Foam Properties Reconciliation

3-60B Cask Impact Limiters

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OBJECTIVE

- To reconcile the differences in the foam properties used by ES in the 3-60B Cask SAR analyses and those derived by the NRC from the General Plastics on-line design guide.

METHOD

- Demonstrate that the "static" stress-strain properties used by ES and derived by the NRC are identical, or near identical.
- Provide a rationale for using the "static" properties versus the "dynamic" properties in the analyses.

STATIC STRESS-STRAIN PROPERTIES COMPARISON

- Using the spread-sheet provided by the NRC, ES produced the "static" stress-strain plots for both 17 lb/ft^3 and 25 lb/ft^3 foam at 100^oF and -20^oF (Figures 1 through 4).

- The differences between the ES and the NRC data are minor. The curves are nearly identical for lower strains and deviate slightly for strains between 40 and 70%.
- The ES curves are always stiffer than the NRC curves.

DISCUSSION OF THE DISCREPENCIES

- ES used General Plastics provided brochure 1997 edition which had more comprehensive data than currently available in the on-line design guide. The current design guide is a little simplified and encompasses the data for a large range of foam densities (11 to 40 lb/ft^3). General Plastics provided a spread-sheet to ES (via the attached e-mail) that yields identical stress-strain data for all compressive stresses with those used by ES.
- ES has provided the referenced FR-3700 foam data from the General Plastics 1997 Brochure as Appendix 1 of ST-557, Pages 3 & 4.
- The stress-strain data used in the analyses are the same that are required to be met by the supplier, per the procurement specification ES-M-172. It should be noted that the foam properties can be tailored by the supplier to meet the specified stress-strain data.

RATIONALE FOR USING "STATIC" STRESS-STRAIN PROPERTIES

- For the development of the methodology to analyze the 3-60B package, using LS-DYNA software, one of the main criteria employed was that the material modeling should require only those foam properties that are used for its procurement. As discussed in details in ST-511, there are several material models available in LS-DYNA to represent foam. ES settled on using Material No. 057 since it requires stress-strain data that can be obtained using the well known ASTM standard.
- The stress-strain data reported by the manufacturer (and invoked in the procurement document) is obtained using ASTM D-1621 which is applicable to the "static" condition.
- There are no well known standards for obtaining the "dynamic" stress-strain data. General Plastics uses their own method to obtain the data reported in their on-line design guide (see the e-mail attached).
- The dynamic data is dependent upon among other parameters, the specimen size, strain rate, the foam density. Its applicability to a large size impact limiter that undergoes a relatively slow (say 50% strain in 50 milliseconds) deformation is uncertain.

- ES calibrated the results of the VHLW drop tests with foam model using the "static" stress-strain data. It was determined that the analyses of the VHLW cask using this method can predict the drop test results conservatively.
- All the parameters, developed for the VHLW cask, including the "static" stress-strain data for the corresponding foam density, were consistently used in the 3-60B cask analyses. It should be noted that VHLW has comparable size and geometry as the 3-60B cask.

CONCLUSIONS

- The "static" stress-strain data developed by the NRC are essentially the same as the ES data used in the analyses.
- The finite element models using the LS-DYNA Material No. 057, with the "static" stress-strain data predict conservative results as compared to the drop test results of the VHLW cask, which has similar dimension and geometry as the 3-60B cask.
- Although it cannot be said universally, but for the given size impact limiter, undergoing slow deformations as in the 3-60B cask, the use of "static" stress-strain data with the LS-DYNA Material Model No. 057 is justified.

