CUMING
CORPORATION

Technical Note 600-6
A DISCUSSION OF IFP-FRANCE INSULATION TEST DATA

June, 2005

INTRODUCTION

Researchers working for IFP-France performed a series of experiments on syntactic foam insulation material. Their work is reported in OMAE2005 paper no. 67449, as described below. The paper is reviewed here, with additional editorial commentary, because: (1) It conveniently summarizes a number of important points about syntactic foam thermal insulation, and (2) It corroborates a great deal of testing performed by Cuming Corporation. It should be noted that our interpretive comments are in terms of relevance to *C-THERM* test data, and do not necessarily reflect the original authors' opinions. Persons wising to study the technical paper in more detail are encouraged to request a reprint of:

OMAE2005-67449
"Wet Aging of Syntactic Foams Under High
Pressure / High Temperature in Deionized Water"
By Gimenez, Sauvant-Moynot, and Sautereau
Presented at OMAE2005, June 12-16, 2005

SAMPLE SIZE AND CONSTRUCTION

All of the IFP samples were of solid syntactic foam construction, using 3M S38 glass microspheres in an amine-cured epoxy matrix. This is a common formulation for "HTHP" insulation. The samples were small, believed to be typically no more than a few inches (<100 mm) on a side. The small size of the samples results in a large area-to-volume ratio, thereby amplifying hydrothermal effects and increasing the percentage weight gain due to water absorption. *C-THERM* testing is usually done with larger samples, reflected in much lower absorption numbers. In all other respects, the IFP data closely parallels our experience. The following is a discussion of results as reported in the charts.

FIGURE 1

Figure 1 is a trio of charts, shown below as Figures 1A, 1B, and 1C. All are the result of long immersion in deionized water at atmospheric pressure. Note that Figures 1B, 1C, and 2 use electrical conductivity (impedance) as a measure of water infiltration, instead of more conventional weight gain or thermal conductivity measurements. Despite the lack of hydrostatic overpressure, the samples show significant weight gain, especially at higher temperature. Figure 1C is of most interest, showing that, after initial stabilization, *the relationship between water absorption and change in thermal conductivity is constant and linear, regardless of temperature or the amount of water uptake.*

FIGURE 2

Figure 2 illustrates the absorption of water into the glass microspheres alone, in this case at 100^{o} C. It should be noted that the microspheres are in their natural (untreated) state. All hydrospace grade microspheres are made of some form of soda-lime-borosilicate glass. The presence of even tiny amounts of unbound sodium in the glass results in a degree of solubility in hot water. For this reason, protecting the microspheres is a major objective in *C-THERM* research. This is done by using only those matrix resins, primarily epoxy, that retain high strength in hot water, and by treating the glass microspheres with proprietary blends of protective coatings. *The conclusion here is that testing of insulation must be performed under realistic "hot, wet" conditions.*

FIGURES 3 & 4

Figures 3 & 4 compare the water absorption rate of “neat” epoxy resin (no glass microspheres) versus that of syntactic foam (epoxy filled with glass microspheres). The contrast is striking, with the epoxy absorbing only a negligible amount of water while the syntactic foam picks up much more. Many theoretical papers have gone to great lengths attempting to estimate the diffusion of moisture into the resin matrix. However, this evidence supports the common sense observation that *almost all weight gain experienced by syntactic foam is the result of water infiltrating the glass microspheres; therefore, extrapolation based on experimental data is a more accurate way of predicting long-term performance than mathematical diffusion models.*

FIGURE 5

Figure 5 compares samples tested at 100^{o} C under three hydrostatic pressures: 1, 150, and 300 bar. It should be pointed out that the 300 bar pressure is probably close to the crush strength of this foam at 100^{o} C. It is interesting to note that the behaviors of the samples are very similar, despite the wide range of pressures. This is in marked contrast to the extreme differences with temperature observed in Figure 1.This confirms our own experience, based on a great deal of testing, that *water temperature is a much more important determinant of syntactic foam performance than hydrostatic pressure.*

