A Joint MSFC/WSTF Test Activity

Cycom 977-2 Composite Material

Impact Test Results

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Four Phase Testing Program Description

Phase I: Ambient (13A) tests of Cycom 977-2 impact characteristics by the Bruceton and statistical method at MSFC & WSTF

Phase II: Repeat (13A) test of tested Cycom from Phase I at MSFC to expanded testing statistical database

Phase III: Conduct High-Pressure tests (13B) in LOX and GOX at MSFC and WSTF to determine Cycom reaction characteristics and batch effects

Phase IV: Conduct expanded Ambient (13A) LOX test at MSFC and High-Pressure (13B) testing to determine pressure effects in LOX. Expand 13B GOX database.

Phase I Objectives

Phase I: Ambient (13A) tests of Cycom 977-2 impact characteristics by the Bruceton and statistical method at MSFC & WSTF

- **Establish Cycom 977-2 reaction characteristics using Bruceton and statistical testing methods**
- **Using the forgoing data, provide a data set for comparison of facility results**

Phase I Test Matrix

Phase I Testing

Ambient 13A LOX Ambient Pressure Multiple Impact

Note: MSFC Nominal Pressure = 14.7 psia
WSTF Nominal Pressure = 12.4 psia

Average Pre test sample Wt. = 0.774 g
Average sample thickness = 0.0895 in

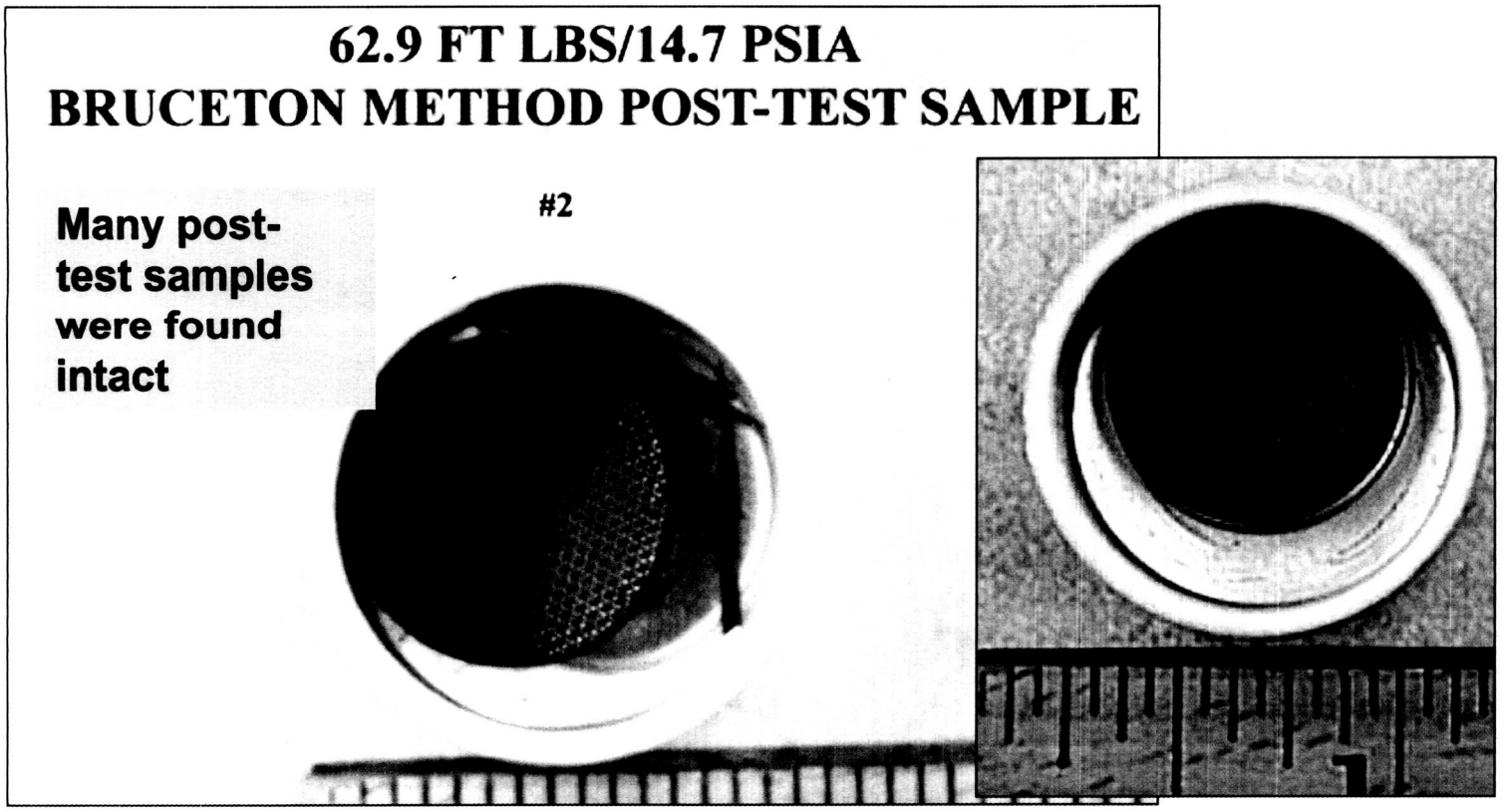
Energy Level ft-lb	MSFC samples	1st impact reactions	all impact reactions	Wt Change w/Reaction %	Wt Change w/o Reaction %
27.2	40	6	18	-0.70%	0.43%
31.2	30	4	17	-0.37%	-0.10%
35.8	30	6	15	-0.38%	0.30%
40.8	30	13	28	-0.55%	-0.19%
54.5	60	51	59	not available	not available
Subtotals=	190	80	137		

Energy Level ft-lb	WSTF samples	1st impact reactions	all impact reactions	Wt Change w/Reaction g	Wt Change w/o Reaction g
31.2	30	10	23	-0.31%	-0.46%
35.8	30	22	29	0.12%	-0.13%
40.8	30	25	30	0.30%	-
Subtotals=	90	57	82		

Single Impact		Bruceton Method	
MSFC	34	50% energy	52.08 ft-lb
MSFC	34	50% energy	46.65 ft-lb
WSTF	34	50% energy	34 ft-lb

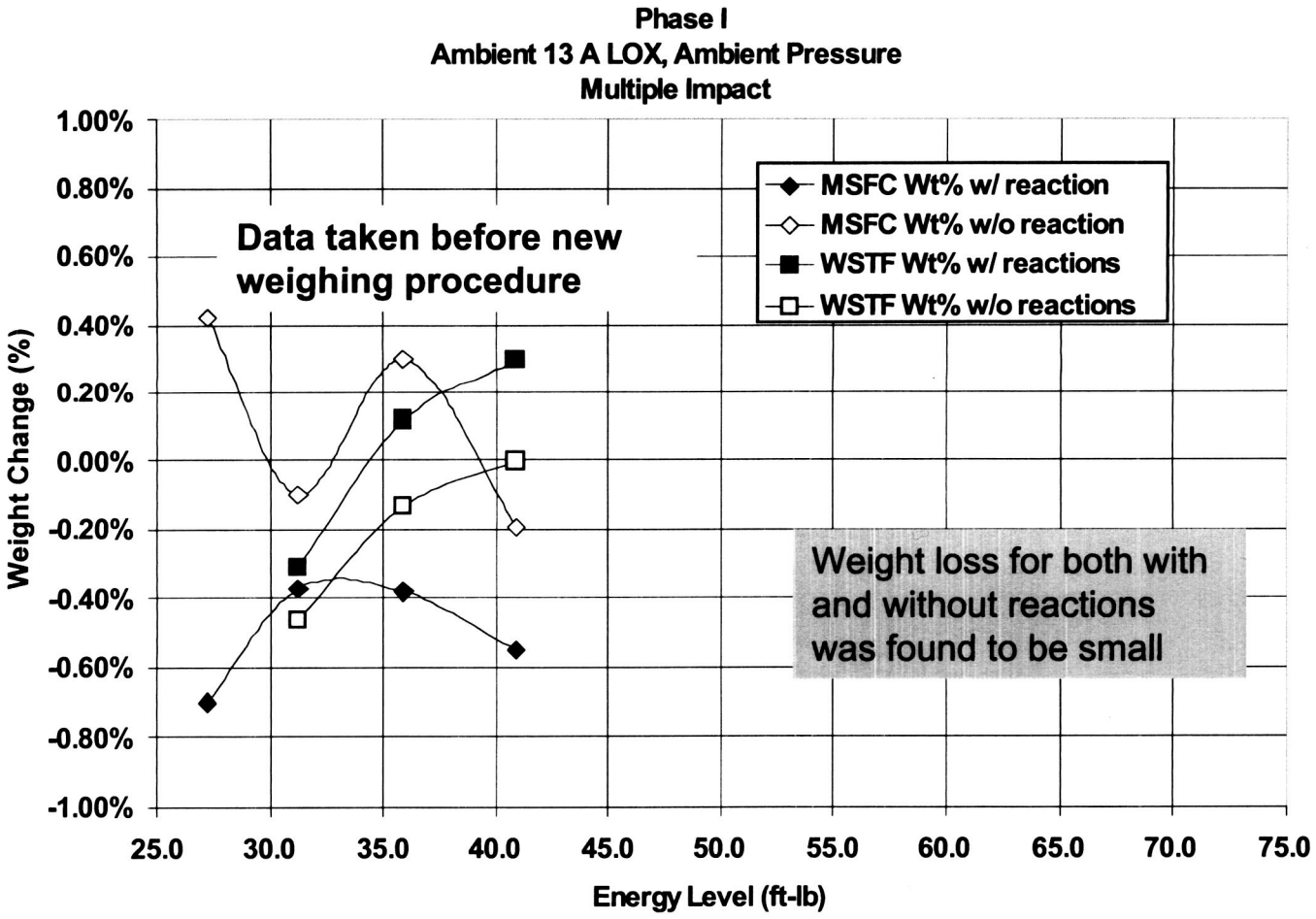
Multiple Impact		Bruceton Method	
MSFC	34	50% energy	24.18 ft-lb

