INTRODUCTION

C-THERM syntactic foam thermal insulation is available in a wide variety of forms, as outlined in Technical Note 600-1 and Technical Bulletin 601. The products designed for field application on subsea equipment are the "F-Types" described in the "625-Series" bulletins; they include the following:

C-THERM FPC "Precast," Technical Bulletin 625-1: A variety of factory-cast sheets, blocks, and shapes for field attachment to subsea equipment.

C-THERM FPP "Pour-in-Place," Technical Bulletin 625-2: Two-part liquid kits for field mixing and casting into molds assembled around subsea equipment.

C-THERM FPG "Pack-in-Place," Technical Bulletin 625-3: Two-part kits of puttylike paste for hand mixing and molding around subsea equipment.

COMPARISONS

The three F-Type products are similar in chemistry, being based on thermosetting epoxy resin and borosilicate glass microspheres. They differ primarily in fabrication technique. Both *C-THERM* FPC and FPP begin as liquids, are processed in much the same way, and are so similar in their finished properties that no comparative distinction between them is necessary. *C-THERM* FPG, however, is formulated as a paste and applied by hand; this results in behavior differences that require further discussion.

ADVANTAGES AND DISADVANTAGES

Because it must be poured into cavities of the desired finished shape, *C-THERM* FPP requires molds. The complexity of trees, manifolds, jumpers, and other subsea equipment requires the molds to be made in a variety of shapes and sizes. This means added cost and longer lead times. FPG, on the other hand, as its "pack-in-place" name implies, requires no molds or tooling. The kits of paste, similar in consistency to modeling clay, are easily and quickly blended by hand or in a simple mixer and applied directly to the equipment to be insulated. The cured material is then covered with an overwrap of fiberglass to provide a tough, durable outer surface. The result is a much faster and less expensive installation.

Since the factory-made kits are pre-measured, packaged, and sealed, the chemistry of all *C-THERM* kits is well controlled and consistent. However, the hand-crafted nature of the FPG application technique introduces a degree of variability that is not a factor in the other systems. The variability lies in the amount of air entrapped in the foam, and the distribution of porosity formed during the mixing and packing process. These variables make it more difficult to interpret FPG test data, and requires an informed approach to predicting long-term performance.

HYDROSTATIC BEHAVIOR

Typically, anywhere from 15% to 25% of the volume of installed FPG is air in the form of tiny, dispersed voids, entrapped during the application process. The voids are not apparent to the naked eye; however, they rapidly fill with water when the equipment is submerged. This means that FPG, as compared to other syntactic foam insulation systems, shows a high rate of initial water uptake. Fortunately, the rate of absorption quickly slows as the voids are filled, eventually reaching an equilibrium state very similar to that of conventional materials. **Figure 1** illustrates this behavior by comparing weight gain due to water absorption for *C-THERM* FPG and FPP.

Once equilibrium has been established, the long-term hydrothermal performance of FPG is very much like that of FPP and FPC, with similar thermal conductivity and specific heat numbers. The explanation for this is the so-called “wet suit phenomenon,” in which entrapped water efficiently retains heat, so long as it is not allowed to circulate. The relationship between water absorption and thermal conductivity is linear and predictable, as shown in **Figure 2**. This permits long-term thermal behavior to be accurately predicted, based on projections of the water uptake rate of the syntactic foam.

THERMAL PERFORMANCE

Because *C-THERM* FPG starts off as a lower density material, the water it absorbs in the initial period merely has the effect of raising its density and thermal properties to numbers on a par with those of conventional syntactic foam. The chart in **Figure 3** shows how thermal conductivity and specific heat of FPG approach the values of FPP over time. After about 1,000 hours of exposure, there is little measurable difference between the two materials. Testing to 10,000 hours and beyond has shown that this similarity is maintained throughout the service life of the insulation.

INTERPRETATION OF TEST DATA

The key to properly evaluating and using *C-THERM* FPG is to understand its unique behavior and attributes. Sort-term testing of the material usually reveals high rates of initial water absorption, sometimes leading to the erroneous conclusion that long-term exposure will result in continued losses. That this is wrong is proven by the experimental evidence cited above, as well as by many thousands of hours of dependable service on subsea equipment, in hundreds of applications over the past decade. Successful use of a pack-in-place material requires careful interpretation of long-term hydrostatic data and overall thermal behavior, as well as a cost/benefit analysis.

CONCLUSION

C-THERM FPG is a safe, effective, and reliable subsea insulation material, with the advantages of relatively low cost and very fast installation under field conditions. It is the ideal material for many insulation requirements, and has accumulated a successful track record. Our service technicians are highly skilled in its application. And, most importantly, FPG, like all *C-THERM* products, is supported by the Cuming Corporation team of offshore engineers and materials scientists, the industry’s most knowledgeable syntactic foam specialists.

