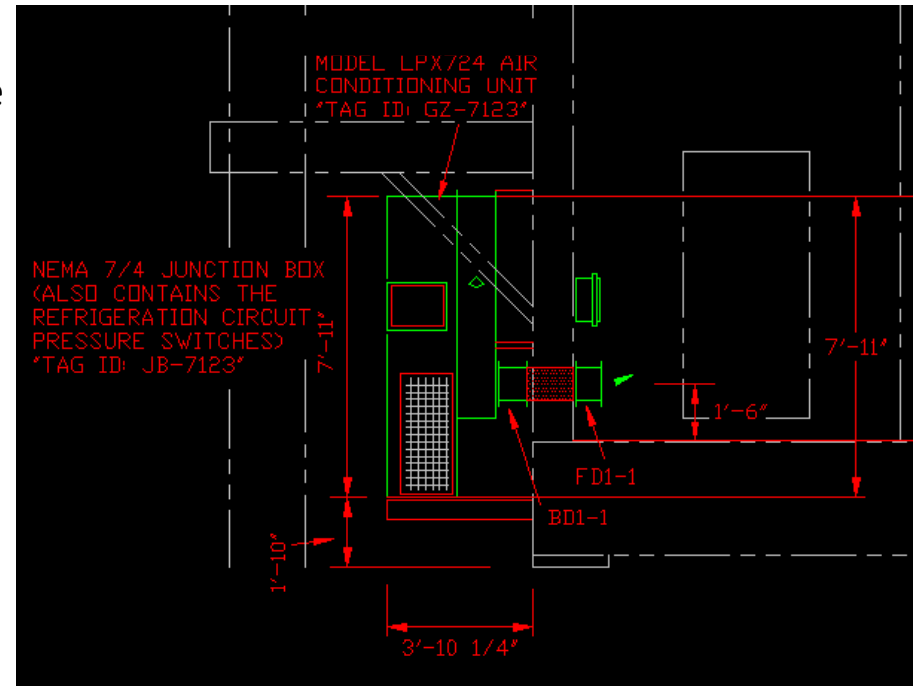
HVAC Duct Design

- Design Considerations
 - Avoid supply registers directly over equipment.
 - Careful coordination with interior cable tray and plenums/arc vents above AR switchgear/mcc
 - Duct Volume for noise requirements...the smaller the duct, the noisier the air flow.
 - Avoid duct routing with many bend and elbows which can restrict airflow, causing an increase in the fan and fan motor size to push air through duct.
 - USCG approved foil faced insulation for interior duct. Hullboard allowed for insulation of exterior duct.



HVAC Duct Wall Penetrations

- USCG / ABS
 - 36", 3mm min sleeves at all "A" rated or above penetrations.
 - Sleeve can be moved further inside building (maintain 36") with permission.
 - Length of the fire damper can be used as part of the sleeve provided it's the same or greater thickness as sleeve.
 - No non-metallic items inside duct at all.
 - ~~UL 555 Certified Dampers accepted per NVIC 9-97~~



HVAC Duct Wall Penetrations

5.27 (2012)

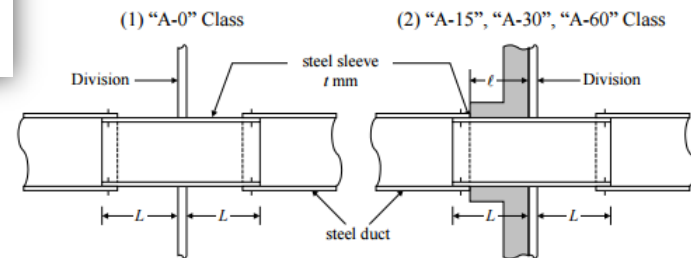
Ventilation ducts having an internal cross-sectional area greater than 0.02 m^2 (0.22 ft^2) penetrating "A" class divisions are to be steel or lined with a steel sheet sleeve that:

- Are at least 3 mm (0.118 in.) thick and at least 900 mm (35.4 in.) long (preferably 450 mm (17.7 in.) on each side of the division), provided with fire insulation having the same fire integrity as the division; and
- Those exceeding 0.075 m^2 (0.81 ft^2), except those serving hazardous areas, are to also have automatic fire damper capable of being closed manually from both sides of the bulkhead or deck and with a position indicator which shows whether the damper is open or closed. The fire dampers are not required where ducts pass through spaces surrounded by "A" class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they penetrate.
- For control stations, where the duct line serves other category spaces, a fire damper is to be provided regardless of size.

Ventilation ducts less than or equal to 0.02 m^2 (0.22 ft^2) penetrating "A" class divisions are to be steel or lined with steel sheet sleeves that are at least 3 mm thick and at least 200 mm (7.88 in.) long (preferably 100 mm (3.93 in.) on each side of bulkhead or, in the case of the deck, wholly laid on the lower side of the deck pierced) and provided with fire insulation having the same fire integrity as the division. See 5-1-1/Figure 3.

ABS MODU 5-1-1/5.27

FIGURE 3
Ventilation Ducts Penetrating "A" Class Divisions (2012)



	L mm (in.)	ℓ mm (in.)	t mm (in.)	Automatic Damper**
$S > 750 \text{ cm}^2$	450 (17.7)	450 (17.7)	3.0 (0.19)	Required *
$750 \text{ cm}^2 \geq S > 200 \text{ cm}^2$	450 (17.7)	450 (17.7)	3.0 (0.19)	Not required
$200 \text{ cm}^2 \geq S$	min. 100 (3.94)	min. 100 (3.94)	3.0 (0.19)	Not required

* Not required if duct passes through spaces surrounded by "A" class divisions, without serving those spaces, provided the duct has the same fire integrity as the divisions it pierces.

** Automatic fire damper capable of being closed manually from both sides of the division.

S = Sectional area of duct



Battery Room Design

- Large Battery Room > 2kW of connected charging device output (based on lead acid service).
- Class 1, Division 1, Group B rated
- A-60 rated interior wall
- Drip Pans required by USCG & ABS
 - Dates back to Lead-Acid & Alkaline battery installations
 - USCG approved coating can be applied with 6 in curb around entire room
- Overhead lifts for installation and maintenance.
- Consideration for material handling outside battery room (i.e. crane access to outdoor porch).



