JSC/EC5 Spacesuit Knowledge Capture (KC) Series Synopsis

All KC events will be approved using NASA Form 1676.

This synopsis provides information about the Knowledge Capture event below.

Topic: Orbiter Water Dump Nozzles Redesign Lessons Learned

Date: April 14, 2017 **Time:** 1:30 p.m. – 2:30 p.m. **Location:** JSC/B29/CR118

DAA 1676 Form #: 39146

This is a link to all lecture material \\js-ea-fs-03\pd01\EC\Knowledge-Capture\FY17 Knowledge Capture\20170414 Rotter_Orbiter Water Dump Nozzle\1676 - Slides.

Assessment of Export Control Applicability:

This presentation has been reviewed by the EC5 Spacesuit Knowledge Capture Manager in collaboration with the author and is assessed to not contain any technical content that is export controlled. It is requested to be publicly released to the NASA Engineering and Safety Center (NESC), JSC Engineering Academy, as well as to STI for distribution through NTRS or NA&SD (public or non-public) and YouTube viewing.

This file is also attached to this 1676 and will be used for distribution:

For 1676 review_Synopsis_Rotter_Orbiter Water Dump_4-14-2017.docx

Presenter: Hank Rotter

Synopsis: Hank Rotter, NASA Technical Fellow for Environmental Control and Life Support System, will provide the causes and lessons learned for the two Space Shuttle Orbiter water dump icicles that formed on the side of the Orbiter. He will present the root causes and the criticality of these icicles, along with the redesign of the water dump nozzles and lessons learned during the redesign phase.

Biography: Hank Rotter's career with NASA began at the Johnson Space Center (JSC) in 1963, where he served as a mechanical and stress engineer for the Flight Acceleration Branch/Crew and Thermal Systems Division manned centrifuge, drop tower, and vacuum chambers. He was also the test director for these facilities. In 1968, he moved to the Apollo Environmental Control System as a subsystem engineer for the entire Apollo mission through the Apollo Soyuz Test Program. In 1975, he moved to the Space Shuttle Orbiter Environmental Control and Life Support System (ECLSS) engineering group and served as multiple ECLSS subsystems manager covering all four ECLSS subsystems. During this time, he was the project manager and NASA point of contact (POC) for the two Orbiter Tunnel Adapters for the design and implementation. In 1988, he became the Orbiter ECLSS Engineering Work Package manager and division chief engineer for all ECLSS, crew equipment, crew escape system, extravehicular activity, and ECLSS mission and payload integration (payload accommodations). He was the ECLSS engineering team lead for the Extended Duration Orbiter designs (JSC engineering lead for 28- and 90-day Orbiter studies and for manned studies tending to the International Space Station (ISS)), Orbiter Docking System/External Airlock, the MIR Phase 1 Program, and Orbiter ISS Multi-Purpose Logistics Module cooling and middeck payload locker cooling systems. He served as the MIR Phase 1 NASA team lead/POC for the MIR Spectra leak location. In 2002, Mr. Rotter became the Crew and Thermal Systems Division

Engineering manager for Life Support and Active Thermal Systems to the Space Launch Initiative Program, and then the Orbital Space Plane team leader for Life Support and Active Thermal Control Systems teams. He was selected in 2003 and currently as the Life Support, Active & Passive Thermal Control and Fluids Systems discipline technical expert for the NASA Engineering & Safety Center. In 2007 and currently, the NASA chief engineer selected Mr. Rotter as the NASA technical fellow for Life Support and Active Thermal Control Systems and as the Lunar Lander Life Support and Active Thermal Systems Architecture and Design team lead. In 2015 and currently, he was selected as the Life Support Systems and Active Thermal Control Systems NASA Technical Capability leader.

Mr. Rotter earned a bachelor of science degree in aerospace engineering from Texas A&M University.

EC5 Spacesuit Knowledge Capture POCs:

Cinda Chullen, Manager
cinda.chullen-1@nasa.gov
(281) 483-8384

Vladenka Oliva, Technical Editor (Jacobs)
vladenka.r.oliva@nasa.gov
(281) 461-5681

