



Pre-Disaster Background

Author(s)

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Description

Background on the events, meetings, and SRM testing leading up to the Morton Thiokol Space Shuttle Challenger Disaster.

Body

The significance of starting with January, 1985, results from my observations made during the post flight inspection of hardware from Flight 51C which was launched on January 14, 1985. I found that hot combustion gases had blown by the primary seals on two field joints and had produced large arc lengths of blackened grease between the primary and secondary seals. Subsequent to reporting my findings, I was ordered to MSFC to present a preliminary report prior to formal FRR meetings.

I participated in the formal FRR's for flight 51E which was scheduled for an April launch. The presentations were given at MSFC in February at three successively higher level review boards with exclusions and refinements in content made at each board level. I spoke about my belief that the low ambient temperature prior to launch was responsible for such a large witness of hot gas (approximately 5500 °F [3040 °C]) blow-by but NASA Program Management insisted on that position being softened for higher and final review board presentations. The ambient temperature was 18 to 22 °F (-8 to -6 °C) several days prior to launch and in the 60 - 65 °F (16 to 18 °C) range at launch time and resulted in a seal temperature of 53 °F (12 °C) - which was calculated after the damage was found.

Accordingly, the final FRR assessment chart read as follows:

Evaluation Summary

STS-51C primary O-ring erosion on two field joints

STS-51C soot between primary and secondary O-rings on both field joints predicted after STS-11 observation, first time observed

Evidence of heat affect on secondary O-ring of A68 (right hand) center field joint but no erosion --first time heat affect on secondary O-ring has been observed

Conclusion

STS-51C consistent with erosion data base

Low temperature enhanced probability of blowby -- STS-51C experienced worst case temperature change in Florida history

STS-51E could exhibit some behavior

Condition is acceptable

STS-51E field joints are acceptable for flight

These conclusions were accepted and the boosters were certified for launch.

I returned to MTI in Utah and met with Arnie Thompson, who was the Supervisor of Structural Design and Analysis for the SRM case segments, to discuss the hot gas blow-by scenario and the affects of cold temperature on O-ring resiliency, which we defined as the ability of the seal to restore itself to a round cross sectional shape after the squeeze on the seal is removed. The preliminary resiliency testing, which was requested by Arnie Thompson, was performed in March and showed that a low temperature of 50 °F (10 °C) was a problem, as the seal material could not follow the rate of gap opening and lost contact with its mating surface. The significance of this data was that the seal erosion and blow-by problem was known to occur within 0.60 seconds during the motor ignition transient. The data was discussed with MTI Engineering Management, but was thought to be too sensitive by them to release to anyone.

Another post flight inspection was performed in June, 1985, at MTI facilities in Utah on a nozzle joint from Flight 51B (SRM 16A) which was launched on April 29, 1985. The nozzle joint configuration is shown in Figure 2 with all dimensions in inches. The bore (radial) seal is the primary seal and the face seal is the secondary seal in this joint.

Diagram of the SRM joint nozzle

Inches Millimeters Inches Millimeters

103.512			
103.508	2629.15	0.275	6.99
103.492			0.2075
103.480	2628.54	0.190	5.05
103.090		0.024	0.61
103.067	2618.45	0.015	0.38
0.380			
0.375	9.59	0.012	0.30

Figure 2. SRM Nozzel Joint

This joint was found to have the primary seal eroded through in three places as shown in Figure 3.

SRM primary O-ring cross sections with measurements

Inches Millimeters Inches Millimeters

0.17	4.32	0.111	2.82
0.23	5.84	0.155	3.94
0.35	8.89	0.104	2.64
0.089	2.03	0.50	12.70
0.186	4.57	0.275	6.98

Figure 3. SRM-16A Nozzel Joint Primary O-Ring

The darkened areas represent the remaining seal material after the hot gas blow-by occurred. The secondary seal in the same joint was eroded to a depth of 0.032 inches (0.81 mm) but sealed as expected. It was postulated from the evidence that the primary seal had not sealed during the full two minutes of booster flight.

