

USE OF COMPOSITE MATERIALS IN PROTECTING AND MAINTAINING SUBSEA EQUIPMENT

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ABSTRACT

This paper summarizes many years of experience in designing and testing composite materials for use on offshore oil and gas pipelines and production equipment. It is the authors' position that properly designed coatings and coverings can materially extend the life and safety of subsea equipment, whereas improper design can often contribute to premature failure and endanger both equipment and personnel. The principal applications of the authors' research fall into four areas: (1) Buoyancy – providing buoyant lift to offset excessive weight of equipment in water; (2) Controlled Strength – providing precision compressibility to mitigate possible downhole annular pressure damage (3) Insulation – providing thermal protection against heat loss; and (4) Corrosion Protection – ensuring that all coatings work with (rather than against) cathodic protection systems. The potential for catastrophic damage in any or all of these areas is increasing daily as production moves into deeper water and hotter, higher-pressure wells. The paper presents case studies, cites test evidence, and suggests guidelines for designing composite materials that enhance safety in each of the subject areas. The resulting information will be useful to engineers, supervisors, and managers whose responsibility includes offshore design, maintenance, and safety.

Buoyancy

Syntactic foam riser buoyancy has been a part of offshore oil operations for over 30 years. The syntactic foam is based on precision glass microspheres in a strong, rigid plastic resin binder with one or more sizes of fiberglass macrospheres for maximum strength with minimum weight. These buoyancy modules are designed to be easy to lift, store, and handle, and work in concert with other rig equipment. Integrally molded flexure lugs inside the modules isolate bending to avoid damage to the riser. Smooth, no-snag outer contours with all hardware recessed below flush minimize the chance of hang-up. Self-shoring features prevent modules rolling around on deck and allow safe stacking, while built-in lift points make for safe, speedy handling.

Straps and attachment systems are available in a wide variety of styles and materials, including carbon steel, stainless steel and Kevlar. External or internal strap designs may be selected. Integral or molded-in attachment brackets simplify assembly and speed the installation process. There are different kinds of accessories that can be used to improve the safety of operations, such as: thrust collars to contain weight and buoyancy loads and prevent dangerous shifting, quick-acting clamps can be adapted to attach all types of electrical cable and hydraulic hose. In high current areas, hydrodynamic fairings may be needed to reduce drag and eliminate vortex-induced vibrations. (1)

Buoyancy Module Density vs. Depth Rating
lbs/ft³ (kg/m³)

Rated Service Depth Ft (m)	Conventional Syntactic Foam	Ultralight Products	Super- Ultralight
2,000(600)	26(417)	22(353)	20(320)
4,000(1200)	30(481)	26(417)	24(385)
6,000(1800)	32(513)	28(449)	26(417)
8,000(2400)	34(545)	30(481)	28(449)
10,000(3000)	36(577)	32(513)	30(481)

Table 1.

For severe service conditions, ruggedized modules may be necessary to provide the maximum protection. Although natural strength and durability are the standard features for the all buoyancy modules, special features are added to the ruggedized modules for the severe conditions. These features include: thicker fiberglass skin, integral web reinforcement, stiffeners and rebar; resilient outer coating of polyurethane, polyethylene or flexibilized high impact epoxy.