FIGURE 7

Figure 7 attempts to correlate actual measured change in thermal conductivity (k-value) as a result of water absorption with the amount of change in conductivity predicted by mathematical calculation. The authors were surprised to find that the measured change progressed at less than half the rate predicted by theory. Their explanation is that “some of the water does not participate [in the thermal behavior].” This agrees with our own testing of the so-called “wet suit” phenomenon resulting from trapped water. *Change in thermal conductivity of syntactic foam insulation varies in direct linear proportion to, but at a lesser rate than, water absorption.*

FIGURE 8

Figure 8 measures decline in mechanical properties (“yield stress”) over time at 100^{o} C under the same three hydrostatic pressures as Figure 5. Two observations here agree very well with *C-THERM* testing: *first, the rate of decline in properties stabilizes and levels off relatively quickly after initial exposure; and second, the amount of degradation is mostly a function of temperature, and largely independent of hydrostatic pressure*.

For more in-depth discussions of *C-THERM* properties, please see the following:

Technical Note 600-1”Thermal Properties of Syntactic Foam”

Technical Note 600-2 “Notes on Design and Construction of Syntactic Foam”

Technical Note 600-3 “Notes on Mechanical Properties of Syntactic Foam”

Technical Note 600-4 “Notes on Heat Transfer Properties of Syntactic Foam”

Technical Note 600-5 “Discussion of Field-Applied Insulation Products”

