Space Shuttle Challenger January 28, 1986 Tragedy

A Retrospective on Causation and Moral Injuries

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My initial goal in researching the January 28, 1986 Challenger tragedy was to solve the internet myth on whether it was caused, or contributed to, by an asbestos substitute that failed. This is a significant issue as the Challenger situation continues to be used as a teaching experience for leadership, ethics, communication, engineering, and group think classes. The Challenger accident remains sufficiently popular that Netflix aired a documentary in 2020 that focused on the effect of the cold temperature on the O-rings that failed in the right-hand solid rocket booster. When I decided to return to school in 2021, the involvement of the asbestos-containing putty that was designed to protect those O-rings seemed to be the perfect topic for me to research. As it turns out, when it comes to the asbestos or the potential asbestos putty substitute, we have all been asking the wrong question. My complete research paper including footnotes and bibliography can be viewed at https://theasbestosblog.com/wp-content/uploads/2022/01/Space-Shuttle-Challenger-Thesis-1282022.pdf.

Using significant original and difficult to obtain primary sources, this presentation examines the causes of the Challenger destruction by analyzing the asbestos-containing putty used in the field joints, along with contributing factors such as NASA diverting its focus from mission safety to encompass other priorities, and problems with the field joint design. This presentation then concludes with a discussion on the moral injuries suffered by certain Thiokol employees arising from their unsuccessful efforts to fix the technology and to communicate their concerns, and who were eventually overruled in their opposition to the launch.

I was amazed at the willingness to help me by those who went before me to develop additional primary source information, including by the rocket scientists who were involved in the design of the space shuttle, participated in the now infamous meeting the night before the launch, watched in horror the launch and aftermath, participated in the Presidential Committee investigation, and those who have had to internalize all of the above in terms of work, their families, and their lives. This project was both humbling and soul-searching.

THE SOLID ROCKET BOOSTERS AND THE INCLUSION OF THE ASBESTOS CONTAINING PUTTY TO PROTECT THE O-RINGS

Our discussion should first focus on the underlying engineering. Thiokol manufactured the four solid motor segments for the right hand solid rocket booster to be used on the Challenger launch in its plant at Brigham City, Utah and then shipped them fully loaded with propellent by rail to Cape Canaveral. These segments were known as the forward, forward center, aft center, and the aft segment. The assembly process took place in the unheated Vertical Assembly Building (VAB) beginning at the bottom of the motors while stacking the components vertically, and including the other booster components. The joints assembled by attaching the four motor segments in the VAB were called field joints while the joints called "nozzle joints" in the aft segment had been assembled at Thiokol in Utah prior to shipment.

The field joint assembly process involved a number of components and steps. As related to the issues involved in this presentation, first the two rubber twelve foot diameter O-rings were inserted into their 0.305-0.310 inches grooves. Next, the vacuum asbestos-containing putty in tape form was applied to the insulation surface of the clevis (bottom segment) in order to provide thermal protection to the O-rings during launch. This thermal protection was to minimize the 5800 degree Fahrenheit propellant exhaust from using gas paths to reach to reach the O-rings prior to their sealing. The putty used on the Challenger flight was supplied to Thiokol by its vendor Randolph Products and it met the two specifications required for its asbestos content: a minimum quantity specification and a specification that the asbestos be of the chrysotile variety.

A review of the published literature is not clear in this regard, as even Thiokol engineer Roger Boisjoly published a post-Challenger article stating that the replacement putty by Randolph Products was asbestos-free; he and others making this claim were mistaken. The putty originally used for protecting the O-rings had changed when the long time supplier, Fuller-O'Brien, decided in the late 1970s to phase out manufacturing all asbestos products due to the new regulation prohibiting the putty's sale in consumer products in combination with societal issues then arising concerning asbestos-related product liability lawsuits.

