Table 2 Comparison of heat of combustion data

Fuel	Heat of combuston, kcal/g	
	Present method	Earlier method[6]
p-Dimethylaminobenzaldehyde-phenylhydrazone	4.52	2.25[9,13]
Furfuraldehydephenylyrazone	5.07	2.16[9,13]
p-Hydroxybenzaldehydedimethyl-hydrazone	4.95	2.16[9,13]
mono-Acetonethiocarbonohydrazone	5.43	2.18

shown are the theoretical heats of combustion of the thiocarbonohydrazones with nitric acid as oxidizer. These theoretical values were calculated from the heat of formation data which in turn were determined from the heats of combustion in oxygen.[12] In the calculations CO_2, N_2 and $H_2SO_4xH_2O$ were assumed to be the products of combustion. In each case, it is found that the maximum heat is liberated when the amount of the oxidizer is slightly more than stoichiometric requirement. In general, the observed heats of combustion of the hybrid systems are in the range of 4 to 6 kcal/g of the fuel. When some solid fuels such as formaldehyde-, acetone- and 2-furadehyde-thiocarbonohydrazones are used, the observed heat of combustion is nearly 97% of the theoretical value, indicating the excellent performance of the device when appropriate propellants are chosen. In other cases, the observed values are somewhat lower than those calculated by assuming complete combustion with HNO_3, using the heats of formation data of the respective fuels. The poor realization of the heat of combustion in these cases could mean incompatibility of the propellants, as a result of which the combustion is incomplete, under these conditions. Usually a small amount of solid/liquid residue was observed in the cup after combustion in such cases. It is also possible, however, that products other than those assumed for calculating the theoretical heat of combustion values, are formed.

In the thiocarbonohydrazones-WFNA systems, it is generally observed that the realization of heat of combustion in aliphatic carbonyl derivatives is higher than the aromatic aldehyde analogs. A comparison of the heat of combustion data shows that they vary with the functional group on the benzene ring in aromatic alehyde derivatives, in the order

$$(CH_3)_2N- > H > Cl$$

The electron-releasing groups appear to facilitate the combustion. When NO_2, a strong electron-withdrawing group, is substituted in the benzene ring the system becomes nonhypergolic. The heats of combustion of the other derivatives are found to be in the order

Formaldehyde < 2 − Furaldehyde < Acetone < Cyclohexanone

which is to be expected on the basis of their theoretical values. However, it is to be noted that the percentage realization of heat does not follow the above order. Of hypergolic biliquid propellant systems, the UDMH-WFNA system gives significantly lower heat of combustion than the theoretical value. This value is improved slightly when RFNA is used as oxidizer instead. The reason for this is not very clear. It could arguably be the incomplete combustion. However, the realization of the heat of combustion in the case of MMH-WFNA system is about 90%.

A comparison of the experimental values of the heat of combustion determined by the present method and those obtained[9,13] using the apparatus described by Rastogi and Kishore is made in Table 2. It is obvious that the present device is far superior. Furthermore, because of its simplicity of operation this device could be conveniently applied in studies relating to the measurements of heats of solution, hydrolysis, neutralization, etc.

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Charging of a Manned Maneuvering Unit in the Shuttle Wake

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Introduction

WHEN the Space Shuttle flies in polar orbit, it will encounter the aurora at times. The aurora is produced by

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streams of electrons with energies in the 10-keV range and currents of up to 10 $\mu A/m^2$. Ionospheric satellites produce a wake due to their suprathermal motion. The ion density in the wake is highly depleted, being reduced at some altitudes by a factor of 10^5. In the presence of auroral electronic streams the Manned Maneuvering Unit (MMU) might charge up negatively.[1] If the MMU charged to a highly negative potential, it would attract ambient positive ions, possibly reducing charging to negligibly small levels. In this paper the problem of charging is dealt with by means of a simple model. The model addresses the question of how high a potential the MMU can charge to before the innermost ion of the Mach cone deviates enough to be collected. This threshold provides a lower bound to the negative charging potential, assuming that the aurora is sufficiently energetic to charge in the absence of ions. To obtain an estimate of the equilibrium potential of the MMU, the ion current, as a function of MMU voltage, is calculated and equated to the incident electron current. It is shown that over a wide range of auroral electron and ionospheric ion conditions, the equilibrium potential depends mainly on the relative sizes of the Shuttle and MMU and the orbital velocity of the Shuttle. The negative potential is of the order of -1350 volts.

The Model

In order to estimate charging in the Shuttle wake, the effect of the terrestial magnetic fields is neglected. The ion larmor radius is about 1 m, so that this assumption is not too drastic. The configuration is shown in Fig. 1.