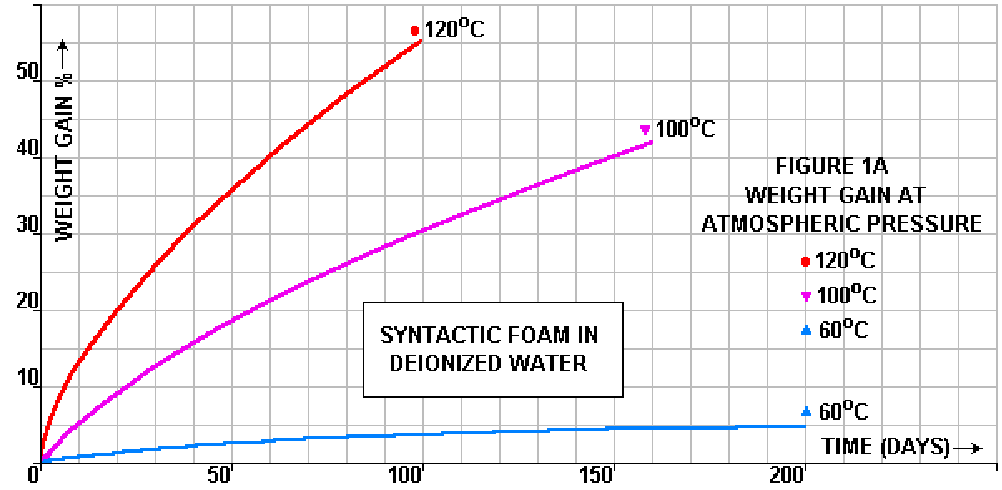


FIGURE 1A
WEIGHT GAIN AT
ATMOSPHERIC PRESSURE

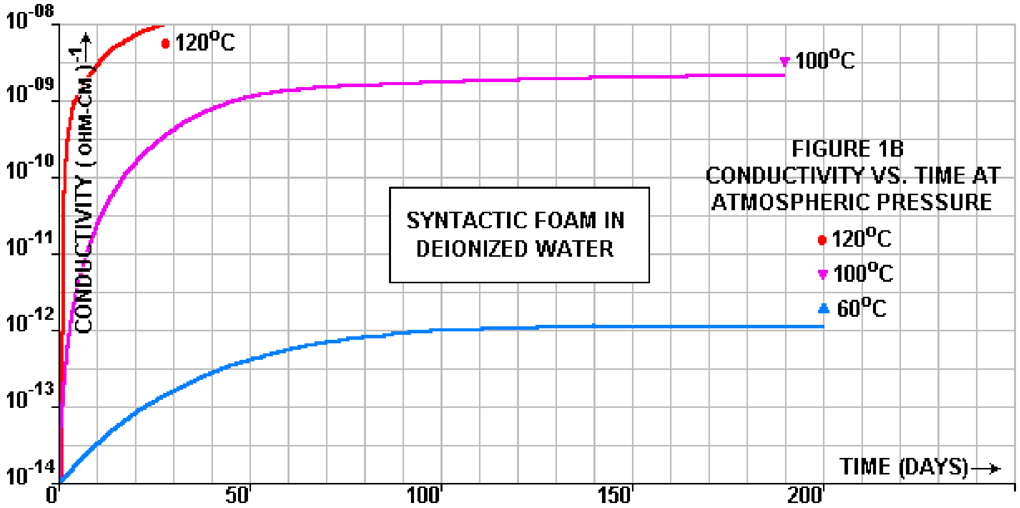


FIGURE 1B
CONDUCTIVITY VS. TIME AT
ATMOSPHERIC PRESSURE