The putty for use in the Space Shuttle solid rocket booster by Thiokol was extruded onto a silicone or other releasing paper by the supplier in strips 3/16" thick and either 3/8" or 3/4" wide. The assembler would use latex or other similar gloves to unroll the putty a little at a time and then lightly press it onto the insulation surfaces according to the drawing in the instructions. The putty would stick to the rubber surface of the insulation. The operator would then pull the paper away as he or she proceeded around the circumference of the joint. Grease was then applied to the exposed metal surfaces as a protection against corrosion and as a lubricant for the O-rings. The top segment was then lowered onto the bottom segment, squeezing the O-rings into their grooves and the putty into the space between the adjoining insulation within the case. The segments were then pinned together using 180 pins. Once assembled, the assembler performed a leak test to ensure that the O-ring was not damaged during assembly and that there was no contamination of the seal. Once the boosters were stacked and mated with the orbiter and external tank, the assembly moved to the launch pad and might sit for months prior to launch.

ACCEPTABLE RISK

Many of those involved in the field joint issues or who supported the decision to launch have been criticized as taking too much risk. However, the space program inherently involves risk. As far back as 1969, the mission requirements provided by NASA for its vendors in the space shuttle program included acknowledging an acceptable level of risk to the crew survivability and the success of the mission. Those specifications stated that "[t]he goal for crew survival probability and for the probability of successful mission completion has to be at least 0.999 and 0.95 respectively." Running the statistics with 445 anticipated missions, that means one out of every twenty missions will fail (five divided by one hundred) and a 44.5% probability existed that one crew during the life span of the shuttle project would not survive (445 divided by 1000). In addition, the highest-risk time frame was between launch and the solid rocket booster burn out. This approximately 122 seconds was considered especially vulnerable because the space shuttle system "was not designed to survive a failure of the Solid Rocket Boosters." Although the literature debates the rationale as to why an abort or crew escape mechanism was unnecessary or unworkable, this lack of a back-up for the astronaut safety during the launch required a heightened concern over operational safety until after the solid rocket boosters completed their burn. Assistant Director for Space Shuttle Flight Crew Operations Warren J. North in 1984 put it best, stating: "The risks associated with first-stage launch warranted a programmatic attempt to provide crew survival," To add an extra layer of safety, the original design for the solid rocket boosters as used in the Titan III rocket program was modified to include a second O-ring. The believed redundant seal provided by this additional O-ring was thought to make the field joint failsafe; but, as it turned out, it did not. Being thought to be failsafe, the design received a Criticality Rating of 1R (1 with redundancy) rather than a 1 (with no redundancy).

Even with the importance of risk control, the budget constraints for the shuttle program required NASA to manage those risks "in a tight fiscal environment" with restrictive funding. As stated by Roger Launius, a Chief Historian for NASA, "[t]he bare-bones funding strategy for the program forced NASA to take short-cuts." In a 1988 survey of NASA employees, 80% responded "agree" or "strongly agree" to the statement: "Cost constraints have forced us to cut corners in carrying out our programs."

THE CHALLENGER TRAGEDY

On January 27, 1986, thirty-four highly trained professionals at three locations participated in a phone discussion on whether the Challenger should launch the following day given the anticipated cold weather in Florida. The fifteen people at NASA Marshall Space Flight Center, fourteen at Morton-Thiokol in Brigham City, Utah, and five at the Kennedy Space Center in Cape Canaveral, Florida were looking at faxed copies of the handwritten and typed analysis. After all, there were no laptops, no internet, and email was yet to be invented.

With NASA on hold, several Thiokol engineers and scientists included Brian Russell, Roger Boisjoly, Arnie Thompson, Jerry Burns, Bob Ebeling, and Kyle Speas were making their case to the Company's four vice presidents not to launch the space shuttle solid rocket boosters at less than 53 degrees Fahrenheit because of concerns about the field joints. Those vice presidents were all technically trained in engineering or math with, between them, 140 years of work experience. As such, they would listen to their technical people, but make their own considered decision. Finally, the discussion led to a decision. The Thiokol management, under pressure from NASA, stated that Thiokol had re-evaluated its original position not to launch, and that Thiokol now supported the client's desire to proceed even given the anticipated cold. During the launch the next day, the aft field joint on the right hand solid rocket booster failed 73 seconds into the flight, leading to the tragic loss of the crew and all equipment. From the launch photographs, a puff of black smoke from the right hand booster aft section is clearly visible immediately after ignition. And suddenly, the world as known by everyone involved with that phone call had changed.