Battery Room Ventilation

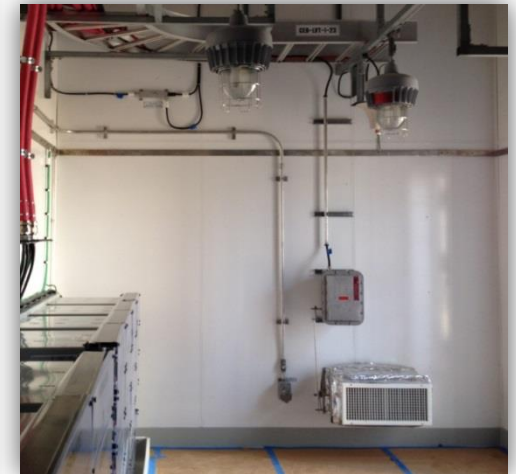
- Design Considerations
 - ABS requires separate ventilation (air intake) for large battery rooms (greater than 2kW total output of charging devices based on lead acid service). Cooling requirement by owner.
 - ABS requires 1 air change every two minutes (30/hr) unless fewer are proven required through hydrogen emission calculations
 - 6-10 recommended for wet cells
 - Since NiCad and VRLA emissions are less than lead acid, ABS allows greater alternate service ratings above 2kW based on the ratio between lead acid H_2 emissions and alternate cell H_2 emissions.
 - Supply air intake must be located 5 ft away from the battery room door.



Battery Room Ventilation

- Design Considerations

- USCG requires mechanical exhaust....redundancy is an owner requirement.
 - SOLAS allows for common supply to battery room with backdraft damper louver for exhaust....mechanical exhaust by owner requirement.
- Difficult to source NEC motors rated for Group B. Can use Group C&D rated motor outside the air stream.
- Exhaust routed 10 ft away from the fan since a hazardous area 'bubble' exists at the point of exhaust
- Supply air near floor, exhaust near ceiling at opposite end of room.



Cabling

- Cable Types
 - **TC** (Tray Cable – standard)
 - “Standard” Tray Cable
 - On offshore applications, do not recommend for outdoor...indoor only
 - Listed Ampacities are based on 30 degree C ambient; must be de-rated for use in 45 degree C ambient
 - Suitable for Unclassified and Division 2 locations only
 - **TC-ER** (Tray Cable – crush and impact resistant)
 - Unarmored Tray Cable complying with UL 2225 (MC)
 - Certain makes are UL Listed both as Marine Shipboard Cable and as TC-ER
 - Suitable for Indoor and Outdoor applications
 - Listed Ampacities are based on 30 degree C ambient; must be de-rated for use in 45 degree C ambient
 - Suitable for Unclassified and Division 2 locations only



Cabling

- Cable Types

- **MC-HL**

- Armored - metalclad
 - Suitable for Indoor and Outdoor applications
 - Listed Ampacities are based at 30 degree C ambient; must be de-rated for use in 45 degree C ambient
 - Suitable for Unclassified, Division 2 and Division 1

- **Marine Shipboard “P”Cable**

- IEEE 45 / IEEE 1580 / UL 1309
 - Sheathed - Armored & Unarmored
 - Suitable for Indoor and Outdoor applications
 - Listed Ampacities are based on 45 degree C – no derating required for floating service
 - Suitable for Unclassified, Division 2 and Division 1 (armored only)
 - Can use IEC 60331 rated cable for fire resistant applications



Cabling

- Cable Sizing
 - NEC Cable
 - Follow sizing per NEC Table 310.16
 - Adjust per ambient temperature correction factors to 45 degrees C

NEC Table 310.16
Table 310.15(B)(2)(a) Adjustment Factors for Not More Than Three Current-Carrying Conductors in a Raceway or Cable

Size AWG or kcmil	Temperature Rating of Conductor								
	60°C (140°F)		75°C (167°F)	90°C (194°F)		60°C (140°F)		75°C (167°F)	90°C (194°F)
	Types TW, UF	Types RHW, THHW, THW, XHHW, USE, ZW	Types TB5, SA, SIS, FEP, FEPB, MJ, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TB5, SA, SIS, THHW, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	ALUMINUM OR COPPER-CLAD ALUMINUM		
18	-	-	COPPER	14	-	-	-	-	-
16	-	-		10	-	-	-	-	-
14*	20	20		25	-	-	-	-	-
12*	25	25							
10*	30	35							
8	40	50							
6	55	65							
4	70	85							
3	5	100							
2	95	115							
1	110	130							
1/0	125	150							
2/0	145	175							
3/0	165	200							
4/0	195	230							
250	215	255							
300	240	285							
350	260	310							
400	280	335							
500	320	380							
600	355	420							
700	385	460							
750	400	475							
800	410	490							
900	435	520							
1000	455	545							
1250	495	590							
1500	520	625							
1750	545	650							
2000	560	665							
Ambient Temp. (°C)	For ambient temperatures other than those shown								
21-25	1.08	1.05							
26-30	1.00	1.00							
31-35	0.91	0.94							
36-40	0.82	0.88							
41-45	0.71	0.82							
46-50	0.58	0.75		0.82	0.58	0.75		0.82	114-122
51-55	0.41	0.67		0.76	0.41	0.67		0.76	123-131
56-60	-	0.58		0.71	-	0.58		0.71	132-140
61-70	-	0.33		0.50	-	0.33		0.50	141-158
71-80	-	-		0.41	-	-		0.41	159-176

For 75 deg terminations



Cabling

- Cable Sizing
 - Shipboard Cable
 - Follow sizing tables in API 14F



Table 1—Ampacities for Marine Shipboard Distribution, Control, and Signal Cables, 2000 Volts or Less, AC or DC, Copper Conductors, Single-banked (Single-layered), Maximum Current-carrying Capacity Based on 45 °C Ambient

			Single-conductor Cable				Two-conductor Cable				Three-conductor Cable			
AWG or kcmil	mm ²	Circular Mils	Maximum Conductor Insulation Temperature Ratings											
			75 °C	90 °C	100 °C	110 °C	75 °C	90 °C	100 °C	110 °C	75 °C	90 °C	100 °C	110 °C
20	0.52	1020	9	11	12	13	8	9	10	10	6	8	9	9
18	0.82	1620	13	15	16	17	11	13	14	15	9	11	12	13
16	1.31	2580	18	21	23	24	15	18	19	21	13	15	16	17
14	2.08	4110	28	34	37	39	24	29	31	33	20	24	25	27
12	3.31	6530	35	43	45	49	31	36	40	41	24	29	31	33
10	5.26	10,380	45	54	58	61	38	46	49	52	32	38	41	43
8	8.37	16,510	56	68	72	77	49	60	64	68	41	48	52	55
7	10.55	20,820	65	77	84	88	59	72	78	82	48	59	63	67
6	13.30	26,240	73	88	96	100	66	79	85	90	54	65	70	74
5	16.77	33,090	84	100	109	114	78	92	101	105	64	75	82	85
4	21.15	41,740	97	118	128	134	84	101	110	115	70	83	92	95
3	26.66	52,620	112	134	146	153	102	121	132	138	83	99	108	113
2	33.62	66,630	129	156	169	178	115	137	149	156	93	111	122	126
1	44.21	83,690	150	180	194	205	134	161	174	183	110	131	143	149
1/0	53.50	105,600	174	207	227	236	153	183	199	208	126	150	164	171
2/0	67.44	137,100	202	240	262	274	187	233	242	265	145	173	188	197
3/0	85.02	167,800	231	278	300	317	205	245	265	279	168	201	218	229
4/0	107.20	211,600	271	324	351	369	237	284	307	323	194	232	252	264
250	126.70	250,000	300	359	389	409	264	316	344	360	217	259	282	295
263	133.10	262,600	314	378	407	431	278	333	358	380	228	273	294	311
313	158.60	313,100	351	432	455	482	303	363	391	414	249	298	321	340
350	177.30	350,000	372	446	485	508	324	387	421	441	265	317	344	361
373	189.30	373,700	393	474	516	540	339	406	442	463	277	332	361	378
444	225.20	444,400	453	546	588	622	391	468	504	534	319	382	411	435
500	253.30	500,000	469	560	609	638	401	479	520	546	329	393	428	448
535	271.20	535,300	485	579	630	660	415	496	538	565	340	407	443	464
646	327.50	646,400	557	671	731	765	485	581	632	662	396	474	516	540
750	380.00	750,000	605	723	786	824	503	602	656	686	413	494	537	563
777	394.00	777,700	627	755	822	861	525	629	684	717	431	516	562	588
1000	506.70	1,000,000	723	867	939	988								
1111	563.10	1,111,000	767	942	1025	1074								
1250	633.30	1,250,000	824	990	1072	1128								
1500	760.00	1,500,000	917	1100	1195	1254								
2000	1013.30	2,000,000	1076	1292	1400	1473								



