

**DESIGNING, MAKING, AND TESTING SYNTACTIC FOAM  
OF PRECISELY CONTROLLED HYDROSTATIC STRENGTH**

by  
Wen-Tsuen (Vincent) Wang and Lou Watkins  
Cuming Corporation

**ABSTRACT**

This paper describes a recently developed syntactic foam material designed to collapse under precisely defined conditions of temperature and pressure to protect ultra-deep high pressure offshore oil and gas wells. 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 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 preset limits, the syntactic foam undergoes a sudden and dramatic collapse, preventing excessive overpressure, and protecting the steel casing. An important advantage of this material is that it is passive, requiring no controls or active intervention. It responds automatically to protect the well casing from overpressures and temperature spikes. The properties of the material can be adjusted to suit a wide range of conditions inside a given well, or from one well to another.

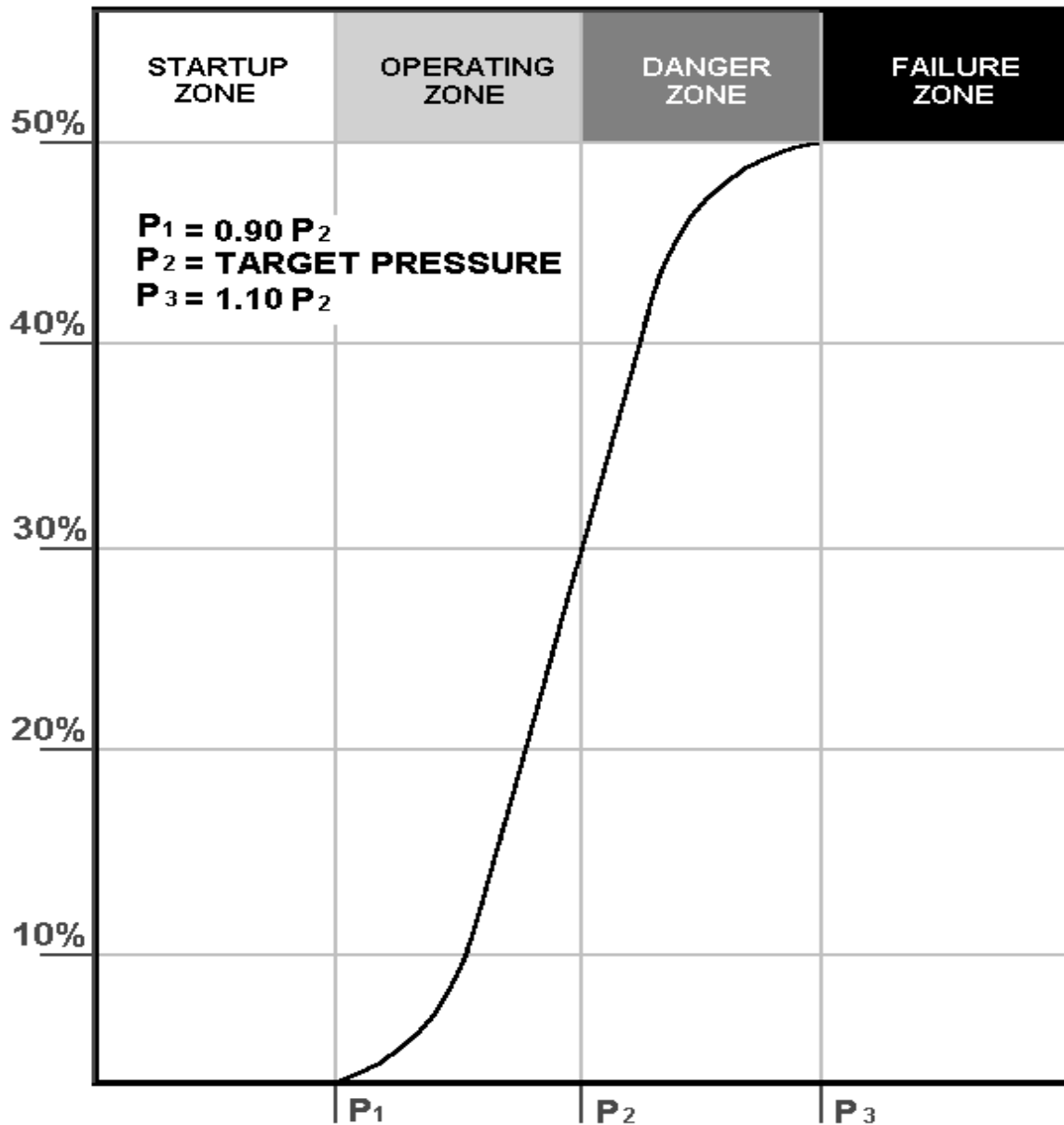
**INTRODUCTION**

Working in cooperation with BP-America, Cuming Corporation (Avon, MA USA) recently developed a new line of syntactic foam materials designed to collapse under precisely defined conditions of temperature and pressure. Although potentially applicable to other fields, the research effort, the first of its kind, was expressly done for *Thunder Horse*, the largest oil and gas field ever found in the Gulf of Mexico. *Thunder Horse* wells are among the deepest ever drilled, in over 6,000 ft water, and the hottest, at 270° F. These extreme conditions create many challenges, including transient overpressures below the mudline that can endanger the steel casing lining each well.

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. In the case of *Thunder Horse*, 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.

**DESIGN**

The hydrostatic behavior of the syntactic foam is depicted in the diagram in **Figure 1**. 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 overpressure, and protecting the steel casing. By varying wall thickness of the glass microspheres and altering properties of the surrounding resin matrix, collapse strength can be adjusted over a wide range of temperatures and pressures. The *Thunder Horse* system is divided into three zones, each with its own nominal crush pressure: Type I, 5300 psi at 240 °F, Type II, 6300 psi at 240 °F, and Type III, 7300 psi at 240 °F.



**Figure 1**  
**IDEALIZED PERFORMANCE CURVE, CRUSH VS. PRESSURE**

### TESTING

To prove the system works, Cuming Corporation had to first create a number of new product formulas, make numerous samples, and then test under conditions that would demonstrate their full range of properties. Because the required test conditions were ultimately so severe (approaching 300° F at 10,000 psi), special testing apparatus had to be designed and built. **Figures 2** and **3** depict some of the test equipment. The devices are electronically instrumented to allow simultaneous recording of temperature, pressure, and volumetric change. Repeated trials were necessary to arrive at the desired behavior at each level in the well. BP engineers were deeply involved in the development process, comparing test results with predictions of *Thunder Horse* well conditions, and providing corrective feedback.

