Lecture 5: Interface Verification and Testing

For additional details, refer to the appropriate Interface Definition Documents (IDD) for the carrier of interest:

Middeck IDD:	http://shuttlepayloads.jsc.nasa.gov/data/PayloadDocs/PayloadDocs.htm
Spacehab IDD:	http://www.boeing.com/nosearch/sh_verification/
ISS IDD	http://stationpayloads.jsc.nasa.gov/J-reference/documents/ssp57000E.pdf
EXPRESS IDD:	SSP 52000-IDD ERP
Payload Safety:	NASA JSC PSRP (Payload Safety Review Panel) http://jsc-web-pub.jsc.nasa.gov/psrp/
Toxicology:	NASA JSC Toxicology http://www.jsc.nasa.gov/toxicology/
Station Documents:	http://stationpayloads.jsc.nasa.gov/J-reference/ Document Tree

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Testing / Interface Verifications

Functional Testing

- Nominal Systems Functionality / Complex system interactions / experiment-facility interaction
- Environmental compatibility (temperature, vacuum, acceleration/microgravity, radiation)
- Off-nominal responses (safety, backup/redundancy, overheat, overpressure, communication loss, etc.)

Science Verifications

- Science compatible with Spaceflight Operational Environment ? – Sanity Check !
- Science in hardware validation ?
- Procedure / protocol verifications / science return (preparation - launch to landing – analysis)
- Compatibility verifications (bio-compatibility, operational constraints, sensitivity, environment: atmosphere, pressure, temperature, microgravity)

Interface Verification

- Interface Verifications - verify proper function and connectivity between experiment and facility (connectors, power, data, video, fluids, ...)
- Test Requirements: http://jsc-web-pub.jsc.nasa.gov/psrp/docs/7002.pdf
- Structural Compatibility
  - Vibrational Loads – “shake test”
  - Acceleration (launch, landing, crash) – analytical, centrifuge
  - Eigenfrequencies – analytical, “shake test”
  - Microgravity disturbance - test

Acoustics:

- Acoustic Emissions
- Acoustic Susceptibility

Containment – depressurization:

- Vented Container - Vent Rate Analysis
- Sealed Container – Structural Integrity under combined loads (pressure + temperature, etc.)
  1. Nominal Ops 2.0 psi/min Repressurization/Depressurization
  2. Contingency (other than Bailout) 9.0 psi/min Depressurization/Repressurization
  3. Emergency Bailout Requirements: Payloads located within the crew compartment area shall be designed to meet the following depressurization requirements in order to insure they will not present a hazard to the crew or to the Orbiter which could jeopardize crew survivability or impede crew egress during emergency bailout procedures:
     Initial (Max) 15.2 PSIA / Final (Min) 3.95 PSIA / Max Depressurization Rate 24.0 PSI/Minute

Human factors

- Push-off (kick-ff): 125 lbf over 4"x4" area (foot)
- Max. Limits of necessary force to actuate / manipulate

Electrical Compatibility

- Connector (pins=unpowered, sockets=powered, recessed), Pin Assignments
- Signal / power / interface compatibility (voltage, softstart, baud rate, data format, ...)
- Wire Size Analysis / Fusing (fire / over-heat)
- Power Draw (current limit) , Energy consumption (fuel / battery limit)
- Electromagnetic Compatibility EMC:
  - Electromagnetic Emissions / Interference (EMI)
  - Electromagnetic Susceptibility
- Batteries – stored energy, hazardous electrolytes, toxic combustion products (Lithium batteries).

Materials Utilization:

- Flammability (MIUL)
  - note: 30% O2 (pre-breath prior to EVA) or 100% O2 (EVA suit) changes flammability characteristics
- Offgas / Toxicity (MIUL):
  - SMAC: Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants
  - SWEG: Spacecraft Water Exposure Guidelines for Selected Waterborne Contaminants
- Corrosion (MIUL)
- Materials Compatibility (safety: containment, corrosion, science: biocompatibility)

Experimental Fluids / Samples:
- Toxicity (health of astronauts)
- Restricted materials (example: alcohol)
- Ionizing radiation (isotope markers)

Thermal Compatibility
- Heat Rejection
- Max. / Min allowable temperatures (touch, bare skin)
- Condensation

Safety Verification

Payload Safety at JSC: http://jsc-web-pub.jsc.nasa.gov/psrp/

Flight Safety – Payload Safety Review Panel (PSRP)

Ground Safety – Ground Safety Review Panel (GSRP)

OSHA, lab safety, handling, pressure, electric, hoisting,.....