Post Test Samples



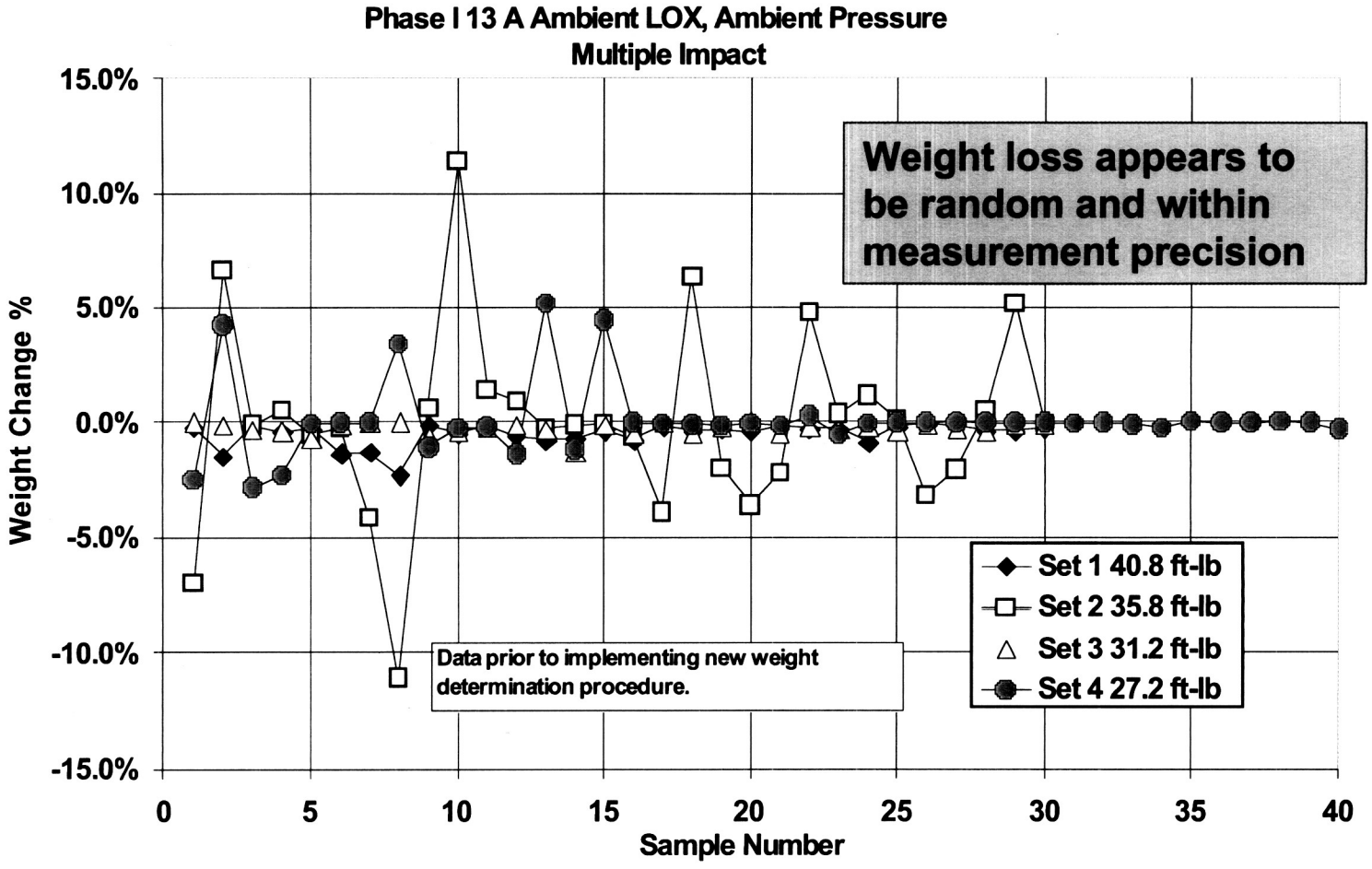
35.9 ft-lb

Weight Change Data

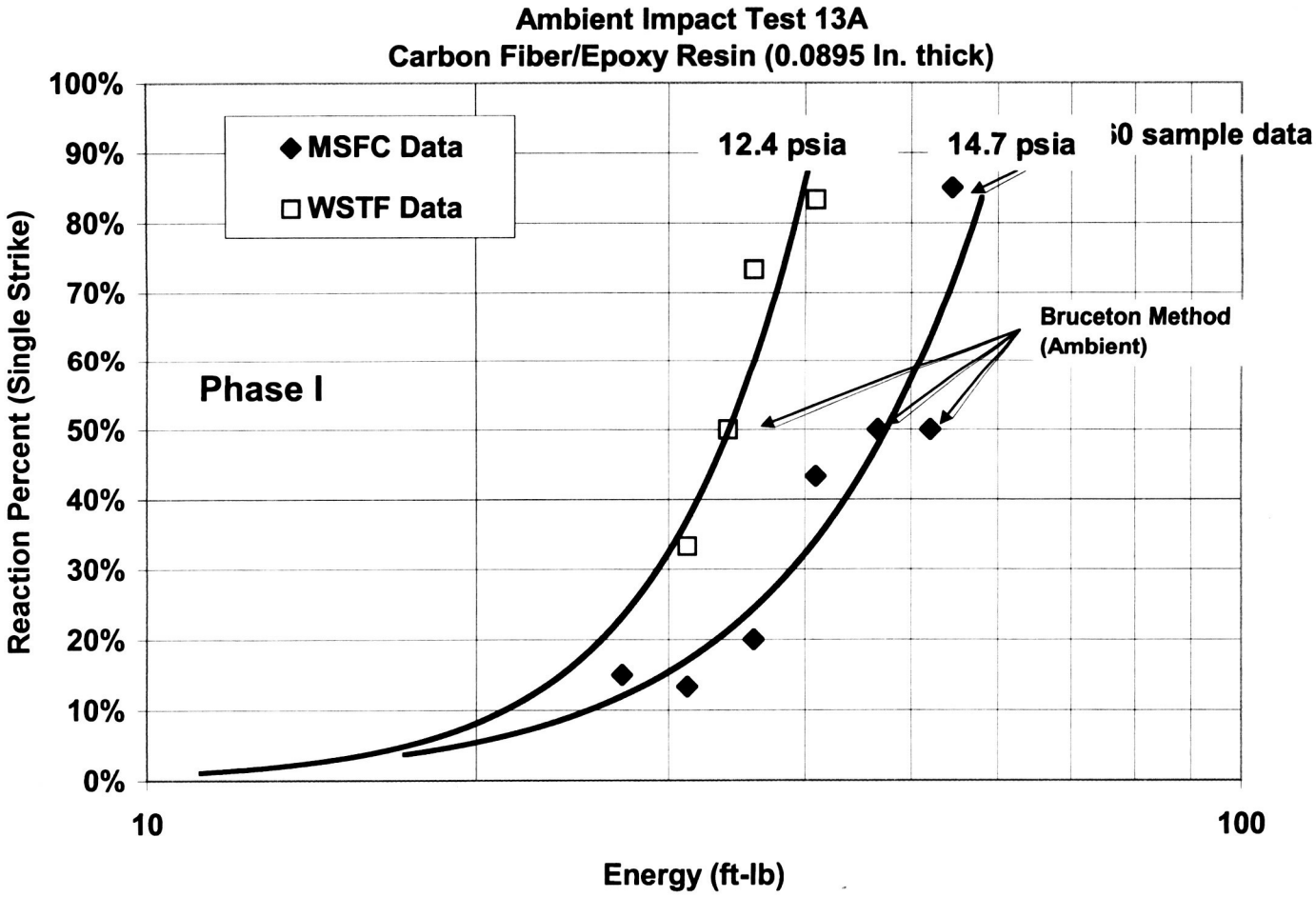


Mass Loss vs. Test Sequence

MSFC Data



First Strike Reaction Frequency



Phase I Conclusions

- MSFC and WSTF reaction frequency data have been compared, revealing a shift between facilities.
- The Bruceton and statistical methods appear consistent.
- MSFC and WSTF weight loss due to reactions is quite small for Phase I conditions and appear consistent between facilities
- For conditions that initiated a reaction, no samples exhibited propagation of the reaction by consuming a significant portion of the material. The initiated reaction was quenched.
- The Phase I test data reveal a characteristic of this composite, which offers the acceptance of this material as impact resistant if the technical community accepts an alternate pass criterion.
- Phase I results encouraged the development of a more accurate methodology for measuring pre- and post-test sample weights and additional testing.

