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Shuttle Measured Contaminant Environment and Modeling for Payloads

Preliminary Assessment of the Space Telescope Environment in the Shuttle Bay

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National Aeronautics and
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SHUTTLE MEASURED CONTAMINANT ENVIRONMENT AND MODELING FOR PAYLOADS

Preliminary Assessment of the Space Telescope Environment in the Shuttle Bay

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Abstract

A baseline gaseous and particulate environment of the Shuttle bay has been developed based on the various measurements which have been made during the first four flights of the Shuttle. The environment is described by the time dependent pressure, density, scattered molecular fluxes, the column densities and including the transient effects of water dumps, engine firings and opening and closing of the bay doors. The particulate conditions in the ambient and on surfaces have been predicted as a function of the mission time based on the available data. This basic Shuttle environment when combined with the outgassing and the particulate contributions of the payloads, can provide a description of the environment of a payload in the Shuttle bay. As an example of this application, the environment of the Space Telescope (ST) in the bay, which may be representative of the environment of several payloads, has been derived. Among the many findings obtained in the process of modeling the environment, one is that the payloads environment in the bay is not substantially different or more objectionable than the self-generated environment of a large payload or spacecraft. It is, however, more severe during ground facilities operations, the first 15 to 20 hours of the flight, during and for a short period after water has been dumped overboard, and the reaction control engines are being fired.

Introduction

The Shuttle bay environment has been measured with the IECM (Induced Environment Contamination Monitors) instruments on STS-1, 2, 3, 4 flights and with other monitors on the same flights and others. The measurements have been reported in References 1 through 4 and in other documents. The measurements indicate that with the exception of during certain events and periods, the Shuttle bay environment is within criteria limits established at the beginning of the Shuttle program. However, the measurements do not provide a specific baseline Shuttle bay environment which can be used to evaluate the environment of Shuttle payloads. They reflect attitude changes and particular maneuvers designed to test and evaluate the Shuttle.

In this paper, a generalization of the Shuttle environment has been carried out based on the various discrete measurements. The resultant baseline environment is needed to evaluate the design and the operational conditions of payloads sensitive to the Shuttle environment. The payloads self-induced gaseous and particulate environment added to that of the Shuttle provide the payload environment. This environment will be used to evaluate possible surfaces degradations and observational constraints on the instruments. The shuttle bay gaseous pressure, density, scattered fluxes, and column density have been derived and shown graphically as a function of time and distance from the bay. Certain events such as engine firings, water rejections, bay door closings and reopenings have been indicated for their effects on the environment. The fractional contents of certain gases in the total gaseous environment have been indicated. A generalization of the particulate environment based on ground and orbit measurements with the IECM and with other ground instruments, has been carried out.

The natural environment at orbital altitude and its effect on the total pressure in the bay and the effect on some materials' performance have also been included. As an example of the application, a prediction of the Space Telescope (ST) environment has been carried out using the baseline Shuttle environment derived here and the ST gaseous contribution as calculated in Reference 5. The resultant environment consisting of pressures, densities, fluxes and column densities around the ST is needed to evaluate among others, any limitation on ST venting imposed by the external pressure and any contamination hazards. The paper concludes by summarizing the theoretical-experimental gaseous and particulate conditions expected in any empty Shuttle bay and the conditions expected when a group of payloads represented by the ST are included.

Ground Environment

The environment surrounding the Shuttle and the payloads (P/L) on the ground is variable and difficult to define. The number of particles and the non-volatile gaseous residues (NVR) from the environment which deposit on surfaces are difficult to assess. Measurements with IECM and other instruments at KSFC in advance of a number of Shuttle flights have given indications on the state of the surfaces previous to the flights (References 2 and 6). Figure 1 shows the number of particles and their size distributions to be found on a Shuttle surface immediately before launch and in orbit, as measured from the Passive Sample Array (PSA) of the IECM. The orbital distribution was obtained by subtracting the ferry flight measurements from those corresponding to about 19 days of deposits in the Operation Processing Facility (OPF) at KSFC. These particulate deposits reflect the Visibly Clean Level 1 (V.C.L.) of Table 1 used for the assessment of surface cleanliness and the conditions at the KSFC facilities during the past Shuttle flights. The IECM cascade impactor measurements during the Shuttle launch portion of the flights provided volumetric particulate sampling of the environment. These sampling measurements appear to be in agreement with the indications given by the passive samples. The passive sample particle measurements have been superposed on the MIL-STD-1246A for product cleanliness. The superposition indicates that for particle sizes up to 25 to 30 μm, the cleanliness level of Shuttle bay surfaces may correspond to product cleanliness level 300 (one particle of size 300 μm rests on one square foot surface). CL-300 coverage is calculated to provide a surface obscuration of about 2.7×10^{-2} percent (Reference 7). Other data taken in the OPF facility (Reference 6) have indicated fall-out of larger particles on the surfaces. The accumulation of several days appears to correspond to a surface CL-750. This level produces an obscuration of about 2.6 percent which is considered at the limit of acceptability for a large optical surface but acceptable for attitude control, thermal control and for solar arrays. The distribution of the particulates measured on the Shuttle surfaces does not follow the distribution indicated in MIL-STD-1246A. More large particles are present than the MIL-STD would predict. The description of the particulate deposits in terms of that specification is being done for convenience. The other indication of surface cleanliness is provided by deposits on a surface of NVR from the ambient. Spectral specular reflectance and transmittance measurements in the region of 120-2500 μm of the PSA monitor surfaces did not indicate NVR deposits. Reflectance and transmittance losses of less than 2 percent were measured when comparing exposed and non-exposed surfaces. These losses were thought to be caused by particulates. The cascade impactors of the IECM which have sensitivity of 10^{-7} g cm^{-2} and were in operation during the same time of the surface monitors, did not indicate film deposits (Reference 2). Contrary to these indications, sample plates located in the OPF, have indicated on certain occasions NVR accumulation rates of 2 to 7A/day which could produce unacceptable deposits in a week. Regardless of the contradictory measurements, improvements on the clean conditions of that facility are being made and more stringent cleaning

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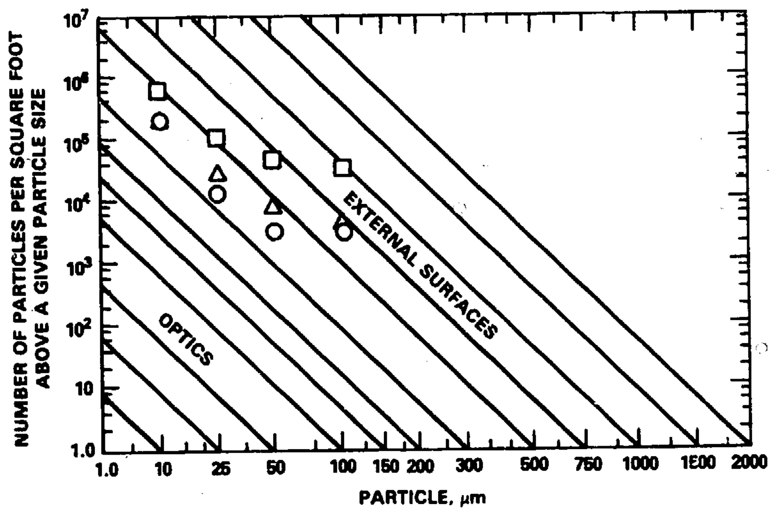

Fig. 1 Passive sample array measurements: average particle size distribution from □ STS-2, ▲ STS-3, ○ STS-4 flights orbital results (total mission – ferry flight).

procedures and inspections are being instituted. In fact, the latest Shuttle flights appear to show improvements in the area of cleanliness. One of the criteria for cleanliness of optical surfaces may be that deposits of thickness greater than $\lambda/40$, where λ is the minimum wavelength to be observed, should be prevented. In fact, a 30A thick deposit of polymeric materials commonly used in spacecraft, is estimated to produce a transmittance loss of about 23 percent in the U.V.