Science Verification

Flight Access: Late Launch / Early Retrieval

- Space Life Sciences: load as late as possible: limited shelf life: L-24 hrs.
- Retrieve as early as possible: typically within 4 hrs. of landing.
- Sample preparation: unique facilities on site (KSC), sample shipment (safety limitations)
- Sample retrieval: backup landing sites
- Sample preservation: ISS cargo flight delay / on-orbit duration

Flight Phases

- Launch/Landing: limited heat rejection / limited power availability / outlets (reduce power / unpowered; passive experiments)
- EVA mission reduced pressure = reduced heat rejection / hotter environment

Crew Access – Automation vs. Crew Operated

- Detailed planning for schedule, resources, timeline, procedures (nominal and off-nominal)

- Shuttle: first and last mission day very busy or debilitating (space sickness)
  ISS: docked operations very busy (loading/unloading)
- Sleep, eat, house-keeping, scheduling, delays due to trouble-shooting; weekend 'off'
- Inaccessibility of astronaut / intermediate layers of bureaucracy
- Complex operations: safety, interfaces etc. – limited flexibility

Materials Compatibility

Testing / 'experience'

- Biocompatibility
    1. Offgassing (internal, external, biogenically produced/accumulating in sealed environment)
    2. Contamination (heavy metals in solution, cleaning agents, fungus / bacteria)
    3. Corrosion by-products
    4. Related resources: Biocompatibility: Assessment of Medical Devices and Materials.
    5. Humans / Animals: better characterized than plants;
    6. Tighter Sealed Environment – potential accumulation / concentration.
- Materials Compatibility
    1. Corrosion (exposure duration, temperature, concentration)
    2. Electrochemical, Oxidation, Stress Corrosion
    3. Cleaning / Sterilization processes (temperature, pressure, chemicals/solvents)
    4. Materials Compatibility examples:
       http://www.coleparmer.com/techinfo/ChemComp.asp
       http://www.rtpcompany.com/info/guide/resistance.htm
       http://www.upchurch.com/TechInfo/ChemSelect.asp

Toxicological Assessment:

http://www.jsc.nasa.gov/toxicology/

Assessing and documenting the health hazards of specific potential contaminants of spacecraft air or water before each flight. The assessments are documented in:

- HMSTs - (Hazardous Materials Summary Tables) are printed documents that list all chemicals or biological materials on a given flight or mission and the toxic hazard level of each material,

- HazMats - (Hazardous Materials data files) are computerized, searchable database files that contain the same data as the corresponding printed HMST,
- SMACs - (Spacecraft Maximum Allowable Concentrations) are printed documents that establish the levels of a specific airborne contaminant that are acceptable for various durations of exposure and document how those values were derived, and
- SWEGs - (Spacecraft Water Exposure Guidelines) are printed documents that establish the levels of specific waterborne contaminants that are acceptable for various exposure durations and document how those values were derived.

Measuring airborne contaminants in the atmospheres of manned spacecraft: This is done by

- Offgas testing - Pre-flight testing of flight hardware for the levels of volatile materials released
- Monitoring - In-flight quantification of atmospheric pollutants, either real-time or near-real-time, and by
- Post-flight analysis - of archived samples of spacecraft atmospheric pollutants.

Quantitative Analysis of Offgassed Volatile Materials:

NASA requirements state that "Materials used in habitable areas of spacecraft, including the materials of the spacecraft, stowed equipment, and experiments, must be evaluated for flammability, odor, and offgassing characteristics". The Toxicology Laboratory performs "offgas" tests on flight hardware to measure the levels of volatile materials outgassed under standard test conditions. To schedule an offgassing test for a flight article, call the JSC Toxicology Laboratory at 281-483-7249. Offgas testing is also performed at several other NASA facilities including White Sands Testing Facility, Marshall Space Flight Center, and Langley Research Center.

Testing:

measure volatile compounds from experiment (solvents, cleaning agent, plastifiers,..): 72 hours in sealed chamber at 120 F, ambient pressure.

Analytical:

MAPTIS Data base (currently restricted access). Materials and Processes Technical Information System (MAPTIS), the only approved NASA-wide materials database chartered to provide materials information for all NASA facilities and NASA support contractors.
http://see.msfc.nasa.gov/mp/db_maptis.html

Electrical Compatibility

Wire Size Analysis / Fusing (fire / over-heat)

- Wire resistance= heat dissipation. Current limited by temperature of insulation (fire).