New Sample Weighing Procedure

- Samples are placed within a humidity chamber at 40% for 24 hours.
- After 24 hours, the samples are weighed via (mg) scale.
- Pretest weights are recorded for all samples.
  - Sample is removed from the humidity chamber.
  - The chamber is closed.
  - The sample is weighed.
  - The sample is placed into its designated bag and the bag is closed.
  - The next sample is removed from the humidity chamber and the weighing procedure is repeated with this sample.
- Immediately after all weights are obtained, standard testing begins.
- After each sample is tested, the entire cup with sample is placed into the humidity chamber at 40% for 24 hours.
- Note: The samples are tested in order and placed on their proper identification labels on a foil sheet inside the humidity chamber after testing.
- The time that each sample is placed into the humidity chamber is noted.
- After 24 hours within the chamber, each sample is weighed in the same manner as the above procedure and the post-test weights are recorded.

Phase II Objectives

Phase II: Repeat (13A) test of tested Cycom from Phase I at MSFC to expand testing statistical database

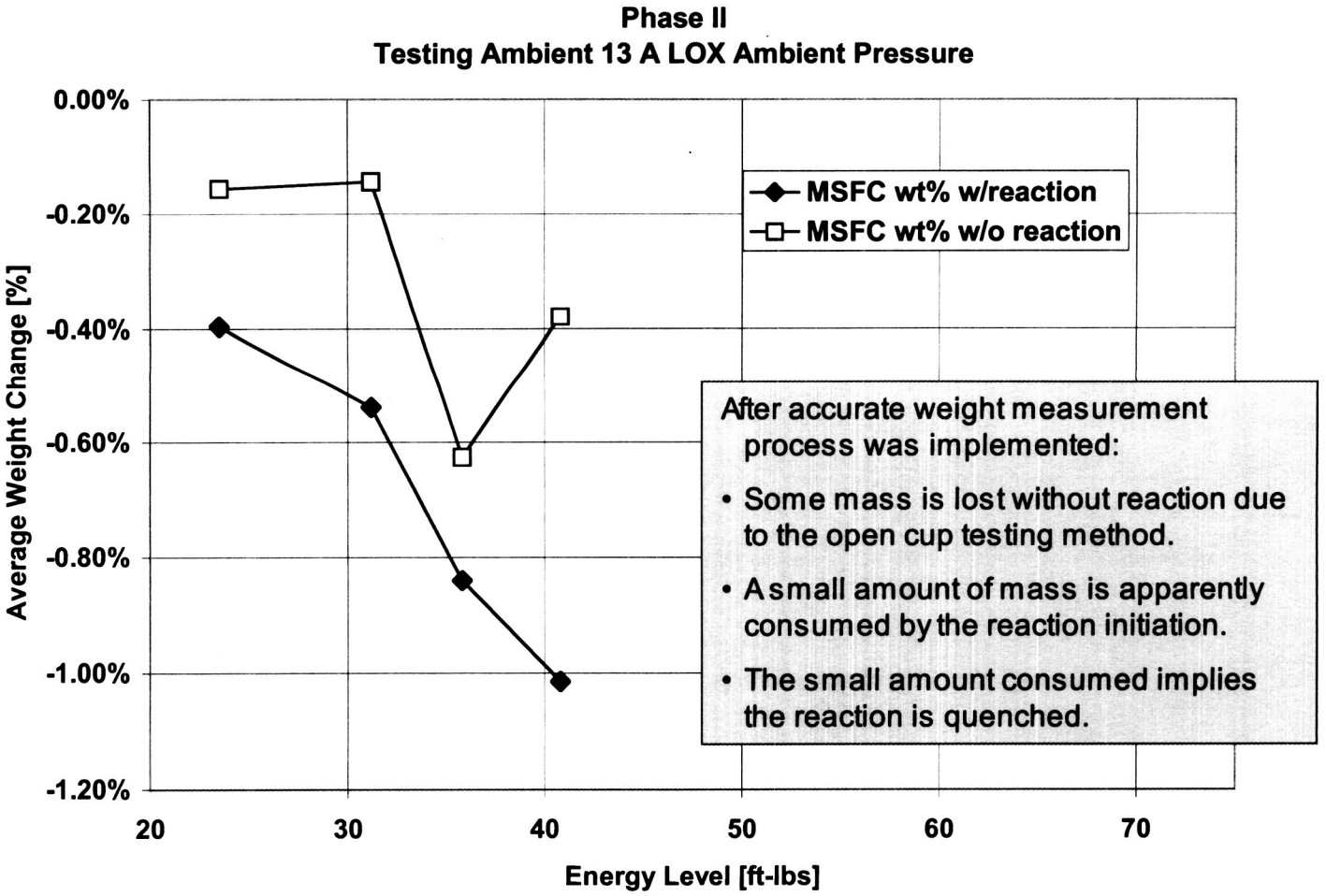
- **Retest tested Phase I samples that remained intact from Phase I testing to expand the database with minimal material available**
- **Implement new accurate pre- and post-test weighing method to determine if the weight loss was from the test procedure or from reaction of the material**

Phase II Test Matrix

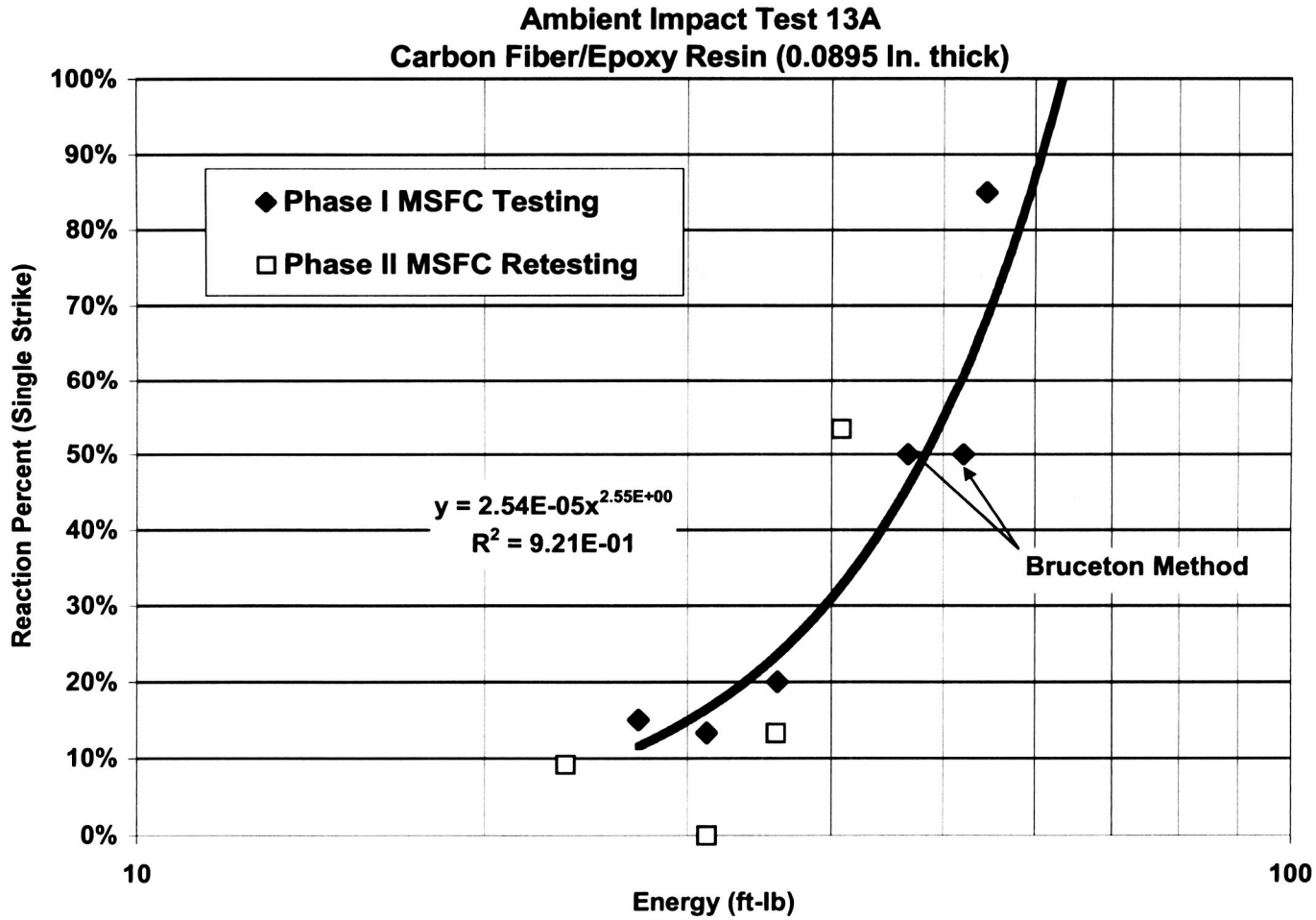
Phase II Material Retest Ambient 13A LOX Ambient Pressure						
Energy level ft-lb	MSFC samples	Sample source (Note: 1, 2, 3)	1st impact reactions	all impact reactions	Wt Change w/Reaction %	Wt Change w/o Reaction %
23.5	65	Prev Multiple Impact Bruceton, Prev Single Impact Bructon, Prev 27.2	6	8	-0.40%	-0.16%
31.2	15	Prev. 31.2 samples	0	6	-0.54%	-0.14%
35.8	15	Prev. 35.8 samples	2	Catcher	-0.84%	-0.63%
40.8	14	Prev. 40.8 samples	8	Catcher	-1.01%	-0.38%
	109					

Note 1: Post Phase I samples hand selected for completed disk. Samples are weighed. Samples greater than 0.72 gm were selected	**Note 2:** Use Std cleaning but keep individual sample identification	**Note 3:** Store 24 hr in 40% humidity before testing. Weigh sampled before testing after storage at controlled humidity. Place samples in controlled 40% humidity for 24 hours after testing Weigh sampled and package samples

Average Weight Change Data



First Strike Reaction Frequency Data



Phase II Conclusions

- The data from the retested material appears consistent with the Phase I material, which had not been tested. The data have been combined with Phase I data.
- The new mass loss measurement techniques and improved care of the post-test samples appear to have improved accuracy of mass loss measurements.
- The mass loss with reactions is small, i.e., less than 1.1%, indicating the reaction initiation did not propagate for any sample.
- The testing process and sample recovery process produce a small mass loss.