In conclusion, the surface conditions of the Shuttle and payloads at the time of launch are difficult to predict. They are dependent on the attentions accorded to surface cleaning, inspection and the environmental control of the ambient during the various stages of pre-flight. From the measurements on these initial flights, it appears that the Shuttle surfaces before launch may be characterized as follows: (1) the surfaces may have particulate deposits corresponding to CL-300 to 750 with a maximum obscuration of 2.6 percent; (2) the NVR on surfaces may not be detectable at certain locations while on others may have deposited up to 100A or more. These NVR deposits may leave the surface before the Shuttle goes into orbit.

Table 1. Visibly clean levels and inspection criteria for the orbiter payload bay, payload canister, and payloads.

VC Level	Illumination	Observation Distance	Remarks
1	≥50 foot candles	5 to 10 ft.	KSC Standard Service
2	100 to 200 foot candles	6 to 18 in.	Optional Service
3	100 to 200 foot candles	6 to 18 in.	Optional Service: 2X to 7X Power Optical Aid Permitted for Inspection
VC + Special	100 to 200 foot candles	6 to 18 in.	Optional Service: Same Inspection as Levels 2 or 3 Plus Special Metrology Requirements

From NASA SN-C-0005A

Shuttle Bay Flight Environment

The Shuttle bay molecular and particulate environment, as deduced from discrete measurements and from the application of theory, is presented in the next sections. The environment applies to the Shuttle bay with the limited payload complements carried with the STS-1, to STS-5 Shuttle flights. As such, this environment can be considered applicable to the Shuttle bay, with monitoring instruments but without payloads. The gaseous environment was derived for a normal temperature of the bay. But, it can be modified, to account for other average bay temperatures and temperature excursions.

Ascent

During ascent, the pressure in the bay drops at a rate of about 0.25 psi/s, as measured at the Air Sampler of the IECM on STS-2 flight, Reference 8. Pressures in the submillimeter range were measured during the STS-1 flight with a gauge (V07P9084A) located at the mid-fuselage coordinates x_0=863, y_0=90, z_0=367, Reference 9. The pressures were measured in lb/ft^2 and for a period of 2.2 hours. Figure 2 shows the bay pressure versus time starting at 1 hour MET (Mission Elapsed Time) when the measured pressure was about 10^{-2} torr. The outgassing of the Shuttle bay at that time can be estimated at 4.8×10^2 torr l/s since the bay venting area and the conductance are about 0.48 m^2 and 4.8×10^4 l/s, respectively. The time constant (l/e pressure drop time) for the bay volume of about 350 m^3 is calculated to be 7.3 sec. At those relatively high pressures with the bay doors closed, temporary deposits of certain contaminant gases can occur on some surfaces. The molecular composition of the outgassing from the Shuttle at that time may consist of about 60 percent H_2O, 25 percent H_2, 10 percent CO_2 and the rest O_2 or other molecules.

The particulate measurements during this period have been carried out with the IECM Cascade Impactors. The volumetric samplings, Reference 2 for flights STS-2, 3, 4 indicated conditions approximating the Clean Rooms Class 100K of the FED-STD-209B which specifies 10^5 particles of 0.5 μm diameter, in a cubic

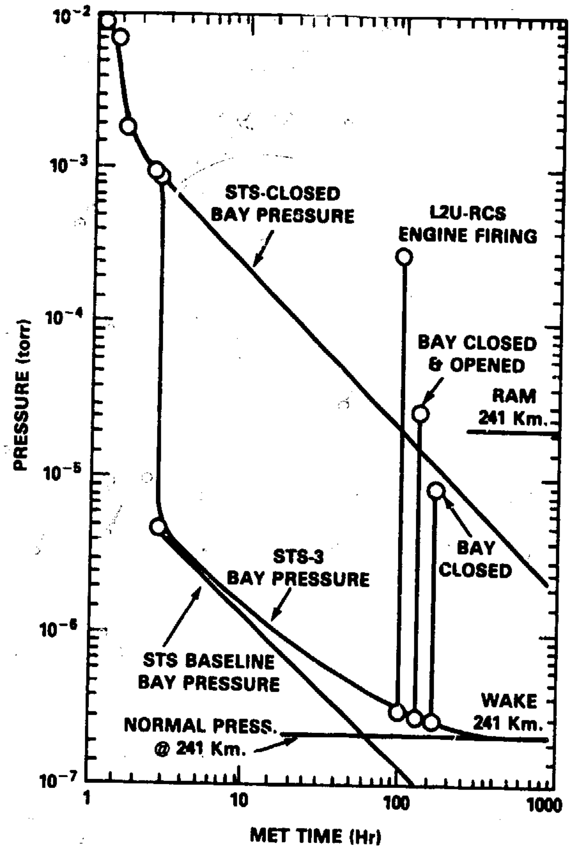

Fig. 2 STS-3 bay pressure and STS–baseline empty bay pressure with open and closed doors at 20°C.

foot. The particulates' conditions improve with time. After about 15 hours MET (Reference 2), the particulate environment becomes acceptable for optical observations. This indicates that during ascent and several hours after, a redistribution and settling of particles occurs. An originally clean surface may become covered with particles to a cleanliness level higher than class 300-750 thought to exist while the Shuttle is on the ground.

Orbit

The bay pressure with closed bay doors has been shown in Figure 2. The data for the early hours of the flight were from the measurements in the STS-1 bay. The pressure before the bay door of the STS-3 were opened at 2:35 MET may have been about 9×10^{-4} torr, the same as that measured in the STS-1 bay. The pressure with closed doors beyond 2:35 MET were derived using measurements made with the IECM mass spectrometer (M/S) and with the gauge of the Plasma Diagnostic Package (PDP), both on STS-3 flight. The M/S measured a pressure of 8.2×10^{-6} torr when the bay doors were closed at 167 hours MET (Reference 3). The PDP gauge indicated a pressure of 3.5×10^{-5} torr at 126 hour MET when the doors were temporarily closed (Reference 4). Also, this instrument indicated that upon reopening the bay the pressure returned to a value of about 2×10^{-7} torr in about 5 minutes. The normal ambient pressure at the STS-3 orbit of 241 km is 2.2×10^{-7} torr (Reference 10).

The pressures at 2:35 and 167 MET have been connected with a straight line. The inclination of the line represents the pressure drop with time and the rate of outgassing drop with time. The slope of the line which happens to be close to 1, indicates an outgassing rate decaying with the first power of time. This decay rate is theoretically and experimentally found to occur when many materials of different chemical nature outgas simultaneously. The resulting pressure for closed doors and normal temperature, is given by

$$P_s(t) = 2.32 \times 10^{-3}\, t^{-1} \quad \text{(torr)} \tag{1}$$

where t is in hours.

The pressure with the bay doors open has also been shown in Figure 2. It has been obtained by considering that when the bay is open the vent area is about 86 m^2, considerably more than 0.48 m^2 for the closed doors. The ratio of the vent areas is also the ratio of the pressures with the open and closed bay doors. The open bay pressure will be about 5.58×10^{-3} of the close bay pressure and, at 2:35 MET upon opening the doors, the pressure should be about 5.02×10^{-6} torr within less than 5 minutes. The outgassing pressure will continue to drop from that initial value according to the decay rate found for the closed door conditions. The pressure in this case is given by:

$$P_s(t) = 1.3 \times 10^{-5}\, t^{-1} \quad \text{(torr)} \tag{2}$$

which is valid from $t > 2{:}40$ (2.66) hour MET. This outgassing pressure drops below the normal ambient pressure of 2.2×10^{-7} torr corresponding to the STS-3 orbit, after about 50 hours MET. The total bay pressure, however, is the sum of the ambient and the pressure produced by the outgassing. The contribution of the ambient becomes noticeable when the outgassing pressure is in the same range and, as shown in Figure 2, the bay pressure will be about 5×10^{-7} torr at 50 hour MET and 2.5 -3.0×10^{-7} torr after 188 hours. These pressures are in good agreement with the PDP measurements of the pressures after thrusts firing at 97 hour and the doors opening and closing at 127 and 167 hours MET. The contribution of the ambient pressure can vary according to the orbit, the solar activity and the relation of the Shuttle bay with respect to the velocity vector. The outgassing pressure will vary according to the outgassing materials temperatures. The Shuttle attitude with respect to the Sun, the length of the exposure time and the material characteristics determine the temperatures. The outgassing pressures of Figure 2 and the other related parameters have been assumed to be produced by materials at 20C. Those parameters can be modified to account for temperature changes. It is reasonable to assume that they may change by a factor of two for each 10C temperature variation. This reflects a well known rule of thumb based on Arrhenius factor for reactions requiring about 10 kcal/mole activation energies.