- Space/Microgravity: reduced convection – lower allowable currents. Compare vacuum vs. pressurized cabin rating.
- Spaceflight: restricted materials: no PVC insulation (70°C), use PTFE Teflon instead.

TABLE 7-2. PAYLOAD WIRING CURRENT RATINGS

Wire Gauge (AWG)	Wire Rating (A) 150°C insul. rating		Wire Rating (A) 175°C insul. Rating		Wire Rating (A) 200°C insul. rating	
	CABIN	PL BAY	CABIN	PL BAY	CABIN	PL BAY
0	310.0	235.0	335.0	285.0	361.1	332.0
2	205.0	160.0	225.0	196.0	245.8	225.0
4	140.0	111.0	153.0	135.0	171.6	157.0
6	107.0	84.0	118.0	101.0	128.9	118.0
8	74.0	58.0	82.0	70.0	88.4	81.0
10	47.5	36.0	52.0	44.0	56.2	51.0
12	34.0	26.0	37.0	31.8	40.9	37.0
14	23.5	18.4	25.7	22.5	28.7	26.0
16	17.4	13.7	19.1	16.5	21.4	20.0
18	15.8	12.0	17.4	14.6	19.1	17.0
20	11.7	9.0	12.8	10.9	13.9	13.0
22	8.7	6.8	9.5	8.1	10.4	9.5
24	6.3	4.8	6.8	5.8	7.5	6.8
26	4.4	3.5	4.9	4.2	5.3	4.8

TABLE 7-1. MAXIMUM POWER INTERFACE CURRENT VALUES

Interface	Circuit Protection Rating (A)	Minimum Blow Rating Current (A)	Protection Device Max. Blow Rating (%)	Maximum Blow Rating Current (A)
DC Rack	80	88	235	188
DC Locker	5	5.5	135	6.75
DC Locker	3	3.3	150	4.5
AC Locker	2.5 (per phase)	2.75	150	4.25
AC Rack	3 (per phase)	3.3	150	4.5
EPSU/RDU	35	38.5	200	70
EPSU/RDU	15	16.5	135	20.25
EPSU/RDU	10	11	135	13.5
EPSU	5	5.5	135	6.75
EPSU/RDU	2.5 (AC)	2.75	150	4.25

Fuses

Mechanical Fuse - Thermal (resistance)

- Requires time to heat up and trip – not an accurate nor rapid protection
- Fastest trip at highest current (short-circuit)
- Only sometimes usable as over-current protection

Electronic Fuse – Current measurement

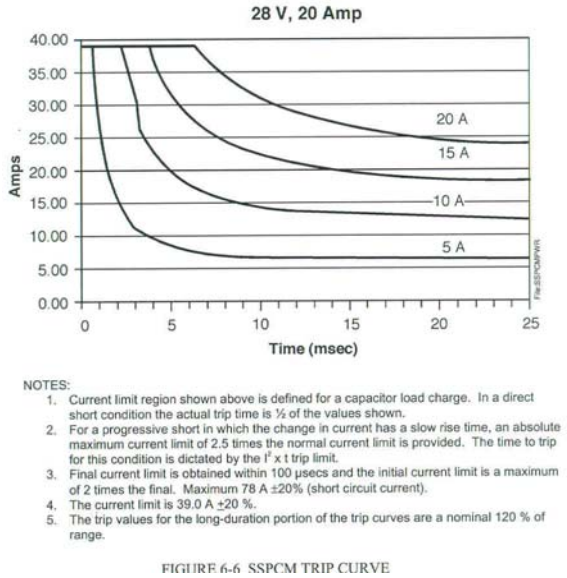
- Fast; may trip due to in-rush current

Thermal derating of fuses – fuse may trip at lower current due to:

- Higher temperatures.
- In microgravity, due to lack of convective cooling.

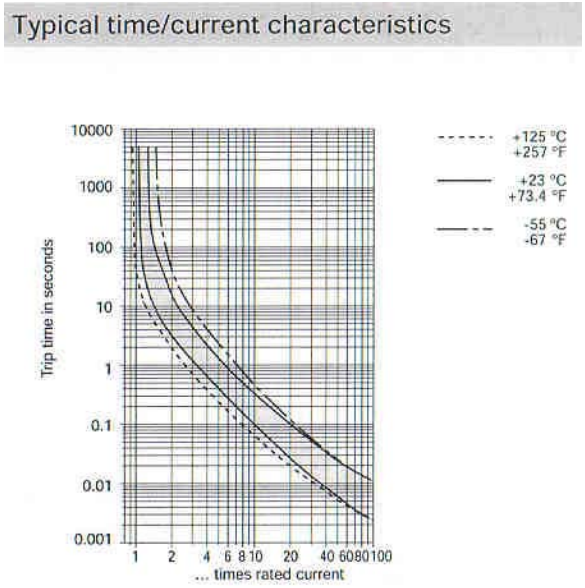
Resettable fuses vs. Blow Fuses:

- limited resupply / crew time / accessibility.