Phase III Objectives

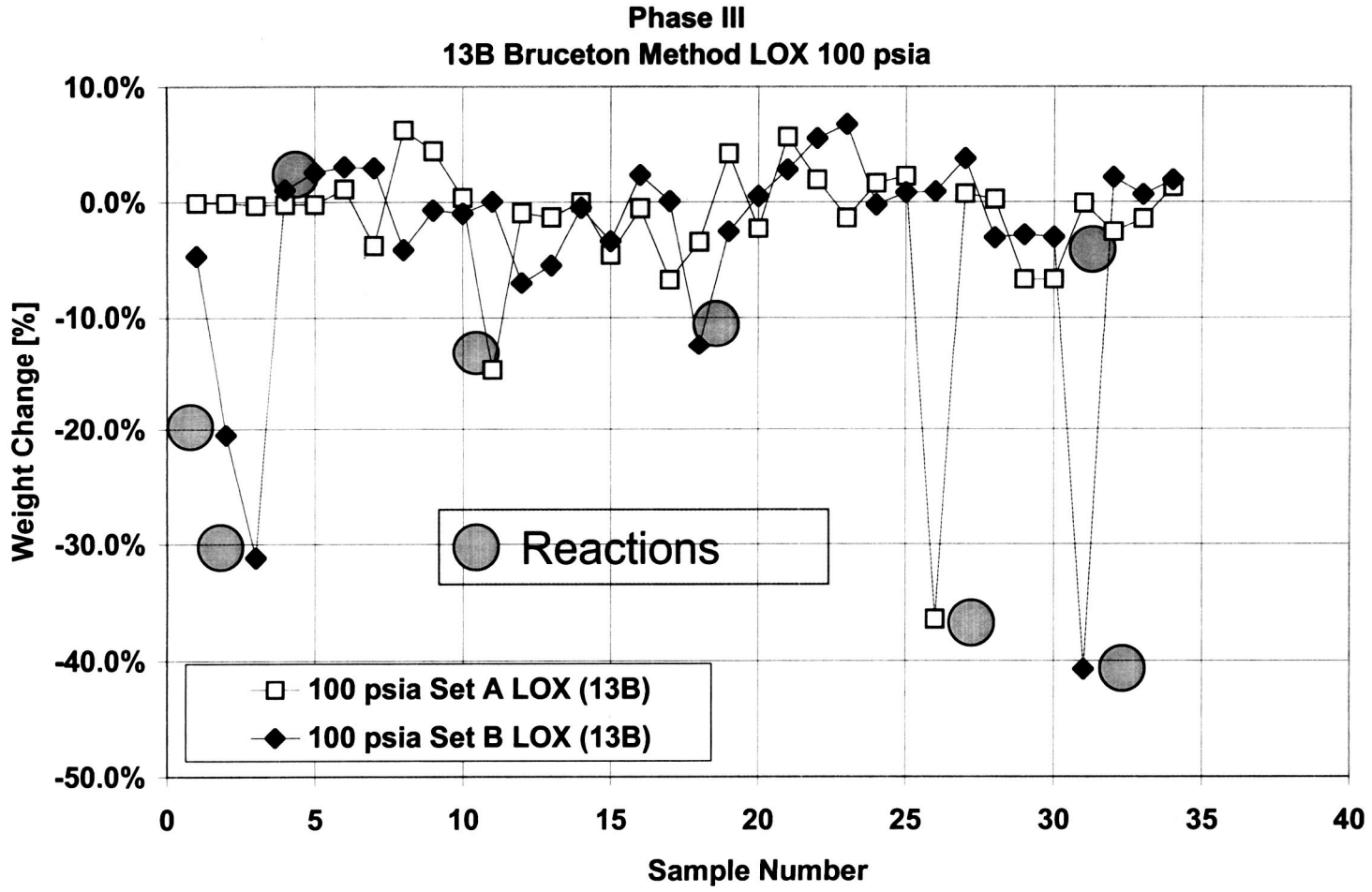
Phase III: Conduct High-Pressure tests (13B) in LOX and GOX at MSFC and WSTF to determine Cycom reaction characteristics and batch effects

- Determine Cycom reactivity in LOX at 100 psia
- Determine Cycom reactivity in GOX at 100 psia
- Examine batch sensitivity in LOX at 100 psia
- Examine batch sensitivity in GOX at 100 psia
- Compare MSFC and WSTF 13B data for Cycom in LOX and GOX

Phase III Test Matrix

Phase III Testing 13 B Bruceton Method									
MSFC									
Batch # (ASDL #)	**Sample Number**	**Test**	**Pressure** psia	**LOX/ GOX**	**Reactions**	**No Reactions**	**50% Energy** ft-lb	**Wt Change w/ reactions** %	**Wt Change w/o reactions** %
Set A, 18110	34	13 B Bruceton Method	100	LOX	4	30	67.23	-14.56%	-0.19%
Set B, 18109	34	13 B Bruceton Method	100	LOX	4	30	64.77	-26.25%	-0.01%
Set A, 18110	34	13 B Bruceton Method	100	GOX	0	34	-	-	0.00%
Set B, 18109	34	13 B Bruceton Method	100	GOX	0	34	-	-	-0.008%
WSTF									
Batch # (ASDL #)	**Sample Number**	**Test**	**Pressure** psia	**LOX/ GOX**	**Reactions**	**No Reactions**	**50% Energy** ft-lb	**Wt Change w/ reactions** %	**Wt Change w/o reactions** %
Set A, 18110	20	13 B Bruceton Method	100	LOX	0	20	-	-	-0.06%
Set A, 18110	25	13 B Bruceton Method	100	GOX	0	25	-	-	-0.03%

Weight Change in LOX at 100 Psia at MSFC



Phase III Conclusions

- Cycom does not support Initiation of reactions or propagate of reactions in GOX at 100 psia based on tests at MSFC and WSTF at 72 ft-lb impact energy.
- No batch effect was identified in LOX or GOX.
- WSTF show no reactions at 72 ft-lb and 100 psia in LOX whereas MSFC showed 4 of 34 reactions (11.7%) for both batches tested.
- Six of the eight reactions in LOX (72 ft-lb at 100 psia) supported initiation and propagation of reaction as indicated by the large amount of mass loss (ave. = 26%) by the impact promoted reaction.

Phase IV Objectives

Phase IV: Ambient (13A) test at MSFC to examine average time of sample in test well effect and (13B) testing to determine pressure effects in LOX. Expand 13B GOX database

Determine the pressure effect on reaction frequency:

Hypothesis: If the reaction frequency is a function of the number of entrained bubbles, then higher pressure will reduce the number of bubbles and lower the reaction probability.

Note: Since no reactions were observed with GOX at 100 psia, the adiabatic compression of bubbles is considered an initiation mechanism for LOX impact.

Phase IV Test Matrix

Phase IV								
Ambient 13A (LOX)								
Batch (ASDL #)	**Energy Level ft-lb**	**MSFC samples**	**Pressure psia**	**1st impact reactions**	**all impact reactions**	**Average Time s**	**Wt change w/ reaction g**	**Wt change w/o reaction g**
18109	72	30	14.7	26	catcher	40	-5.88%	0.96%
18110	72	30	14.7	20	catcher	80	-8.39%	-5.40%
	Subtotals	60						