When the bay is in the direction of the velocity vector, the ramming ambient pressure as measured by an instrument in the bay is about two orders of magnitude higher than if no ramming occurred. The ramming pressure increase will be detectable if the outgassing pressure is sufficiently low or it is in the same range of magnitude. The PDP gauge on the STS-3 measured a total bay pressure of about 10^{-5} torr at about 5 hours MET when the bay was in the velocity vector. At that time, the outgassing pressure, as shown in Figure 2 was about 2×10^{-6} torr. The ram pressure can be predicted (Reference 11) by the relation:

$$P_r = 4\, P_w\, (v/u)^2 \tag{3}$$

where P_w is the normal ambient pressure, $v \sim 8$ km/s is the ramming velocity and u is the ambient gas velocity. The velocity of the oxygen is about 1.5 km/s and that of the nitrogen about 1.6 km/s at the STS-3 orbit. These values substituted in the above indicate that $P_r = 112\, P_w$ and for the orbit normal pressure of 2.2×10^{-7} torr, the ramming pressure is 2.5×10^{-5} torr in close agreement with the measured pressure. The ramming effect on the outgassing is to increase the pressure near the outgassing surface by a factor of 2 or 3 as a consequence of molecular reflection (Reference 12).

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The firing of the Shuttle L2U, PRCS engine at 97 hours MET produced a bay pressure of about 3×10^{-4} torr as recorded with the PDP gauge. The bay pressure returned to about 3×10^{-7} torr after 7 minutes from the cessation of the firing. This was the single firing event in all of the STS missions which has been recorded to produce a pressure increase and a temporary accretion of about 175 ng on the 30C TQCM. That deposit dissipated with a time constant of about 15 minutes. There are some indications that more than one engine may have been fired during this event. The pressure produced by the engine firing has been shown as a spike in Figure 2. The duration of the firings, the time needed to return to normal pressures, and the frequency of firings will indicate the periods when protection against contamination and other observational restrictions are necessary.

An estimate of the normal gas composition in the bay was obtained from the M/S measurements on the STS-3 and STS-4 as reported in References 1, 2, 3, 4 and 13. Table 2 shows the percentage compositions, recorded in the STS-3 with the bay doors open and closed at 7 hours and 167 hours MET, respectively. The H_2O partial pressures measured on the STS-4 with the bay door open at 5 and 140 hours MET are indicated as is the composition of the RCS engine firing obtained during the M/S mapping of the STS-4. From these, it appears that the outgassing composition

Table 2. IECM mass spectrometer measurements of the gaseous environment in the shuttle bay

		STS-3		
		7.2 hrs*	167 hrs	94 hrs
AMU	Gas	Bay Open (%)	Bay Closed (%)	RCS Engine Firing, Bay Open (%)
2	H_2	–	–	4.2
4	H_e	24.9	18	–
16	CH_4	5.5	3.53	–
18	H_2O	1.6	3.3	23
17	NH_3	–	–	Trace
28	$N_2 + CO$	65	73	70
30	NO	0.05	–	–
32	O_2	0.03	0.41	–
40	Ar	1.4	1.21	–
44	CO_2	1.5	0.07	Trace
45–150	Hyd. Carb.	0.02	0.15**	–

H_2O count rates in the Open Bay of the STS-4 indicate partial pres of 7.7×10^{-9} and 1.5×10^{-10} torr at about 5 hours and 140 hours MET. The H_2O time constant (l/e) was about 10 hours.

*Mission Elapsed Times
**Includes a Large Freon Leak

may consist of less than 3.3 percent of H_2O, and less than 0.15 percent for materials with 45 to 150 amu. With regard to the percentages of the high amu materials, one can reason that many of the materials in the bay are of the same nature of the polymeric materials such as the adhesive RTV-566, the paint S-13G and other similar materials. The vapor pressure of these materials (Methyl Phenil Trisiloxane) at normal temperatures is about 3×10^{-8} torr (Reference 5) which would be maintained in the bay with closed doors. This partial pressure when compared to the measured total pressure of 8.2×10^{-6} at 167 hours MET, with closed doors indicates that the outgassing fraction of these materials would be 0.36 percent. With the bay open, the above partial pressure would be less and the fraction of these components would approach the value 0.02 percent measured with the doors open at 7 MET. One may assume, therefore, that the contaminant partial pressure is about 0.1 percent of the total pressure, at all time. This is in accordance with the material selection criteria which states that materials for space use should produce not more than 0.1 percent Volatile Condensable Material on a 25C collector when the sample material is at 125C for 24 hours in a vacuum.

In summary, the pressure as a function of time in an empty Shuttle bay has been constructed based on measurements and other considerations. The bay pressure shown in Figure 2, can be the basis for the evaluation of the total pressure and other gaseous parameters for payloads in the Shuttle bay. The payloads pressure will be the sum of the Shuttle, the payloads and the natural environment induced pressures. The content of the H_2O and of the heavy molecular mass materials in the total outgassing have been indicated as well as the suggested correction for temperatures other than the 20°C. The density, the scattered fluxes and the column densities can be derived, from the bay pressure and the nature of the outgassing, as indicated below.

Density In and Above Bay

The molecular density at the measurement location, for isotropic conditions and constant temperature, is given by

$$n(t) = P(t)/KT \quad (cm^{-3}) \tag{4}$$

where P(torr) is the pressure, T(K) is the gas temperature and K = 1.04×10^{-19} (torr cm^3/mole °K) is the Boltzmann constant. The density corresponding to the outgassing pressure of Figure 2 has been plotted in Figure 3. The molecular density of each outgassing component is in direct proportion with the fraction of that

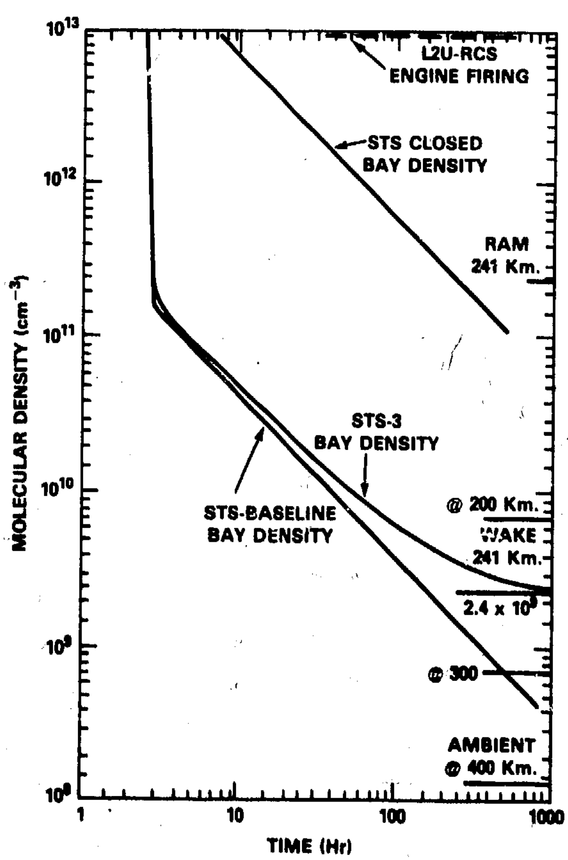

Fig. 3 STS-3 bay density and STS baseline empty bay density at 20°C.

component in the total density. The normal density of the natural environment at 241 km orbit is 2.4×10^9 cm^{-3} and is indicated on the graph for reference. The pressure at this orbit is $P = 2.2\times10^{-7}$ torr and the molecular mass is $M = 19.56$ kg/Kmole. The drop in density and pressure as a function of distance from the measurement location in the bay has been shown in Figure 4. The plots show the densities at 3 hours, 10 hours and 100 hours MET as a function of distance. They show that at about 10 meters from the bay, the density (and pressure) is more than an order of magnitude lower than that at 1 m. The equation employed to calculate the drop is from Reference 12,

$$n/n_o = 3/2 \ \left[\exp(-4\alpha R/\lambda_o) / (1+\alpha)^2\right] \qquad (5)$$

where $\alpha = x/R$, with x, (m) being the distance from the surface of an hemisphere of radius $R = 2.4$ m for the Shuttle bay, $\lambda_o = 7\times10^2$ m the gas mean free path at 241 km and n_o is the density at the surface. For orbits greater than 200 km and for the range of radii used here, the drops of density with distance are approximately the same as those shown in this figure. The mass density, ρ (gr/cm^3) is given by $\rho = n(M/N)$ where M is the molecular mass (gr/mole) and $N = 6.023\times10^{23}$ molec/grmole is the Avogadro number. The molecular mass densities for each species can be obtained in the same manner as for the molecular densities.