Orbiter Water Dump Nozzles Redesign Lessons Learned

Hank Rotter

April 14, 2017

U.S. Spacesuit Knowledge Capture Program

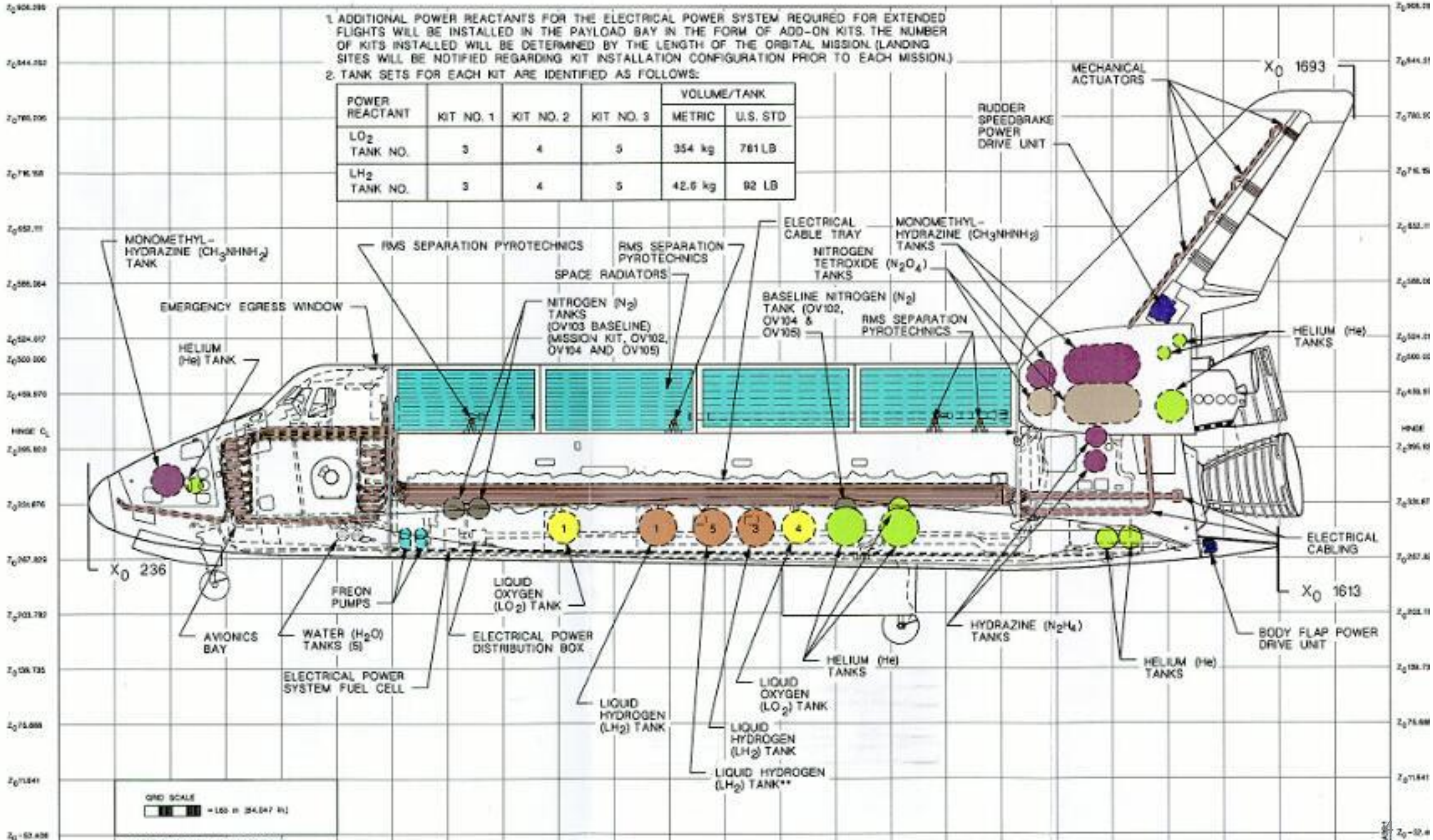
Orbiter Water Dump Nozzle Redesign

- During STS-41B and STS-41D Space Shuttle missions, an icicle formed over the supply and wastewater dump nozzles. This could have caused hazardous impacts on the side and aft end of the Orbiter during entry.
- The two occurrences of this problem had two different causes:
    - STS-41B – problem caused by a water pressure drop to the nozzles that widened the spray patterns.
    - STS-41D – problem caused by the new thermal protection blankets installation around the nozzles.
- The concern was that during the entry, the air flow path was aligned from the Orbiter side nozzles' location to the Orbital Maneuvering System (OMS) pod location, and any ice on the nozzles could strike the OMS pod when released.
- My task was to redesign the nozzle configuration to prevent icicle formation.


United States
Dump Nozzles
OMS Pod

1. ADDITIONAL POWER REACTANTS FOR THE ELECTRICAL POWER SYSTEM REQUIRED FOR EXTENDED FLIGHTS WILL BE INSTALLED IN THE PAYLOAD BAY IN THE FORM OF ADD-ON KITS. THE NUMBER OF KITS INSTALLED WILL BE DETERMINED BY THE LENGTH OF THE ORBITAL MISSION. (LANDING SITES WILL BE NOTIFIED REGARDING KIT INSTALLATION CONFIGURATION PRIOR TO EACH MISSION.)
2. TANK SETS FOR EACH KIT ARE IDENTIFIED AS FOLLOWS:

POWER REACTANT	KIT NO. 1	KIT NO. 2	KIT NO. 3	VOLUME/TANK	
				METRIC	U.S. STD
LO_2 TANK NO.	3	4	5	354 kg	781 LB
LH_2 TANK NO.	3	4	5	42.6 kg	92 LB