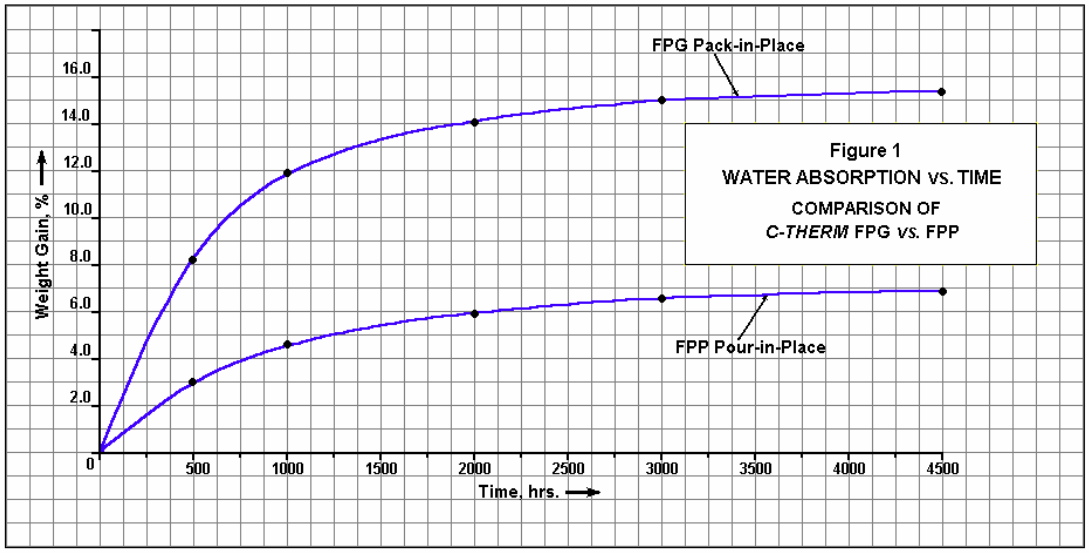

Figure 1
WATER ABSORPTION vs. TIME
COMPARISON OF
C-THERM FPG *vs.* FPP

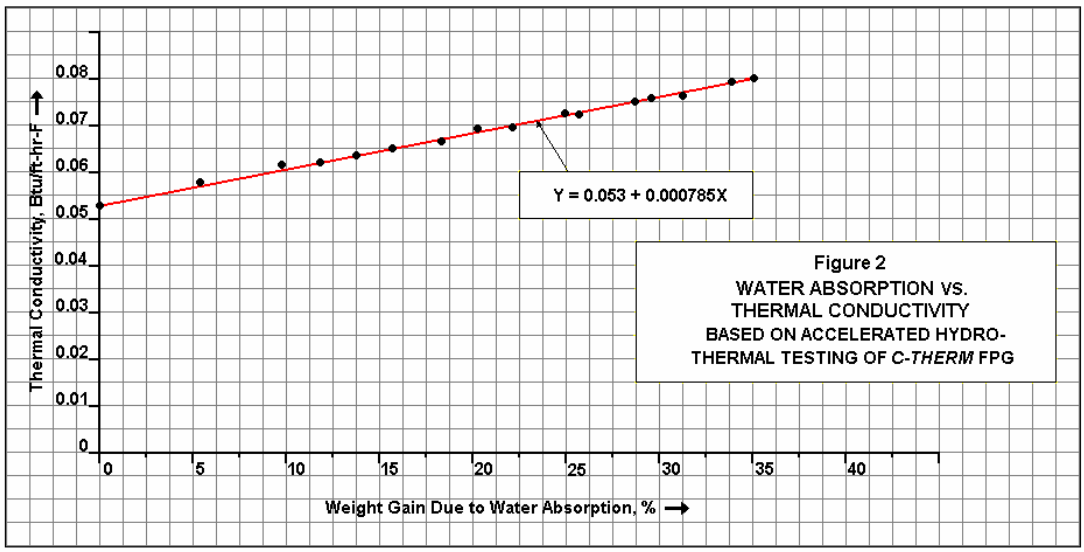

Figure 2
WATER ABSORPTION vs.
THERMAL CONDUCTIVITY
BASED ON ACCELERATED HYDRO-
THERMAL TESTING OF *C-THERM* FPG

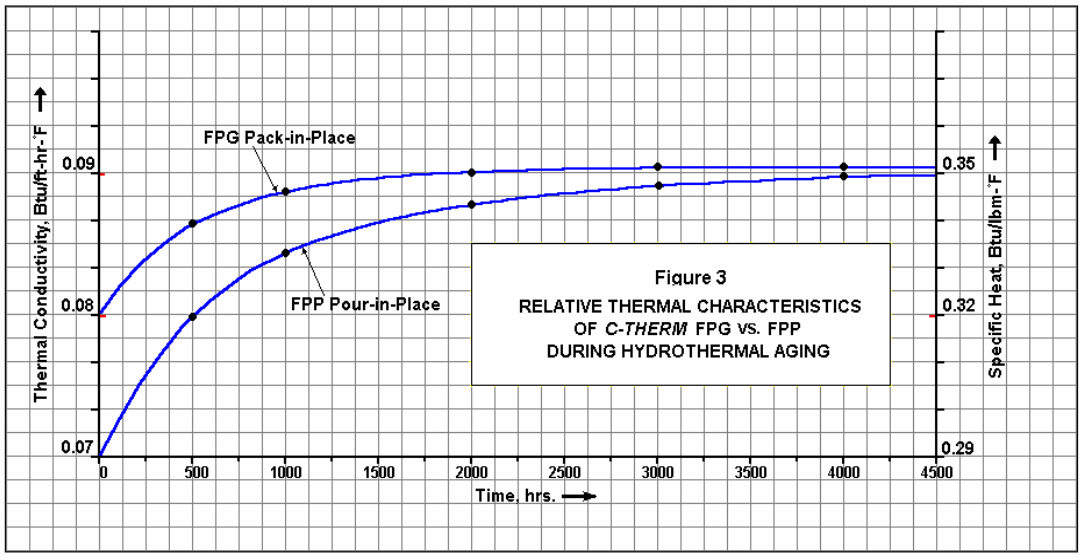

Figure 3
RELATIVE THERMAL CHARACTERISTICS
OF *C-THERM* FPG vs. FPP
DURING HYDROTHERMAL AGING