Direct Gaseous Fluxes

The incident molecular flux on a surface resulting from the random motion of the gas molecules is given by $\phi_D = \frac{1}{4}nv$. With the substitution for the velocity v, the flux is

$$\phi_D(t) = n(t)\ [(KT/2\pi m)^{1/2}] \quad (cm^{-2}\ s^{-1}) \qquad (6)$$

where $n(t)$ (cm^{-3}) is the gas density, $m = M/N$ (g/molec) is the molecular mass, T(K) the gas temperature and $K = 1.35\times10^{-16}$ (erg/mol°K) the Boltzmann constant. The empty bay direct flux for a temperature of 293K and for nitrogen gas ($M = 28$ g/mole) is plotted in Figure 5. The flux of H_2O molecules, with the H_2O molecules being about 3 percent of the total outgassing, can be estimated at $\phi = 3.74\times10^{-2}\ \phi_D$. The flux of heavy molecular mass contaminants, estimated to be present in the ratio of about 0.1 percent, is $\phi = 2.64\times10^{-4}\ \phi_D$. The corresponding mass fluxes are $M/N\ \phi$ ($gr/cm^2/s$) where N is the Avogadro number. A comparison of some experimentally measured fluxes and those calculated from Figure 5 is obtained from the following. The fluxes recorded on all QCM at temperature less than 30°C were reported to have varied from 0 to 1.0×10^{-11} $gr/cm^2/s$ on the STS-2 flight, from 0 to 4.9×10^{-11} for top sun conditions on the STS-3 and similarly for the STS-4 flight (Reference 1). Calculations using the fluxes of Figure 5 for a mass $M = 100$ gr/mole and for the 0.1 percent presence, indicate that the flux may be about 3×10^{-11} at 2.5 hours MET and 9×10^{-13} $gr/cm^2/s$ at 150 hours MET.

Scattered Fluxes

The return fluxes ϕ_R, produced from the scattering of emitted molecular fluxes ϕ_D with the ambient molecules and particles having a mean free path λ_o, can be estimated using the relation

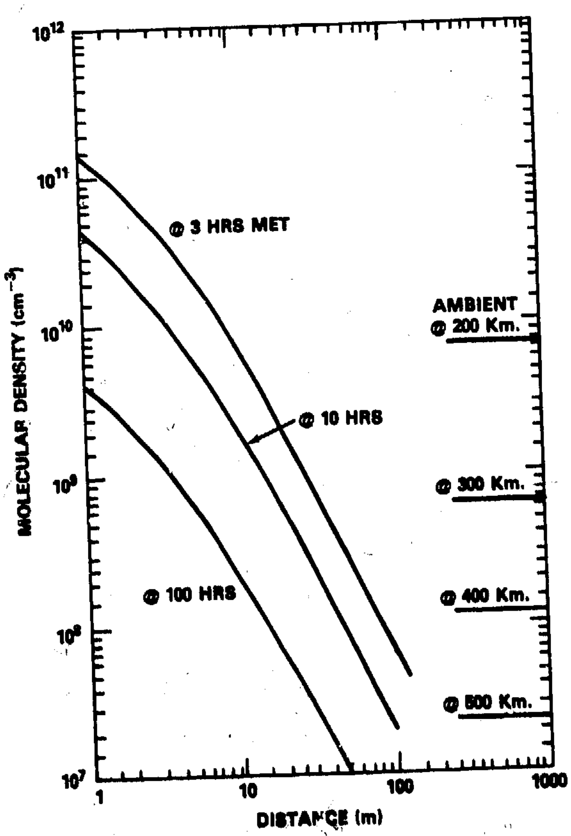

Fig. 4. STS baseline outgas density vs. distance above bay at 241 km.

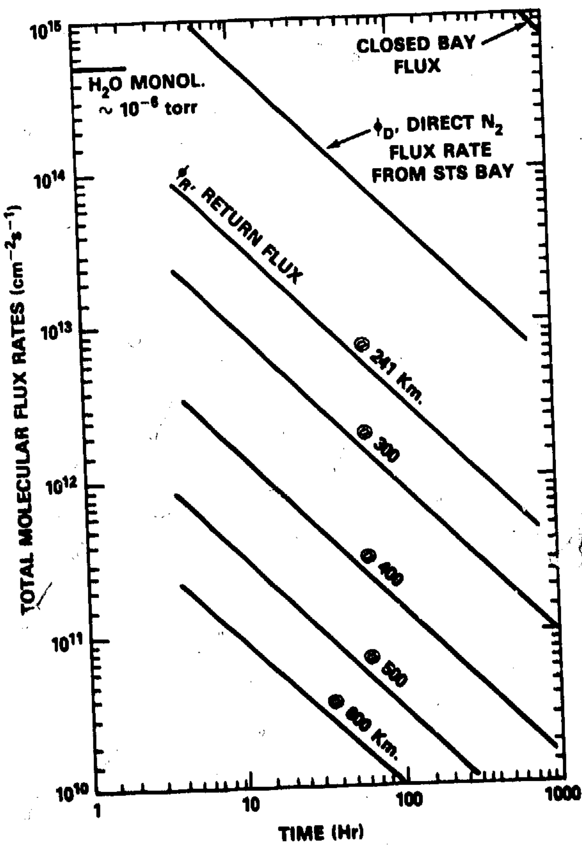

Fig. 5 Total direct and return flux vs. time in baseline STS bay (std. atmosphere).

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(Reference 12):

$$\phi_R = \phi_D (R/\lambda_o) [(v_s/v_D + 1)] \sim 21 (R/\lambda_o) \phi_D \quad (7)$$

where $R \sim 2.4$ m is the hemisphere radius assumed for the Shuttle bay, $v_s = 8$ km/s is the orbit velocity and $v_D = 0.4$ km/s is the average velocity of emitted molecules. The return fluxes out of the total direct flux have been calculated for 241, 300, 400, 500, and 600 km orbits. They have been shown in Figure 5. The return flux of H_2O molecules at 241 km orbit has been calculated to be about $2x10^{13}$ (cm^{-2} s^{-1}) at 2:35 MET and about $1x10^{11}$ at 150 MET. These compare to the water initial return flux of 10^{12} min to 10^{14} max and fluxes of 10^{11} to 10^{13} at the end of the flight for STS-2, 3 and 4 (Reference 2). The scattering of the outgassed molecules among themselves is about three orders of magnitude less than the direct flux and less than the return flux at 240 km orbit. It can be estimated (Reference 14) using the equation

$$\phi_{ss} = 1.78x10^{-2} (\sigma R/v_D) \phi_D^2 \quad (cm^{-2}\ s^{-1}) \quad (8)$$

where σ (cm^2) is the average cross section of the outgassing molecules and the other symbols are as defined previously.