Cabling

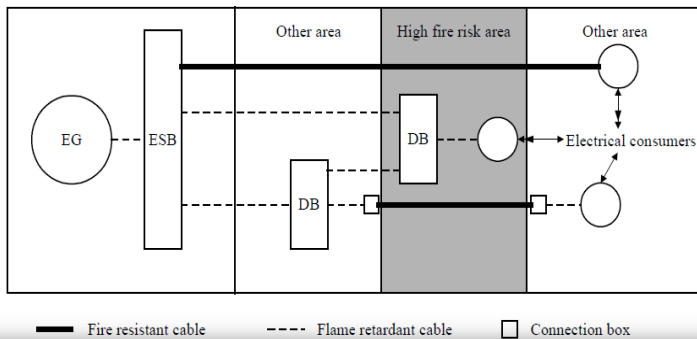
- **Critical Circuits:** Circuits for services that must maintain operation under a fire condition.

5.17.2 Services Necessary Under a Fire Condition (2013)

Where cables for services required to be operable under a fire condition (see 4-3-3/3.29) including their power supplies pass through high fire risk areas (see 4-3-3/3.31) other than those which they serve, they are to be so arranged that a fire in any of these areas does not affect the operation of the service in any other area. For Emergency Fire Pumps, see requirements in 4-3-3/5.17.3. This may be achieved by any of the following measures:

5.17.2(a) Fire resistant cables in accordance with 4-3-4/7.1.3 are installed and run continuous to keep the fire integrity within the high fire risk area. See 4-3-3/Figure 2.

FIGURE 2
Cables within High Fire Risk Areas (2008)



5.17.2(b) At least two loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

Systems that are self-monitoring, fail safe or duplicated with cable runs separated as widely as practicable, may be exempted from the requirements in 4-3-3/5.17.2(a) and 4-3-3/5.17.2(b).

3.29 Services Required to be Operable Under a Fire Condition (2008)

For the purpose of 4-3-3/5.17.2, services required to be operable under a fire condition include, but not limited thereto, are the following:

- Fire and general alarm system
- Fire extinguishing system including fire extinguishing medium release alarms
- Emergency Fire Pump
- Fire detection system
- Control and power systems for all power operated fire doors and their status indicating systems
- Control and power systems for all power operated watertight doors and their status indicating systems
- Emergency lighting
- Public address system
- Remote emergency stop/shutdown arrangement for systems which may support the propagation of fire and/or explosion

3.31 High Fire Risk Areas (2008)

For the purpose of 4-3-3/5.17, the examples of the high fire risk areas are the following:

- Machinery spaces as defined by 5-1-1/3.9.2(6) and (7)
- Spaces containing fuel treatment equipment and other highly flammable substances
- Galley and pantries containing cooking appliances
- Laundry containing drying equipment

(7) (1999) Other Machinery Spaces are those spaces, including trunks to such spaces, containing propulsion machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery (SCR, MCC and switchgear); oil filling station; refrigerating, ventilation and air-conditioning machinery with motors having an aggregate capacity greater than 7.5 kW (10 hp); and similar spaces, but are not machinery spaces of Category A.



Fire Resistant Cable

- IEC 60331 fire resistant rated cable meets these requirements.
 - Temperature: 750°C
 - Duration: 90 minutes
 - Cable under nominal voltage
- Colored outer jacket – optional
- Minimum Order Quantities



7.1.3 Fire Resistant Property (2008)

When electric cables are required to be fire-resistant, they are to comply with the requirements of IEC Standard 60331-31 for cables greater than 20 mm overall in diameter, otherwise they are to comply with the IEC Standard 60331-21 for cable diameters 20 mm or less. For special cables, requirements in the following standards may be used:

- IEC Standard 60331-23: Procedures and requirements – Electric data cables
- IEC Standard 60331-25: Procedures and requirements – Optical fiber cables

Cables complying with alternative national standards suitable for use in a marine environment may be considered. Fire resistant type cables are to be easily distinguishable. See also 4-3-3/3.29 and 4-3-3/5.17.



Cable Tray

- Tray Types

- Aluminum
 - Interior
 - Light Weight
 - Lower Install Cost
 - Exterior (must isolate)
- Stainless Steel
 - Exterior
 - Emergency Circuits
- Conductive Fiberglass
 - Exterior
 - Superior corrosion resistance
 - Subject to impact damage
 - Must seal after cutting
- Basket Tray
 - Consider as light weight alternative in specific installations.

*Be sure you specify marine rung tray (rungs slotted for tie wraps)



Cable Transits

- Cable transits typically provide for the entry of cables into spaces where the following types of barriers are required:
 - “Gas-tight” (to maintain barrier for Area Classification)
 - “Water-tight” (to withstand a hydro-static pressure differential
 - Primarily encountered within hulls where a relatively high pressure differential must be withstood (e.g., 4-5 bar). The design and installation details must be carefully evaluated. Consideration is also required as to how the installation will be tested.
 - “Fire-barrier” (to withstand fire on the outside from affecting inside)
 - The rating is dependent not only on the type of transits but also on the type of cable. Careful evaluation is required to ensure a safe installation.



Cable Transits

- Proper installation is key!
 - Issues have been encountered in past Fire-tight and Water-tight installations



Safety Alert

MMS

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

Safety Alert No. 235
December 15, 2005

Contact: David Dykes
(504) 736-3249

Multiple Cable Transit Failures

Following the passage of Hurricane Dennis, personnel returned to the Thunder Horse facility to find it listing at approximately 20 degrees with the top deck in the water on the port side. This incident is currently under investigation and the exact source/cause of the water influx/listing has not been determined at this time; however, information has been discovered that needs to be shared with industry.