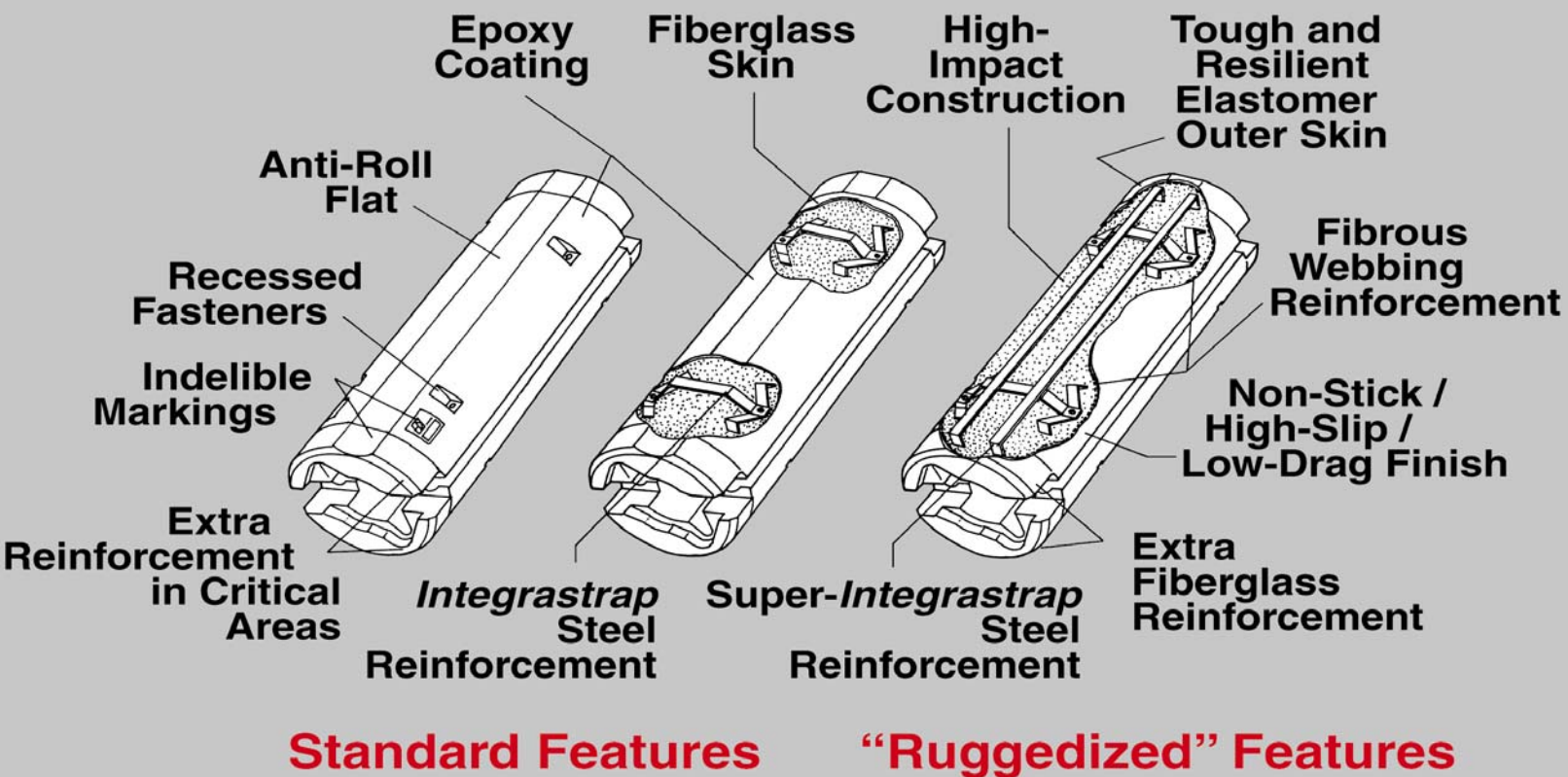


Figure 1.