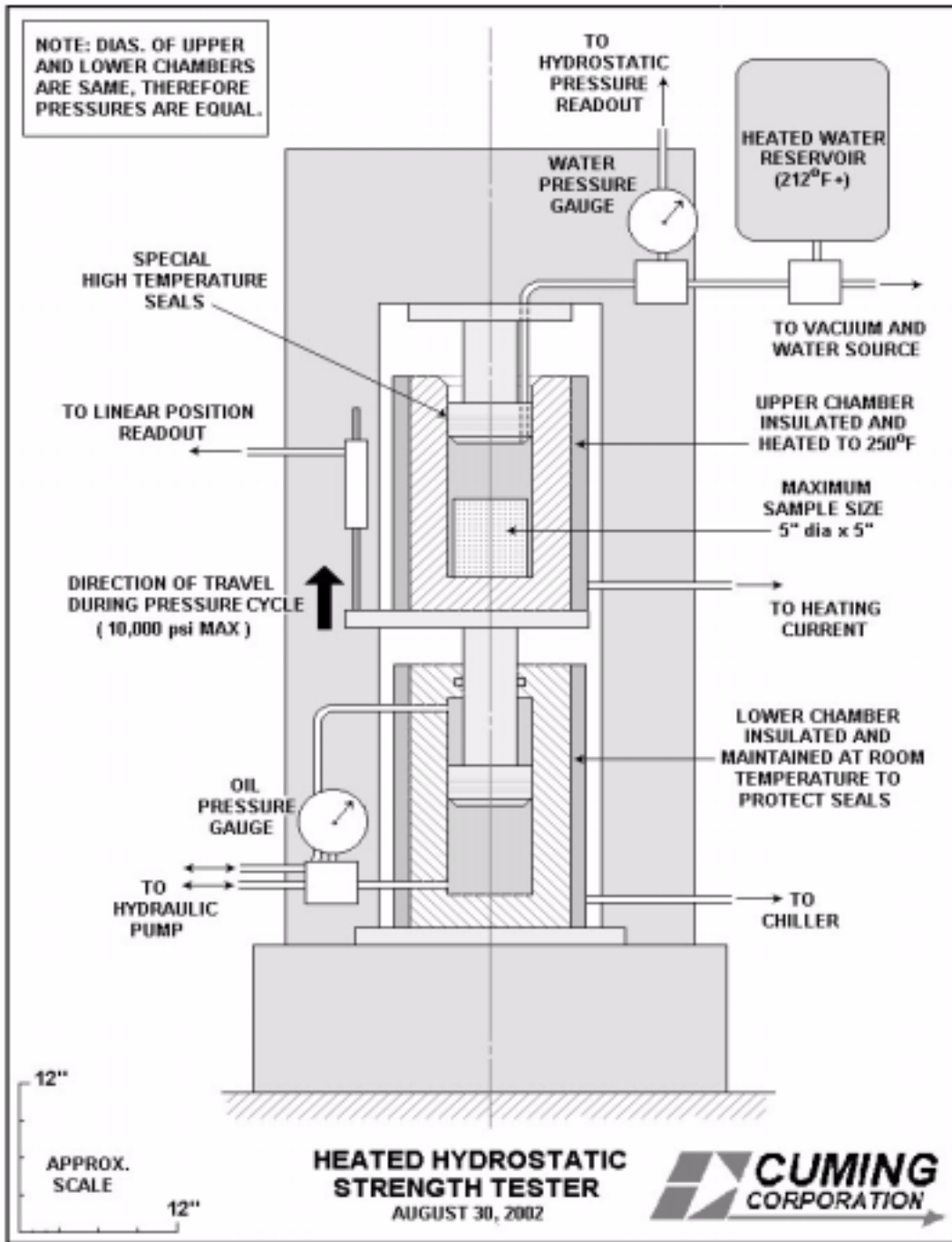


Figure 2  
SCHEMATIC OF TEST APPARATUS



**Figure 3**  
**PHOTOGRAPH OF CONTROL STATION**

### TEST RESULTS

**Figure 4** is the actual test data for typical *Thunder Horse* conditions. As seen from the curve, very little volume compression (less than 10%) occurs before reaching the design pressure of 7,900 psi. After that, more than 30% volume compression rapidly occurs. **Figure 5** summarizes behavior at different temperatures; as temperature increases, crush pressures of all grades drop accordingly.

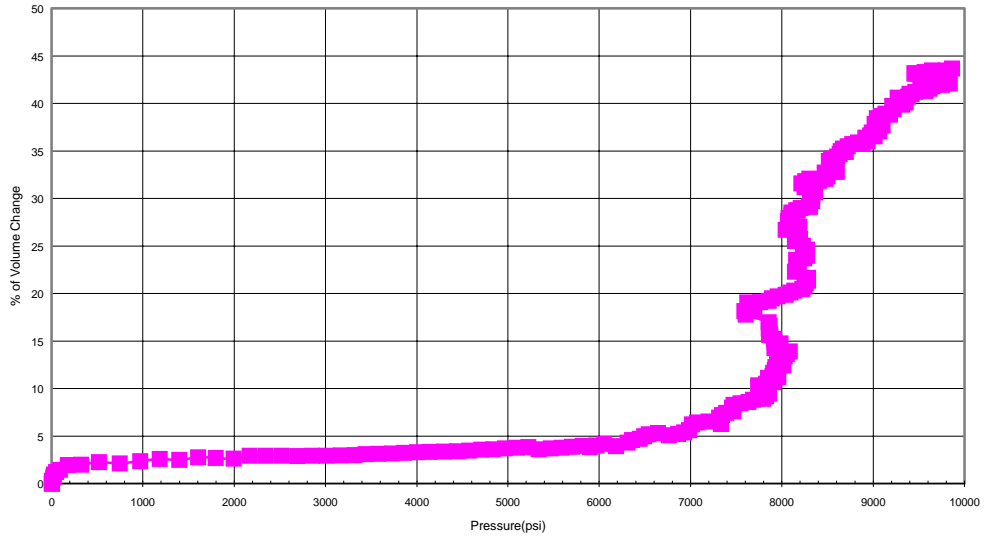
### MANUFACTURE

In parallel with the materials research effort, manufacturing engineers were busy at Cuming Corporation's Louisiana factory, preparing for production to meet BP's demanding delivery schedule. The patented cast-on-pipe process has many advantages in this kind of application, but to efficiently achieve the rapid mixing and casting of large quantities of extremely rigid, high-strength syntactic foam directly onto the steel casing proved to be a major challenge. Success came as casing started rolling through the factory and finished coated joints made their way out to sea and the waiting rig, where new records were established daily in drilling and spudding wells.