Preliminary findings from the investigation indicate that water movement among the access spaces occurred through failed multiple cable transits (MCT's). MCT's are the points in the watertight bulkheads where cables that carry electrical power and instrument signals pass through the watertight bulkheads. Essentially, MCT's are molded blocks of plastic that seal around each cable. Failure occurred in the spaces filled with blank blocks. Specifically, the findings indicate that either the MCT's may not have been installed properly, may have been installed using the wrong procedures, or may not have been properly pressure rated for the configurations being used.



Subsea Power Distribution

- Use of Subsea pumps and/or compressors may be required to increase deep water field recoverables
- Use of subsea switchgear and ASD's reduces the number of hang-offs from a floating structure (> 40 planned for one project) and expected clashing damage during hurricanes
- Use of subsea switchgear and ASD's is more economical for several very long step-outs and where topsides space is limited

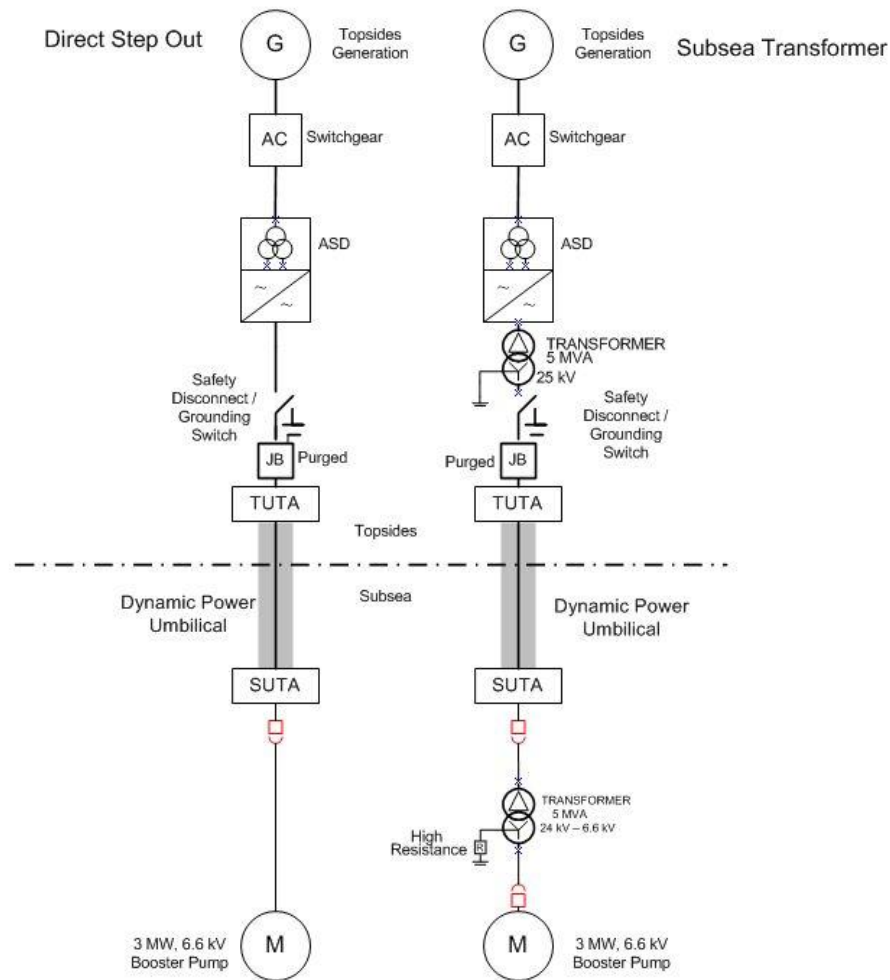


Design Considerations for Subsea Systems

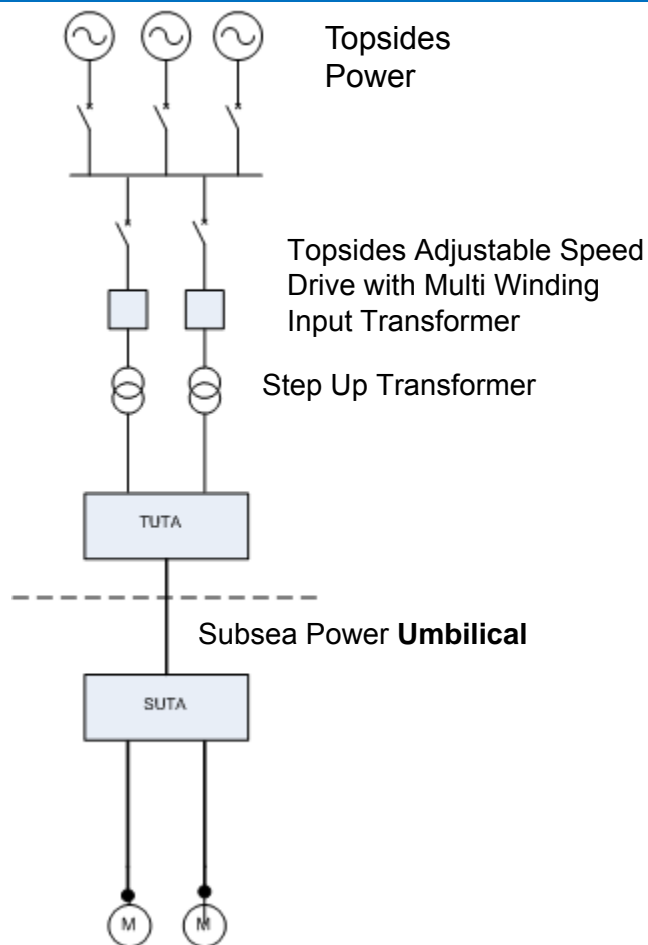
- ASD w/ & w/o topsides step up transformer
 - DC component in output of ASD and saturation concerns when step up transformer is used
 - Greater volts / hertz in topsides step up transformer
 - ≥ 18 pulse or active front end to limit harmonics injected into supply system; clean output required – some options include stacked AC output or sine wave output filter
 - May need additional output filter to shift frequency in case of circuit resonance
- Grounding switch for personnel safety
- Purged junction boxes for hydrogen and / or methane gas from umbilical – small explosion at junction box with no purge has been experienced