NOTES:
1. Current limit region shown above is defined for a capacitor load charge. In a direct short condition the actual trip time is ½ of the values shown.
2. For a progressive short in which the change in current has a slow rise time, an absolute maximum current limit of 2.5 times the normal current limit is provided. The time to trip for this condition is dictated by the $I^2 x t$ trip limit.
3. Final current limit is obtained within 100 µsecs and the initial current limit is a maximum of 2 times the final. Maximum 78 A ±20% (short circuit current).
4. The current limit is 39.0 A ±20 %.
5. The trip values for the long-duration portion of the trip curves are a nominal 120 % of range.

FIGURE 6-6 SSPCM TRIP CURVE



- SSPCM Trip Characteristics
- E-T-A Trip Characteristics

Power Draw (current limit), Energy consumption (fuel / battery limit)

- Power typical limited by max. allowable current.
- Short inrush current may be problem with fast electronic fuses / switches (start-up current, voltage drop, reboot).
- Energy limiting for stored energy (fuel cell – fuel, battery-capacity)
- For thermal analysis: assume all electric energy = thermal energy.
- Voltage drop in supply lines (28VDC line at 10 A = as low as 20 V.

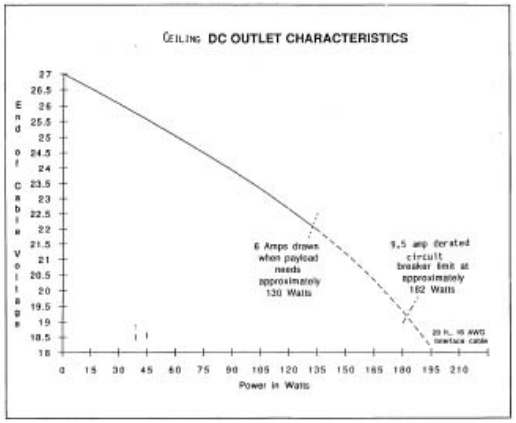


FIGURE 7.2.1-1-2 10 AMP MUP OUTLET CHARACTERISTIC

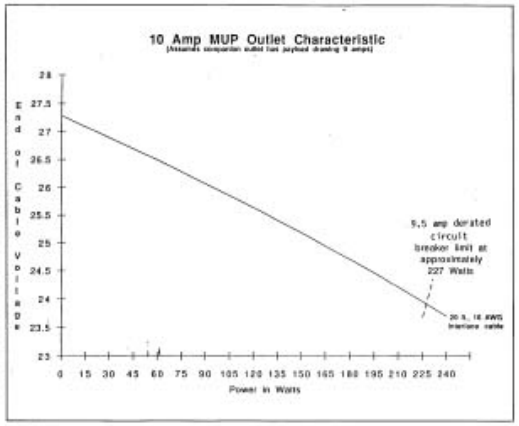
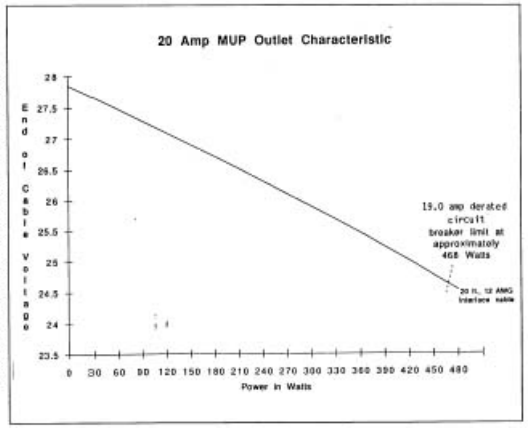


FIGURE 7.2.1-2-1 20 AMP MUP OUTLET CHARACTERISTIC



Electromagnetic Compatibility EMC:

EMISSIONS: Radiated and conducted electromagnetic EMISSIONS from payload, or SUSCEPTIBILITY to radiated and conducted emissions from others

Electromagnetic Emissions / Interference (EMI)