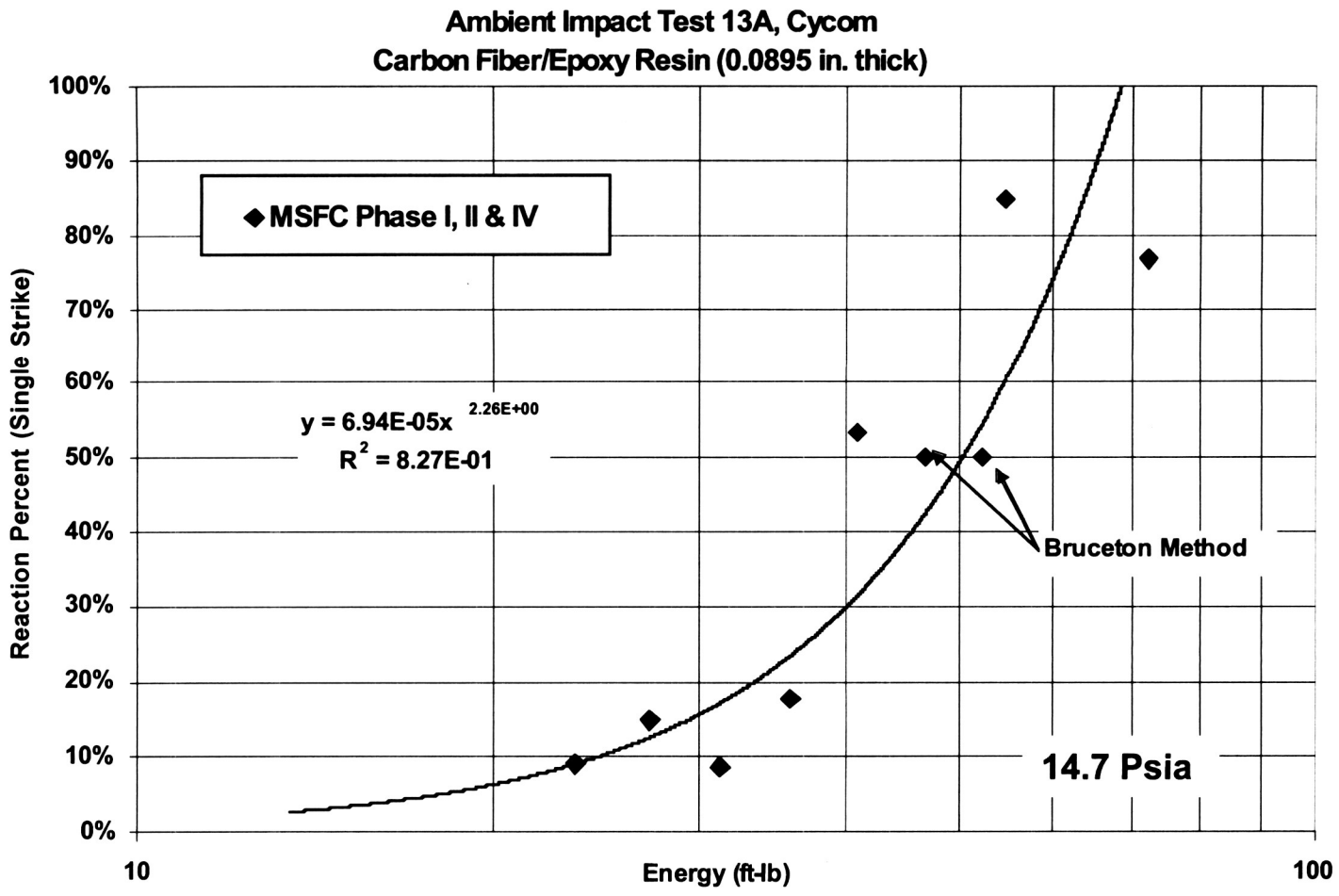
Average time is defined as the time between the sample being placed into the sample well to the time the sample is impacted. Fourty, 40, seconds is the average time ffor a 13A sample at MSFC under normal conditions.

Phase IV								
13B (LOX)								
Batch (ASDL #)	**Energy Level ft-lb**	**MSFC samples**	**Pressure psia**	**Reactions**	**No reactions**	**Average Time**	**Wt change w/ reaction g**	**Wt change w/o reaction g**
18109	72	30	50	13	17	-	-57.07%	-5.75%
18110	72	30	200	18	12	-	-51.51%	-0.44%
18110	72	2	500	2	0	-	-37.33%	-
	Subtotals	62						

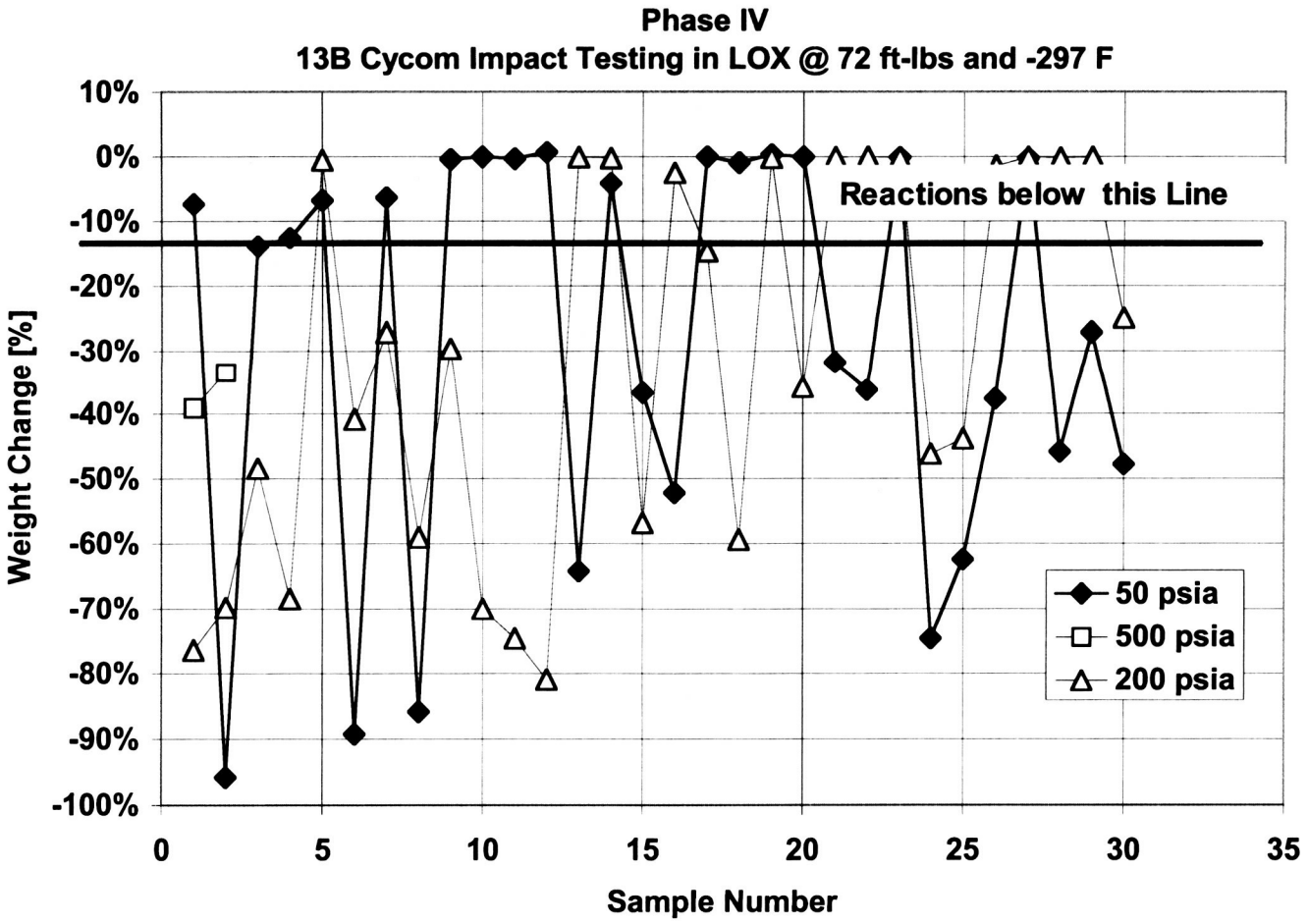
Phase IV Test Matrix Continued

Phase IV-A							
Cycom Impact Testing 13B							
Batch (ASDL #)	**Medium**	**Energy Level** ft-lb	**MSFC** samples	**Pressure** psia	**1st impact** reactions	**Wt change w/ reaction** g	**Wt change w/o reaction** g
18109	**GOX**	72	30	500	22	-6.223%	-0.147%
18109	**GOX**	72	30	200	4	-0.395%	0.208%
		Subtotals	60				