**Module Bend Test
"Ruggedized" vs. "Standard"
Buoyancy Modules**

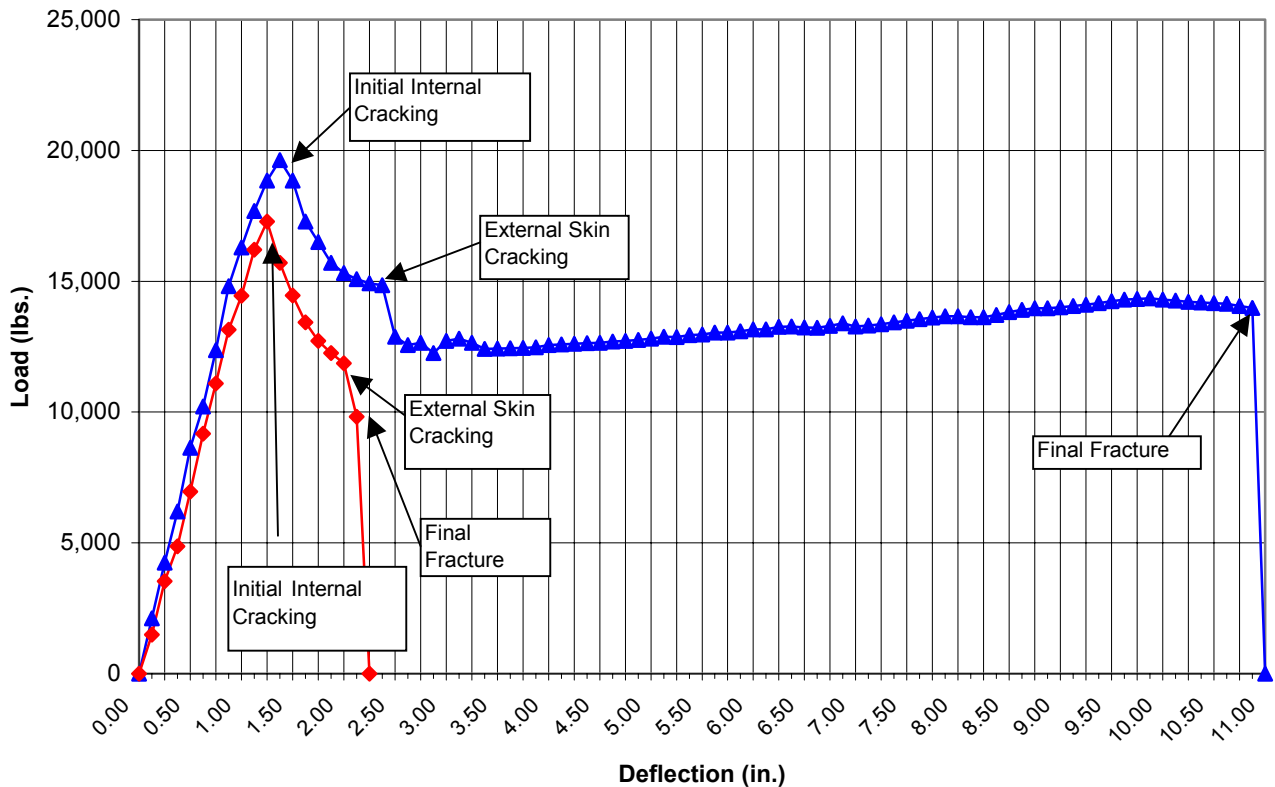


Figure 2.

Precision Strength

An offshore oil well is a complex structure of pipes and valves to control the flow of oil and gas from deep in the Earth. Sometimes, its wells start over a mile below sea level and continue down through mud, soil, and rock for thousands more feet. To seal and support the drilled hole, the well bore is lined with steel casing. Where successive lengths of casing overlap, they form a trapped void space called an *annulus*. Under extreme conditions of heat and pressure, expanding fluids and gases in the annulus can create so much stress on the inner casing wall that it buckles and collapses inward, possibly shutting down the well.

The hydrostatic behavior of the syntactic foam is depicted in the diagram in **Figure 3**. Each grade of syntactic foam is engineered to have a specific set of characteristics, tailored for the region of the well it occupies. In the drilling startup phase, the materials remain intact, with no significant volume change.

As pressure and temperature in the well rise during operations, the materials begin to compress and relieve pressure in the narrow, confined space of the annulus. Finally, when conditions reach certain preset limits, the syntactic foam undergoes a sudden and dramatic collapse, preventing excessive over-pressure, and protecting the steel casing.

