

National Aeronautics and  
Space Administration

George C. Marshall Space Flight Center  
Marshall Space Flight Center, AL 35812



JAN 13 2000

Reply to Attn of:

MP51-007-00  
Goldberg/4-2683

TO: MP31 / Mr. Counts  
FROM: MP51 / Dr. Goldberg  
Subject: Closure of the External Tank (ET) Foam Anomaly Investigation Team and Recommendation for closure of the In Flight Anomaly (IFA)

The team has completed successful development, implementation and validation of corrective action for the foam debris anomaly. A summary status of current team actions and issues is as follows:

Fault tree item disposition:

All fault tree items have been dispositioned and formal closures signed. Items identified as causal were limited to the "Debris due to design" block. Subtended to this block were 53 intermediate and basic event blocks. The "Inadequate design methodology" intermediate event block was identified as causal, with enabling lower level intermediate events of "Inadequate material testing" and "Inadequate treatment of critical loads/ environments configuration interactions". Basic events identified as causal were limited to combinations of loads and environments requirements used for testing, the time history of those assessed loads, and the number of tests performed. Other intermediate and basic events were identified as contributors, one - "Inadequate design requirements" was indeterminate as to whether it was causal or not.

The root cause were summarized as follows:

- Inability of the foam, with its reduced mechanical properties (due to changes in the blowing agent), to withstand the stresses induced by the environment (vacuum and heat combined with effects associated with humidity exposure) on the intertank and skin stringer areas.
- Stress concentrating geometry of the foam most pronounced on the intertank thrust panels and to a lesser extent on the skin-stringer panels.

Screening/corrective action demonstration:

Cause determination has focused on the mechanism identified as "popcorning" of the foam. This mechanism results from a heated foam, with consequences of reduced capability, internal stress fields driven both by thermal gradient and pyrolysis gas development, and externally imposed vacuum conditions. Screening methodology

currently in place to determine susceptibility to "popcorning" is limited to process records and three plug pull measurements and has been assessed as appropriate to evaluate "in-family" nature of the foam but not susceptibility to "popcorning".

Corrective action implementation is represented by the Space Shuttle Program approval both of sanded down configurations and venting of the foam in areas including both thrust panel and skin stringer regions. Although potentially confounded by processing and environmental variations, the corrective nature of the sanded and vented configurations has been substantially verified by the data presented through the Certification of Flight Readiness (CoFR) process for STS-88, STS-96, STS-93, STS-95, STS-100 and STS-103 assessed performance. STS-96, STS-93 and STS-103 post-flight assessment and the CoFR reported testing provides all necessary verification for the corrective nature of the venting process.

Additional corrective action avenues, for which performance verification across the viable processing and storage windows will be demonstrated have been identified and are being pursued. In the interim, in-family foam performance has been processed through the CoFR Boards and is assessed, without challenge, as remaining bounded within ET Critical End Item (CEI) waiver levels.

In addition to the CoFR presented actions the Team has recommended several focused tasks, following this recommendation for closure of the IFA, which should lead to elimination of the CEI waiver. These "remedial recommendations" have been accepted by the Project as identified components for ET efforts:

#### Remedial Recommendations:

1. A data package, encompassing all data generated or evaluated as part of this IFA should be finalized and made available to the community. A common format for data, allowing specific users to use unique or individualized data evaluation programs should be identified and utilized wherever possible.
2. The project should continue to record process and mechanical test parameters and data and evaluate against the flight to flight performance and reporting in appropriate Level 3 forums prior to each successive flight. These data should be added to the IFA database.
3. Process modification to allow measurement of plug pull rates is strongly encouraged.

#### Recommendations for process, geometry, constituent, vendor or chemical changes to foam systems (including surfaces and surface preparation):

1. A significant portion of the properties data appear to be confounded by other contemporaneous changes (e.g. blowing agent, geometry effects, panel to panel variation, spray gun). Evaluate a specific Design of Experiments (DOE) series to determine value added of de-confounding the data sets for selected variables. This evaluation should be completed prior to any foam process, chemical or constituent (including vendor) change certification effort.

2. A formal risk assessment process should be performed and documented for relevant testing included and excluded from future foam process, chemical or constituent (including vendor) certification efforts. Items such as AEDC protuberance testing, SR-71 value added, process box testing or margin test philosophies, post test sample / cell damage evaluations, ultraviolet effects, convective vs. radiative heat transfer testing (including foam transmissibility measurements) etc. should be delineated in the assessments.

3. Analytical code development activities should continue and be matured to a level whereby the risk assessment described above would include an analytical basis for evaluation of trends, tendencies and potential sensitivities.

Additionally, the Team recognized several avenues of continued interest for focused technology development:

1. Evaluate whether continued infrared monitoring on intertank processing provides additional value added.

2. The value of the plug pull data in determining in-family process is challenged due to the variability noted for plug pull data. The value in determining a relationship to tank performance, and consequent Orbiter damage is similarly challenged due to confounding of the data set with geometry changes, changes in weather conditions and other parametric variables. Initial testing to de-confound plug pull results should center upon determination of the variability of the test itself. This testing should include

- Movement and rocking motion of test cores due to bond attachment of the Hysol button
- Effects of a dull coring tool
- Effects of aggressive, incautious attachment of the button to the plug puller
- Effects of within process pull rates
- Effects of potential dynamic loading due to slack in the chain or other credible process variables.

3. Definition and implementation of a foam characterization test series (i.e. density, plug pulls, cell characterization) on all future mechanical property or performance test panels is strongly recommended.

4. The Project should continue to evaluate in-process diagnostics as well as post process acceptance testing to develop understanding of "as-built" foam margins.

5. Investigation, demonstration and incremental certification of a foam formulation and application process optimized for the particular environments of interest, and designed to eliminate the need for venting.

While the flight safety activities have been completed for in-family foam, the Team recognizes the benefit to the ET Project of maintaining an insight role during the remainder of the manufacturing change implementation. The Team recommends transitioning the stewardship role for the remainder of the baselined activities planned in support of the corrective action item closures to the ET Project, with the Team

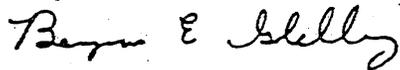
support of the corrective action item closures to the ET Project, with the Team membership performing a final review / assessment at the conclusion of the baselined work.

Summary schedule for Baseline Milestones:

Discipline experts from the team will continue to be a part of the review process under the stewardship of the ET Project as the effort evolves to maturity in the CY00 timeframe. This memorandum is intended to serve as the NASA Teams' final report and documents the discontinuation of the Team, as noted above.

STS-99 Flight Data Assessment	February 2000
STS 101 Flight Data Assessment	April 2000
Phase II SRI Testing	February 2000
Lead / Trail Edge Study	February 2000
Team Review I (NCFI 24-124 Combined Raw Material Optimization testing and corrective action implementation decision)	July 2000
Team Review II (Qualification Program Status Review)	February 2001
Team Review III (Qualification Program Status Review)	August 2001
Team Review IV (Qualification Program Closure Review)	March 2002

The recommendations presented represent a consensus of the integrated Lockheed Martin Corporation/NASA team.



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