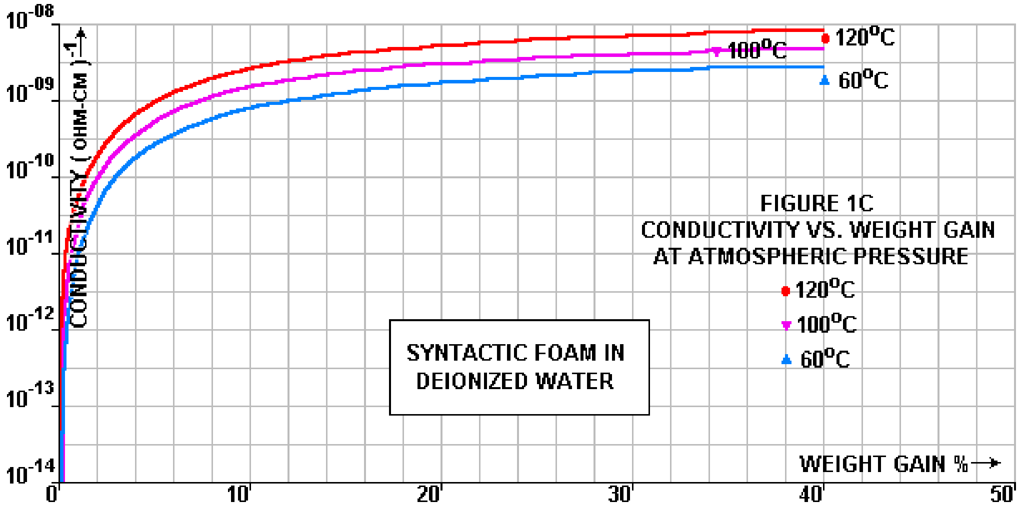


FIGURE 1C
CONDUCTIVITY VS. WEIGHT GAIN
AT ATMOSPHERIC PRESSURE

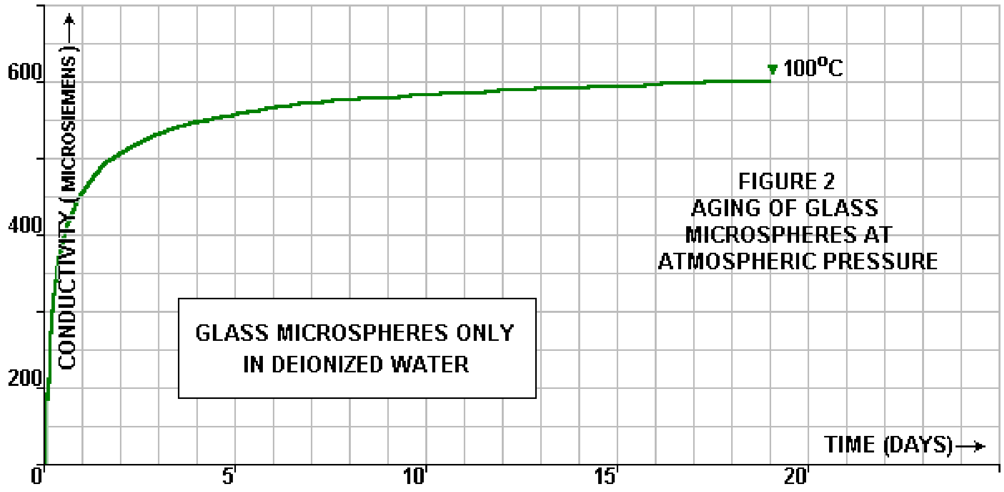
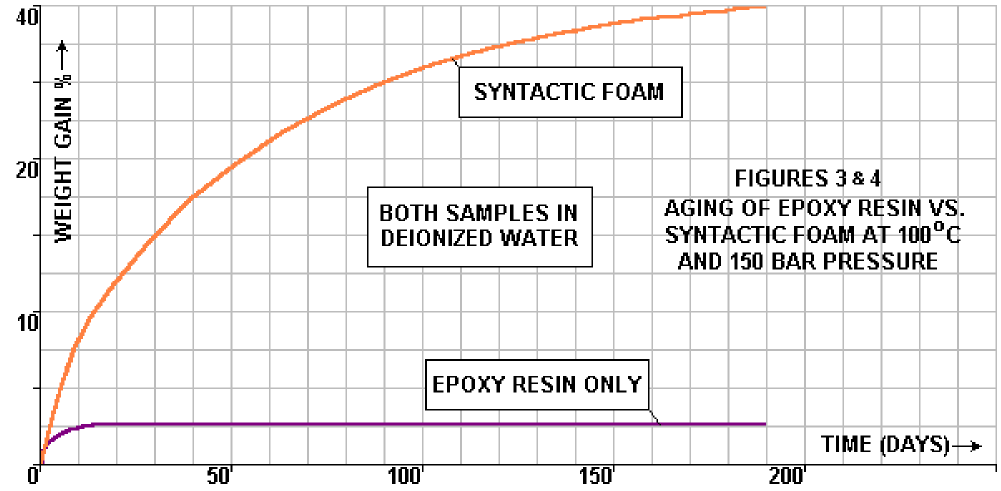