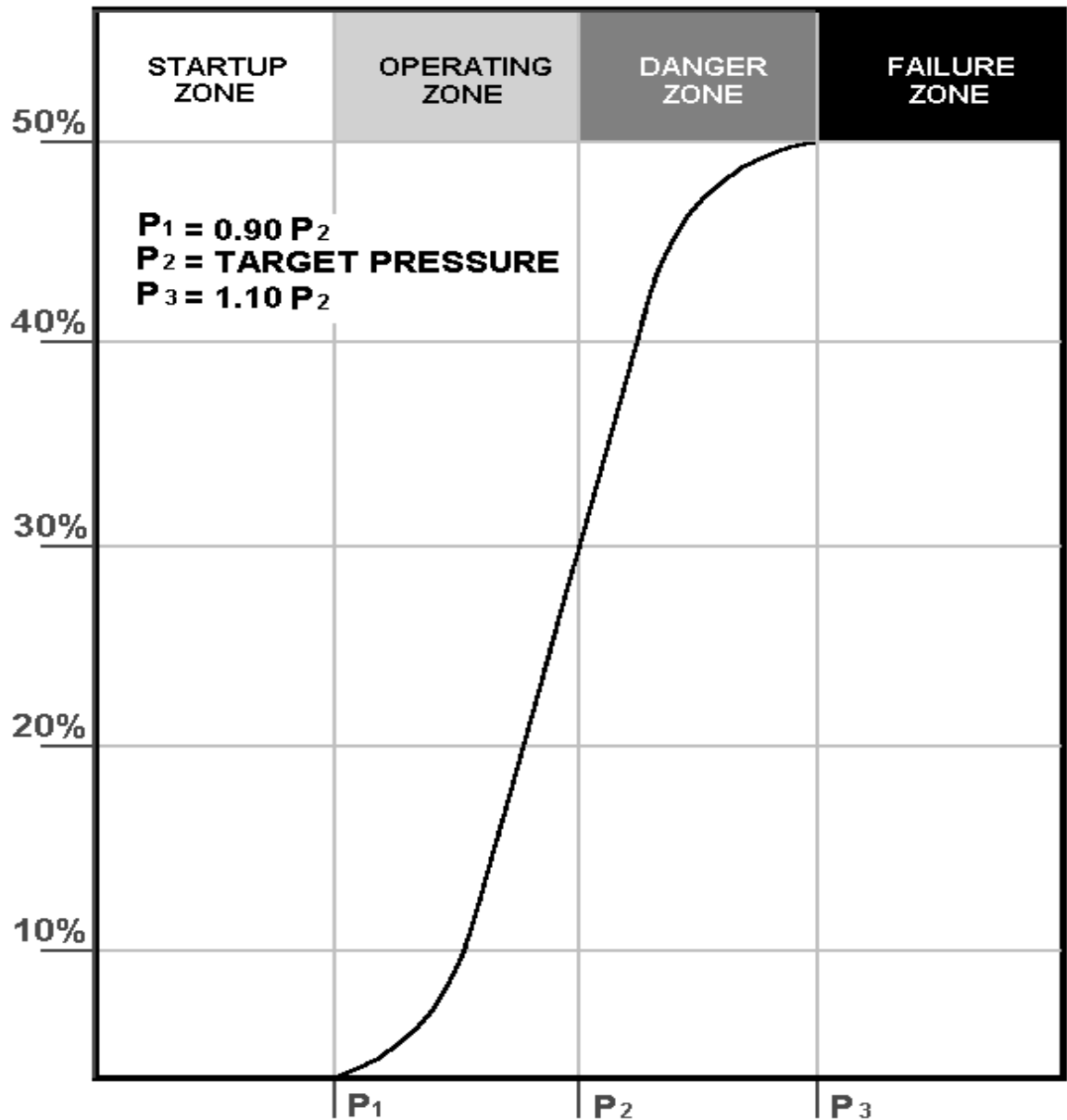


Figure 3
IDEALIZED PERFORMANCE CURVE, CRUSH VS. PRESSURE

The diagram in **Figure 4** is a greatly simplified schematic of a typical well. Hydrostatic pressure acting on the well can be many thousands of lbs per square inch, thanks to the weight of the water column overhead. Forces generated inside the well can add to and amplify this pressure, and the magnitude and timing of these forces are difficult to define and predict. To mitigate these effects, special grades of newly developed syntactic foam are cast directly onto the OD of the casing pipe in Cuming

Corporation's New Iberia, Louisiana, factory, and a stone's throw from the Gulf of Mexico. The function of the syntactic foam is to collapse in a controlled manner, relieving pressure surges in the annulus and thereby protecting the casing, serving, in effect, as an "insurance policy" for the multi-billion-dollar production program. (2)

