The fate of number 13

When the time came for Apollo 13, many people thought: Why number 13? Why not 14 or 12 bis?
However, either of these solutions was like trying to deceive reality.
On the other hand, NASA, a Federal Administration and an organization as serious as could be, could not admit the prejudices inherent to the superstition related to number 13 so…Apollo **13.**

Moreover, launch took place on April 11 at **13** hours and **13** minutes, Houston time, and the accident two days later, April **13**.

However, the problem that caused the accident, which almost killed three astronauts, started much earlier.

With the start of Project Apollo, NASA developed an additional program based on what they expected to be the *"lessons learned"*. This was the AAP (Apollo Applications Program), which comprised three main objectives:

1. The ***"GRAND TOUR".*** Launch two groups of robotized spacecraft to study all of the exterior planets. A total of four satellites two of which would visit Jupiter, Saturn and Pluto, while the other two would go to Jupiter, Uranus, and Neptune. The calculated cost was so big, around a billion dollars, that the project was cancelled.
2. Design, construction, and launch into Earth´s orbit of an ***"Orbital Space Station"***. However, here NASA also faced a not affordable cost and had to cancel the objective.

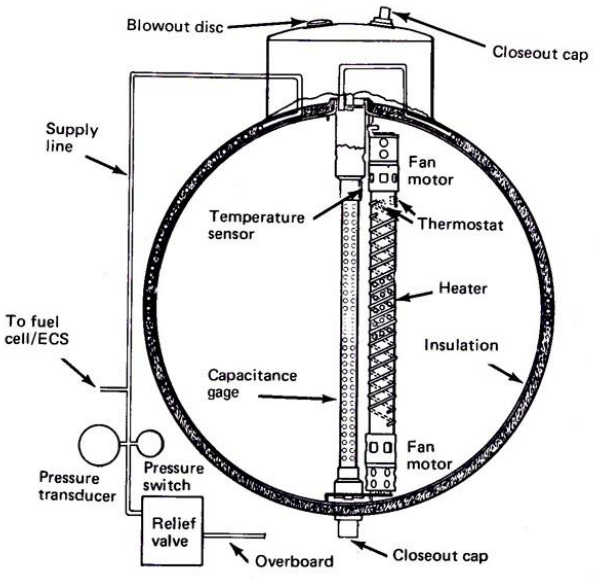
3. Construction of a ***"lunar permanent base".*** Thinking of this last objective, NASA ordered the fabrication of the parts needed to deliver enough Saturn and Apollo vehicles to perform 20 flights.

This last objective was also discarded. After Apollo XI, the taxpayer lost interest in the trips to the Moon. They questioned the big cost and started asking why keep going to the Moon once they had been there first and had proven the world their technological and economic leadership. Therefore, NASA´s budget underwent a serious cut and placed this last objective into the recycle bin. However, the contract for the construction of the 20 vehicles was already underway.

The different parts that made out the elements of the vehicles were manufactured in series, and were assigned a code that would fit them to a specific flight

The disaster of Apollo 1 forced a revision of all the safety protocols as well as the quality of electric material, cable insulation, flammable elements etc. Moreover, the capsule itself underwent structural modifications to increase safety. In addition, many parameters were modified for the same reason. A very important modification was to change the 28 VDC energy supply to 65 VDC.

All manufactures and subcontractors took immediate note and restarted their assembly lines to adapt to the new requirements where applicable.



Beechcraft was the manufacturer of the LOX (liquid oxygen) tanks that were mounted inside sector 4 of the Service Module. They comprised a couple of fans with their respective motors, a heater to augment pressure if necessary and a temperature sensor all of which worked at 28 VDC. Obviously, they all had to be replaced with 65 VDC elements.

During the process of the substitution of the old parts for the new ones, one of the tanks fell to the floor from a high stand. It was one of the assigned to the Apollo 10 flight and it was immediately substituted by other until checks proofed no damage was present.

The tank went through all the testing with no problems and was assigned to the next available opening, which happened to be Apollo **13**. Everything seemed to

be normal so far however, with all the verifications and testing, the changing of the 28 VDC components with the 65 VDC ones was overlooked. The quality of the material was excellent and so was the safety margin so no problem should have occurred…But.

