Fig. 2 Surface pressure distributions on sharp cones;
$$0.3 \lesssim T_w/T_0 \lesssim 1.$$

and the factor $(1 + S_w)$ should be replaced by $8/(1 + S_w)$ in Eq. (4.24). It then follows that the factor $(2 + 2S_w)/(1 + 3S_w)$ appearing in Eqs. (4.25) and (4.26) should be replaced by $8/[1 + 3S_w)(1 + S_w)]$ and the right side of Eq. (4.27) should be multiplied by S_w.

Note that all the final results of Ref. 3 are incorrect for $S_w \neq 1$. The errors are most severe when the wall is highly cooled (i.e., $S_w \simeq 0$). In particular, the surface pressure p_c should be

$$p_c = [(1 + S_w)/2](p_c)_{\text{Ref. 3}}$$

In Figs. 1 and 2, the corrected surface pressure is superimposed on McCroskey's original figures. It appears that in both the highly cooled wall and the moderately cooled wall cases, there are regions in which the surface pressure from strong interaction theory agrees with the experimental data.

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Comment on "Carbon-Silica Reaction in Silica-Phenolic Composites"

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REFERENCE 1 considers the effect of subsurface reactions between silica and carbon upon the ablative response of silica-phenolic char layers. The analysis includes consideration of the energetic effect of silica-carbon reactions relative to other energy events prevailing in the immediate vicinity of the silica-carbon reaction zone. One of the conclusions reached in the reference from equilibrium chemistry considerations, that "the silica-carbon reaction is the dominant heat effect in the eroding wall," is believed misleading because it follows from considering only part of the over-all reaction events of importance. The present Comment gives further

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consideration to silica-carbon reaction events within the constraints of chemical equilibrium, and concludes that the net energetic effect is small and may be either endothermic or exothermic depending upon environmental gas composition. An opinion is also offered relative to the role played by silica-carbon reactions in affecting ablative performance of materials such as silica-phenolic.

In the analysis of Ref. 1, the endothermic silica-carbon reaction (reaction 1) is considered, but other (exothermic) reactions, such as reactions 2–4, between the products of reaction 1 and oxidizing species present for most ablative material applications are not considered. The oxidizing species represented in reactions 2–4 are typical of those present in boundary-layer flows for several applications of interest, i.e., earth entry or exhaust products in many rocket environments of current interest. Chemical equilibrium considerations dictate that all reactions in Table 1 (reactions 1–7) proceed strongly to the right for surface temperatures in the vicinity of 2,000°K and above. Hence, it is concluded that virtually all SiO generated below the surface will be reoxidized at the surface to form SiO_2 (l), provided the following conditions are satisfied: 1) that chemical equilibrium is achieved at the surface, and 2) that the rate of transfer of oxidizing species to the surface is at least as great as the rate of injection of SiO from below the surface. It is pertinent to consider the validity of these two provisions.

If chemical kinetic effects are such as to cause reactions 2–4 to proceed more slowly than reaction 1, the conclusion of Ref. 1 must be accepted to the extent that kinetic mechanisms dominate. We are not aware of evidence that reactions 2–4 are slower than reaction 1, and since they occur at the surface where temperature levels are generally higher than in depth, it seems reasonable to expect reactions 2–4 to be at least as fast as reaction 1. The second provision to be considered relates to the quantity of oxidizing species available and this clearly depends upon the environment. Our experience with analyzing silica-phenolic response in air, and rocket nozzle environments for oxygen-hydrogen and nitrogen tetroxide-Aerozine propellants,[2,3] indicates that sufficient oxygen is available to reoxidize virtually all SiO at the surface for a wide range of pressure and heat flux levels. Consideration of advanced propellant systems such as oxygen difluoride-diborane, however, does result in less SiO_2 formation at the ablating surface because less oxygen is available.

If virtually all SiO gas generated by reaction 1 is reoxidized at the surface by reactions such as 2, 3, or 4, then it is apparent that the net energy effect of silica-carbon reactions is more typically indicated by reactions 5, 6, or 7, and is small relative to the energy effect of reaction 1. This is the case because the net effect of the reactions is the oxidization of the carbonaceous char, with SiO_2 entering only as an intermediary. This conclusion has been analytically verified in computer experiments[3] we have performed with an ablation code which does account for the kinetically controlled silica-carbon reaction 1 in depth. Dual runs respectively allowing and excluding reaction 1 in depth resulted in substantially the same predicted surface temperature (presuming chemical equilibrium at the surface).

Table 1 Reactions of interest

Reaction[a]	Energy absorbed (+) or released (−) at 2200°K, kcal/mole	Reaction no.
$SiO_2(l) + C(s) \rightarrow SiO + CO$	+154	1
$SiO + \frac{1}{2}O_2 \rightarrow SiO_2(l)$	−182	2
$SiO + H_2O \rightarrow SiO_2(l) + H_2$	−122	3
$SiO + CO_2 \rightarrow SiO_2(l) + CO$	−116	4
$C(s) + \frac{1}{2}O_2 \rightarrow CO$	−29	5
$C(s) + H_2O \rightarrow CO + H_2$	+32	6
$C(s) + CO_2 \rightarrow 2 CO$	+37	7

[a] (l) and (s) refer to liquid and solid, respectively. Unmarked species are gases.

Our experience with attempting to corroborate experimental ablation data with computer code predictions[3] leads us to believe that the primary importance of silica-carbon reactions in depth lies with the dominating changes in thermal and mechanical properties of the char which result when the reaction proceeds rather than with an energy effect. Comparisons of computer predictions to test data and post-test samples tend to support this opinion, but of course much work remains to be done before all aspects of the complex response of silica reinforced materials are well characterized.

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[1] Romie, F. W., "Carbon-Silica Reaction in Silica-Phenolic Composites," *AIAA Journal*, Vol. 5, No. 8, Aug. 1967, pp. 1511–1513.

[2] Rindal, R. A., Flood, D. T., and Kendall, R. M., "Analytical and Experimental Study of Ablation Materials for Rocket Engine Application," NASA CR-54757, May 15, 1966, Vidya Div., Itek Corp., Palo Alto, Calif.

[3] Rindal, R. A. et al., "Experimental and Theoretical Analysis of Ablative Material Response in a Liquid-Propellant Rocket Engine," NASA CR-72301, Sept. 21, 1967, Aerotherm Corp., Palo Alto, Calif.

Erratum: "Some Comments on the Laminar Compressible Boundary-Layer Analysis with Arbitrary Pressure Gradient"

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EQUATION (16) on page 331 should read:

$$n = 2(1 + \epsilon)n_{\text{stag}} \cdot \frac{du_e}{dx} \left(1 + \frac{\gamma - 1}{2} M_e^2\right) \cdot \frac{\int_0^x p_e^{\alpha} u_e r_w^{2\epsilon} dx}{p_e^{\alpha} u_e^2 r_w^{2\epsilon}}$$