Column Densities

The molecular column density N_c (cm^{-2}) or the mass column density M_C (gr/cm^2), representing the number of molecules or the mass of all the molecules in a column 1 cm^2 extending from the bay to infinity can be estimated using (Reference 15) the relations

$$N_c = (\lambda_o/v_s) \phi_R \sim (R/v_s) \phi_D \sim nR \quad (cm^{-2}) \quad (9)$$

where all the terms have been defined previously. The baseline column density for the Shuttle resulting from the measured pressure in the bay, has been shown in Figure 6. The criteria for the Shuttle to produce a column density of less than 10^{12} cm^{-2} water molecules is seen to be met after 3 to 4 hours MET. This is obtained when considering that the water is about 3 percent of the total column. The column densities in Figure 6 agree with the measured maximum and minimum values of $3x10^{13}$ and $4x10^{10}$ cm^{-2} reported in Reference 2 for flights STS-2, 3 and 4. The column density during engine firing is expected to be approximately $2.3x10^{15}$ cm^{-2}.

In Orbit Shuttle Bay Particulate Environment

The particulate environment in the bay will be dictated mainly by the Shuttle surface conditions which existed during ground operations and immediately before launch. The surface conditions on flights 1 to 6 which were inspected according to cleanliness level 1 and did not benefit of the OPF improvements, were estimated to correspond to class 300 for small particles and 750 for large particles. The particulate volumetric conditions in the bay during the early hours of flight were measured with the cascade impactors. They indicated conditions equivalent to those of clean room class 100K. The camera photometer also indicated that after 15 to 17 hours the number of observed particles in the bay were about two orders of magnitude lower than those observed 2 to 7 hours in the flight (Reference 2). These measurements seem to indicate that in the early hours a particulate environment is created in the bay by the release of the particles which were on the surfaces on the ground. These particles eventually re-settle on the original surfaces or on other surfaces. The settling may produce surface deposits corresponding to class 300-750 or larger on surfaces which had been cleaned or were clean before launch. It is also apparent that any surface on the ground which has not been cleaned can become the source of contamination of a clean surface and the extent of the contamination may be of the same magnitude or larger of the nonclean surface. It may be expected that an unprotected surface in the bay under the present ground cleaning conditions, may become a minimum of $2.7x10^{-2}$ percent (class 300) to more than 2.6 percent (class 750) obscured while in orbit.

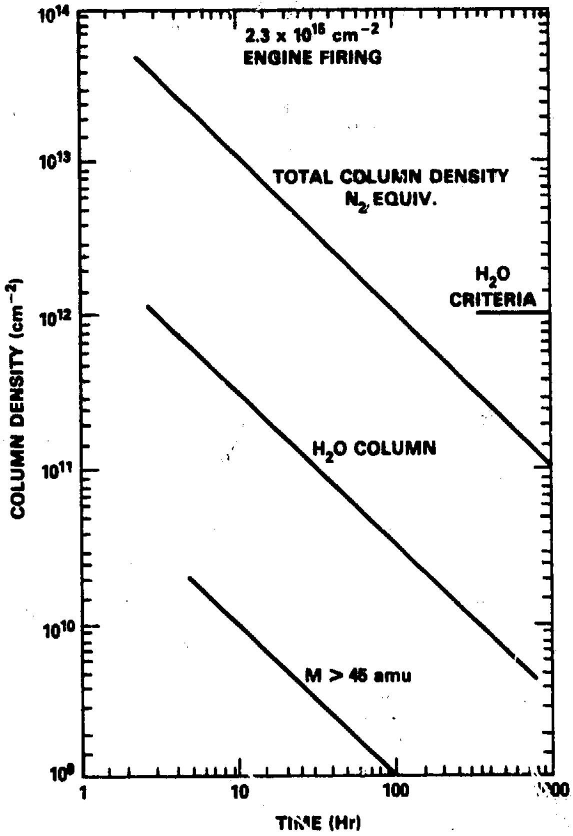

Fig. 6 Column densities vs. time for baseline STS bay.

The residual number of particles in the environment after 15-17 hours in orbit is reported to be such that a telescope with 1°FOV would detect one particle of 25 μm or larger diameter every two orbits. It was also indicated that after the same period of time, stars as faint as the 10th magnitude are visible and the observations are not impaired by particle radiations.

The dumping of excess water generated at the fuel cells occurs periodically. The water dumping rate is about 68 kg/hr and lasts usually about an hour. Some of the water is used for cooling and is rejected as a vapor via the Flash Evaporator System (FES). None of the 25 FES dumps carried out during three missions have been detected by the IECM M/S. Only one at 11.8 hours MET of the STS-2 was correlated with the M/S and no increase in return flux was detected (Reference 2). However, during the direct water dumps, the particulate counts in the camera photometers frames are very high. The scattered light from those particles have limited the photometer exposures to less than one second. The number of particles counted in the one second exposure have been more than one hundred immediately after the dump. The count shows less than 10 particles about 12 minutes after termination of the dump, and full observation can be resumed after about 25 minutes. It is apparent that to avoid water condensation, surface damages and particulate deposits, cryosurfaces, mirrors and other critical surfaces should be protected during and for a period of time after a water dump.

In summary, the particulate environment of the Shuttle bay appears to have these characteristics: (1) it corresponds to a clean room class 100K during the first 17 hours of flight; (2) the settlement of the particulates on the surface after the 17 hours may

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produce obscurations of 2.6 percent or more corresponding to 750 surface cleanliness levels; (3) protection of surfaces and instruments is needed during and after H_2O dump for a period of about 15 minutes; (4) optical observations can be resumed after about 25 minutes after the dump; (5) background brightness from particles is not detectable in the visible region of the spectrum after 15 to 17 hours MET (with exception of H_2O dumps); (6) the IECM measurements appear to indicate that no problem will exist in the UV and IR regions with the exception of the dump period and the early 17 hours of flight. However, measurements have not been made in those regions.

Natural Environment – Oxygen and Glow/Material Degradation

Atomic oxygen present in the earth extended atmosphere appears to cause measureable changes in the properties of several materials in the spacecraft which are exposed to its flux for a few days. Kapton insulations, silver films, aluminum, osmium coating and other materials are significantly affected by oxygen. These materials show thickness losses which have been correlated (Reference 16) to the oxygen fluence and to an empirically derived reaction rate constant. The rate constant K(cm^3/atom) varies with the materials ranging from about 0.46×10^{-24} for Tedlar to 3.3×10^{-24} for Kapton and does not appear to change at the operating temperatures being experienced in orbit. It also seems to be unaffected by the relative location of the material with respect to the spacecraft velocity vector. The loss of thickness of these materials can be estimated using the following: $h = n_o v_s t\, K$(cm) where n_o (atoms/cm^3) is the ambient oxygen density at flight altitude, v_s (cm/s) is the s/c velocity, t(s) is the exposure time of the material to the oxygen and K is the reaction rate constant. It is thought that the same process producing a loss of materials may be responsible for the cleaning of some surfaces. This cleaning may involve a process of converting chemically some outgassed complex molecules to lighter molecules or to atoms which are volatile.

Another process noted during these flights and requiring additional investigations is the presence of an optical emission surrounding the vehicle surfaces exposed to the ram direction. The glow from these emissions competes in intensity with bright stars and as such it is an optical contaminant and modifier of the environment. The process producing the glow is unknown at the present time, but it has been conjectured that excited states of the hydroxyl radical (OH) and certain states of molecular oxygen and nitric oxide may be responsible. The glow appears to have a diffuse spectral component in the spectral region of 6300 to 8000Å (Reference 4).

Payloads Environment in the Shuttle Bay

The inclusion of payloads in the Shuttle bay modifies the baseline Shuttle environment developed and described in the previous pages. The additional outgassing and particulates contribute to the modification of the environment. The resultant environment provides the data for the evaluation of contamination hazards internally and externally to the payloads, and the evaluation of the visibility and interferences in their field-of-view. It also controls the rate of pressure drop and the ultimate pressure achievable inside a payload. The application of the baseline Shuttle environment to the development of the payload's environment in the bay will be employed for the evaluation of the Space Telescope (ST) environment in the Shuttle bay. This particular application is not only important for its future use, but it also makes use of the development carried out in another document (Reference 5), of methods for the evaluation of payloads produced environment.

