Effective Martian Sky Temperatures for Inclined Plates

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Nomenclature

$F_{dA\text{-Sky}}$ = 0.5 (1 + cosα), view factor from the plate to the sky
P_s = surface pressure, mbar
Q = heat flux from the sky incident on the plate, gcal/cm² day
T_s = surface temperature, °K
T_{Sky} = $(Q/\sigma F_{dA\text{-Sky}})^{1/4}$, effective sky temperature, °K
X_i = volumetric percentage
α = vertex angle between the normal to the plate and the vertical
σ = Stefan-Boltzman constant

IN an earlier paper,[1] the author has calculated the downward atmospheric radiation fluxes, for several Martian atmospheric models, incident on a horizontal plate located on the Martian surface. These calculations have been extended to the case of a plate inclined to the horizontal using updated Martian atmospheric models which reflect the data obtained from Mariners 6 and 7. Elsasser's approach to atmospheric radiation calculations was extended to include inclined plates, and radiation tables were prepared for several inclination angles. Effective Martian sky temperatures, defined as the temperature of a black hemisphere with the same total emittance as the atmosphere, were calculated as previously.

The effective sky temperatures were calculated for the five model atmospheres of the Viking 75 Project Mars Engineering Model[2] and for the Jet Propulsion Laboratory (JPL) Lower Atmosphere Model I[3] for four surface temperatures. The Viking Project atmospheres include the results of the measurements made dy Mariners 6 and 7; however, the older JPL atmosphere does not. All of these atmospheric models were developed primarily for preliminary design purposes. It should be emphasized that the assumptions of the various atmospheric models vary considerably, and this should be taken into account when comparing their respective sky temperatures. The atmospheric composition, surface pressures and temperatrues, and the effective sky temperatures for plate inclinations of 0°, 30° 60°, 75°, and 90° are presented in Tables 1 and 2. In addition, effective sky temperatures were computed for several surface altitudes for the Viking Project atmospheres, Table 3.

Table 1 Effective sky temperatures (°K) for the 1970 Viking Engineering Model Mars atmospheres as a function of surface inclinations

Atmospheric model	Composition, X_i: CO_2	Ar	P_s, mbar	T_s, °K	CO_2 Abundance m-atm
Minimum surface density	100	0	4	280	55
Minimum surface density scale height	100	0	4	180	55
Mean	87	13	6	230	72
Maximum surface density	71.1	28.9	10	180	100
Maximum surface density scale height	71.1	28.9	10	280	100
	T_{Sky}, °K				
	α = 0°	30°	60°	75°	90°
Minimum surface density	166.8	167.7	169.1	170.0	171.1
Minimum surface density scale height	100.4	103.0	103.8	104.3	104.9
Mean	140.2	142.0	143.0	143.7	144.4
Maximum surface density	107.3	111.2	111.9	112.2	113.0
Maximum surface density scale height	173.1	173.9	174.9	175.6	176.9

Table 2 Effective sky temperatures (°K) for the 1967 JPL Mars Lower Atmosphere Model I

Composition, X_i					T_{Sky}, °K				
CO_2	Ar	N_2	P_s, mbar	T_s, °K	α = 0°	30°	60°	75°	90°
80	10	10	10	180	111.9	113.6	114.1	114.4	115.5
80	10	10	10	210	131.9	133.4	134.1	134.6	135.7
80	10	10	10	230	145.4	146.8	147.6	148.1	149.3
80	10	10	10	290	183.2	184.1	185.2	185.9	187.3

Table 3 Variation of T_{Sky} with altitude for a horizontal plate

Atmospheric model	Altitude, km: 10	7	3	0	−3	−7	−10
Minimum surface density	135.1	141.7	155.9	166.8	177.4	191.0	200.9
Minimum surface density scale height	68.0	77.7	90.1	100.4	111.3	126.3	138.2
Mean	115.4	121.4	128.9	140.2	152.2	168.2	179.8
Maximum surface density	88.4	93.8	101.2	107.3	114.5	124.1	131.7
Maximum surface density scale height	149.5	154.1	161.8	173.1	184.6	199.5	210.3

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It is interesting to note that the effective sky temperatures were found to increase only slightly with increasing plate inclination. The effect of surface temperature on the effective sky temperature is shown for the JPL atmospheric model. The Viking Project atmospheres were published for only a single surface temperature.

The normal variations in altitude and temperature that a Martian lander would expect to encounter would have a greater effect on the effective sky temperature than the effect of vehicle surface inclinations.

References

[1] Wachter, J. P., "Effective Sky Temperatures for Several Martian Atmospheric Models," *Journal of Spacecraft and Rockets*, Vol. 7, No. 3, March 1970, pp. 350–352.

[2] Schmitz, R. A. and Soffen, G. A., "Viking 75 Project Mars Engineering Model," M75-125-0, March 13, 1970, Viking Project Office, NASA.