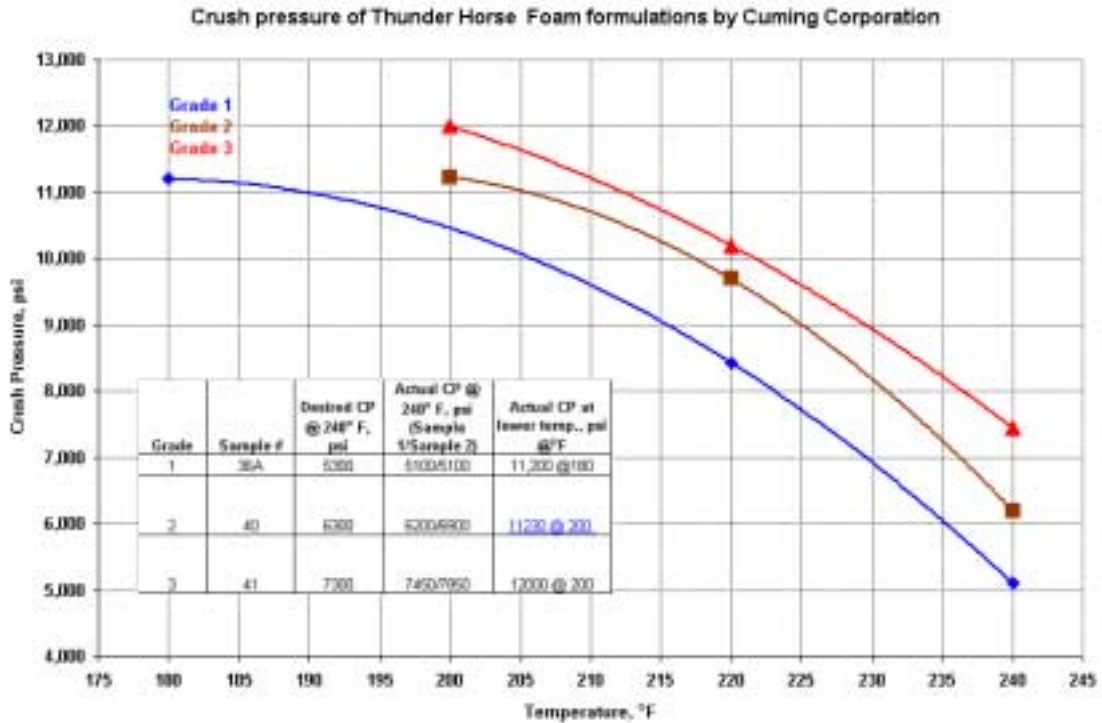
### APPLICATION

The diagram in **Figure 6** 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, 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. **Figures 7** and **8** are photos of the actual finished pipe.

BP Crushable Foam Project (Type III, 7900 psi @ 130°F)