During the last part of the countdown, once the Saturn V was already in the launch pad, there were still a whole lot of verification checks to be completed before the launch was ready. Some of these included the pressurization of LOX and LH2 (liquid hydrogen) tanks in the Service Module, fuel in the main tanks, electrical continuity, etc. Out of all of these, the LOX tanks had to go through a sequence of being pressurized to 100%, then purge to 50%, and be pressurized to 100% again.

Oxygen tank number 1 went through the sequence with no problems, but tank number 2 (the one originally assigned to Apollo 10) didn´t purge below 92%. High-pressure gas was used to try to clean the supply lines and relieve valves but the results were anything but successful.

The final decision was to use the heaters to take the O^2 to the boiling point. This should increase inside pressure enough to purge to the desired value.

And it did it, but…The heaters had to remain ON for 8 hours. (1)

As the switches had been connected at 65 VDC *(37 VDC more than what they were meant for)* during such a long time, the contacts melted and the heaters remained ON permanently increasing the temperature and, thus, the pressure such that the relieve valves could hardly maintain integrity. Moreover, the heat damaged the Teflon insulation of the cables. (2)

And it happened. They were already at more than 2/3 the distance from the Earth to the Moon (more than 322,000 km) and the planned activities for the day were almost over. The rest period per the flight plan was getting close and Fred Haise and Gene Krantz were having a chat through a TV transmission from the craft. The last activity for the day was to stir the LOX and the LH2 tanks to get better pressure readings, and Houston requested the astronauts to do so. *(This procedure was both, periodic and usual during all Apollo fights)*.

93 seconds later, the crew heard a loud explosion-like sound followed by a strong vibration and electrical energy fluctuations. The crew thought a meteoroid had hit the Lunar Module.

However, reality was that LOX tank number 2 (YES, the one that had had all previous problems) had experienced a rupture due to an increase of pressure that went over the limit. Due to this situation, the tank itself broke open and thus, the oxygen inside expanded rapidly fulfilling the zone where the fuel cells were located. *(Sector 4)*.

The pressure, which kept increasing, broke down the nuts that were holding down the aluminum panel that covered Sector 4, expelling outside the rest of the oxygen and the broken pieces from the structure. This subsequent rupture most probably caused minor damage to the antenna that was being used for communications at the time, thus the reason for a 1.8 seconds interruption of the ground station link. The system acted automatically going from wide band to narrow band and the problem corrected itself.

The shock wave forced the oxygen valves of fuel cells 1 and 3 to shut down so they could only operate for 3 minutes.

One of two other things also happened. Either there was a possible partial rupture of a line that was attached to tank 1, or its through valve developed a leak, but oxygen from that tank started drifting into space during the following 130 minutes until the tank was empty and the total oxygen available to the Service Module was totally depleted.

As the fuel cells combine LOX and LH2 to generate electricity and produce potable water, number 2 finally deactivated leaving the Apollo Command and Service Modules with the limited energy available from the batteries. The crew were, thereby, forced to shut down the Command Module completely and use the Lunar Module as a lifeboat. This had been previously suggested during a training simulation but was never considered a valid scenario.

How the astronauts made it from here is outside of the scope of this writing and I have it in one of my essays about Project Apollo.

QUESTIONS:

(1) Think for a moment that you were the person responsible for filling out the checklist related to the purge sequence of the LOX and LH2 tanks.
   a. Would you send the Saturn V back to the VAB to get the tank changed? With the cost it implied? And the delay in launch?
   b. Alternatively, would you try something that could possibly work even if it was not in the procedures?

(2) When the stirring fans were turned on, the increase in electrical current caused the cable insulation (which was already deteriorated) to start a fire. Later investigation calculated the inside temperature of the tank to probably reach more than 500^{o} C. This temperature raised the pressure to the point of tank rupture.
   a. Why was such a raise in temperature not detected? The way the tank was built should have not allowed the temperature inside to go above 21^{o} C, so the sensors high reading was 21.
   b. Why was such an increase in pressure not detected? Pressure sensors of one of the LH2 tanks had been given erroneous alarms previously and to eliminate the annoying sound the alarm was inhibited.