My former concerns about seal erosion and blow-by now escalated because if the same scenario should occur in a field joint, the secondary seal could also be compromised because it was a bore seal instead of the very safe face seal in the nozzle joint. This heightened concern was especially true for a low temperature launch because of the preliminary test results on seal resiliency at 50 °F (10 °C).

An FRR was held at MSFC on July 1, 1985 for flight 51F which was scheduled for launch on July 29, 1985, with an additional presentation given on July 2nd which covered the overall problem status with all the booster seals. The preliminary test results on O-ring resiliency that were obtained in March and kept secret were presented to NASA for the first time at this meeting.

The preliminary test configuration placed an O-ring seal into a flight size groove in a flat plate and compressed the seal 0.040 inches (1.02 mm) with another flat plate. After temperature conditioning of the assembly, the plates were separated 0.030 inches (0.76 mm) at a 2.0 inch (5.08 cm) per minute rate to simulate a flight rate of approximately 3.2 inches (8.13 cm) per minute (slightly unconservative).

The test results showed no loss of seal contact at 100 °F (38 °C); loss of seal contact for 2.4 seconds at 75 °F (24 °C) and loss of seal contact for in excess of 10 minutes at 50 °F (10 °C). The testing also showed that a larger diameter seal (0.295 in - 7.49 mm) lost contact for 2 to 3 seconds at 50 °F (10 °C). This showed that the larger diameter seal performed at 50 °F (10 °C) similar to the operational flight seal (0.280 in - 7.11 mm) at 75 °F (24 °C), which was why the larger seal was being considered for a short-term fix.

Everyone on the program, working with the joint seal problems, was now aware of the influence of low temperature on the field joint seals.

Again, my concern about the joints increased due to the lack of attention being given to this problem by MTI. My notebook entry on August 15, 1985 reads as follows: "An attempt to form the team (I was referring to the SIRM Seal Erosion Task Team) was made on 19 July 1985. This attempt virtually failed and resulted in my writing memo 2870:FY86:073. This memo finally got some response and a team was formed officially. The first meeting was held on August 15, 1985 at 2:30 p.m." The memo I referred to is the one I wrote to the Vice President of Engineering at MTI on July 31, 1985. The memo was stamped COMPANY PRIVATE by my boss and had a very limited distribution until I read it to the Presidential Commission on February 25, 1986. The memo reads as follows:

"Subject: SRM O-Ring Erosion/Potential Failure Criticality. This letter is written to insure that management is fully aware of the seriousness of the current O-ring erosion problem in the SRM joints from an engineering standpoint. The mistakenly accepted position on the joint problem was to fly without fear of failure and to run a

series of design evaluations which would ultimately lead to a solution or at least a significant reduction of the erosion problem. This position is now drastically changed as a result of the SRM 16A nozzle joint erosion which eroded a secondary O-ring with the primary O-ring never sealing."

"If the same scenario should occur in a field joint (and it could), then it is a jump ball as to the success or failure of the joint because the secondary O-ring cannot respond to the clevis opening rate and may not be capable of pressurization. The result would be a catastrophe of the highest order--loss of human life."

"An unofficial team (a memo defining the team and its purpose was never published) with leader was formed on 19 July 1985 and was tasked with solving the problem for both the short and long term. This unofficial team is essentially nonexistent at this time. In my opinion, the team must be officially given the responsibility and the authority to execute the work that needs to be done on a noninterference basis (full-time assignment until completed)."

"It is my honest and very real fear that if we do not take immediate action to dedicate a team to solve the problem, with the field joint having the number one priority, then we stand in jeopardy of losing a flight along with all the launch pad facilities."

The memo was signed by R. M. Boisjoly and concurred to by J. R. Kopp, Manager, Applied Mechanics, who was my boss.

During the July-August time period, NASA headquarters in Washington, D. C. asked MTI to prepare and present a summary of problems with all the booster seals on August 19, 1985. This was done and that is why I find it so incredible that top NASA management denies knowing anything about the problems with the joint seals, when questioned by the Presidential Commission.