CAUSE OF THE FAILURE

Was the failure caused, or contributed to, by an asbestos substitute that failed? That is the wrong question as there was no asbestos substitute. Both the original Fuller-O'Brien putty and the replacement Randolph putty contained the same asbestos related specifications. However, the correct question is whether the change in the putties themselves may have caused the failure. The answer to that question, based on the statistical analysis undertaken at my request by Thiokol retiree Jerry Burn is that "Randolph Putty had 3.1 times more Gas Path occurrences on Field Joints than Fuller O'Brien." The critical nature of this increase in risk cannot be overstated. The higher the probability of a gas path, the higher the probability of an O-ring failure, and the higher the probably of a joint failure like the one which caused the Challenger tragedy. To be clear, gas paths in the joints were formed during assembly, and not created by cold temperature at launch. Rather, the cold launch temperature affected the O-rings such that they could not seal in time as the cold caused them to be harder and therefore less responsive. This was a race between 5800 degree Fahrenheit propellant exhaust through a gas path that was formed during assembly in comparison with the O-ring timing to seal at the moment of the launch. On this day, the exhaust won.

Given the passage of time, we will never know the precise differences in the putties that caused or contributed to the increase in gas paths. However, one potential contributing factor is that the asbestos fibers in the replacement putty were thicker and longer, and therefore weaker, than the asbestos fibers used in the original putty. The difference in diameter and length identified by visual observation was noted on page 8 in the March 8, 1983 report analysis by

Thiokol chemist Frank Bares, and confirmed by him during our interview. However, that testing and putty comparison also showed significant differences in the non-asbestos material properties.

The additional gas paths caused by the Randolph putty exposed two weaknesses that were the secondary causes of the tragedy. The first was the decision-making process by NASA, including its focus on day-to-day issues and priorities without resolving or fully understanding the joint related safety issues arising during the critical first 122 seconds of the flight. The record is replete with NASA ignoring warnings prior to the January 27, 1986 launch discussion meeting. Further, NASA then changed the rules by requiring its vendors (both Thiokol on the solid rocket motors and Rockwell on the orbiter) to prove that a cold weather launch outside of the relevant known databases was unsafe instead of presuming such a launch to be unsafe absent acceptable data supporting the safety. This was the ultimate mistake on January 27, 1986 and the day of launch. As often heard at NASA, "In God we Trust, all others bring data."

The second weakness was the flawed field joint design that had previously been masked by the rheological qualities of the Fuller-O'Brien putty. In summary, because of the Fuller-O'Brien putty material flow and better consistency during changing humidity and temperatures, NASA and Thiokol did not realize the full extent of the flaws in the original field joint design until after the January 28, 1986 tragedy and their work to re-design the field joints for future shuttle flights. Without a gas path forming during the assembly process, there is no field joint failure. With a gas path having formed, a great number of unknowns came into play.

<u>MORAL INJURIES TO THIOKOL EMPLOYEES</u>

Everyone who attended the January 27, 1986 meeting to discuss whether the Challenger should launch was fundamentally changed by the experience. Those at NASA and Thiokol who were in favor and approved the launch, were devastated. Those at Thiokol who opposed the launch were equally devasted, especially if they also had been involved in the failed attempts to understand the joint-related issues. Each individual had to handle their feelings, potential guilt, sadness, and fear of the unknown in their own way. For some, their involvement gave rise to moral injuries, typically evidenced by guilt arising from a moral failing or trauma.

For one small group of Thiokol employees consisting of Allan McDonald, Brian Russell, Bob Ebeling, Arnie Thompson, and Roger Boisjoly, their injuries did not stop with the explosion. Rather, they helped the Presidential Commission and others to investigate and determine the truth and to make the situation transparent. For this, they at times were ostracized at work, potentially demoted, and otherwise made by some co-workers or senior management to feel unwelcome. Because of this treatment, they at times felt isolated at work and dubbed themselves as “the Five Lepers.” In contrast, however, they also received support from many of their co-workers and so this feeling of ostracization was felt more by some than by others.