** PART OF POWER REACTANT STORAGE KITS REFER TO FIGURE 2-9, ELECTRICAL POWER SYSTEM, FOR ADDITIONAL INFORMATION.

Orbiter Water Dump Nozzle Redesign

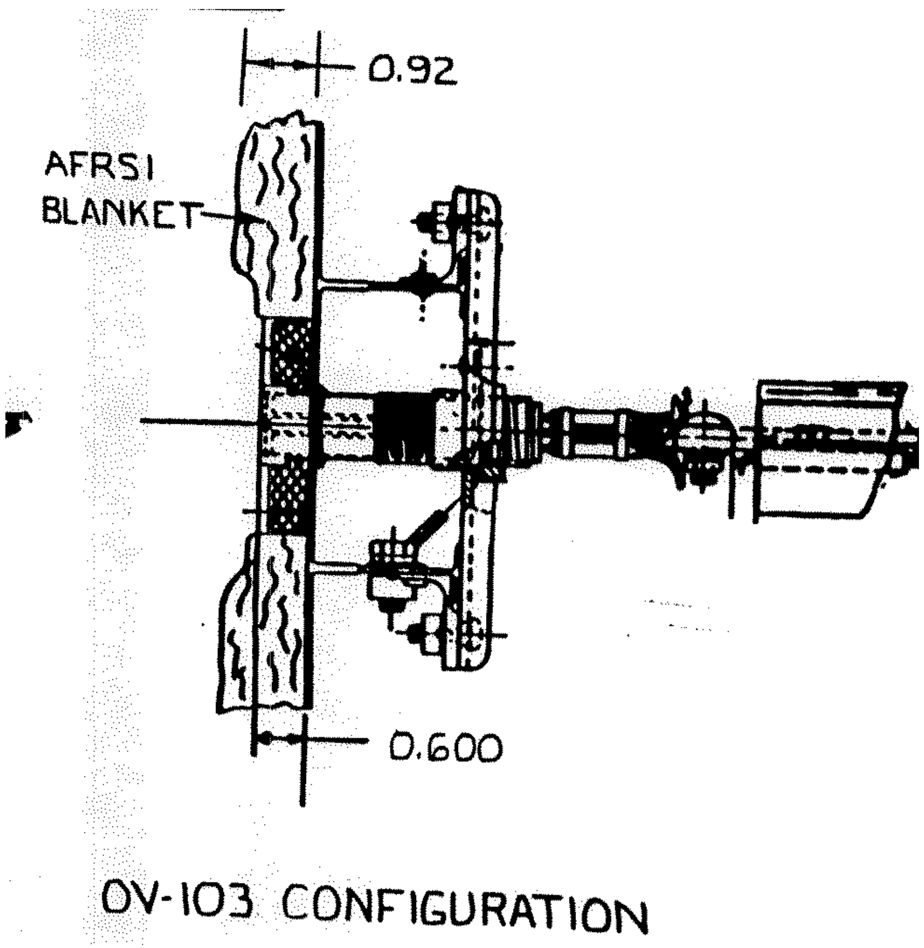
- The STS-41B icicle that formed in a vacuum at about 80% density of solid ice was about 200 lbs of fuel cell water and wastewater (humidity water and urine ice pellets):
  - The base of the icicle was about 2+ ft diameter over both nozzles, and estimated to be about 5+ ft long:
    - This was based on the entry burn stain from the urine solids on the Orbiter Thermal Protection System (TPS) tile.
    - The length was based on vacuum chamber testing.
- Post-landing inspection found several tiles damaged in line to the OMS pod, and several hits on top of the left wing.
- The big concern – the OMS fuel tank's pod structural cover, which had about 2 sq ft damage on pod tile with the non-metallic structure, crumbled behind the tile, with only the wire mesh holding the tile together.
- Note that no tile was missing during the decent.