MTI was then asked by NASA MSFC in September to send a representative to the SAE Conference in October to discuss the joint seal designs and solicit help from the technical experts in attendance. However, I was given strict instructions, which come from MSFC, not to express the critical urgency of fixing the joints but to only emphasize the joint improvement aspect during my presentation. I prepared and presented seven Viewgraphs to approximately 130 technical experts at the conference.

I then asked for help in the form of design improvement suggestions and stated that we were not asking for free advice but were willing to contract for work, but no one said a word. So Bob Ebeling and I spent the remainder of the convention time meeting with seal vendors whom we had previously contacted for help. In retrospect, I'm not surprised that no one responded to my pleas for help when I showed them the parameters of the joints. What they saw and heard were joint gap configurations (both static and dynamic) that were approximately an order of magnitude worse than anything they had previously encountered. I don't blame them for avoiding any comments and suggestions when asked.

The seal erosion task team was frustrated right from the start due to lack of management support to provide manpower and material resources necessary for us to accomplish the task of fixing the joints. Accordingly, I wrote a series of very damning activity reports in which I left no room for error about my feelings due to the lack of management support. The last such report written was on October 4, 1985 and reads as follows:

"SRM Seal Problem Task Team Status. The team generally has been experiencing trouble from the business-as-usual attitude from supporting organizations. Part of this is due to lack of understanding of how important this task team activity is and the rest is due to pure operating procedure inertia which prevents timely results to a specific request.

The team met with Joe Kilminster on October 3, 1985 to discuss this problem. He wanted specific examples which he was given and he simply concluded that it was every team member's responsibility to flog problems that occurred to organizational supervision and work to remove the road block by getting the required support to solve the problem. The problem was further explained to require almost full-time nursing of each task to insure it is taken to completion by a support group. Joe simply agreed and said we should then nurse every task we have.

He plain doesn't understand that there are not enough people to do that kind of nursing of each task, but he doesn't seem to mind directing that the task nevertheless gets done. For example, the team just found out that when we submit a request to purchase an item, that it goes through approximately six to eight people before a purchase order is written and the item actually ordered.

The vendors we are working with on seals and spacer rings have responded to our requests in a timely manner, yet, we (MTI) cannot get a purchase order to them in a timely manner. Our lab has been waiting for a function generator since September 15, 1985. The paperwork authorizing the purchase was finished by Engineering on September 24, 1985 and placed into the system. We have yet to receive the requested item. This type of example is typical and results in lost resources that had been planned to do test work for us in a timely manner.

I for one resent working at full capacity all week long and then being required to support activity on the weekend that could have been accomplished during the week. I might add that even NASA perceives that the team is being blocked in its engineering efforts to accomplish its task. NASA is sending an engineering representative to stay with us starting October 14th. We feel that this is the direct result of their feelings that we (MTI) are not responding quickly enough on the seal problem. I should add that several of the team members requested that we be given a specific manufacturing engineer, quality engineer, safety engineer and four to six technicians to allow us to do our tests on a noninterference basis with the rest of the system. This request was deemed not necessary when Joe decided that the nursing of the task approach was directed.

Finally, the basic problem boils down to the fact that all MTI problems have #1 priority and that upper management apparently feels that the SRM program is ours for sure and the customer be damned."

The Activity Report was signed by Roger M. Boisjoly on October 4, 1985 and given to my boss's secretary. Unfortunately, I never received any comments back and I never knew if the contents of my activity reports were incorporated into the reports up through the management organization to the top.

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Notes

Author: Roger M. Boisjoly, Former Morton Thiokol Engineer, Willard, Utah.

Rights

Use of Materials on the OEC

Resource Type

Case Study / Scenario

Topics

Catastrophes, Hazards, Disasters

Employer/Employee Relationships

Lab and Workplace Safety

Social Responsibility

Workplace Ethics

Discipline(s)

Aerospace Engineering

Mechanical Engineering

Engineering