Pressure and Other Gaseous Parameters in the Shuttle Bay Carrying a Large Payload (ST)

The pressure in the bay increases in proportion to the additional sources of outgassing. The outgassing of the payloads can be obtained from vacuum chamber tests knowing certain parameters of the system or by a combination of tests and analytical evaluation of the outgassing contribution of certain elements of the payload (Reference 5). In the case of the ST, the throughput was obtained from the vacuum chamber test of one of the instruments, complemented by estimates of the outgassing of other elements based on sample material tests. That estimate which was used to calculate the internal pressure of the ST assuming a sufficiently low external pressure is indicated in Table 3 in terms of the individual contributions. The total outgassing throughput is given by

$$Q = 72\, t^{-1} + 6.81\, e^{-t/0.27} + 12.6\, e^{-t/34} \quad (\text{torr}\cdot\ell/\text{s}) \qquad (10)$$

where t is the time in hours.

The pressures which this throughput will produce in the bay are a function of the bay conductances. These were previously indicated to be about 4.8×10^4 l/s when the bay doors are closed and to be about 8.6×10^6 l/s with the bay open. These ST pressure contributions in the bay have been shown in Figure 7 together with the basic Shuttle bay outgassing pressures. The payload contributions are:

Table 3. Major outgassing sources of the Space Telescope.

	Quantity	Surface (cm^2)	Weight (kg)	Outgassing Rate (torr ℓ/s); T(hr)	Notes
Instruments	8	–	~318 ea	48/t	Data from FOC T/V test Ref. CCWG 12/80
Aft-shroud paint (Z-306 + 9992)	–	1.43×10^6	–	$2.8 \times 10^2\, e^{-t/0.27}$	From test sample data of MMC & GSFC Ref. CCWG 12/80
Telescope tube paint (Z-306 + 9992)	–	2.06×10^6	–	$4.01 \times 10^2\, e^{-t/0.27}$	Same as above
Structure [CFRP (GE)]	–	–	516	$12.6\, e^{-t/34.4}$	From test on 20 lb by MMC Ref. same as above
Multilayer insulation (double aluminized Mylar 6.35 μm thick)	5000	1.42×10^{10}	–	24/t	From LMSC tests Ref. J. Vac ST Vol. 17(3) 6/80

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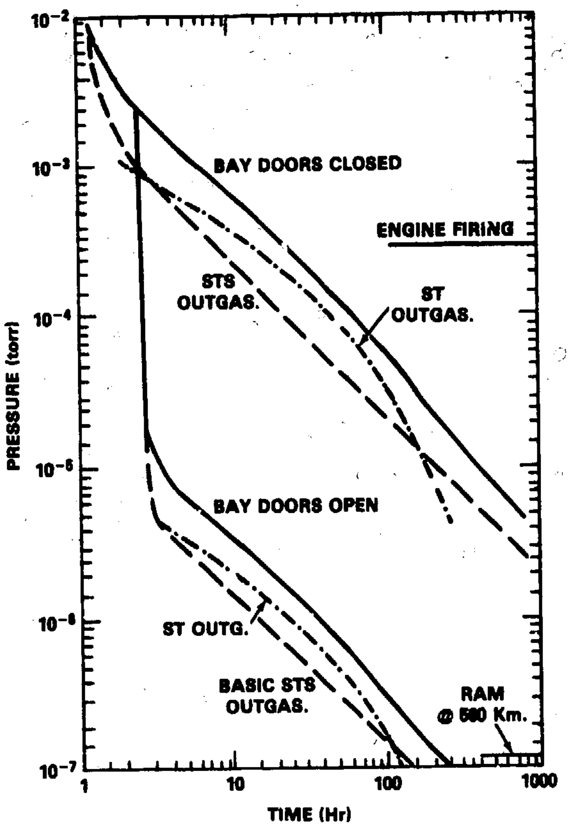

Fig. 7 STS bay with space telescope, pressure vs. time at 20°C.

for closed bay;

$$P_P = Q/4.8\mathrm{x}10^4 \quad \text{(torr)} \tag{11}$$

and for open bay;

$$P_P = Q/8.6\mathrm{x}10^6 \quad \text{(torr)} \tag{12}$$

where Q is given by Equation 10.

The pressures in the bay produced by the material outgassing of the Shuttle, Equations 1 and 2, and of the payload, Equations 11 and 12, are the sum of the two i.e.

for closed bay,

$$P = P_P + P_S = (1.5\mathrm{x}10^{-3}\,t^{-1} + 1.41\mathrm{x}10^{-4}\,e^{-t/0.27} + 2.62\mathrm{x}10^{-4}\,e^{-t/34}) + 2.32\mathrm{x}10^{-3}\,t^{-1} \quad \text{(torr)} \tag{13}$$

for open bay,

$$P = (8.31\mathrm{x}10^{-6}\,t^{-1} + 7.97\mathrm{x}10^{-7}\,e^{-t/0.27} + 1.46\mathrm{x}10^{-6}\,e^{-t/34}) + 1.33\mathrm{x}10^{-5}\,t^{-1} \quad \text{(torr)} \tag{14}$$

These pressures affect the natural environment and cause contaminations and obscuration. In addition to the outgassing pressure, one must add the natural environment pressure which is a function of altitude, of solar activity and attitude of the bay with respect to the velocity vector. The total bay pressure P_T is then

$$P_T = P_P + P_S + nP_E$$

where P_E is the natural pressure and n may have a value of one or $n = 4\,(v/u)^2 = 112$ as previously indicated for the ramming conditions. It should be noted that the pressure of the environment nP_E is noticeable only when the two other pressures are in the same range of value i.e., when the outgassing has become sufficiently low. In Figure 7, the pressure P_P produced by the ST, and that of the Shuttle P_S have been shown individually. Their sum is shown with heavy lines. With regard to the ambient pressure, the ST will orbit at an altitude of 560 km or higher. The normal parameters of the ambient at 560 km are:

$$P_E = 9.97\mathrm{x}10^{-10}\ \text{torr},\ \lambda_o = 1.8\mathrm{x}10^5\ \text{m},$$

$$\rho = 1.67\,\rho_o,\ M = 12.8\ \text{g/gmole}$$

This pressure has a limited effect when the bay is in the wake region. It will influence the total pressure when the outgassing pressure is in the range of 10^{-8} to 10^{-9} torr, i.e., after many hours in orbit. On the other end, if the bay is in the ram direction, the environment contribution will be $nP_E = 112\mathrm{x}9.97\mathrm{x}10^{-10} = 1.11\mathrm{x}10^{-7}$ torr. The total pressure in which the ST will be immersed at 560 km with the bay in the ram direction can be expressed, for open bay conditions as

$$P_T = (8.31\mathrm{x}10^{-6}\,t^{-1} + 7.97\mathrm{x}10^{-7}\,e^{-t/0.27} + 1.46\mathrm{x}10^{-6}\,e^{-t/34}) + (1.33\mathrm{x}10^{-5}\,t^{-1}) + 1.11\mathrm{x}10^{-7} \quad \text{(torr)} \tag{15}$$

and for closed bay:

$$P_T = (1.5\mathrm{x}10^{-3}\,t^{-1} + 1.41\mathrm{x}10^{-4}\,e^{-t/0.27} + 2.62\mathrm{x}10^{-4}\,e^{-t/34}) + 2.32\mathrm{x}10^{-3}\,t^{-1} + 1.11\mathrm{x}10^{-7} \quad \text{(torr)} \tag{16}$$

It is apparent that for closed bay conditions, the environment pressure is a very small contribution for a long time. At this time it seems appropriate to make a digression. Comparing the total pressures calculated above with the internal pressure of the ST calculated assuming zero external pressure (Figure 3 of Reference 5), one finds that the internal pressure is always about two orders of magnitude higher than the external when the bay is open. This implies no limitations on the rate of ST internal pressure drop. On the other case, when the doors are closed, the ST internal pressure is controlled by the bay external pressure. This suggests that the ST should be released from the bay within 4 to 5 hours after being in orbit if one wishes to avoid delays in the internal pressure decay. The other observation is that when the RCS engines are fired, the pressure in the bay is about $4\mathrm{x}10^{-4}$ torr. This pressure is higher than the ST internal pressure after the ST has been in orbit for 20 to 30 hours. Consequently, a firing after 20 to 30 hours MET would produce a back flow of gases into the ST.