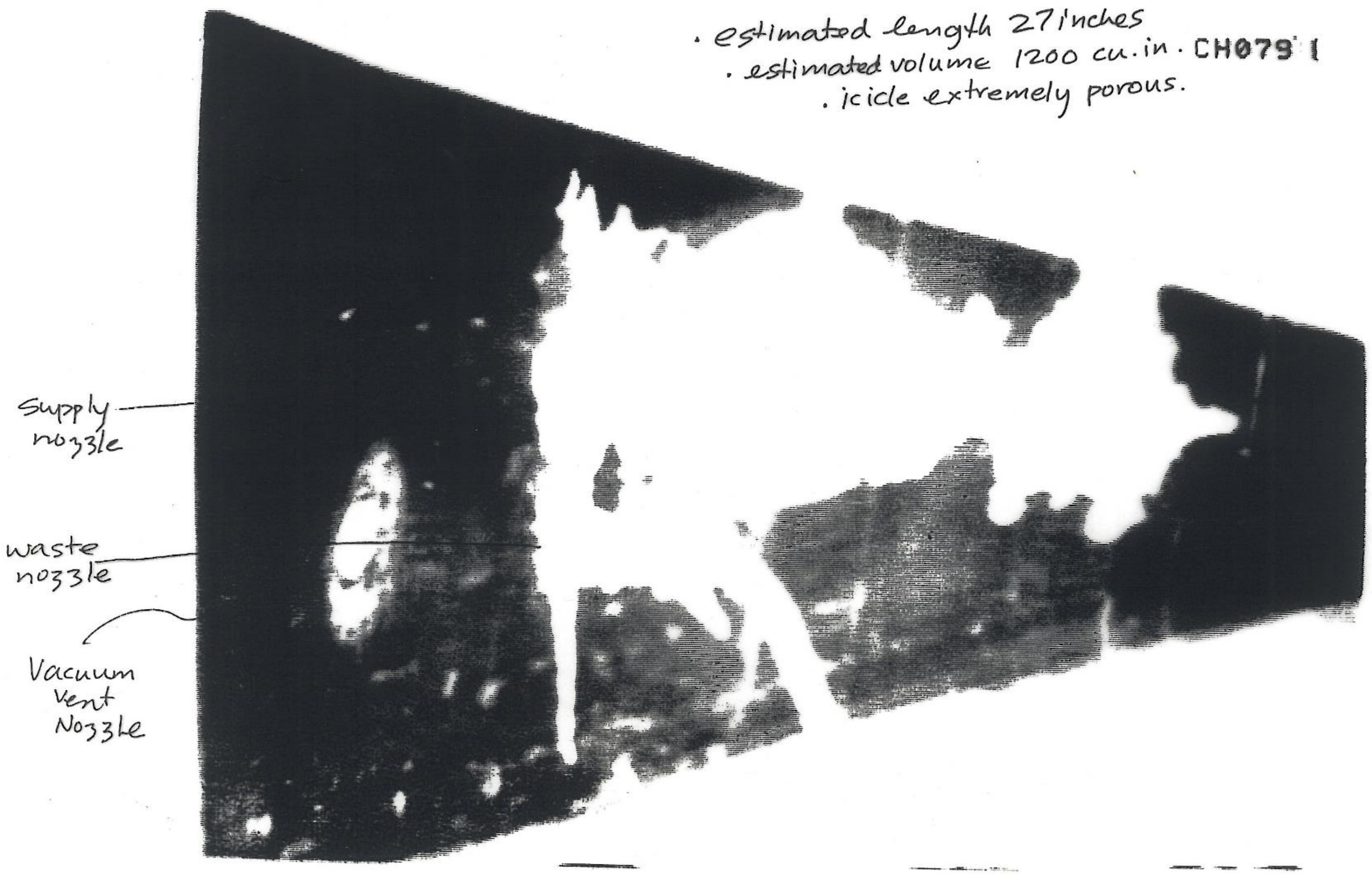
First Lesson Learned

- **Mission Operations desired to do a dual potable and wastewater dump:**
  - We did not do a full analysis of the pressure control system for a dual dump of potable water and wastewater systems.
  - There were two pressure control regulators and a relief valve, but only one system was active as designed for one active dump system.
  - The pressure regulator had a max flow rate of 1.2 lb/hr.
  - Post event, I did the analysis of the reg flow rate vs. the potable and wastewater tanks' dual dump nozzle water flow rates that verified that the single regulator could not maintain the pressure on the water tanks.

Orbiter Water Dump Nozzle Redesign

- STS-41D was the first flight with TPS blankets on the side of the Orbiter that formed an ideal trap for ice collection around the nozzles:
    - The nozzle was recessed in a blanket circular valley.
    - This time, the flight directors listened and the Orbiter arm was moved to view the icicle.
    - A procedure was developed to bump the icicle off with the arm after testing the strength of the ice attachment to the side blankets in a vacuum chamber.
    - The icicle removal was successful.



