The History of Venting (Part I)

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Venting techniques and design are an important implementation strategy for observatory and payload contamination control, and yet venting analysis has seen a topsey turvey history, at lease from the perspective of the simple Layman trying to design a black box.

Additionally, designing the vent has competing controls from Safety and EMI/EMC. In the days of Shuttle, Safety placed liens against the vents of blankets, boxes, and large structural items principally to protect cargo bay vents but also from a flammability perspective.

What continues to elude the Designer Community is a stable, simple way of designing vents for black boxes that satisfies everybody. But we continue to try.
Overview of Year-Events

• 1983 – TM-85016 published (CC for telescopes in cargo bay)
• 1983 – Venting of Space Shuttle Payloads TP
• 1986 – GEVS-SE Revision Dash published
• 1991 – Hubble SIC&DH (etc.) box-level Venting Specification produced
• 1993 – Safety (ISRP) gets tagged with Venting Duty
• 1996 – Spacecraft Compartment Venting TP
• 1997 – Hubble Servicing Mission -2 is flown
• 2011 – JSC ISRP inserts MEVR requirements in standard hazard reports
• 2015 – Bail-out tactics when you forgot to put vent holes
• 2017 – ISRP retracts from MEVR & replaces with no-vent FSu
• 1983 – TM-85016 published (CC for telescopes in cargo bay)
  – “Abatement of Gaseous and Particulate Contamination in a Space Instrument Application to a Solar Telescope” by John J. Scialdone April 1983
    • Highly detailed paper (9 pages) with Keywords: gaseous purging, internal gas dynamics, gas diffusion, Shuttle environment, rarefied gas dynamics
    • I infer that OSL (Orbiting Solar Laboratory) was the primary sponsor for this paper. OSL became a Delta Launch (not a Shuttle launch) at the finished-proposal level, many years later
    • Paper quantitatively shows the benefits of having K-bottle purge plumbed into a telescope wherein the k-bottle is “Airborne Support Equipment”
    • Paper might have also had sponsorship from Starlab and/or the ASTRO mission (BBXRT, IUT, HUT) on a Spacelab Pallet via IPS (Instrument Pointing Subsystem)
    • BBXRT had a dewar and a dewar pumping system plumbed onto it’s side (flew)

• 1983 – Venting of Space Shuttle Payloads Technical Paper
  – Very practical and useful 2 pages description of test-venting an enclosure as the external pressure is dropping off to mimic Shuttle bay venting (AIAA paper 83-2600 and A84-10936)
1986 - 1991

• 1986 – GEVS-SE Revision ‘Dash’ published
  – GEVS-SE is General Envi. Verification Specification – Shuttle and ELV
  – Does anybody have a copy of revision dash from about 1986?
  – Clearly it published that 0.25 square-inch vent per cubic foot of otherwise sealed volume will be deemed No-Test
  – The requirement seems to have made good use of the “Venting of Space Shuttle Payloads” Technical Paper and deemed that a few seconds of 0.5 psi differential pressure was close enough to nothing as to qualify for no-test
  – This satisfactory situation disappeared upon revision A (forever)

• 1991 – Hubble SIC&DH box-level Venting Spec produced
  – The Science Instrument Command & Data Handling is an expensive ORU (orbital replacement unit) consisting of several metal boxes with EMI containment requirements. Demanded a A/V versus residual-pressure curve for boxes inside the telescope
  – The Design community settled on 0.10 inch⁻¹ and 0.11 psi for box use
1993 - 1996

• **1993 – Safety (ISRP) gets tagged with Venting Duty**
  – ISRP is ISS Safety Review Panel (was) PSRP
  – ELV Payloads never had an external panel like manned space flight
  – For the Hubble servicing missions and other Shuttle-based missions, Safety incurred many sets of requirements for Multi-Layered Insulation construction and Box venting, including:
    • Flammability – crew sits on top of payload in air during Interface Verification Test
    • Grounding of each layer of MLI – A single failure in an Orbiter APU can infuse cargo bay with hydrazine vapors
    • Do Not Clog – the cargo bay vents with MLI debris either from:
      – a loose piece of MLI coming off the payload
      – or a puffed-up and split MLI assembly not adequately vented within itself

• **1996 – Spacecraft Compartment Venting Technical Paper**
  – GSFC has thermal-vacuum chambers with rapid-enough pump-down capability to serve as an ascent simulator
  – Tried for “A simple rule for the evaluation of the compartment response........”
1997 - 2011