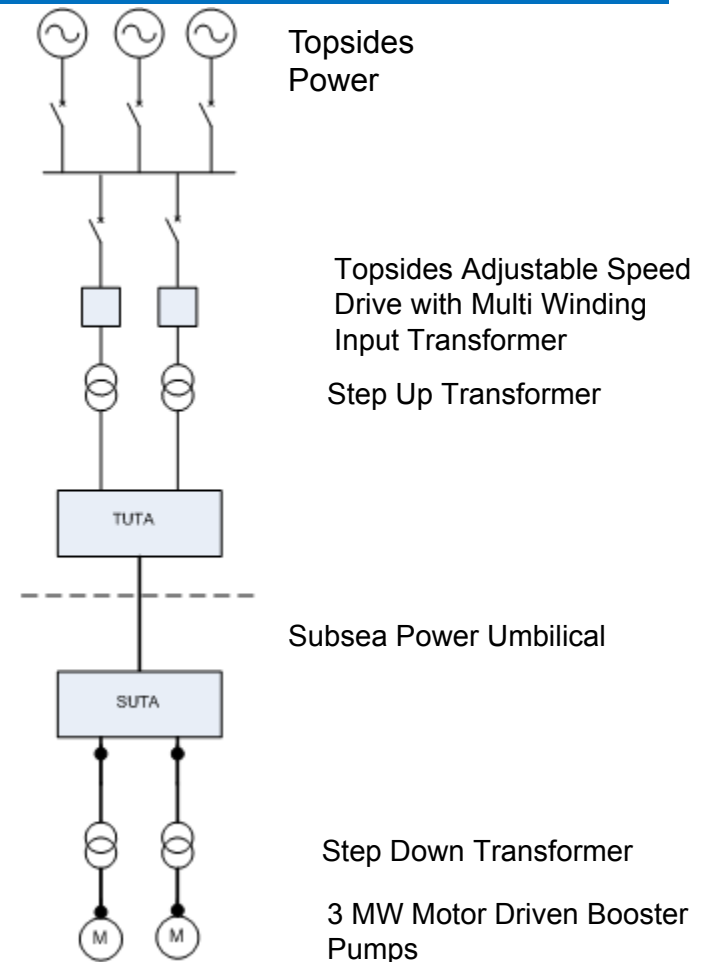
Subsea Distribution w/ Topsides ASD's



Direct Drive



Transformer Step Up/ Step Down



3 MW Motor Driven Booster Pumps

Design Considerations for Subsea Systems (cont)

- Torque available at motor terminals
- Voltage regulation limits of topsides drives (generally up to $\sim 25\%$), drive modeling issues - modeling of circuit to control volts / Hertz at motor
- Standards
 - BSEE is the authority having jurisdiction in the Gulf of Mexico. Recommend qualifying equipment to both ANSI/ IEEE/ ICEA and IEC standards to allow application worldwide; Generally ANSI more stringent; ANSI required by BSEE
 - Joint IEC/IEEE standards are being developed for subsea equipment



Design Considerations for Subsea Systems (cont)

System Grounding

- High resistance grounding of subsea transformers ≤ 11 kV to control escalating voltages – allows operation during ground fault
- Solid or low resistance grounding of transformers $\geq \sim 11$ kV to avoid severe damage from voltage escalation during ground fault
- A ground fault on ungrounded systems may require an immediate shutdown



Design Considerations for Subsea Systems (cont)

- Ferranti effect
- Energization and de energization transients
- Energization of long cables and transformers w/o circuit breakers
- Individual pole switching
- Transformer pre charging
- Temporary over voltages
- On load tap changers on supply transformers
- Reactive Compensation
- Subsea pressures
- Marinization



Dynamic Power Umbilicals

Dynamic Power Umbilical

- Size, weight, and weight to diameter ratio are design, manufacture, transport, installation, and operation constraints
- Scrutiny in qualification of manufacturer of power cores and factory splices in umbilical is required. Use of strand sealing compound is crucial to reduce both water penetration and hydrogen migration to topsides.

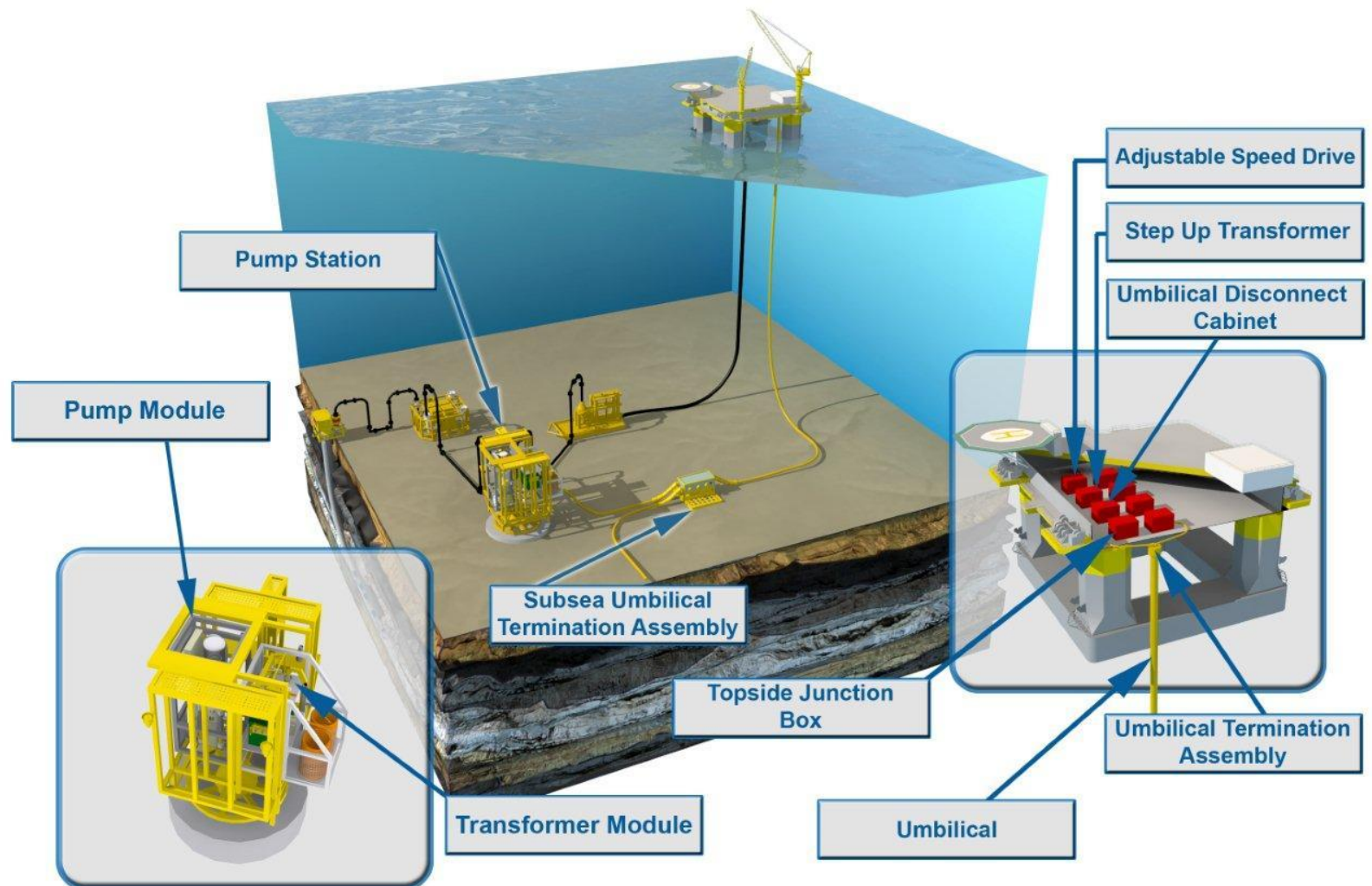


Dynamic Power Umbilicals (cont)