The additional characterizations of the payload environment are obtained from the total pressure using Equation 4 for the density, Equation 6 for the direct flux, Equation 7 for the return flux and Equation 9 for the column density. One may assume for simplicity that the gas consists of nitrogen at normal temperature. The parameters applying to each gas component can be estimated by using the gases composition fractions indicated in Table 2 for the Shuttle bay. The effect of temperature can be accounted using the rule previously suggested. The graphical presentations of the density, direct and return flux, and column density for the ST in the bay, have not been included in this paper. However, the ratio of the pressures in the bay with and without the ST as obtained from Figure 7, can be used to estimate those parameters as a function of time. Those ratios applied to the results for the empty bay in Figures 3 to 6 provide the needed data. It is seen that the inclusion of the ST does not change drastically the

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baseline environment. The fractions of the direct flux which can be used to estimate the deposits of contaminant, the column density and the return flux can be estimated, as previously indicated, by: $\phi = 2.64 \times 10^{-4}\ \phi_D(t)$ for M = 400 gr/mole and $\phi = 3.74 \times 10^{-2}\ \phi_D(t)$ for water M = 18 g/mole, where $\phi_D(t)$ represents the total flux as a function of time.

The evaluation of the contaminant deposits can be predicted using the inpinging flux data as obtained here and using the methods indicated in Reference 5. For example, for the ST it is seen from the pressure curve for open doors, Figure 7, that a material M = 400 which would have a partial pressure of 10^{-3} of the total pressure (P_t) can deposit on a surface at 20°C ($P_{sat} = 3 \times 10^{-8}$ torr) for only about 2.5 hours when the inpinging flux on the surface will be greater than the evaporating flux of the same material from the surface. Water (P_{sat} = 17.5 torr at 20°C) can condense only during the first few minutes, hence, any water deposit on normal temperature surfaces must involve an adsorption process. The acceptable H_2O column density of 10^{12} cm^{-2} above the bay for the ST will occur 10 hours MET.

Particulate Environment of Payloads

The number and distribution of particulates on surfaces and the NVR deposits will depend on the environmental conditions to which the payload (P/L) and the Shuttle were exposed, and on the frequency, effectiveness and timing of the cleaning operations before launch. A visibly clean P/L (visibly clean according to any of the definitions of Table 1) installed in the Shuttle bay which is expected to be clean as per visible clean level 1, may end up having the surfaces covered by particulates corresponding to class 300 to 750. The particulates from the Shuttle bay will create in orbit an environment which is equivalent to clean room class 100 K. The eventual settling after 15 to 17 hours in orbit of these particulates on any surface in the bay will produce the cleanliness level of the order of 300–750 or more. If the surface conditions of a P/L are the same as those of the Shuttle, the P/L may end up more contaminated than it was originally. It is reasonable to assume that additional particles from the P/L surfaces will not alter significantly (not by order of magnitude) the volumetric particulate densities (cleanliness class 100K) in the bay. The settling distribution and the number of particles on a unit surface should remain about the same. One may conclude that for the present unimproved OPF and the standard visibly clean level 1 inspection, a payload surface in orbit may be described to have cleanliness level of about 750 and that unprotected optics become degraded by as much as 2 percent by those particulates.

Results

A generalized baseline environment of the empty Shuttle bay has been developed and characterized by its pressure, density, column density, scattered fluxes and surface particulates coverage. This baseline environment combined with the self-generated environment of the payloads and that of the natural environments can be used to derive the parameters needed to evaluate the visibility limitations, the contamination hazard and other ambiental conditions of importance to a P/L mounted in the Shuttle bay. The estimation of the Space Telescope environment in the Shuttle has been used as an example of the application. For that example, the ST self-generated gaseous environment was available from a previous study carried out to define the in-orbit ST internal pressure and contamination. The empty Shuttle environment has been derived from discrete measurements of different parameters made with instruments mounted in the bay of the first four Shuttle flights. Those missions were evaluating, among others, the various systems without any concern for the ameliorization of the environment. These measurements combined with theory have provided a description of the environmental parameters and criteria which may be used to evaluate the gaseous and particulate conditions of a payload in the bay. The results which have been presented in Figures 1 to 6 and in Tables 1 and 2 are as follows:

(a) The Basic Shuttle Environment

- The pressure in the bay which includes monitoring instruments and is at normal temperature, drops to about 10^{-3} torr after 2 hours in orbit while the bay doors are closed. With the doors closed, the pressure would drop to 10^{-5} torr after 200 hours. With the bay being opened, the bay pressure drops between two and three orders of magnitude (1/178) and is about 1×10^{-7} torr after 100 hours.
- The lowest pressure attainable in the bay is dictated by the ambient pressure and the direction of the bay with respect to the velocity vector. At 241 km (STS–3 orbit), the normal ambient pressure is 2.2×10^{-7} torr. This pressure in an empty bay not in the velocity vector, would be reached in about 200 hours. For a bay in the velocity vector, the rammed ambient pressure produces a pressure about 112 times the normal or about 2.4×10^{-5} torr. In the early hours of the mission, the ram pressure could be increased noticeably by the initial high outgassing pressure.
- The gaseous composition in the bay may include about 3 percent H_2O and probably less than 0.1 percent heavy molecular components.
- The density and pressure above the bay is about 1 order of magnitude lower at 10 meters distance.
- A total column density of 10^{13} (cm^{-2}) exists over the bay after about 10 hours in orbit. However, the acceptable H_2O column of 10^{12} (cm^{-2}) is established after 4 hours in orbit.
- The random flux of H_2O molecules is about 1.1×10^{-9} gr/cm^2/s when the bay is opened and drops linearly to about 6×10^{-11} gr/cm^2/s after 100 hours in orbit. Correspondingly, the flux of molecules having M = 400 gr/mole drops from about 1.7×10^{-10} to about 1.05×10^{-11} gr/cm^2/s.
- The indirect return fluxes are dependent on the orbit and solar conditions. At 241 km orbit, the return under normal conditions are approximately 7.2 percent of the above random fluxes. The percentage drops inversely with the ambient mean free path.
- The firing of the RCS engines may increase the bay pressure to about 3×10^{-4} torr. The engine effluent contains about 30 percent H_2O and traces of NH_3 and CO_2. This high pressure which can be deleterious to high voltage experiments and to the internal pressures of instruments drops to the normal bay pressure after 7 minutes from the termination of the firing.
- The particulates carried in orbit by the Shuttle and other generated particles create in the bay an environment equivalent to air cleanliness class 100K clean room. The settlement of these particles after about 15 to 17 hours in orbit produces surface deposits of about the same cleanliness levels existing previous to launch. These levels are describable by product cleanliness level 300 for particles < 25 μm and level 750 for larger particles. The deposits can produce reflection and transmittance losses of less than 2 percent. These deposits result from the unimproved ambiental conditions at KSFC, OPF facility and from the cleaning inspection procedure described as Visibly Clean level 1.
- The background brightness from particles and molecules is not detected in the visible and probably in the UV and IR regions (no measurements, however, have been made in these regions) after 15 to 17 hours in orbit. This reflects the fact that particles will be settling.
- The direct dumping of excess H_2O produces a large number of ice particles. The scattered light from these particles limits severely the optical observations from the bay. The particulate level drops about an order of magnitude within 10–12

minutes and full observations can be made after about 25 minutes.