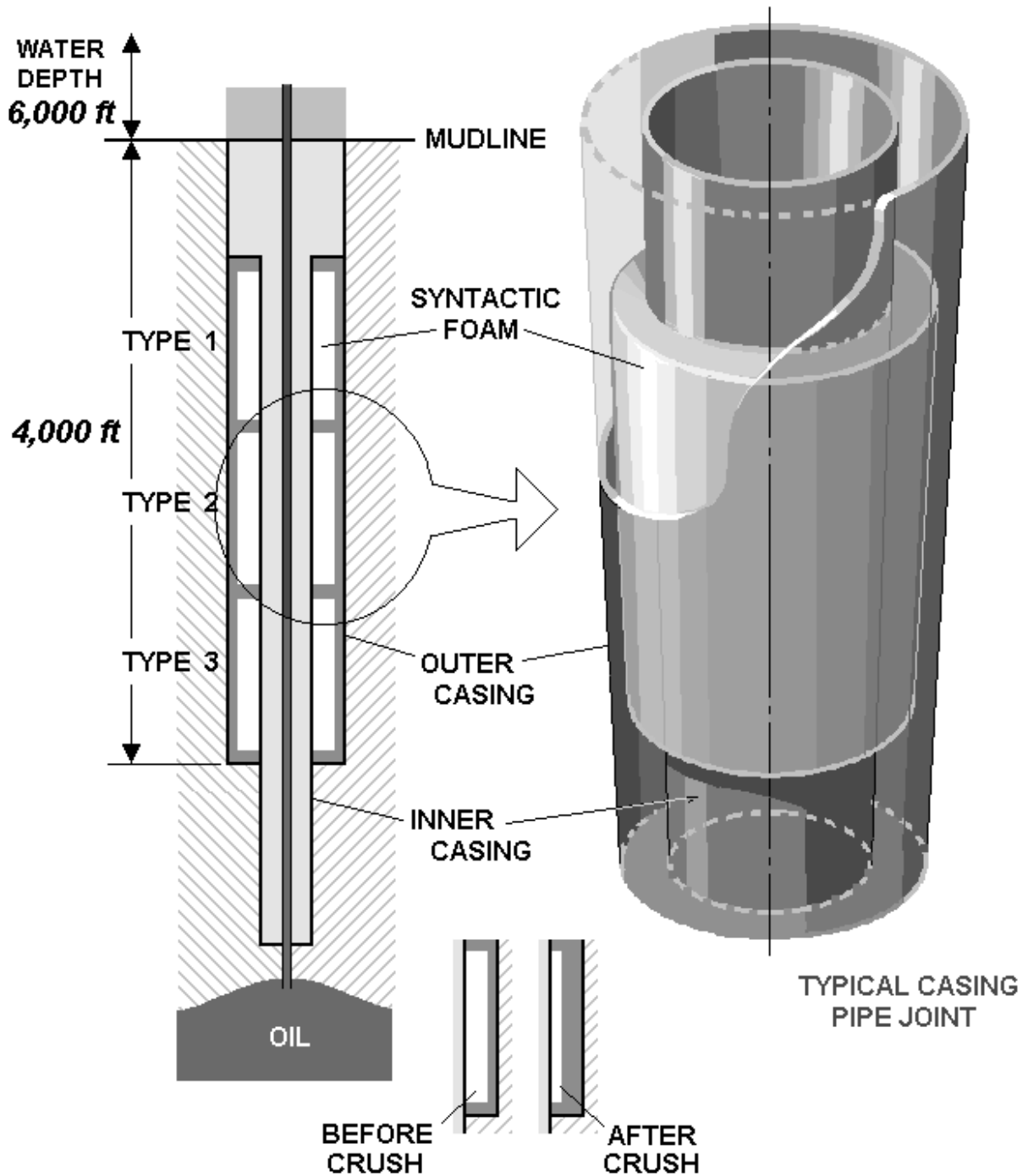


Figure 4
"PRECISION STRENGTH" MATERIAL PROTECTS THE WELL

Thermal Insulation

Offshore production of hydrocarbons has spread rapidly into deep water, moving from a thousand meters or less to depths well in excess of two thousand meters. As the water depth has increased, so too has the temperature of the product, from under 100° C to more than 150° C. At the same time, the size of fields and length of transport are growing, worsening the risk of blockage due to thermal precipitates. In response, a number of different flow assurance measures have evolved, including insulation of flowlines, risers, and wellhead equipment. Until recently, however, the effectiveness of insulation materials was limited by their vulnerability to the subsea environment. To meet this challenge, specialized syntactic foam systems have recently undergone a remarkably intense period of research and development. (3)

Syntactic foam offers many performance and cost advantages over competing materials. It is a lightweight composite providing higher thermal efficiency and better resistance to hydrostatic pressure than conventional insulation technologies, at a lower cost. Our insulation comes in many forms - pack in place, flat and curved panels, collars and tapes - adapting readily to all surfaces and shapes. These can be used to insulate the entire subsea system - risers, connecting lines, trees and pipeline weld joints - forming a complete deepwater thermal barrier.