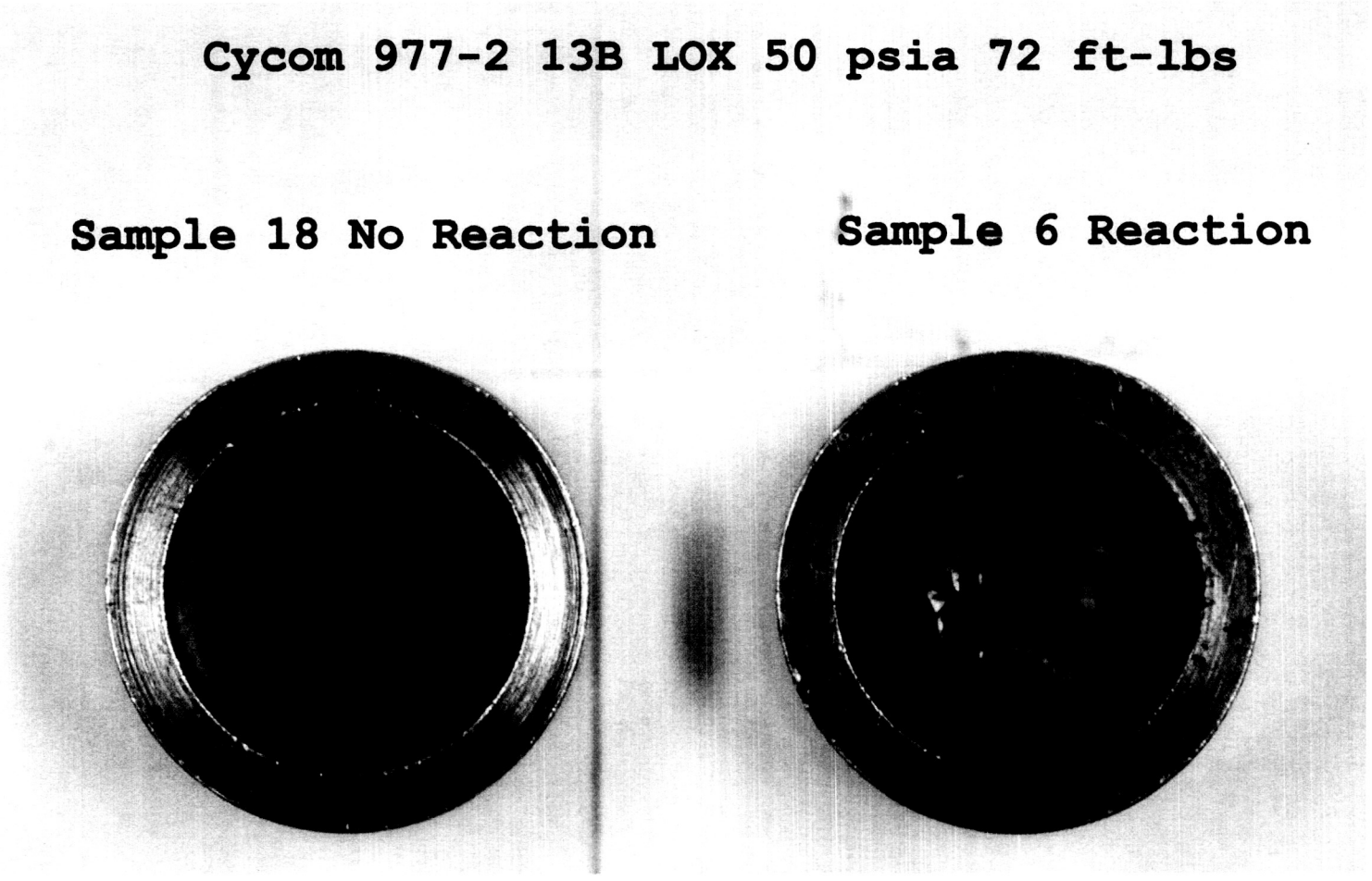
Combined First Strike
Reaction Frequency Data



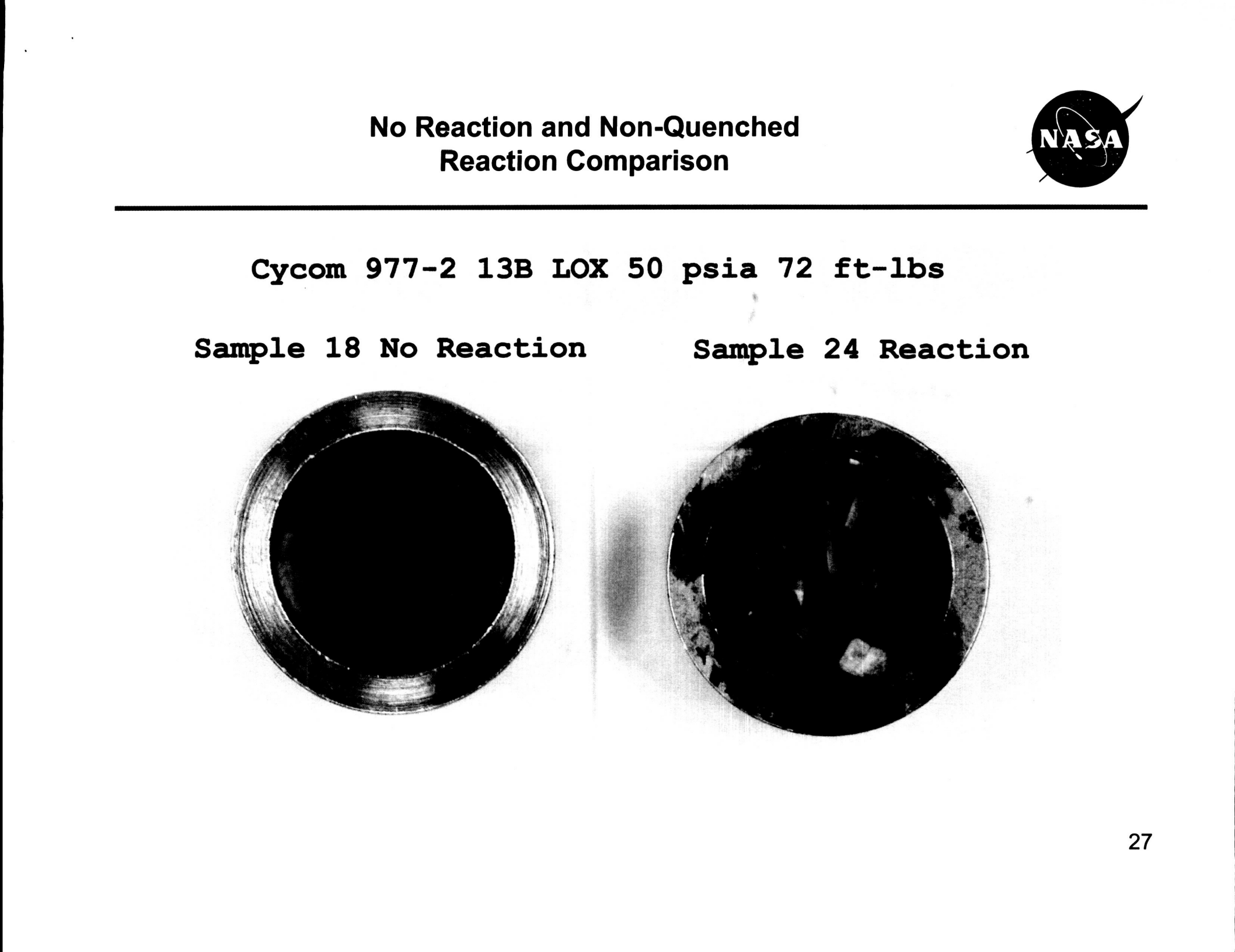
Mass Loss in LOX Testing



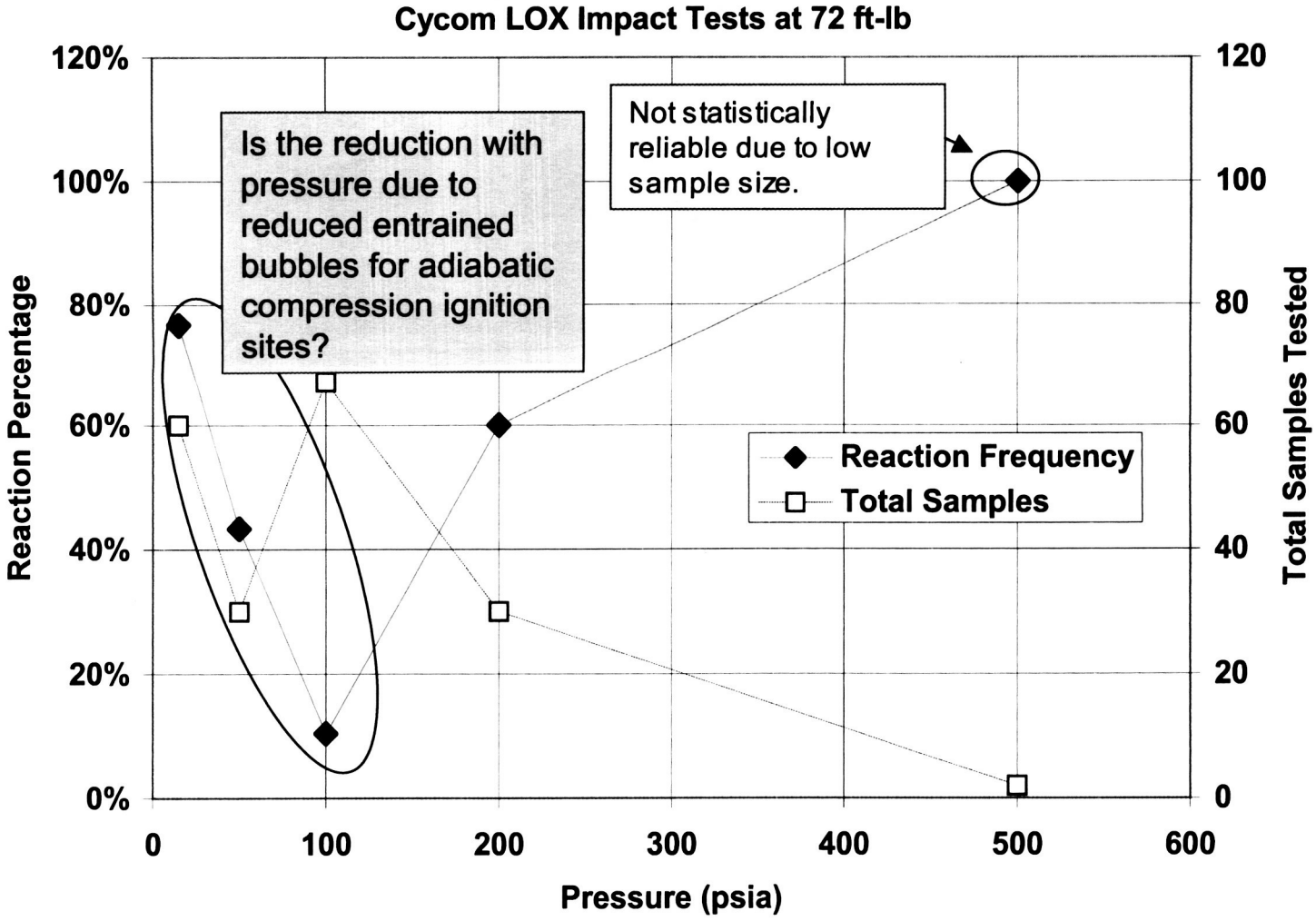
No Reaction and
Non-Quenched Reaction Comparison