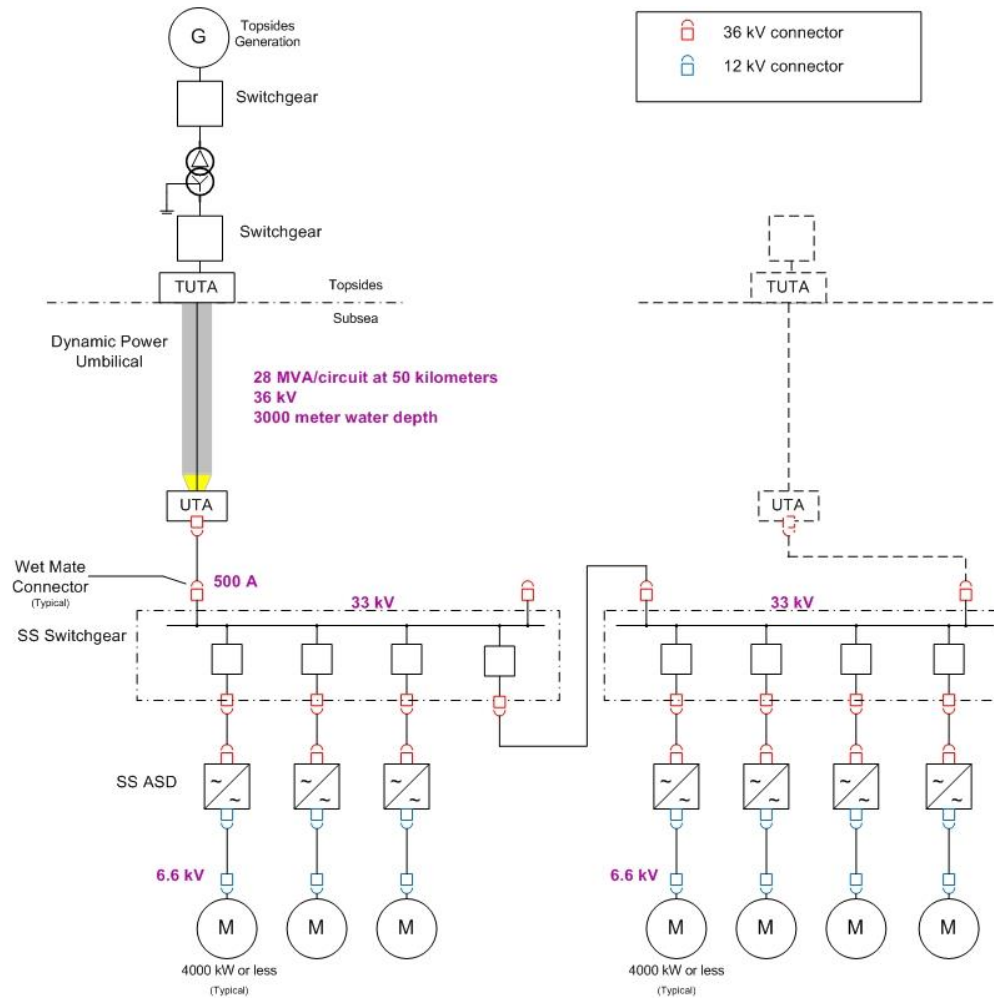
- Use of minimum requirements of topsides cable standards is not adequate for long life
 - Limit conductor insulation to 80° C, 80° C for fiber optics, 70° C at XLPE subsea termination
 - Limit voltage stress for XLPE to ≤ 2 kV/ mm
- Multi circuit issues: Induced voltages and resulting pulsating torques, helical lay of circuits in separate passes for mitigation of induced voltages



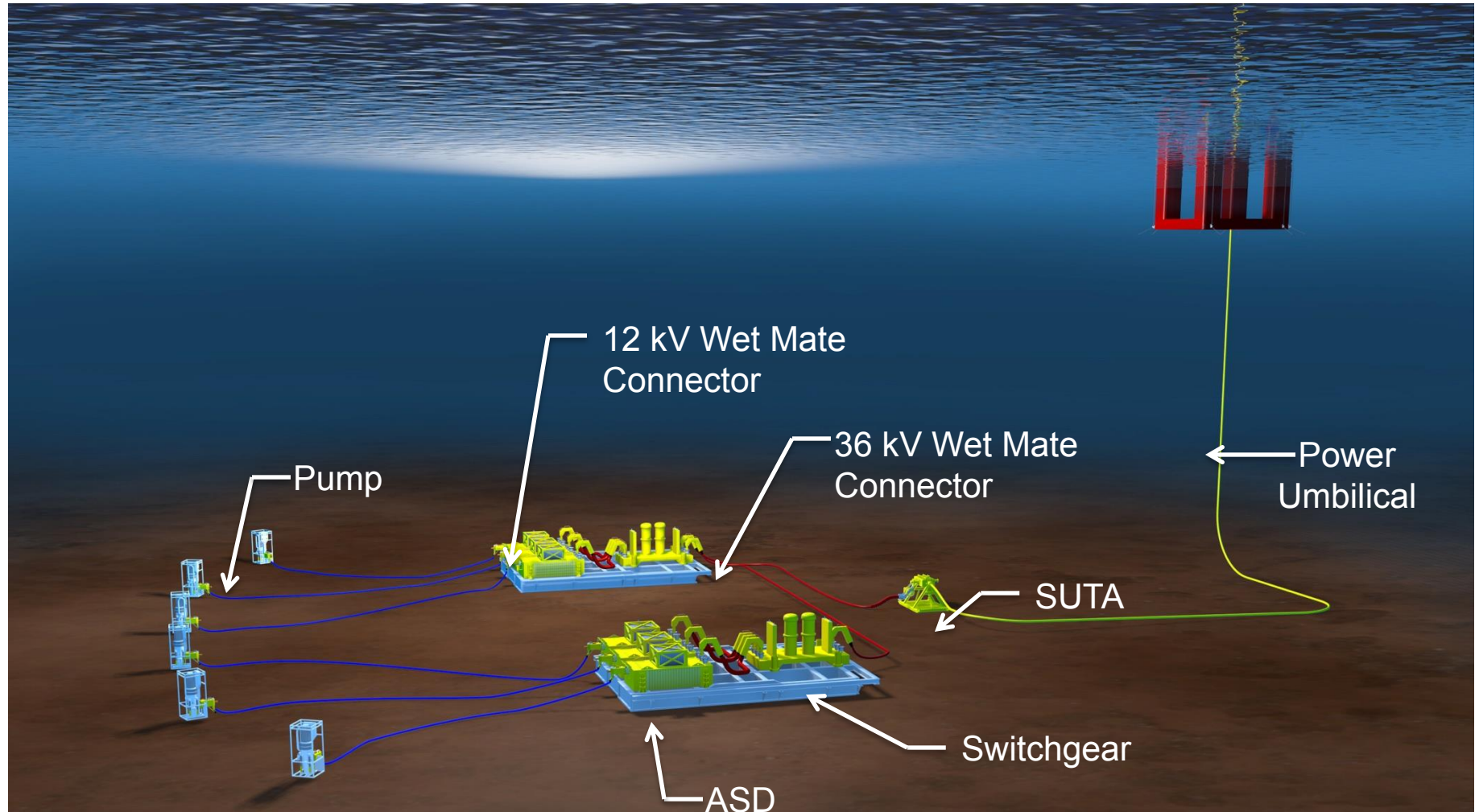
Subsea Booster Pump System w/Topside ASD