Electromagnetic Susceptibility

- EM noise,
- lightning strike,
- voltage fluctuation: 28 VDC, +/- 4 VDC

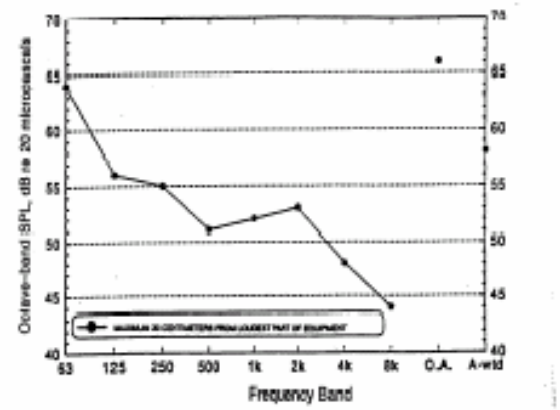
Acoustic Emissions:

- noise emitted by payload (fans, airflow, motors, valves, ...) = human health

TABLE 4.7.3-1
INTERMITTENT NOISE LIMITS

A-Weighted SPL* (BA)	Maximum Allowable Duration**
55-60	8 Hours
61-65	4 Hours
66-70	2 Hours
71-75	1 Hour
76-80	5 Minutes
81-85	1 Minute
86 & Above	Not Allowed

* A-Weighted Sound Pressure Level, dB re 20 micropascals. Measured at 0.3 meters distance from noisiest surface with equipment operating in the mode or condition that produce the maximum acoustic noise. Round dBA to nearest whole number.

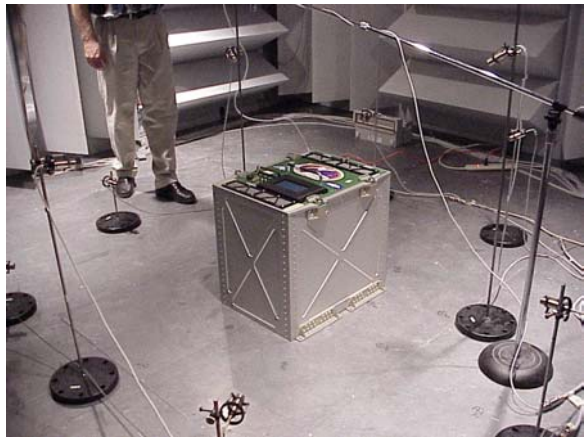


FREQ BAND	63	125	250	500	1000	2000	4000	8000	O.A.	A-wtd
LIMIT	64	56	50	45	41	39	38	37	50	59

TABLE 4-IX NOISE LIMITS FOR CONTINUOUS PAYLOADS

RACK NOISE LIMITS AT 0.6 METERS DISTANCE		MAXIMUM DESIGN LEVELS FOR ACTIVE HARDWARE ITEMS	
A	B	C	D
FREQUENCY BAND [Hz]	TOTAL RACK [dB*]	EXPRESS RACK PAYLOAD [dB*]	SINGLE ITEM OPERATED OUTSIDE OF THE RACK [dB]
63	64	58	59
125	56	50	52
250	50	42	45
500	45	38	39
1000	41	32	35
2000	39	32	33
4000	38	32	32
8000	37	31	31

*dB, re 20 μ Pa

a)  b) 