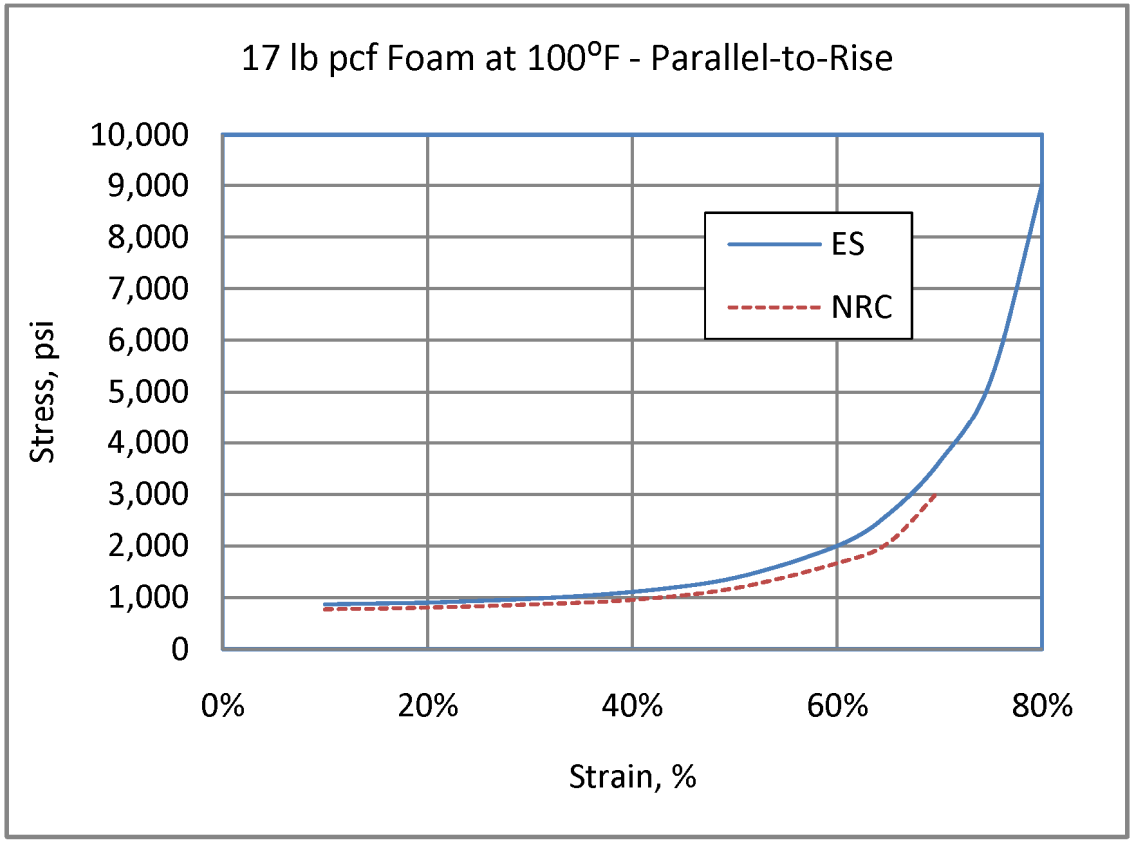

Figure 1 - 17 lb/ft^3 at 100°F (ST-551)