• 1997 – Hubble Servicing Mission -2 is flown
  – Because boxes and flat ends of cylinders make poor pressure vessels (due to corner bending loads) we had three safety rules of thumb:
    • For effective vent ratio of 0.25 square-inch per cubic foot (or better), no further analysis is necessary for “adequate venting”
      – Note that almost all of our avionic and ORU boxes were legacy-built prior to the loss of GEVS-SE revision dash
    • For effective vent ratio of 0.10 square-inch per cubic foot (or better), a distributed pressure analysis for 0.11 psi is necessary for “adequate venting”
      – Note that this was applied to macro-level avionic boxes, not the small Interpoint power converter lids
    • Mesh-covered vents need to account for the effective loss of vent area versus that which would exist if this was a clear through-hole
      – For example, we used 500 strands per inch 0.001” diameter strands loomed into a mesh material. The effective vent area is only 26% of the total area of the mesh

• 2011 – JSC ISRP inserts MEVR requirements as ‘Standard’
  – Maximum Effective Vent Ratio (cubic inches enclosed/square inches vent) to be < 2000 inches.
  – In GEVS-speak this would be 0.864 square-inch vents per cubic foot
  – Resulting in 0.01 psi residual pressure (modules >> avionic boxes)
2015 - 2017

• 2015 – Leiter develops Bail-out tactics when designer people forget to put vent holes into the box:
  – It is a project policy whether to fill unused pin-sockets on D-sub connectors or not
  – There is the opportunity to recover vent holes by leaving unused sockets as Open

• 2017 – In at least one case, ISRP retreats from MEVR requirements and replaces with no-vent FSu
  – The same complexities exist for the Trunk environment as before (choked-flow, transonic, max-Q, the system effect of a few seconds of choked flow) but with less data
  – ISRP seems to have reassessed their original charter for requirements. Safety is basically strength requirements
  – Most cargo is OFF for two days cruising to the ISS dock (i.e. no Corona by the time the ISS is proximate to a powered payload)
  – What to do? Follow the HST SM-2 example
Honeycomb Panels

• Strength is not the issue for intra-cellular burst
• However, Virtual Leaks would be a major concern for I&T
• Residual pressure can add-up quickly for a large enclosure. For example a 4x8 plywood panel with 0.5 psi has 2,304 pounds on it, so vent the Observatory carefully in a way that carries the particulates out

• Vent the panels for intra-cellular air by specifying vented core and then venting the Outside skins at 1” centers
• This will carry the manufacturing debris away from the interior of the instrument
• Also the inside might need flat black paint and this would clog the small vent holes in the skins
Multi-Layered Insulation (MLI)

- 3.0 MIL ALUMINIZED (INNER SURFACE) KAPTON
- EACH PLEAT IS BONDED
- SLIT
- SPLICE
- ALTERNATE INTERNAL 0.25 MIL ALUMINIZED KAPTON
- 12 KAPTON LAYERS
- DACRON MESH SPACER LAYERS
- ALL LAYERS NOT SHOWN
- LENGTH TO BE DETERMINED AT INSTALLATION

- 5.0 MIL KAPTON (ALUMINIZED INSIDE) (INNER AND OUTER LAYER)
- 12 LAYERS OF 1/3 MIL KAPTON (ALUMINIZED BOTH SIDES)
- 13 LAYERS OF DACRON NET

TYPICAL VENT INSTALLATION
- CUT 1" SQUARE OF FILTER SPECTRUM FILTERS
- TEFLOM CATALOG #146276
- MESH OPENINGS (IN MICRONS) 74
- % OPEN AREA 21

WASHER
SNAP RINGS
MLI STAND-OFF
EPoxy-HySO EA934

- #24 TEFLON COVERED WIRE
- BRASS WASHER
- THESE LAYERS OF NETTING GET CUT AWAY
- TYPICAL ELECTRICAL GROUND
- BRASS WASHER
- BRASS EVELIT
Typical Black Box

- EMI/EMC controls are typically unappreciative of through-holes. Solutions are to use mesh or labyrinth seals that approximate a light-tight box.
- Flammability “Chimney Effect” requires a metal box to not-vent more than 1% of the total box surface area (six sides).
- Bake-out Circuit Card Assemblies prior to installation into an avionics box.
- Bake-out box intra-harnesses prior to installation.