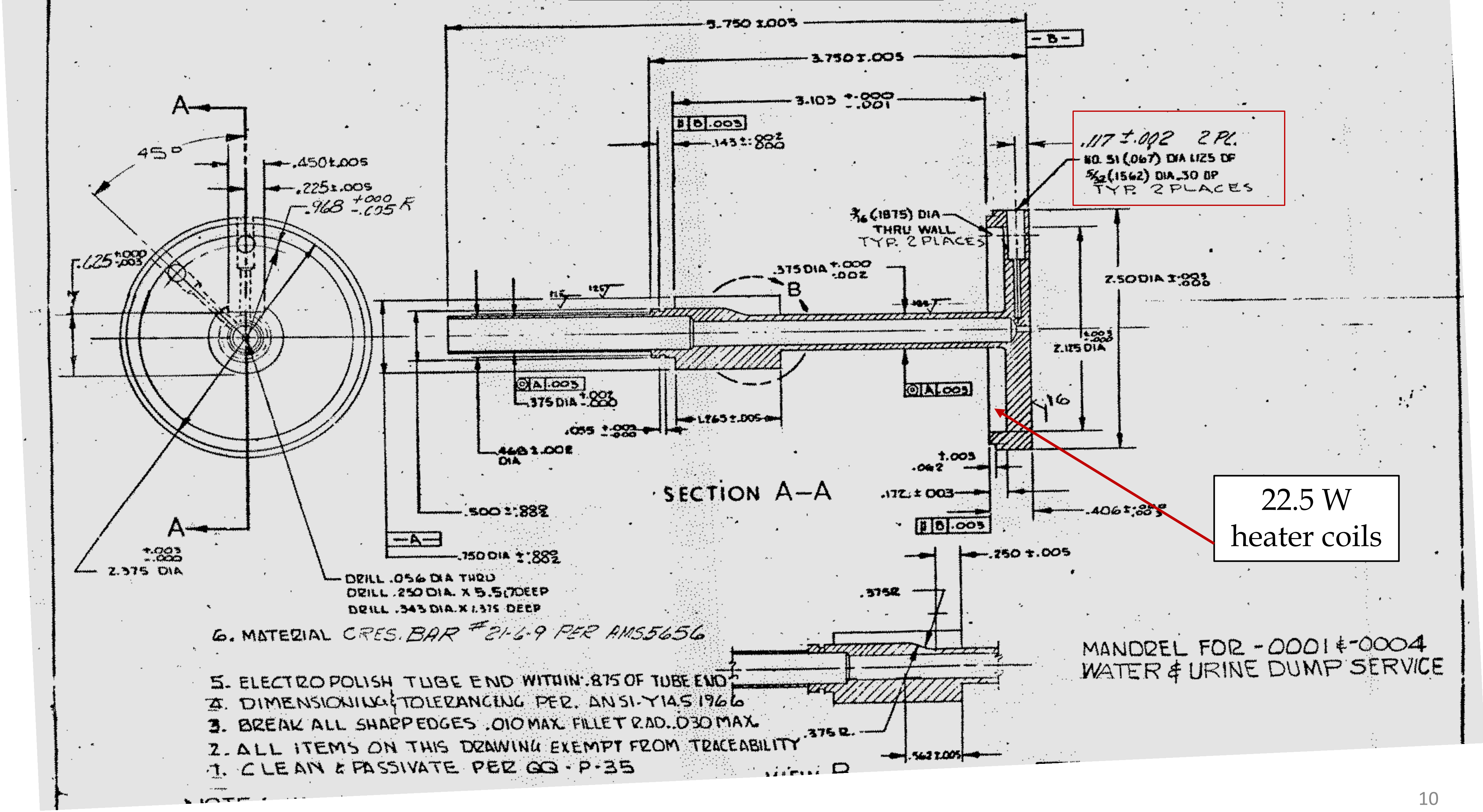


STS-41D (Inverted Image)

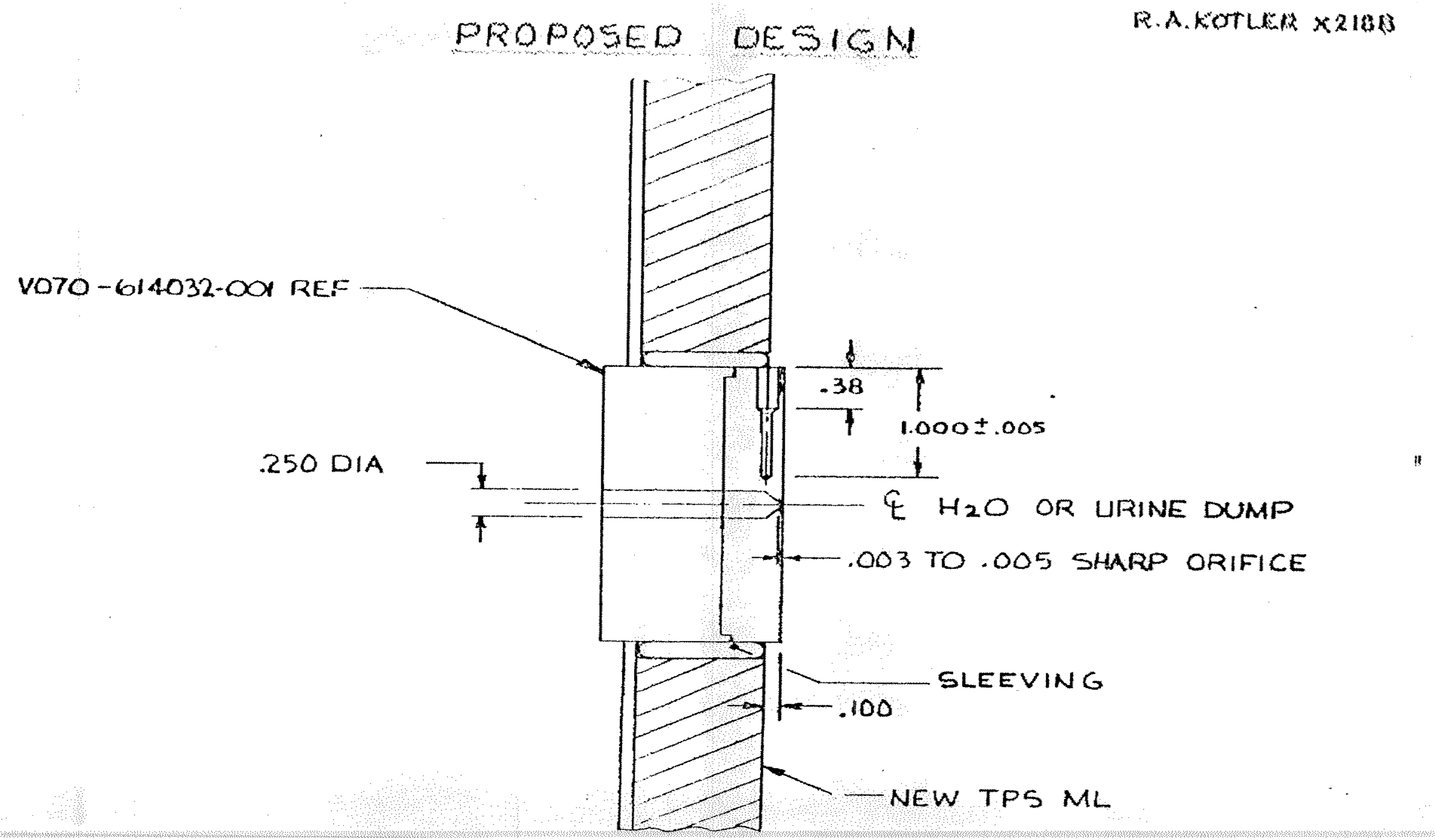
Orbiter Water Dump Nozzle Redesign

- After testing several nozzle designs, a sharp edge orifice was selected that had a near zero spray pattern:
    - At 20 ft, it had less than 2 ft diameter spray pattern vs. the old nozzle of about 6+ ft diameter at normal water pressure.
    - At 50% pressure, the sharp edge nozzle spray pattern had almost no change.
- I directed Rockwell and the nozzle vendor to drill out the current straight-edge nozzle to a sharp-edge nozzle and assumed that Rockwell and the vendor would do the drawing dimensional tolerance analysis. This led to the following problems:
    - Because this was a simple drill out of the flow path with ¼ bit, no one did the analysis.
    - Because of this, we drilled out two spare dump nozzles, and installed them for the next flight.
- Directed Rockwell to install black tile around the two nozzles with the nozzle 0.1 inch above the tile on vehicles with the TPS blankets.