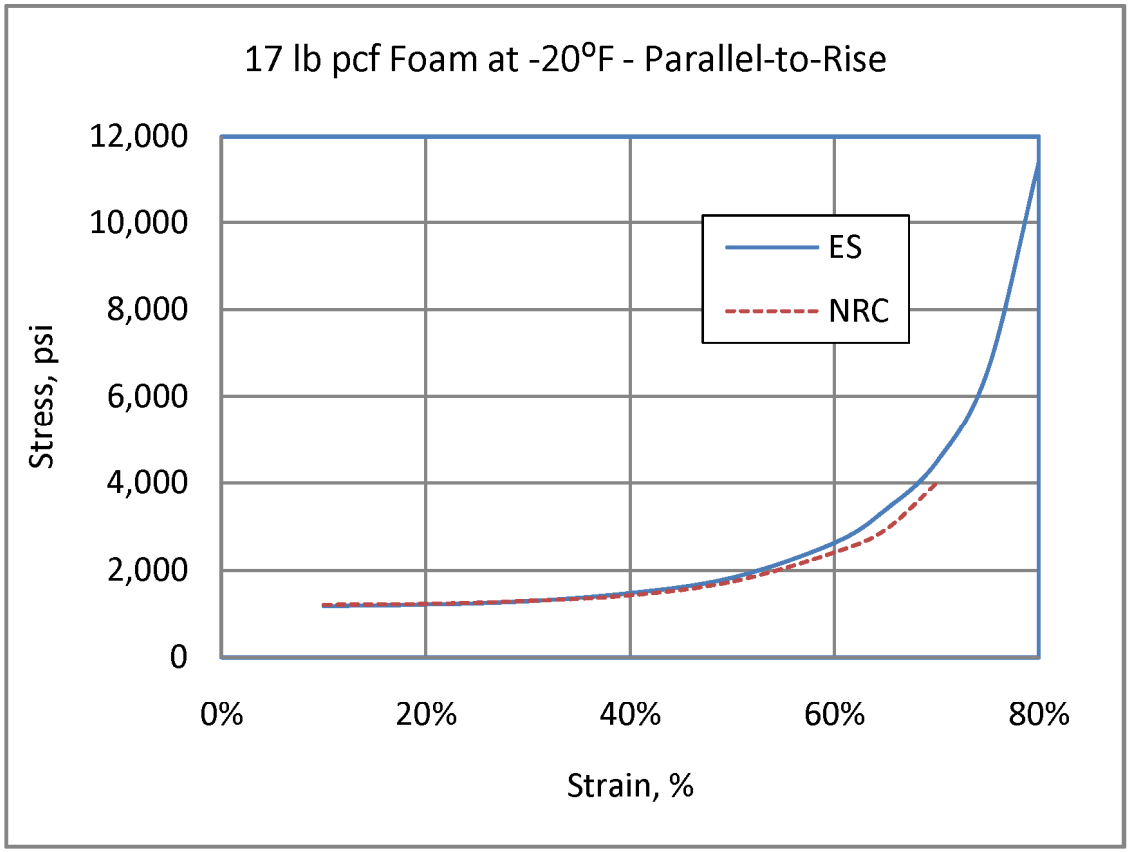

Figure 2 - 17 lb/ft^3 at -20°F (ST-551)