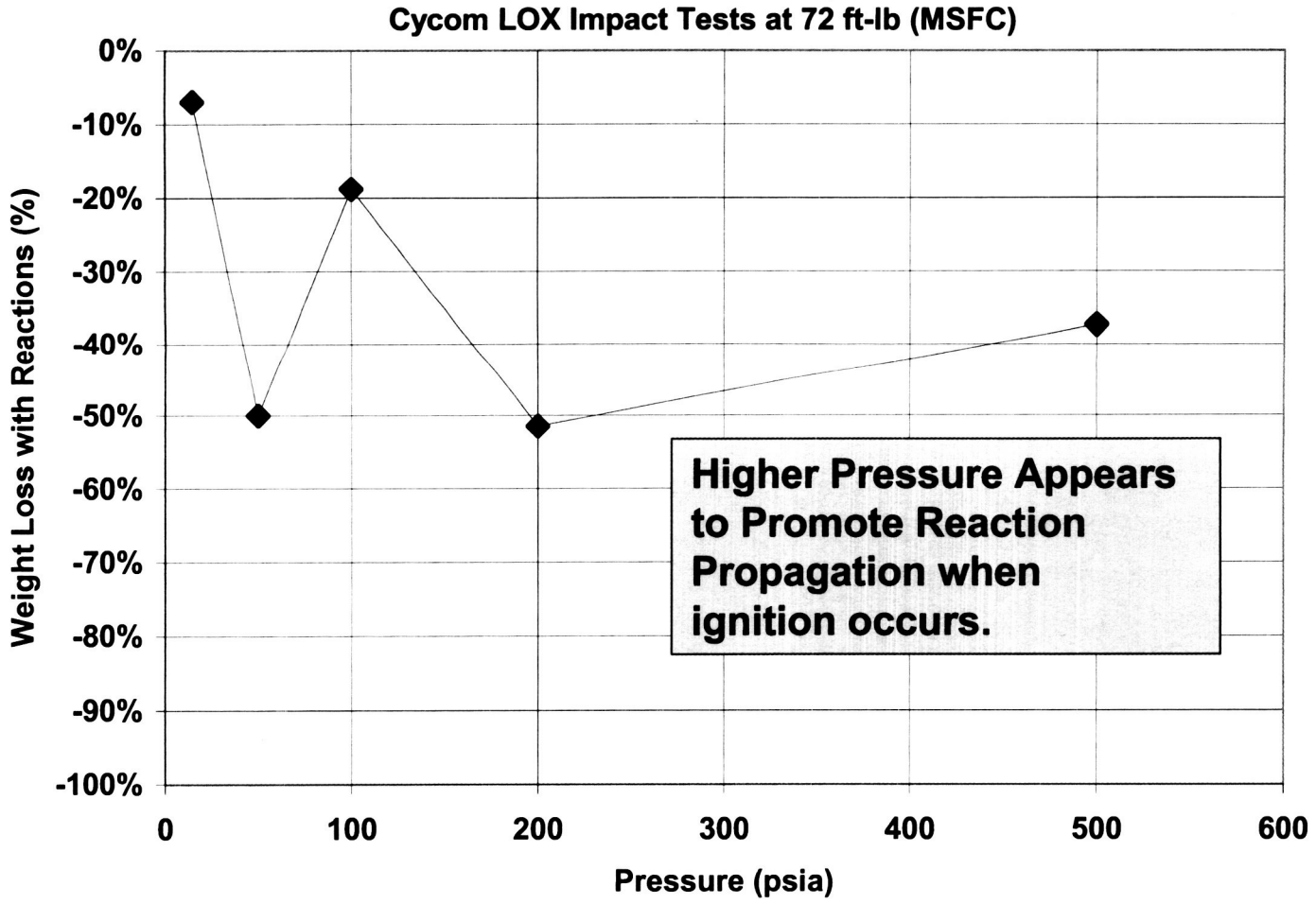
No Reaction and Non-Quenched Reaction Comparison