Old Nozzle Design



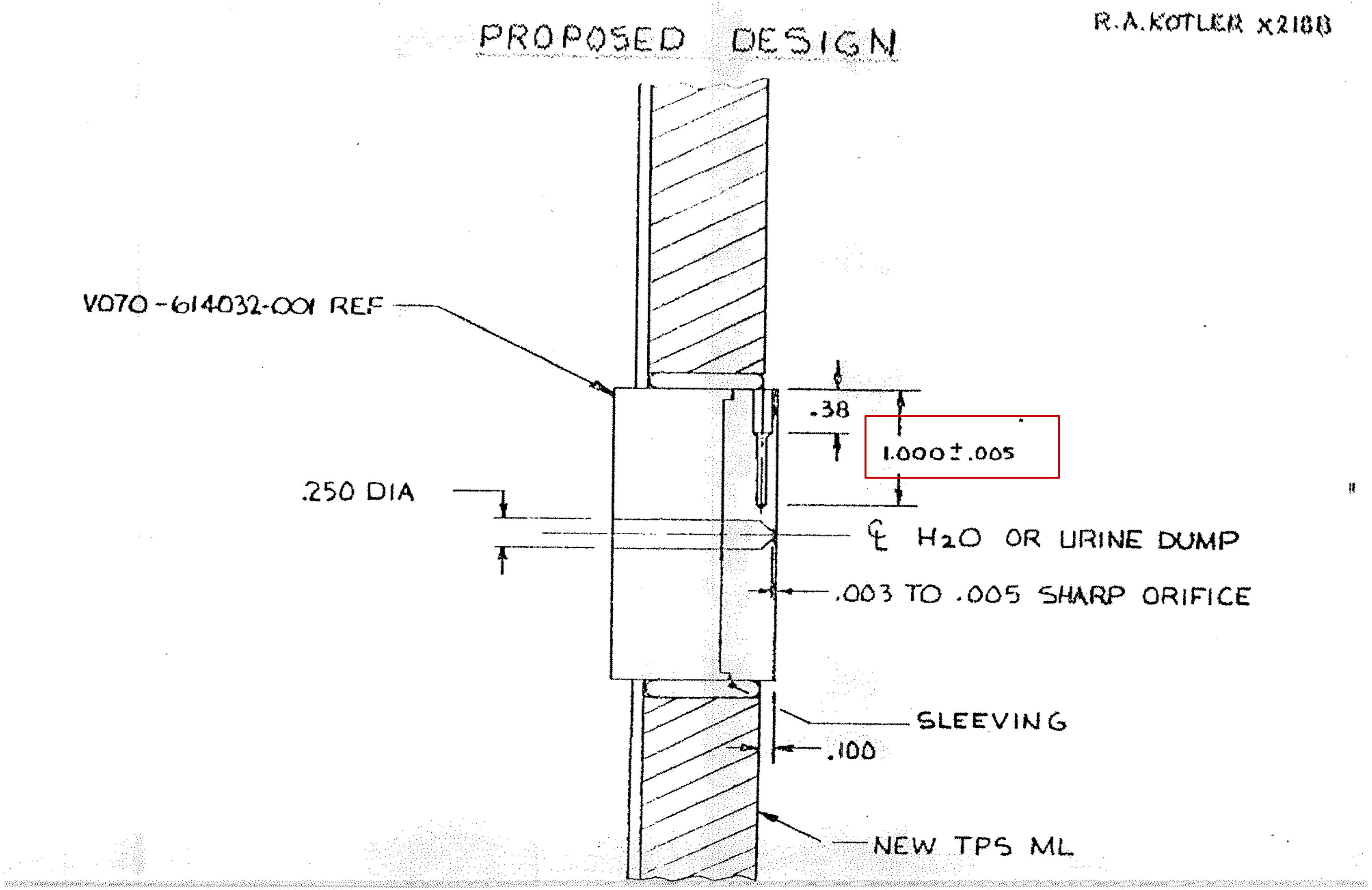
Orbiter Water Dump Nozzle Redesign



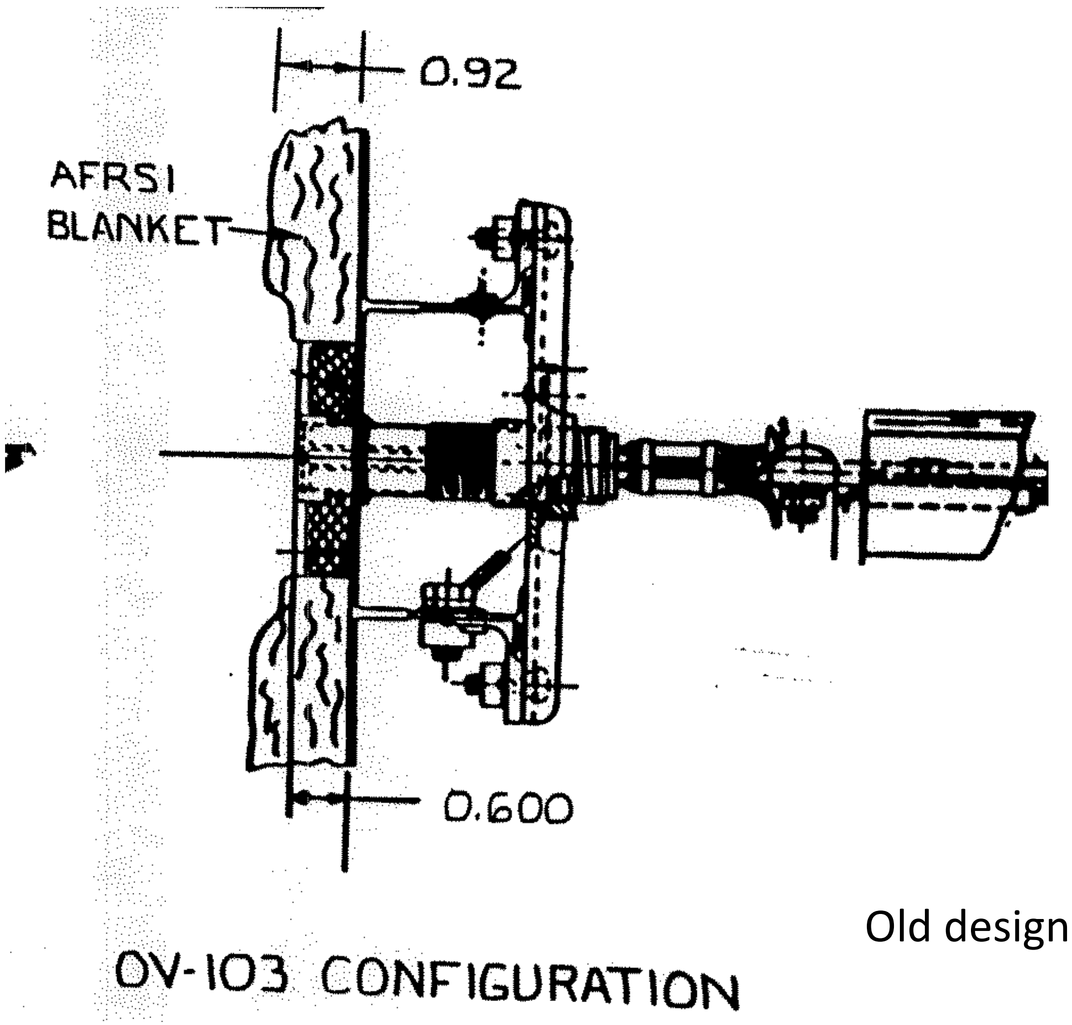
Orbiter Water Dump Nozzle Redesign

- One of the four sensor wells had a small water leak path through it and unusual temperature drops during the supply water dumps – the first error.
- Rockwell or their vendor suggested putting a braze plug in the bottom of the sensor well about 0.1 to 0.2 inch thick.
- I assumed that they had a solder expert to review this, but no one did it.
- The next flight had two new nozzles installed with a braze plug, and we had the same problem with a water leak into a sensor well.
- Brazen requires two surfaces with no more than a 0.0005-inch thick layer of braze compound.
- Then we brazed a metal plug into the bottom of old nozzle sensor wells and changed the drawing to include a new nozzle that did not require the plug.