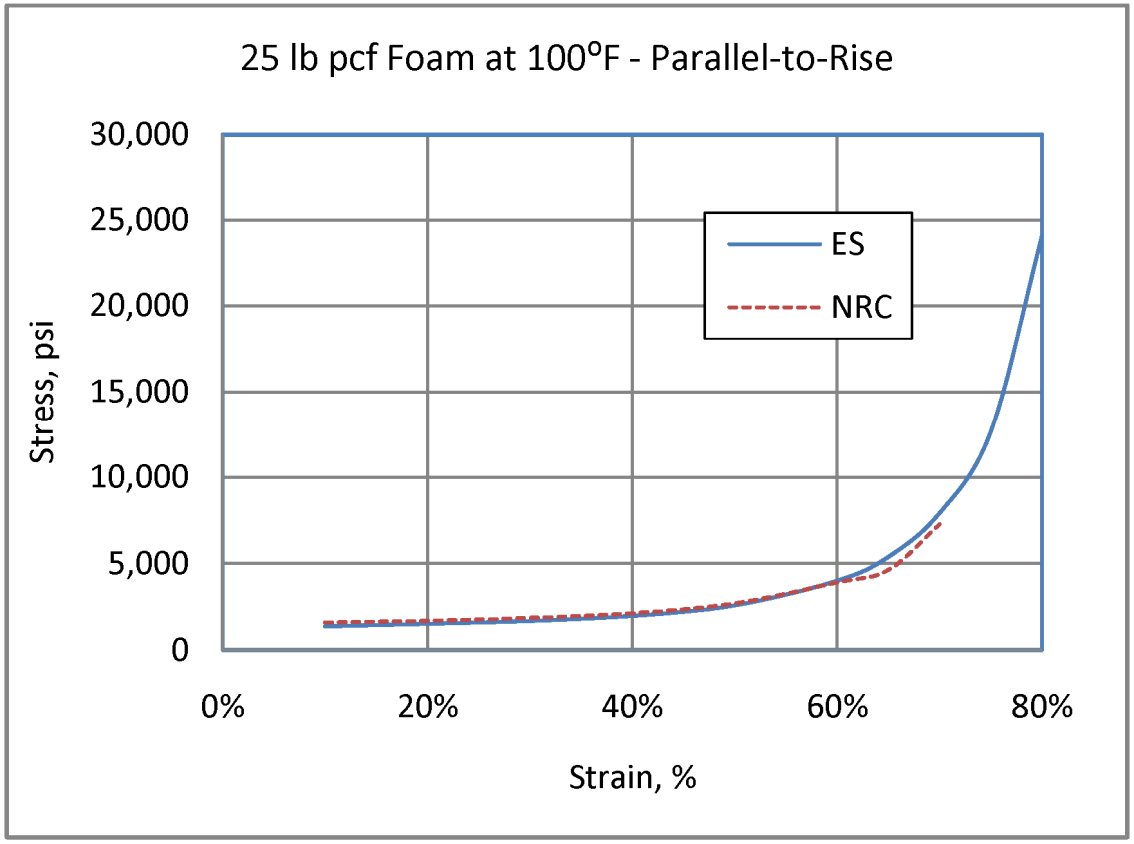

Figure 3 - 25 lb/ft^3 at 100°F (ST-557)

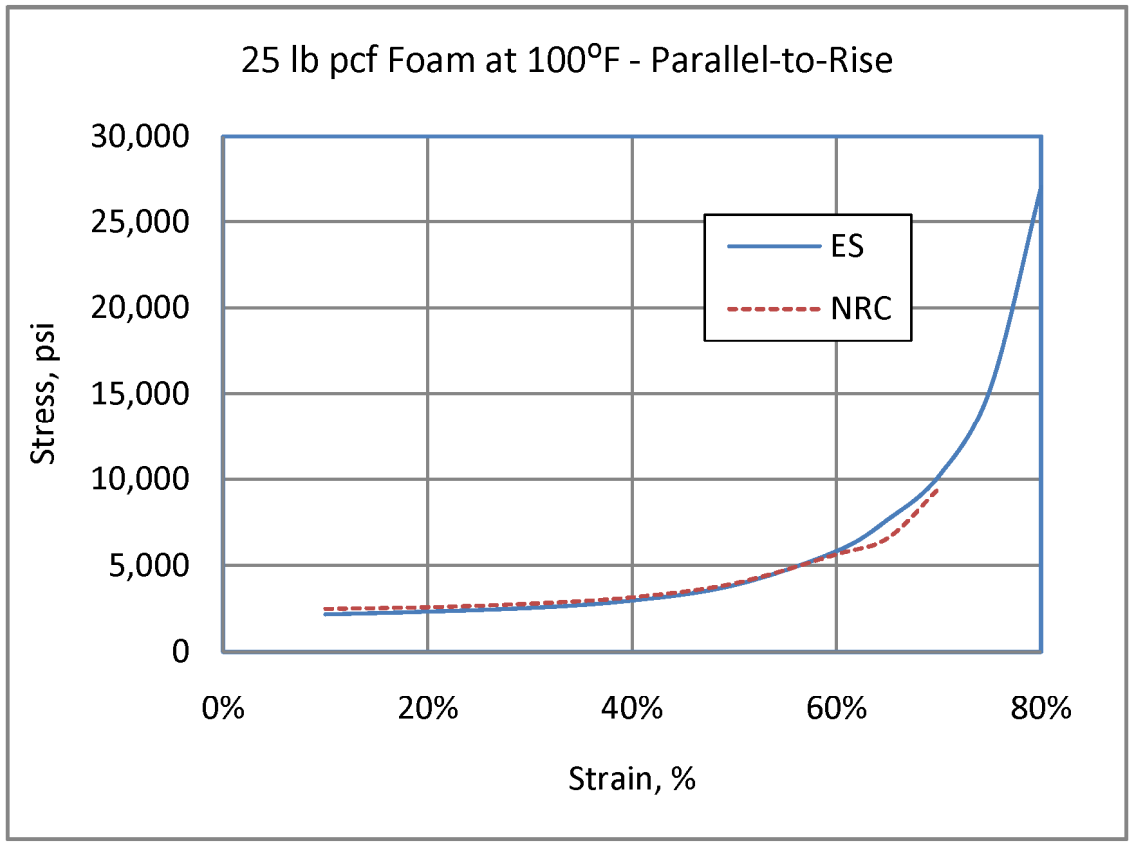

Figure 4 - 25 lb/ft^3 at -20°F (ST-557)