Thermal management is very important when choosing a suitable insulation system. The most accurate data can be gathered from a simulated service vessel. However, it is very expensive and time consuming. Some computer simulation models can get close results if the model is carefully designed. **Figure 5** and **Figure 6** are the cool down simulation results for a field joint; **Figure 7** is the actual test result. We can see both of their numbers are very close to each other.

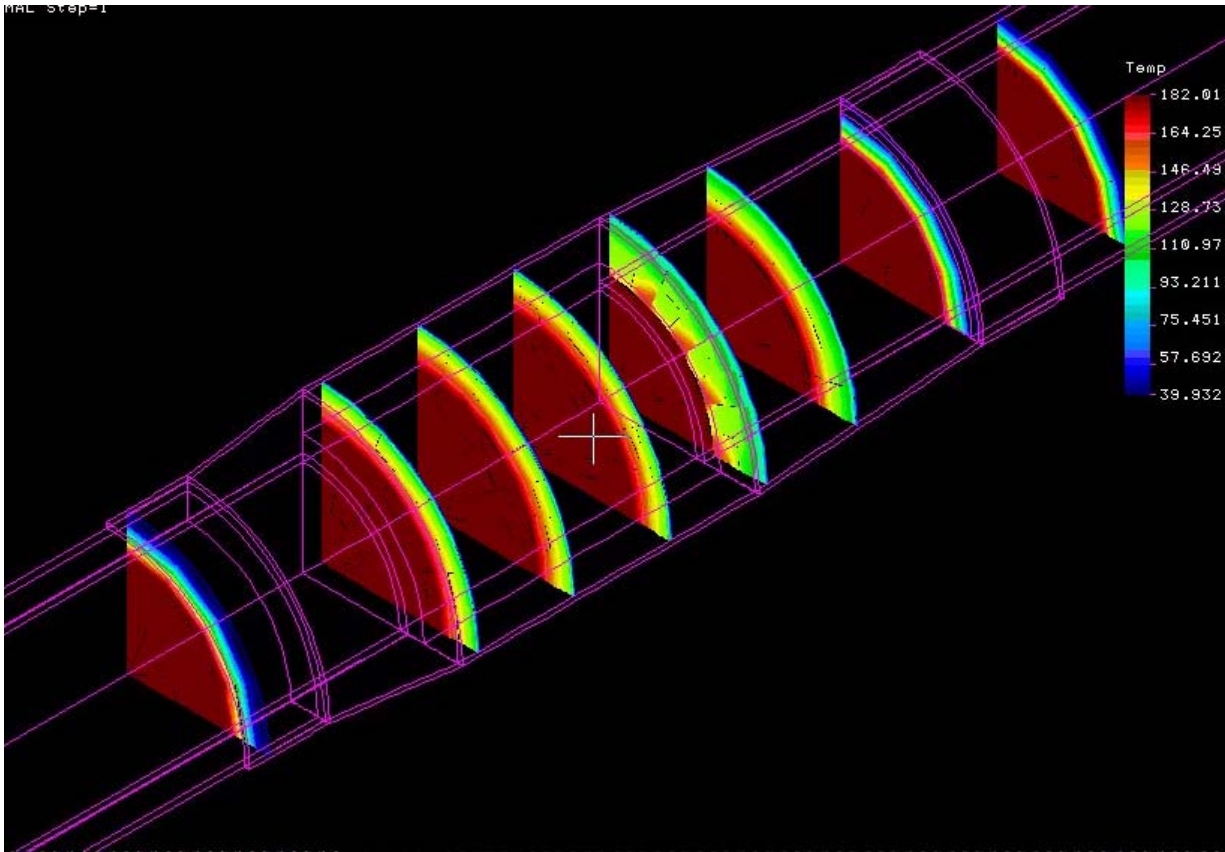


Figure 5 Field Joint Cool Down Simulation by Cosmos V2.8

Cosmos V 2.8 Cool Down Simulation for Field Joint

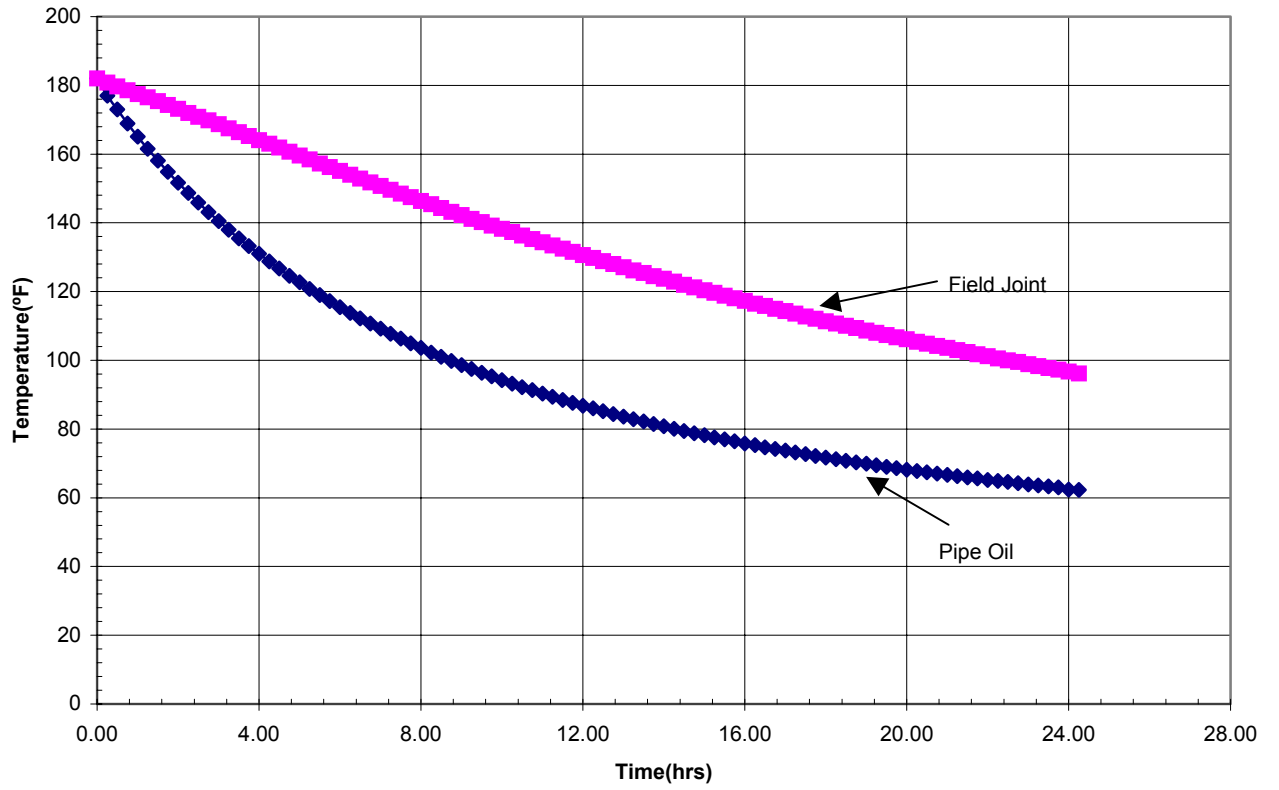


Figure 6

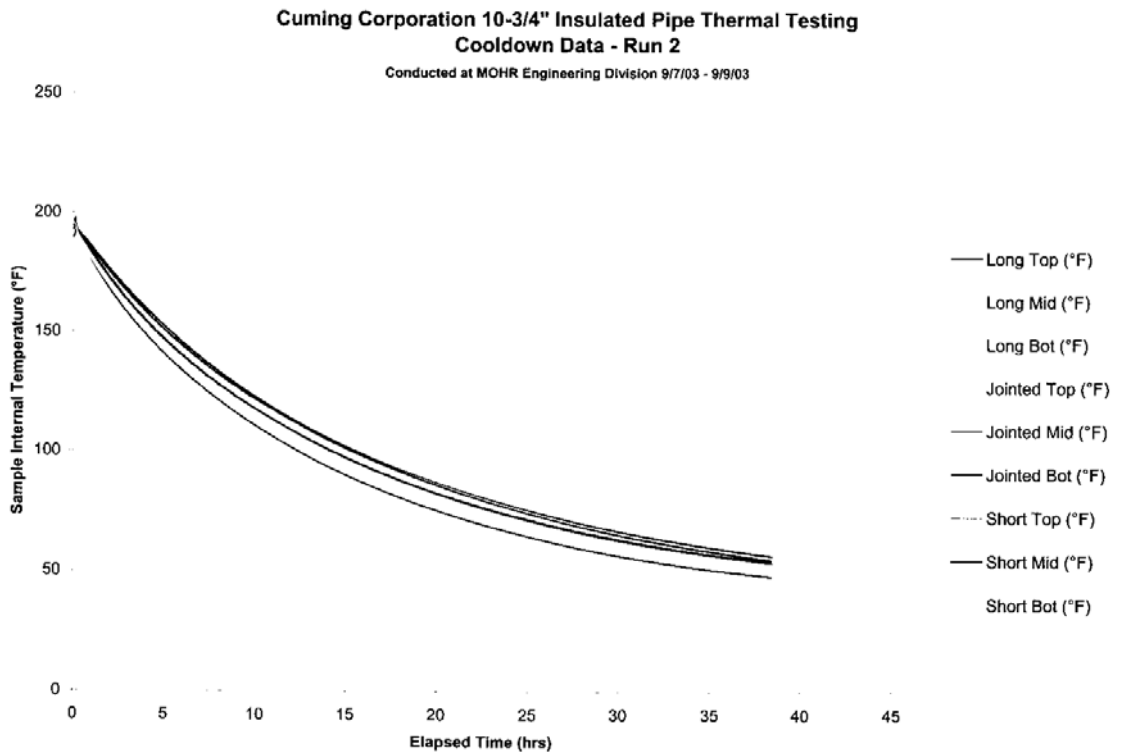


Figure 7

Corrosion:

To protect the subsea equipment or pipeline for corrosion, normally the operators will coat a thin layer of FBE (fusion bond epoxy) or