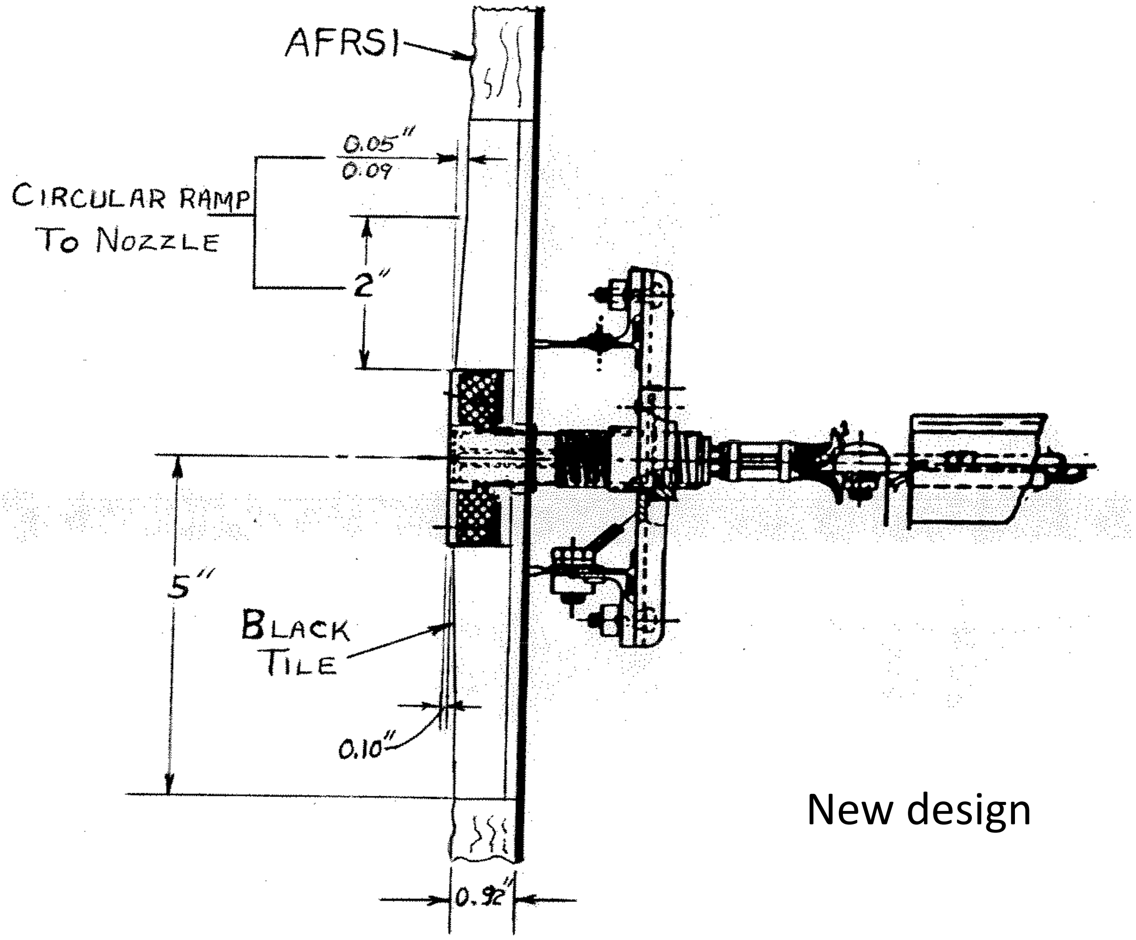
Orbiter Water Dump Nozzle Redesign



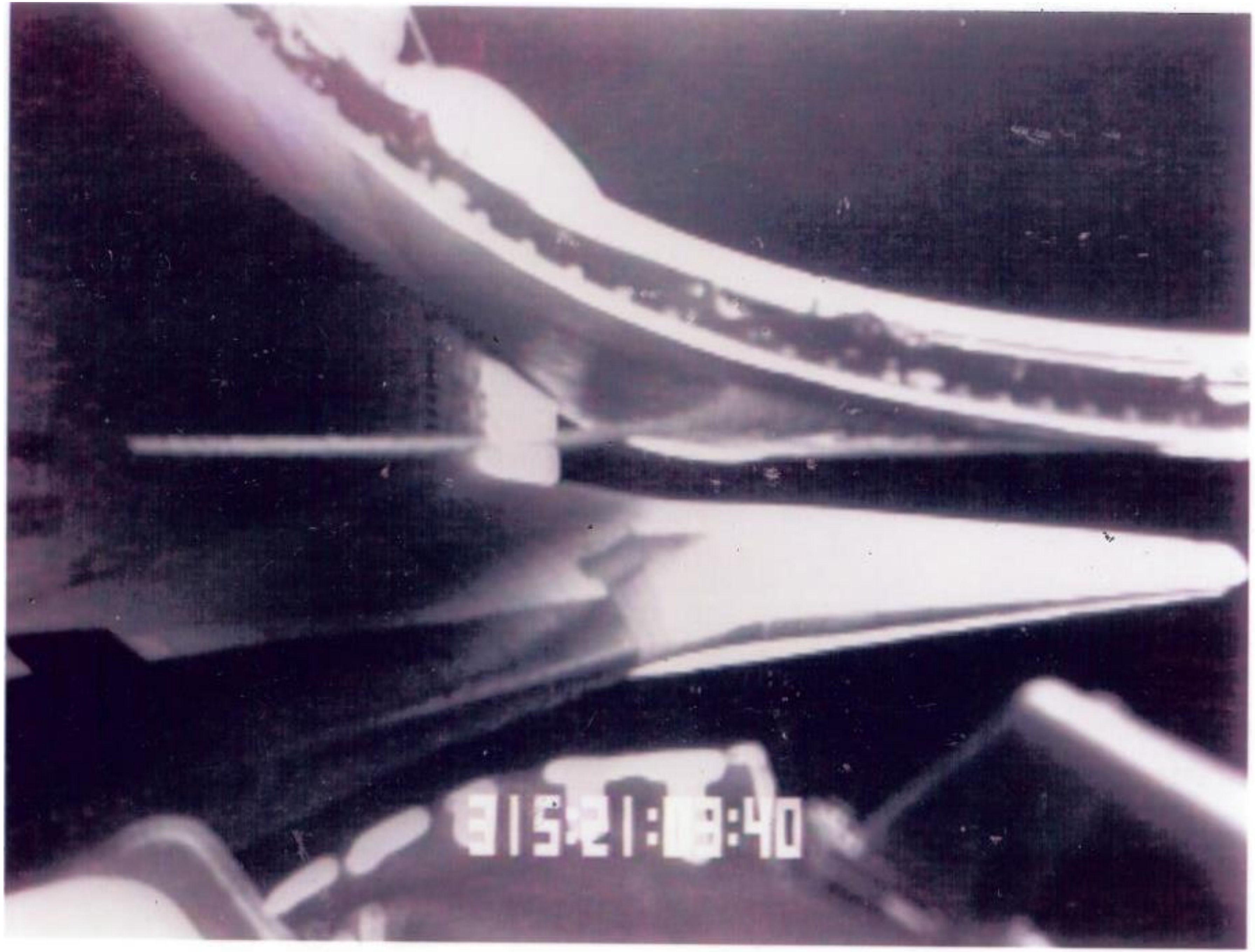
Orbiter Water Dump Nozzle Redesign



Old design



New design



Orbiter Water Dump Nozzle Redesign

- Lessons learned:
  - No change is simple; all changes must be integrated with other systems that can be impacted.
  - Must fully analyze, test, and/or assess any new off-normal operations.
  - Engineers are not experts in all technical areas. An expert is needed to check any technique used in design change.