In this scenario, the MMU is represented by a sphere covered with either a single conductor or dielectric material. This sphere of radius r_p is in the wake of a vehicle of radius r_s. Assuming that we are in the coordinate system of the vehicle moving at velocity $-v_0$, the ions and electrons of the ambient plasma will stream at a velocity v_0. The total energy of an ion streaming by just at the surface of the Shuttle is

$$E = \tfrac{1}{2} m(\dot{r}^2 + r^2\dot{\theta}^2) + qV(r) \tag{1}$$

where m is the ion mass, q the ion charge and $V(r)$ the potential.

If the ion initial velocity is the streaming velocity v_0 and p is the perpendicular distance from the center of the sphere to the orbit, then conservation of angular momentum gives

$$pv_0 = r^2\dot{\theta} \tag{2}$$

When the ion is far away from the sphere

$$E = \tfrac{1}{2} m v_0^2 \tag{3}$$

$$\dot{r} = \frac{v_0}{r}\left(\left[r^2\left(1 - \frac{2qV(r)}{mv_0^2}\right)\right] - p^2\right)^{1/2} \tag{4}$$

where qV is negative for accelerating fields. For an impact parameter p, the orbit grazes the probe when $\dot{r} = 0$, or

$$p^2 = r_p^2\left(1 - \frac{2qV_p}{mv_0^2}\right) \tag{5}$$

solving for the probe or MMU voltage:

$$-qV_p = \tfrac{1}{2} m v^2\left(\frac{p^2}{r_p^2} - 1\right) \tag{6}$$

This is the voltage to which the MMU will charge before it is able to attract ions from the inner edge of the Mach cone. Taking an example of an MMU radius of 1 m, a Shuttle radius of 15 m, as well as an O^+ ion energy of 6 eV, a potential of -1344 volts is obtained, which represents a lower limit to charging.

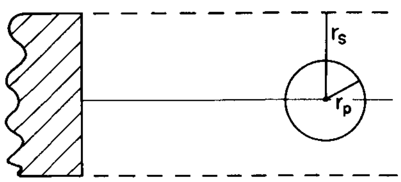

Fig. 1 The MMU is represented by a sphere of radius r_p in the wake of a cylindrically symmetric vehicle of radius r_s.

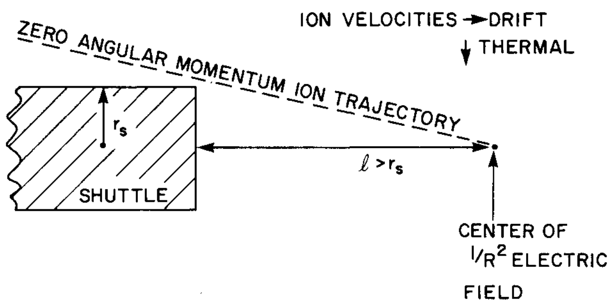

Fig. 2 The limiting case of a very small MMU in the wake.

As the negative potential of the MMU rises above this threshold value, a copious current of ions is available for neutralization. The MMU voltage cannot be more than a few volts higher, so that the MMU will charge almost precisely to the threshold value.

Current Needed for Charging

Auroral electron currents usually occur in thin sheets, so that the shortest time of exposure for the MMU would be for those orbits which traverse the current sheet across its narrowest dimension. The minimum exposure time is

$$t_{min} = L/v_0 \tag{7}$$

where L is the current sheet minimum thickness and v_0 is the shuttle velocity. For a 1 km minimum current sheet thickness and an orbital velocity of 8 km/s the minimum charging time is $t_{min} = 0.125$ s. Assuming an MMU radius of 1 m the MMU's capacitance is $C = 4\pi\epsilon_0 r_p$ and the minimum auroral current necessary for charging to the threshold voltage V_0 is

$$i = \frac{CV_0}{t_{min}} \tag{8}$$

For auroral charging charging currents which are isotropic over the upper hemisphere, which is the usual case, for $C = 4\pi\epsilon_0 r_p$, $V_0 = -1350$ volts, and $t_{min} = 0.125$ s, $j_{min} = 0.11$ $\mu A/m^2$.

This minimum current density is about 0.002 times the highest measured auroral current density in the kiloelectronvolt energy range. Typically auroral electron spectra have high-energy peak, and it is the current in this peak which is relevant for high voltage charging.