(b) The Payload Environment in the Shuttle Bay

The payloads environment can be evaluated by combining the Shuttle basic environment with the payloads self-generated environment which can be obtained from vacuum chamber tests, and/or, a combination of tests and theory. One can calculate the additional pressure in the Shuttle bay knowing the gaseous throughput and the Shuttle vent conductance. The other parameters are then obtained from the known total pressure and kinetic theory relationships. With these parameters and a knowledge of the environment chemical composition one can evaluate the payloads internal and external contamination deposits, the observational constraints, and the limitations imposed on some instruments internal venting. The above technique has been employed to estimate the environment of the Space Telescope in the bay. The gaseous throughput of the ST which was available from another study is equivalent to the throughput of several payloads. As such, the ST environment in the bay will approximate closely the environment to be expected in the Shuttle with a full complement of payloads. Some of the results are as follows:

- The pressure, density, fluxes and column densities in a Shuttle bay containing several payloads, are expected to be two or three times higher than those for the empty bay. This was obtained by including the outgassing of the ST which includes its paint, structure and eight equivalent full instruments. The bay pressure will be about $7x10^{-6}$ and $3x10^{-7}$ torr after 4 and 100 hours in orbit, respectively. These compare to $3x10^{-6}$ and $1.2x10^{-7}$ torr for the Shuttle without payloads (but including measuring instruments).

- The contaminant fluxes assuming the composition of 3 percent water and 0.1 percent gas of molecular mass of 400 g/mole, will be again about 2 or 3 times higher than the empty bay fluxes or $2.5x10^{-9}$ gr/cm^2/s for H_2O and $3.9x10^{-10}$ gr/cm^2/s for M = 400 upon opening the bay doors. These will become $1.1x10^{-10}$ gr/cm^2/s and $1.9x10^{-11}$ gr/cm^2/s after 100 hours in orbit. The rate of drop of the pressure and of the other descriptive parameters are not linear with time but are a combination of several rates.

- The return fluxes will be about $2.8x10^{-4}$ of the direct fluxes at 560 km altitude, which is the orbit of the Space Telescope.

- The total column density over the bay is about $2.2x10^{13}$ (cm^{-2}) after 10 hours and $2.2x10^{12}$ cm^{-2} after 100 hours. The water column density of 10^{12} will be available after 6-7 hours in orbit.

- The pressure and density drop by an order of magnitude at a distance of 10 m over the bay.

- The long term pressure in the bay is dictated by the natural orbit pressure. For the ST, at 560 km the normal pressure is about $9.97x10^{-10}$ torr. This would be obtained after many days. However, with the bay in the velocity vector, the ambient ram pressure is about $1.1x10^{-7}$ torr which will be approached within 200 hours. The contaminant fluxes which originate from the outgassing are not limited by this pressure.

- The bay pressure does not limit the venting of payloads. The venting time constant of the bay with the closed doors is about 7 seconds. For the ST, the bay doors should be opened after about 4 hours in orbit to prevent the bay pressure for being the downstream controlling factor in the venting of the instrument.

- The firing of the RCS engines produces a pressure of $3x10^{-4}$ torr inside the bay which lasts for about 7 minutes. Reverse flow into a payload will occur if the payload internal pressure is lower than $3x10^{-4}$ torr. For the ST, this may occur when the firing is carried out when the ST telescope door is open or if the firing is made about 10 hours after launch and the ST aperture door is closed.

With regard to the payloads particulate environment two alternative conditions exist: a payload was protected during ground operations and is clean at launch while the rest of the Shuttle and other payloads have received limited cleaning attention; or the opposite situation exist at launch. In either case a clean surface in the bay may end up being contaminated by particulates. The number and distribution of the particles on the surface [illegible] equal or worse than the dirty surface in the bay. It [illegible] the particle environment described for the basic Sh[illegible] also applicable to the payloads. For the unimprove[illegible] facility and for an inspection described by the visib[illegible] level 1, one may have:

- a payload will be exposed for about 15 to 17 hours [illegible] orbit to an environment corresponding to clean room class 100K.

- the redistribution of particulates during that time will produce surface coverage described by cleanliness level 300 for particles less than 25 μm and class 750 for large particles.

- A payload optical surface may acquire a loss of reflectivity and transmittance of less than 2 percent.

- Dumping of H_2O produces a large number of particulates which precludes observations during and for a period of about 25 minutes after the dumping.

- Visible region observations are not affected by background brightness of particles and molecules except during the early 15 to 17 hours, the water dumps and the engine firings. Although tests have not been made, it is probably that UV and IR observations are also not affected during the same periods.

Conclusions

The general conclusions which transpire from this analysis are:

The payload gaseous and particulate environment in the Shuttle bay is not substantially different or more objectionable than the self-generated environment of a large payload or spacecraft. However, the environment is different during the following periods when the P/L may require protection and/or one should take certain precautions:

- during ground facility operations
- for the first 15 to 17 hours of flight
- while dumping water and for 25 minutes after
- while the RCS engines are being fired and for 7 minutes after

The inclusion of a reasonable number of payloads with normal outgassing characteristics in the bay does not alter by order of magnitude the basic Shuttle environment.

The environment calculated for the ST may be representative of the environment to be expected for a full complement of payloads in the bay.

Other environmental difficulties such as material damage and optical emissions of certain surfaces are common to a free flyer or a payload, when orbiting at the same altitude.

References

1. H. K. Ehlers, S. Jacobs, L. J. Leger and E. R. Miller, "Space Shuttle Contamination Measurements From Flights STS-1 through STS-4." AIAA 21st Aerospace Sciences Meeting, January 10-13, 1983, Reno, Nevada, Paper No. AIAA-83-0331.

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2. E. R. Miller, "Update of Induced Environment Contamination Monitor Results." AIAA Shuttle Environment and Operation Meeting, October 31, November 2, 1983, Paper No. AIAA-83-2582-CP.

3. E. R. Miller, Editor, "STS-2, -3, -4 Induced Environment Contamination Monitor (IECM) Summary Report, NASA TM-82524, MSFC, February 1983.

4. S. G. Tanner, T. Wilkerson, Editors, "The Shuttle Environment Workshop," J. Lehmann, Organizer, Workshop Sponsored NASA Office Space Science and Application, October 5, 1982, Calverton, MD.

5. J. J. Scialdone, "A Preliminary Assessment of the Self-Induced Environment and Contamination of the Space Telescope," NASA TM-83936, GSFC, April, 1982.

6. E. N. Borson, "Evaluation of the Ground Contamination Environment for STS Payloads," Paper in the Shuttle Environment Workshop, S.G. Tanner, T. Wilkerson, Editors, October 1982, Calverton, MD, Contract No. NAS5-27367.

7. J. D. Austin "Contamination Control Plan for Prelaunch Operations," Proceedings of SPIE, Volume 338, Paper No. 338-03, May 4, 1982, Arlington, VA.

8. P. N. Peters, H. B. Hester, W. Bertsch, H. Mayfield, D. Zatko, "Induced Environment Contamination Monitor (IECM), Air Sampler Results from STS-2 Flight," Proceedings of SPIE, Volume 338, May 4, 1982, Arlington, Virginia.

9. S. Jacobs, Personal Communication, August 11, 1982.

10. Anon., "U.S. Standard Atmosphere, 1976" National Oceanic and Atmospheric Adm/NASA/USAF, October 1976.

11. D. J. Santeler, D. H. Holkeboer, D. W. Jones, F. Pagano, "Vacuum Technology and Space Simulation," NASA SP-105, 1966.

12. J. J. Scialdone, "Self-Contamination and Environment of an Orbiting Satellite," NASA TN-D-6645, May, 1972.

13. G. R. Carignan, Personal Communication, August 15, 1983, and in STS-2, -3, -4, "Induced Environment Contamination Monitor," Summary Report, NASA TM-82524, February 1983.

14. J. J. Scialdone, "Assessment of Shuttle Payloads Gaseous Environment," NASA TM-80286, GSFC, May 1979.

15. J. J. Scialdone, "Correlation of Self-Contamination Experiments in Orbit and Scattering Return Flux Calculation," NASA TND-8438, March, 1977.

16. L. J. Leger, "Oxygen Atom Reaction with Shuttle Materials at Orbital Altitudes-Data and Experimental Status," AIAA 21st Aerospace Sciences Meeting, January 10, 1983, Reno, Nevada, Paper No. AIAA-83-0073.