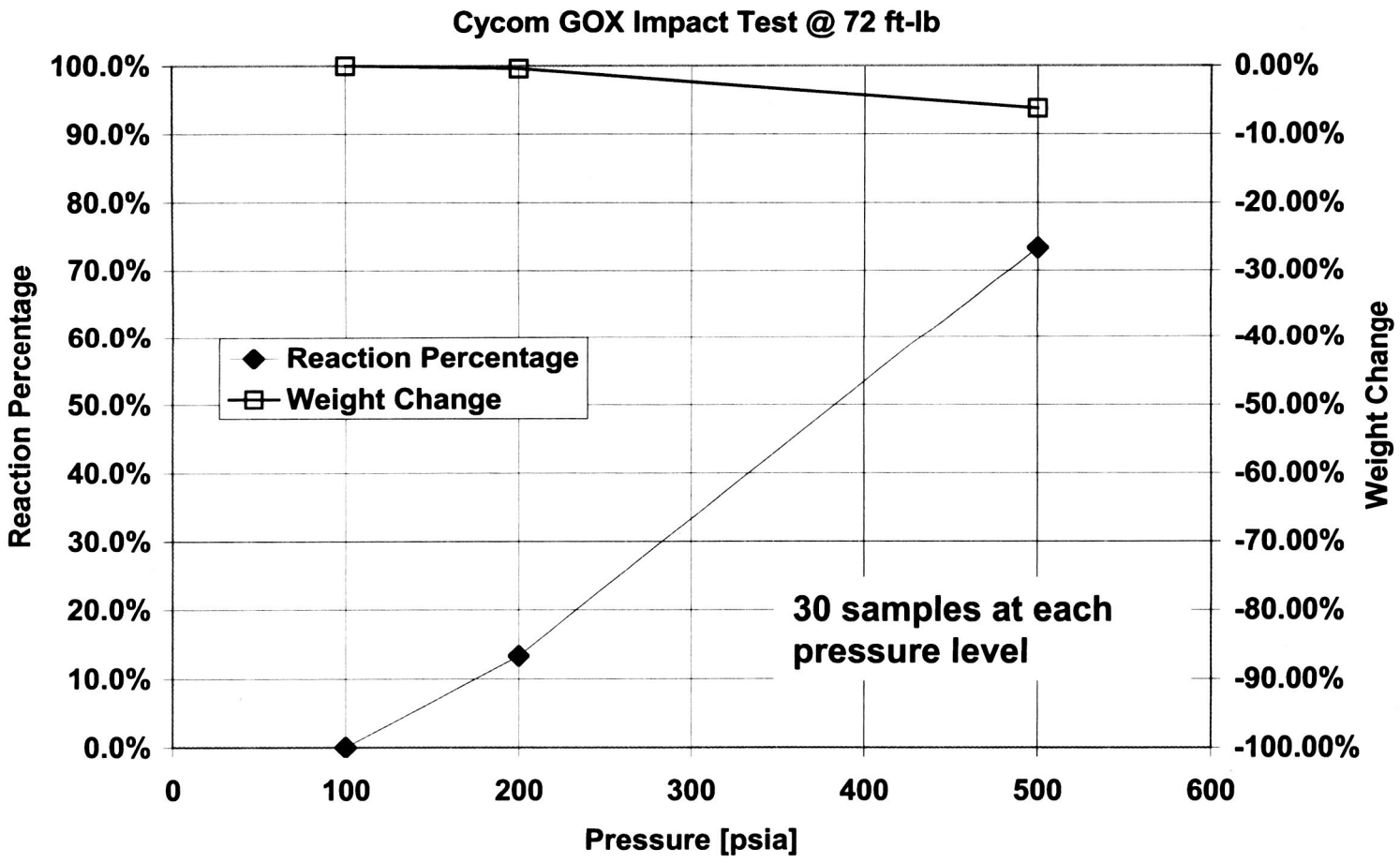
Pressure Effect on Reaction Frequency



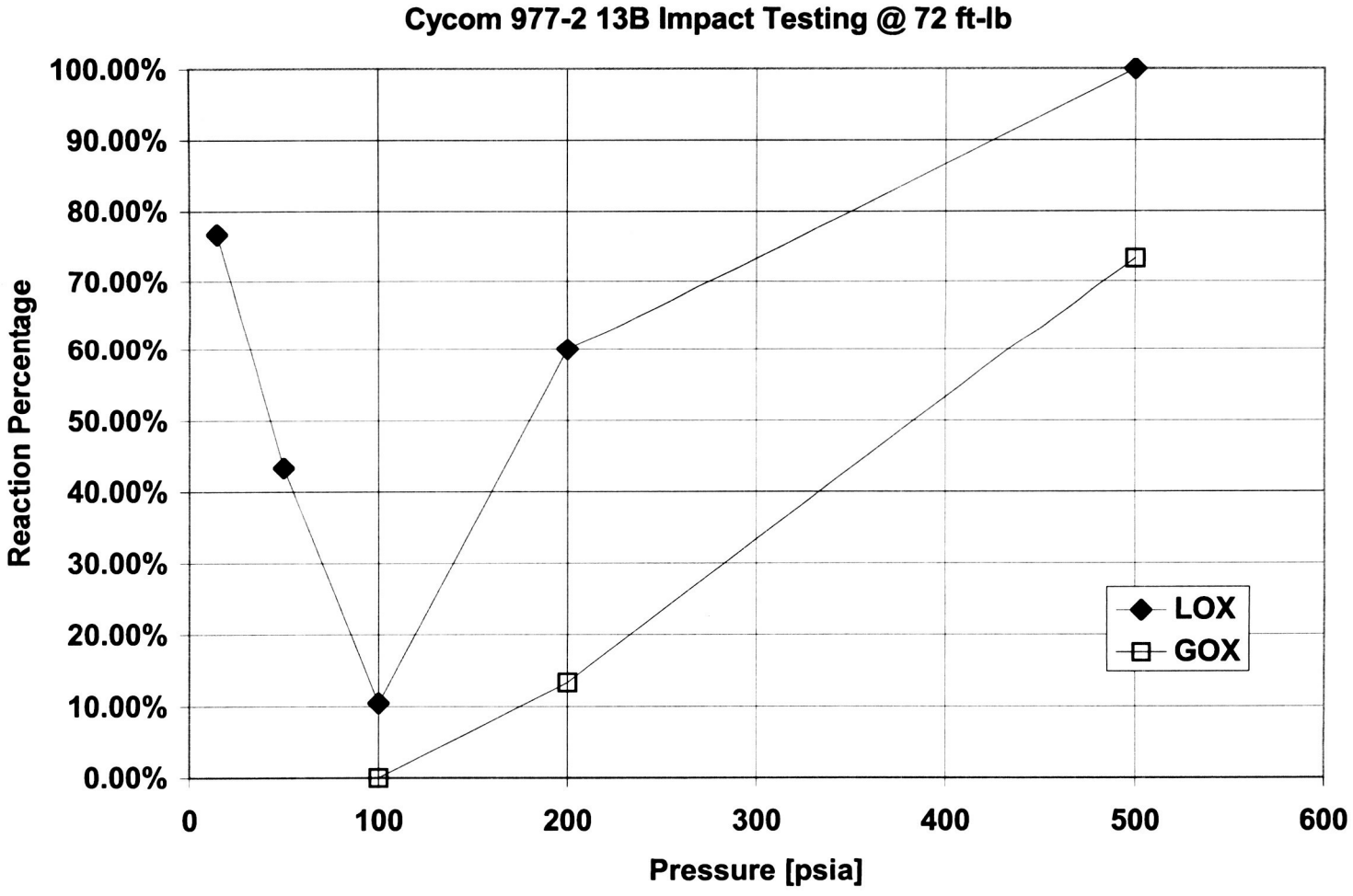
Average Weight Loss with Reactions at 72 ft-lb



Reaction Frequency in GOX at 72 ft-lb



LOX/GOX Reaction Frequency Comparison



Phase IV Conclusions

- Phase IV 13A results were combined with Phases I to III data to provide a more complete reaction frequency data set.
- A small, but statistically insignificant, reduction in reaction frequency was observed by testing at double the sample dwell time before testing.
- Phase III and IV LOX data were combined to show a decrease in reaction frequency with increasing pressure and a corresponding increase in mass loss due to combustion.
- Cycom reaction frequency was shown to increase with pressure from 0% at 100 psia to xx% at 500 psia in GOX.

Overall Observations and Conclusions

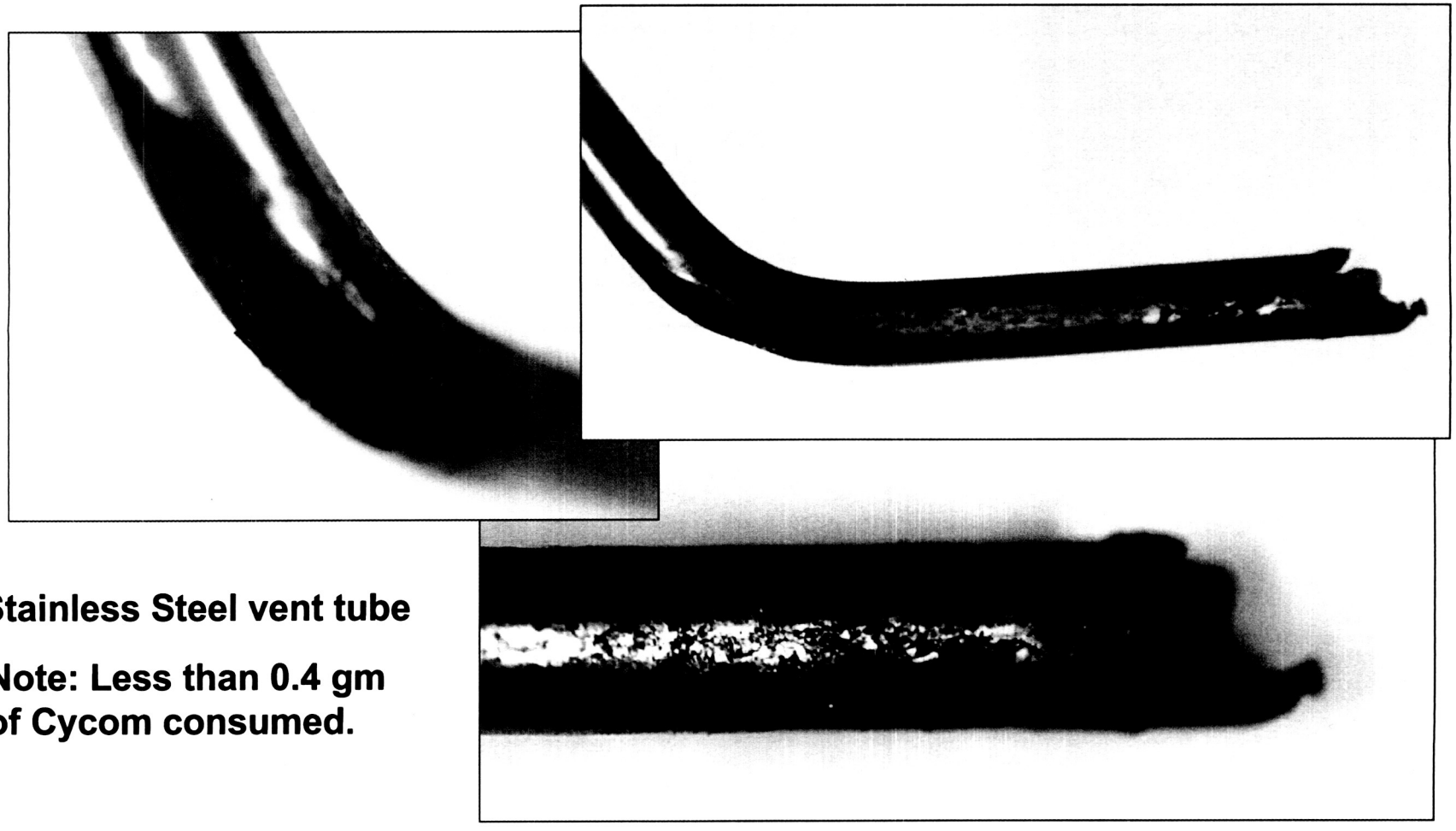
- The reaction frequency data from 13A testing by MSFC and WSTF appear well behaved for the sample number used by each and exhibit the same type of energy level dependency. The reaction frequency shift in energy level is unexplained at this time.
- All the 13A data suggest that only a small amount of material is consumed when reactions take place.
- At ambient pressure, most if not all reactions are quenched as indicated by the small mass loss.
- As test pressure is increased in LOX, using 13B results,
  - The impact initiation has a greater probability of propagation.
  - The probability of ignition is reduced.
- Cycom does not support initiation of reactions or propagation of reactions in GOX at 100 psia based on tests at MSFC and WSTF at 72 ft-lb impact energy. Reactions do occur at higher test pressures.
- No batch effect was identified in LOX or GOX.

Recommendations

- The technical community consider accepting a material for use, which exhibits consistent and universal quenching of impact induced reactions over the potential energy levels at the planned material use thickness.
- The technical committee formulating changes to NASA-STD- 6001 consider altering the testing method to require measurement of pre- and post-test weights.
- Impact combustion initiation be considered a quenched reaction when the mass loss is consistently below 10% of the pre-test mass when a reaction is observed.
- A quenched reaction condition be considered an acceptable risk similar to a flammability test burn length of less than 6.0 inches.

In case we forget that initiation to sustained reaction of Cycom 977-2 can produce significant energy release, see the following slide.

Impact Tester Vent Tube Burn Through
(Cycom with LOX @ 500 psia & 72 ft-lb)



Stainless Steel vent tube

Note: Less than 0.4 gm of Cycom consumed.