This threshold charging current is quite low, so that objects in the wake, such as the MMU, should exhibit charging to high negative potentials quite frequently. In contrast, charging of the Shuttle requires auroral currents which are nearly the highest measured value.[2]

Limitations

If the probe is less than a Shuttle radius behind the Shuttle, the electric field surrounding the probe will be substantially influenced by the Shuttle. The field will no longer be spherically symmetric. Angular momentum will not be conserved and the calculation becomes invalid. The theory predicts that if the probe is well behind the Shuttle, its equilibrium potential will become increasingly negative as its radius is reduced approaching minus infinity as the radius squared approaches zero. The following argument will be used to show that the potential in fact will approach some finite limiting value and not minus infinity. For an ion to reach the center of an r^{-2} field it must have zero angular velocity. As shown in the figure, this requires a substantial thermal velocity perpendicular to the drift velocity.

The approximate thermal radial velocity of zero angular momentum ion is

$$v_r = \left(\frac{p}{1}\right) v \tag{9}$$

The current density seen by a very small object in the center of the wake is approximately

$$i = i_0\left(1+\frac{2qV}{mv^2}\right)\exp\left[-\left(\frac{pv}{1}\right)^2\frac{m}{2kT_i}\right] \tag{10}$$

where i_0 = undisturbed ion drift current density. The approximate current balance equation is then

$$i = i_0\left(1+\frac{2qV}{mv^2}\right)\exp\left[-\left(\frac{pv}{1}\right)^2\frac{m}{2kT_i}\right] = i_0\exp\left(\frac{qV}{kT_e}\right) \tag{11}$$

This then gives the limiting potential as r_p approaches zero. Note that this equation determines how far behind the Shuttle wake effects dominate charging. The effective wake length is roughly:

$$1 = pv\left(\frac{m}{2kT}\right)^{1/2} \tag{12}$$

Conclusions

The Manned Maneuvering Unit can charge to about −1400 volts in the wake of the Shuttle as an oxygen ion plasma. One percent hydrogen would lower the potentials by 14%, and 6% hydrogen would reduce the potential by a factor of two. The presence of a higher percentage of hydrogen ions at higher altitudes would substantially decrease the maximum potential. Is a potential of −1400 volts hazardous to the man in the Manned Maneuvering Unit? Perhaps a spark will occur when the unit touches the Shuttle. This potential, if sufficiently nonuniform on the MMU surface, may produce a surface discharge. Radiation from these arcs may be harmful to electronics in the vicinity and therefore affect the MMU mission.

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Radiative and Convective Effects on the Vibrational Heating of Semitransparent Polymers

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Nomenclature

A_r = a constant related to the effect of temperature on viscosity
a_r = Rosseland absorption coefficient for the optically thick limit
Bi = Biot number, $= hL_c/k$
k = thermal conductivity of medium
L = slab half thickness, L_c = characteristic length, with L for planar geometry and R for cyclindrical and spherical geometries
N = radiation-conduction parameter for the optically thick limit defined as $N = 16\,n^2\sigma T_\infty^3/3a_r k$
n = material index of refraction
q_r = radiative heat flux; q_{r1} = radiative heat flux at the surface
R = radius of cylindrical and spherical samples
T = temperature; T_s = surface temperature; T_0 = centerline temperature at $x = L$ or $r = 0$; T_1 = effective slip temperature at boundary; T_∞ = ambient temperature
x = distance from the wall
β = dimensionless heat generation, $= \gamma A_r L^2/k$; β_c = critical value of β
γ = $= \frac{1}{2}\tau_0^2\omega^{1-m}B$ with B and m being parameters
δ = $A_r T_\infty$
ξ = dimensionless distance $= x/L$ for planar geometry and $= 1 - r/R$ for cylindrical and spherical geometries
σ = Stefan-Boltzmann constant
τ_0 = stress amplitude; τ_{xy} = stress in slab; τ_{rz} = stress in cylinder
ϕ = dimensionless temperature $= A_r(T - T_\infty)$; $\phi_0 = A_r(T_0 - T_\infty)$
ψ = dimensionless temperature $= T/T_\infty$; $\psi_0 = T_0/T_\infty$; $\psi_1 = T_1/T_\infty$
ω = frequency of oscillating axial stress

Introduction

TESTING of material samples under cyclic loading may not, at times, lead to a thermal steady state in which the nonlinear rate of heat generation by the viscous resistance of the material is balanced by the rate of heat transfer from the material to its surroundings. It has been found[1,2] that testing with a constant stress amplitude leads to certain critical states beyond which thermal explosion or disintegration of the sample takes place.

In a previous study,[3] the effects of radiative transport exhibited by sample emission and absorption during cyclic loading were considered for the optically thin and thick limits. Prescribed temperatures at the boundary with an effective slip coefficient for combined conduction and optically thick radiation were imposed on the model. The results obtained from the study demonstrated the significance of the radiative transport in assessing the tolerance limit of a semitransparent sample to cyclic loading.

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