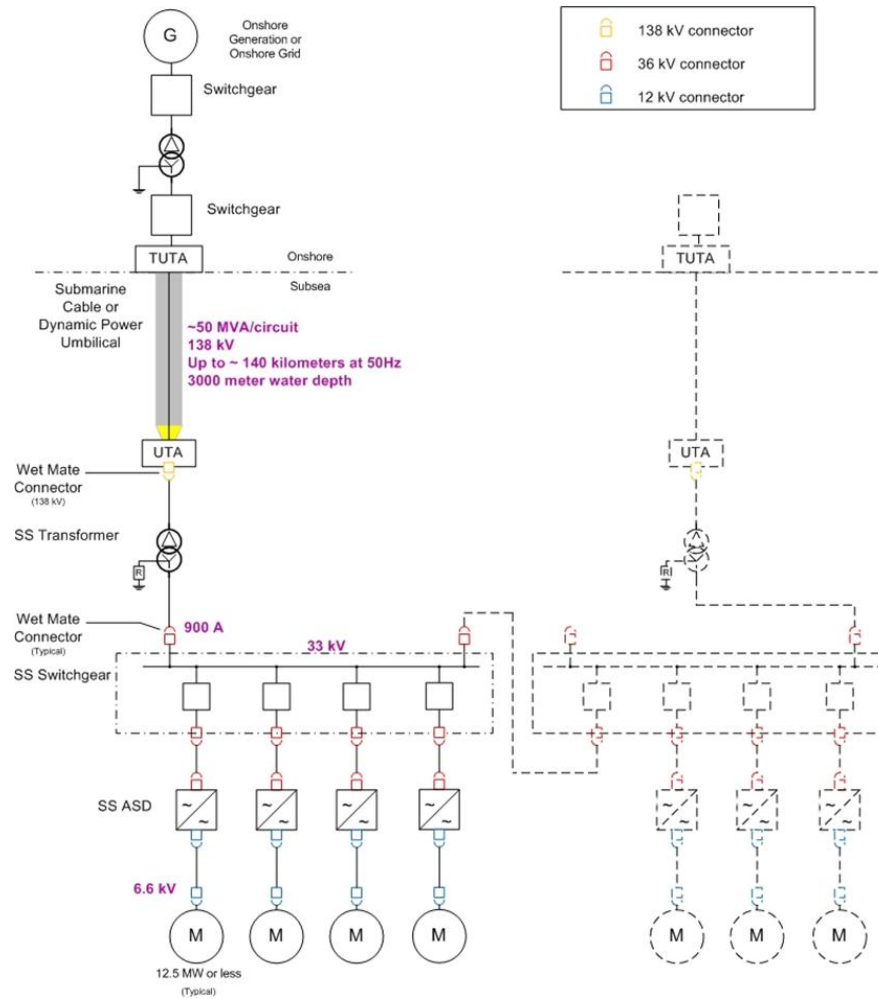
36 kV Subsea System Scheduled for Qualification by 2017