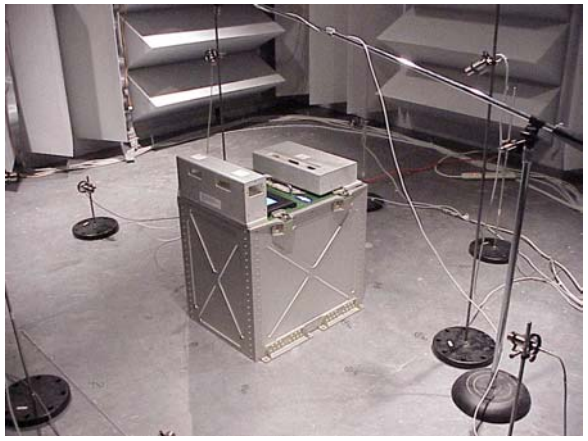
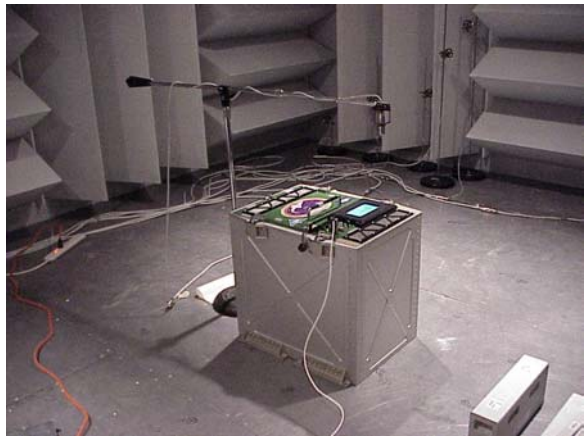
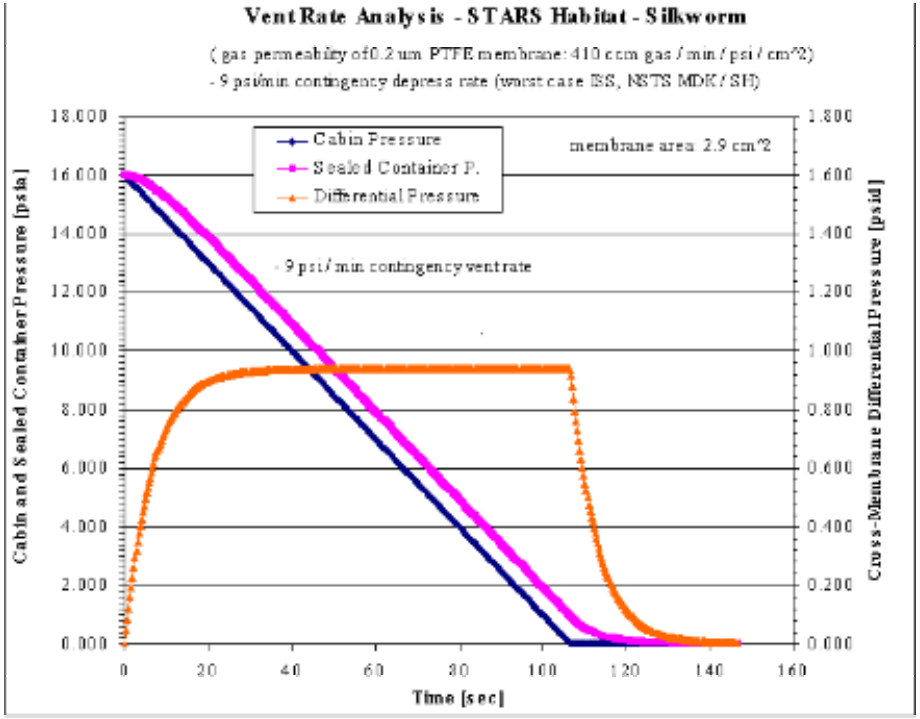
c)  d) 

Figure 4. PGBA in Maxtor Hemi-Anechoic Test Chamber – Sound Power Setup (a, b, c) using 10 microphones (and 180° payload rotation for microphone positions 11-20) and a 1.15 meter radius (2x payload dimensions). Sound Pressure Setup (d) from air inlet (loudest location). Mufflers seen in picture c.

Decompression – Vented Container / Sealed Container

- structural integrity for 16 psid often not feasible – vented container
- But: it takes time to vent !! Large enough hole / permeability to ensure differential pressure build-up is acceptable.



Thermal Interfaces:

Touch Temperature:

- Intentional contact is defined as contact for normal operational manipulation such as lifting, holding, or grasping. Incidental contact is defined as accidental or unintended contact. For both cases, the temperature range of -18°Celsius to +49°Celsius (0° Fahrenheit to 120° Fahrenheit) is the acceptable range for “bare skin contact” for metallic surfaces. The upper temperature limit for “bare skin contact” is higher than 49° Celsius for surfaces having thermal properties of nonmetallic materials.
- Max. allowed touch temperature limits max. possible exhaust temperature, and therefore max. Amount of rejected heat: Q = m(dot) * Cp * Delta-T.

Heat Rejection:

- Q = m(dot) * Cp * Delta-T [Watt]
  Delta-T = Tout – Tin
- Payloads: Cabin air, avionics air (STS, ISS) or water cooling (ISS only).
- Acoustic limits cabin air cooling (also: clogged inlets, ‘dirty’ air).
- Air – low density, lower heat capacity – large volumetric flow (large ducts)
  H2O – higher density, higher heat capacity – smaller volumetric flow (thinner/smaller tubes)

Condensation:

- All surfaces exposed to cabin air must be above dew point (17°C).
- Add insulation (closed cell or similar to prevent diffusion of moist air – water accumulation).