The moral injury affected each of the employees differently. Bob Ebeling, who coined the term “the Five Lepers,” never recovered. Having also suffered the suicide of his son prior to the Challenger, he was no stranger to sorrow. Although he was assigned to the re-design team, he took a leave of absence and then retired. Over the next thirty years, he donated substantial time and money to a nearby bird refuge. Shortly after his passing in 2016, Howard Berkes of NPR provided an epitaph stating “Bob Ebeling spent a third of his life consumed with guilt about the explosion of the space shuttle Challenger. But at the end of his life, his family says, he was finally able to find peace.” The Washington Post stated in the notice of his passing: “This is what Bob Ebeling planned to demand of God, when he saw him: “Why me? You picked a loser.”

Roger Boisjoly suffered from issues compounded by a similar situation where he was at risk of being fired after refusing to sign off on an unsafe practice occurring at a prior employer, Hughes Helicopter. In regard to the Challenger, Boisjoly regretted that he did not do more to stop the January 28, 1986 launch. As noted by sociologist Diane Vaughn, "Boisjoly tortured himself with thoughts that he might have been able to stop the launch by calling the newspapers." In addition, Boisjoly believed that he was blackballed from the industry by Thiokol's management and could not find a job until changing professions to become an expert witness for attorneys in California. As stated by Boisjoly in his unpublished manuscript: "However, the bottom line was very clear to the Commission, Roger and Al were being punished for their previous testimony, period."

As to Allan McDonald, his feelings immediately hit home. As stated in his book chapter entitled "A Leper in the Limelight":

> I had a difficult time going to sleep that night, because I was starting to get the feeling that the whole world was against me. I dreaded going out to the plant the next day and facing all of those people. I was also totally exhausted to a point that I was so emotionally drained and tired that I couldn't relax.[1]

The pressure and treatment related to McDonald continued after his testimony to the Presidential Commission investigating the failure. For the remainder of his career at Thiokol, McDonald felt that the management at Thiokol would have pushed him out or made it uncomfortable for him to stay if not for the protection he received from those on the Presidential Commission.

Brian Russell has felt and continues to feel the touch of moral injuries arising out of the Challenger tragedy. Mr. Russell has not been vocal about the injuries as they are private and subject to much reflection over the years. But, he has found his way. For several months after the explosion, he was lost and without a sturdy foundation in how to move forward. At that time, Mr. Russell realized that he had a life to continue to lead and, as such, worked to be as good a husband, father, co-worker, and friend as he could be. He vowed to never allow a similar situation to occur, became the moral conscience (in his own mind) of those co-workers around him, and was known at work as a Boy Scout, in the good sort of way. He has also strongly relied on his religion, the Church of Jesus Christ of Latter-day Saints, not as a missionary or to try to convince others but, rather, to build and support his internal strength. Mr. Russell still feels that if he had spoken up more during the January 27, 1986 meeting, it may have made a difference, at least to the NASA people attending the meeting. He continues to carry the burden of guilt, not all-consuming as it was for the first four months after the accident, but it never completely goes away. Russell also takes great solace in having been contacted by Alison Smith Balch, daughter of Challenger pilot Michael Smith, after the 2020 Netflix documentary on the Challenger explosion. She reported to Mr. Russell that she is happy, has a family, and has been strengthened by her faith. Both feel that such is the way to honor the loved ones lost on that day.

In conclusion, as stated by Brian Russell in regard to the research:

> Marty's extensive research on asbestos and its application to the Space Shuttle Challenger disaster are impressive to say the least.

And by Professor Mark Maier of Chapman University, the Principle Technical Consultant to the Netflix 2020 documentary titled "Challenger: The Final Flight:"

> Ditkof's work represents a significant contribution to the historical record on Challenger.

If you would like to read the entire report, it is posted on my January 27, 2022 blog at https://theasbestosblog.com/?p=9723.