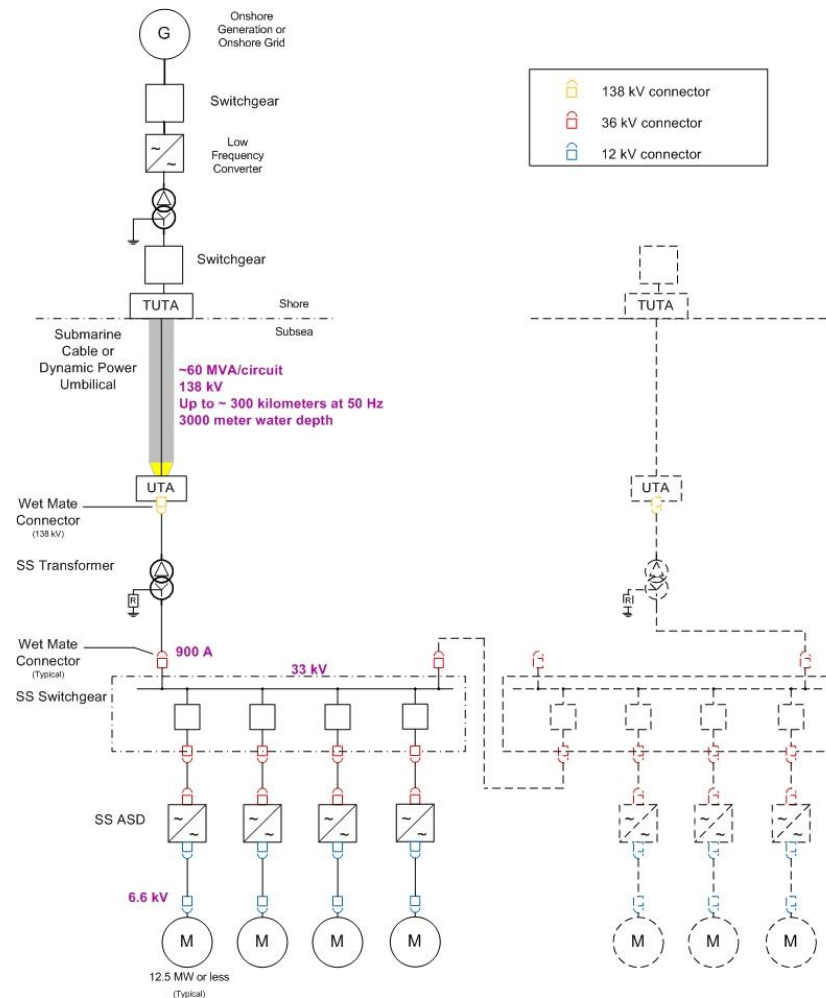
36 kV AC Distribution



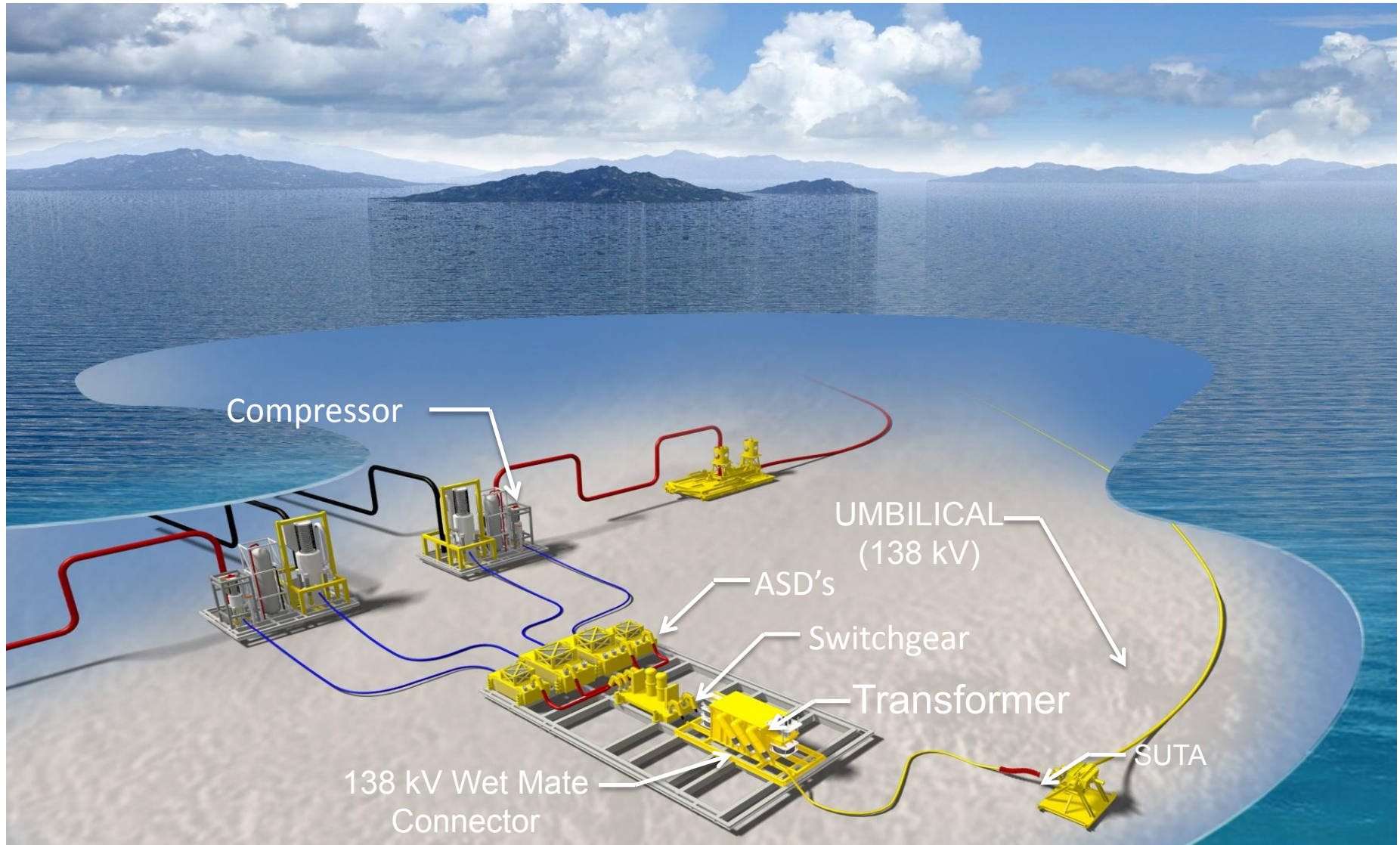
138 kV 50/60 Hz AC System



138 kV Low Frequency AC System

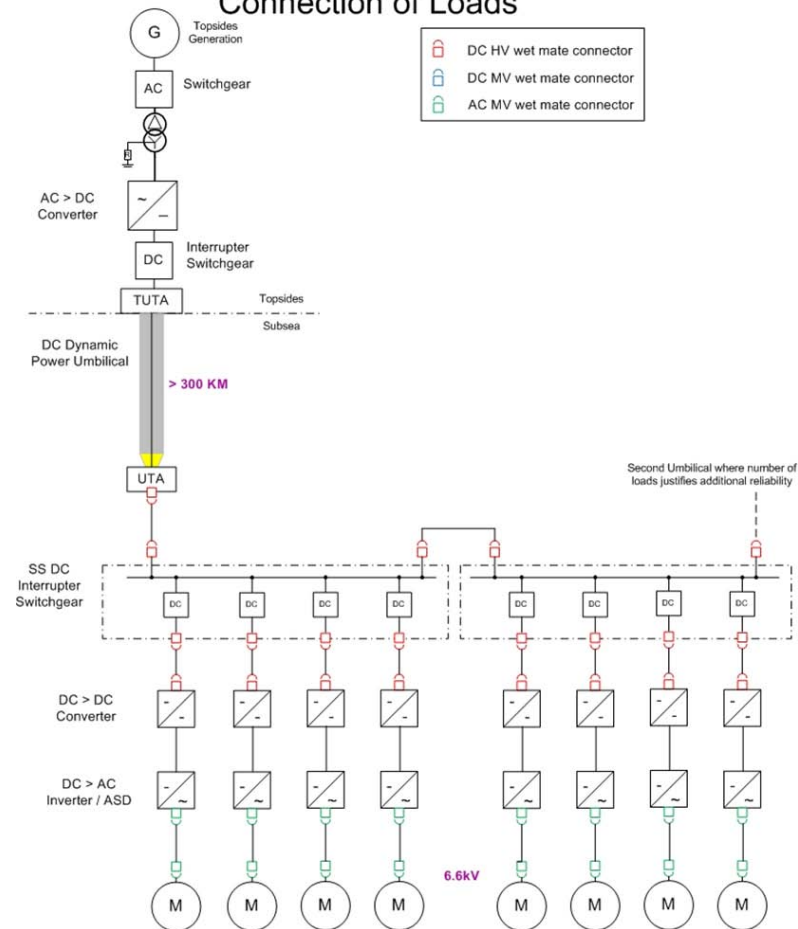


138 kV AC Transmission



Subsea DC Distribution ?

Future DC Distribution? – Parallel Connection of Loads



Gaps

- Wet Mate Connectors – AC Now limited to 36 kV; DC to 10 kV
- XLPE Cables limited to ~ 44 kV w/o sealed metal sheath
- EPR Cables limited to ~ 72 kV w/o metal sheath
- DC circuit breakers with ratings greater than 1000 volts are not yet available for subsea application
- Subsea reactive compensation has not yet been qualified
- Subsea switchgear and ASD's



Thank You

We hope that this seminar has been informative and provided you with a high level overview of electrical installation and application requirements. If you take anything away, we hope that it is that the authorities having jurisdiction (BSEE & USCG) and certification agencies (ABS) should be contacted early during the design phase to clearly define the regulatory and standard requirements. Open communication channels with these entities will be a key factor to successful project design and execution