[3] Jet Propulsion Laboratory Lunar and Planetary Sciences Section Staff, "Mars Scientific Model," JPL Document 606-1, Vol. 1, July 1968, Jet Propulsion Lab., Pasadena, Calif., Sec. 5.1, pp. 1–13, Sec. 5.2, pp. 1–11, Sec. 5.3, pp. 1–22.

Ignition of Metal Powders in Gaseous ClF_3

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IN Ref. 1, data were presented on the hypergolic ignition of metals in gaseous and liquid ClF_3 and ClF_5, in respect to their use as spacecraft chemical heaters. Since ClF_3 has also been proposed for use in the primary combustors of air-augmented rockets, the hypergolicity of gaseous ClF_3 with several additional metal powders has now been investigated. Preliminary tests were performed by passing gaseous ClF_3 over the metal powders contained in a small porcelain crucible at ambient conditions. The materials of most interest were tested for spontaneous ignition on a surface mixing burner (Fig. 1). The metal powders were entrained in a stream of N_2 gas in the mixing chamber A of the powder-dispersing device B of an S. S. White abrasive cutting machine. The suspended material was then transported into the center tube of the burner D. The ClF_3 was introduced through the bundle of tubes surrounding the center tube and mixed rapidly with the dust cloud at the surface of the burner. The tubes were $\frac{1}{8}$-in.-o.d. stainless steel, and the body of the burner was 1-in. i.d. Dust concentrations up to 300 mg/l of N_2 were attainable, and the normal procedure was to vary the concentration from zero to the maximum.

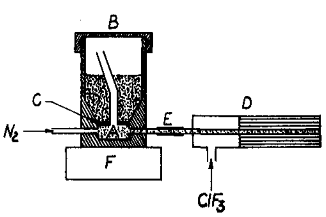

Fig. 1 Surface mixing burner apparatus: A, mixing chamber; B, powder dispersing unit; C, orifice plate; D, surface mixing burner; E, "Tygon" tubing; and F, vibrating table.

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Table 1 Ignition of materials with gaseous ClF_3 (crucible tests)

Material	Ignition	Comments
Cabot carbon black, Sterling MTX	Yes	Glowed, no vigorous burning
Acheson graphite (Dag Ultrafine, 4–5 μ)	Yes	
Valley Metallurgical H-30 Al[a] (30 μ)	No	
Valley Metallurgical H-5 Al[a] (5 μ)	No	
Kawecki boron, Grade I, Lot 362 × 18, neutralized (2–4 μ)	Yes	
Boron carbide, Fisher Cat. B-377	Yes	
Magnesium, 44 μ	Yes	Vigorous, self-sustaining flame
Nickel, 200 mesh, C B 528, 311187, The Matheson Co., Inc.	No	
Zinc dust, Merck 41598, 90% Zn	Yes	Bright flash
Molybdenum, lot MO-1501, grade 150–250, Sylvania Electric Products Inc.	Yes	
Iron filings	Yes	Very reactive
Steel wool, Federal Grade O	Yes	Very reactive
Tungsten, 2 μ	Yes	
Zirconium hydride	No	
Zirconium, 5 μ	Yes	Self-sustaining flame

[a] The hypergolic ignition of aluminum reported in Ref. 1 could be accounted for by the presence of small amounts of a reactive impurity, such as moisture or a hydrocarbon, or by an experimental configuration which more effectively reduced heat loss.

Results and Discussion

The results of the simple crucible tests presented in Table 1 are self-explanatory. The surface mixing burner experiments are summarized in Table 2. The B and B_4C powders ignited spontaneously very close to the surface of the burner at all dust concentrations investigated and burned with a steady flame. The Al powder ignited intermittently 1 or 2 in. from the burner surface, but a steady flame could not be established. Graphite showed no evidence of reaction, even though it ignited in the crucible tests (Table 1); apparently the reaction is very slow, and heat losses in the burner experiments preclude ignition. At low dust concentrations the B/Al mixture behaved as if the B and Al were burning independently; i.e., the boron flame was readily established, but the aluminum ignited intermittently. At higher dust concentrations, the heat released by the combustion of the boron was sufficient to promote rapid ignition of the aluminum, and a steady, very bright flame resulted.

These results indicate that B, B_4C, and B/Al mixtures should ignite spontaneously with ClF_3 in the primary combustors of air-augmented rockets even when introduced as the

Table 2 Ignition of powdered materials with gaseous chlorine trifluoride (surface-mixing burner tests)

Material	Ignition	Comments
Amorphous boron, Kawecki Grade I, 4–5 μ diam	Yes	Stable flame established
Boron carbide, Norton Grade 6 (0.2 μ diam)	Yes	Stable flame established
Spherical aluminum Valley Metallurgical H-5 (5 μ diam)	Yes	Intermittent combustion
Graphite, Acheson "Dag Ultrafine" (4–5 μ diam)	No	No evidence of reaction
60 wt % Kawecki boron/40 wt % Valley Metallurgical Al H-5 (5 μ diam)	Yes	Stable flame at high dust concentrations (see text)