FIGURE 2
AGING OF GLASS
MICROSPHERES AT
ATMOSPHERIC PRESSURE



FIGURES 3 & 4
AGING OF EPOXY RESIN VS.
SYNTACTIC FOAM AT 100°C
AND 150 BAR PRESSURE

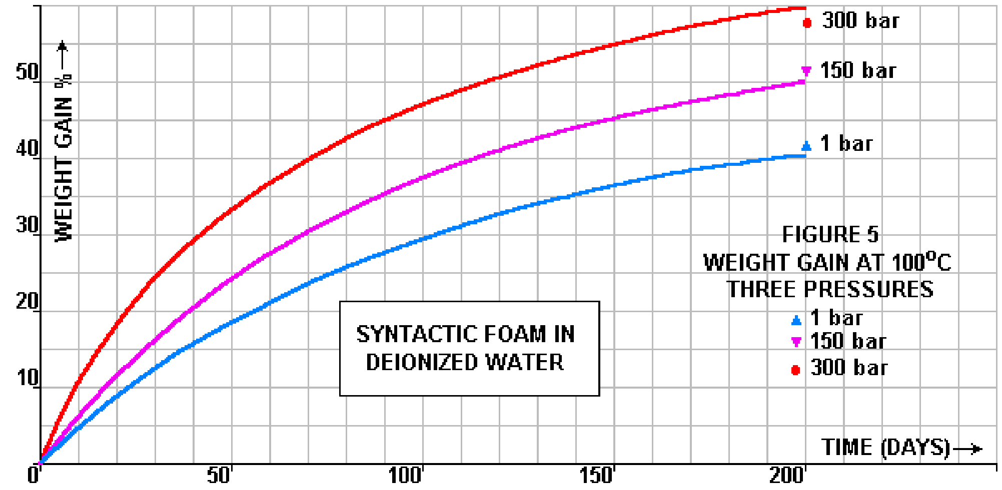


FIGURE 5
WEIGHT GAIN AT 100°C
THREE PRESSURES

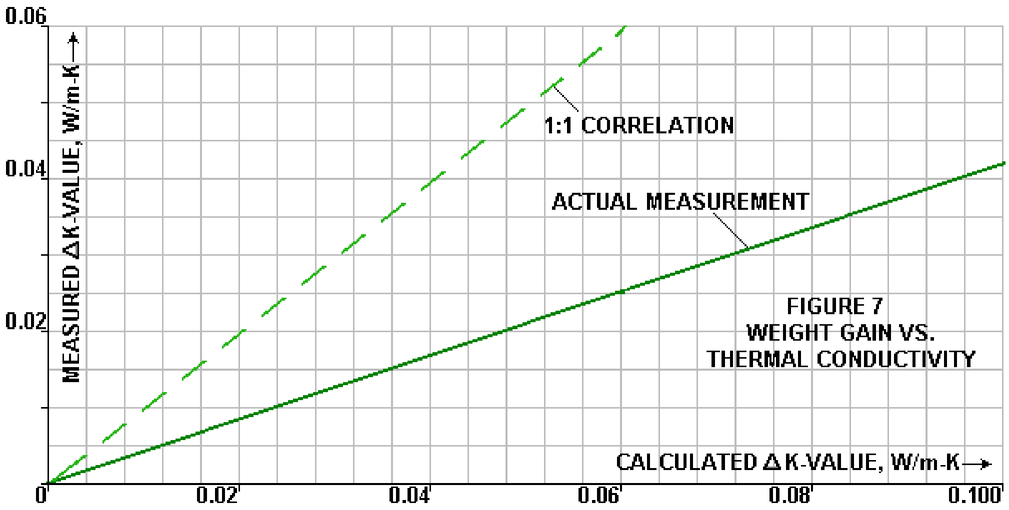


FIGURE 7
WEIGHT GAIN VS.
THERMAL CONDUCTIVITY

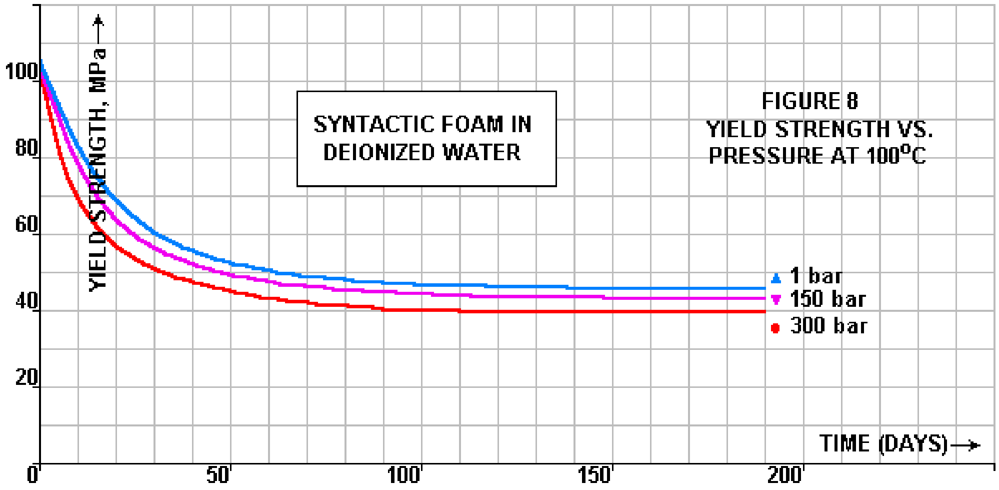


FIGURE 8
YIELD STRENGTH VS.
PRESSURE AT 100°C