**Figure 4**  
**PLOT OF TYPICAL TEST DATA**



**Figure 5**  
**EFFECT OF TEMPERATURE ON STRENGTH**

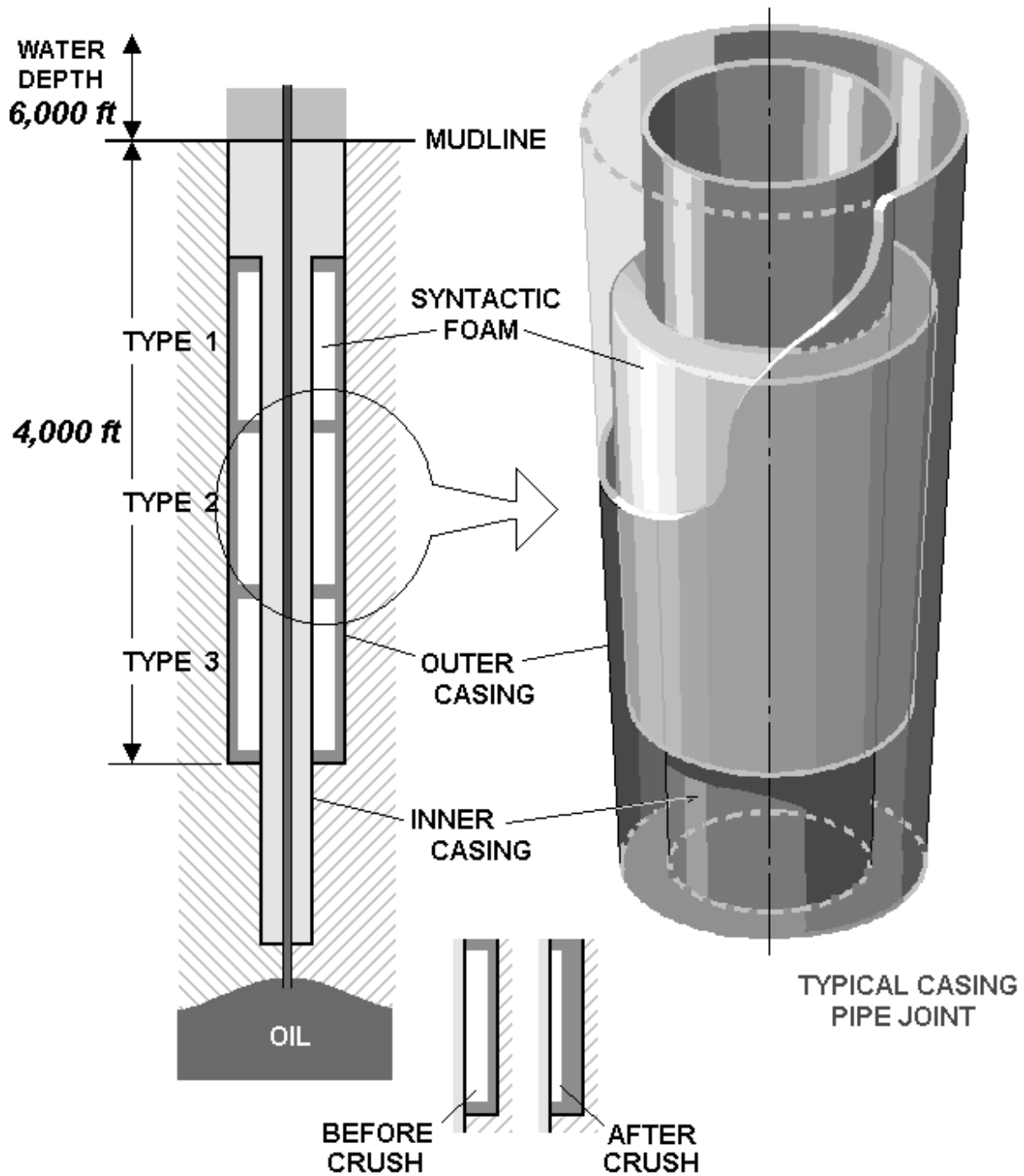


Figure 6  
“PRECISION STRENGTH” MATERIAL PROTECTS THE WELL



**Figure 7**  
**CASTING OPERATION IN THE FACTORY**



**Figure 8**  
**FINISHED JOINTS BEING INSPECTED**

## **CONCLUSION**

An important advantage of this materials approach is that it results in a passive system requiring no controls or active intervention. The syntactic foam responds automatically to protect the well casing from overpressures and temperature spikes. The properties of the material can be adjusted to suit a wide range of conditions inside a given well, or from one well to another. It is expected that this material will prove to be an important factor in many new oil and gas wells in ultradeep water, permitting production from fields previously believed impossible or uneconomical. Cuming Corporation is proud to be part of this pioneering technology, and salutes the energy companies and offshore engineers who are making it happen.

## **REFERENCES**

1. "Handbook of Epoxy Resin" Lee & Neville, 1982
2. ASM Handbook, Volume 21 Composite pp.3 – 17
3. ASTM D 2736