TSA (thermal spray aluminum). To work with the cathodic protection system, the insulation material suppliers need be very careful to formulate their material to insure the best performance. **Table 2** is the test results of two of our insulation material with the two different FBE coatings. **Figure 8** and **Figure 9** are the pictures of tested samples.

Sample No.	Identity of Coated Test Panel	Testing Duration (days)	Average Coating Thickness DFT (mils)	Length of Cathodic Disbondment circle (mm)*
1	A1	7	275	No Change
2	A2	14	273	No Change
3	A3	21	301	No Change
4	A4	28	276	1.1
5	B1	14	250	4
6	B2	28	245	6.5

Table 2. Cathodic Disbondment Test Per ASTM G-42



Figure 8, Sample A4



Figure 9, Sample B2

Conclusion:

Syntactic foam materials are available for most of the applications for the subsea equipments and drill operations to protect and maintain the systems. The potential for catastrophic damage in any or all of these areas is increasing daily as production moves into deeper water and hotter, higher-pressure wells. By carefully selecting the right material and design , we can help to ensure the safety of the operation.

While it is every engineer's goal to design a 100 % waterproof system, the possibility always exists for some leakage to occur during twenty or more years under high hydrostatic pressure. Therefore, it is advisable to design and test insulation materials under conservative "hot, wet" conditions.

Reference

1. Cuming Corporation Technical Bulletin: "C-FLOAT Riser Buoyancy Modules"
2. "Design, Making & Testing Foam of Precisely Controlled Hydrostatic Strength" by Wen-Tsuen Wang and Lou Watkins, OMAE 2003
3. "Syntactic Foam Thermal Insulation for Ultradeep High Temperature Application" by Wen-Tsuen Wang and Lou Watkins, OMAE 2002