reaction layer thickness as long as the rate of burning during the pulse is fast enough. A plot of peak pressure vs reaction layer thickness, also shown in Fig. 3, exhibits a remarkably good linearity.

Experiments conducted at higher levels of K, but at comparable L^*-range, have shown that the chuffing frequency is nearly the same, but that the peak pressure level increases with K (resembling the steady-state behavior of the rocket). The L^*-K (or equivalent chamber pressure) boundary for transition from chuffing to stable combustion is similar to the ones identified by earlier workers.[6,7]

Conclusions

From the results of the experiments conducted to study the chuffing behavior in composite propellants, it can be concluded that the frequency of chuffing and the pressure amplitudes vary systematically with L^*. The experiments have enabled the measurement of reaction layer thickness at different L^* ranges. The level of L^* seems to influence the reaction layer thickness, which gives rise to a definite pressure pulse for sufficiently low values of K. Any description of chuffing, therefore, must consider motor characteristics such as L^* and K in addition to the condensed phase processes.

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Estimate of the Probability of a Lightning Strike to the Galileo Probe

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MOST lightning strikes to aerospace vehicles occur in or near clouds. Because the Galileo entry probe will spend most of its operational lifetime in the clouds of Jupiter, and because Jupiter is known to have lightning activity,[1] it seems appropriate to consider the risk of a lightning strike to the probe. A strike to the probe could cause physical damage to the structure and/or damage to the electronic equipment aboard the probe, depending on the location of the strike and the size and shape of the current pulse.[2,3] It is possible that the instrumentation failures that occurred on all four Pioneer Venus entry probes at an altitude of 12 km were due to an external electric discharge.[4]

Although a strike to a vehicle is more probable when the vehicle is in a thundercloud, strikes to vehicles can and do occur when the vehicle is within a cloud that is not producing lightning flashes. Such strikes are often caused by the presence of the vehicle, i.e., strikes occur in a region where no strikes occur before or after the presence of the vehicle.[5,6] One of the more spectacular examples of an aerospace vehicle triggering lightning flashes was the launch of Apollo 12 (Ref. 3). It was struck twice as it rose through the cloud layer above Cape Canaveral on Nov. 14, 1969. No lightning was observed before or after the launch.[3] The fundamental cause of a strike to a vehicle is believed to be the intensification of a preexisting electric field by the vehicle. Consequently, large vehicles can cause strikes where smaller vehicles would not.

No general theory exists for predicting the strike frequency to a vehicle. However, aircraft experience is available and is used here to develop an estimate of the strike probability. The estimation of the strike probability P_s naturally breaks into two parts, the probability P_t of a strike occurring while a vehicle is penetrating a thundercloud, and the probability P_c of a strike occuring while a vehicle is penetrating clouds in which no activity is observed prior to entry. To estimate P_c, the data tabulated in Ref. 2 for Air Force and Commercial aircraft operating in the United States will be used. A better estimate for P_c could be obtained if data on probability of a strike per hour of operation in nonthunderstorm clouds were available. Unfortunately, no value for that parameter could be found. Air Force aircraft suffer fewer strikes per hour of operation than do commercial aicraft because Air Force operations are curtailed in poor weather. For example, Air Force trainer aircraft are struck once per 3×10^5 h of operation. Air Force bombers are struck only once per 5×10^4 h. In Europe, the F-4 fighter aircraft is struck once per 1×10^4 h. Commercial aircraft flying in the United States are struck once per 3×10^3 h. The implication of these values is that as the fraction of time spent in clouds increases, so does the probability of a strike. The high rate of strikes to commercial planes is believed to be due to the commercial need to fly in all types of weather. It should be noted, however, that commercial aircraft do make every effort to avoid thunderstorm clouds and that commercial aircraft spend much operation time above clouds where there is little possiblity of a strike. In contrast to spending most of its operation time ouside the clouds, the Galileo Probe will spend most of its operational time in the clouds of Jupiter. If the electrification of the Jovian clouds is similar to that of terrestrial clouds, then P_c will be at least 3×10^{-4} per h.

To get an estimate of P_t, the results of the Storm Hazards program at the Langley Research Center will be used.[7] In that flight test program, an F-106B aircraft was flown through thunderstorms a total of 421 times. The aircraft received 176 direct strikes and 54 near misses. Therefore, a reasonable estimate for P_t is 0.42.

Next, the probability estimates should be corrected for differences in lightning activity on the two planets and for the differences in size between the Galileo Probe and the aircraft used to derive the estimates.

It is expected that the probabilities of a strike depend on the specific planetary flash rate, i.e., the global average number of flashes per square kilometer per hour. In Ref. 1 it is shown that the specific flash rate is similar for both planets. Hence, no correction for this parameter is needed.

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Both P_c and P_t are expected to be dependent upon the projection of the length of the vehicle on the direction of the electric field gradient. Because the Galileo Probe is substantially smaller than the aircraft considered, it might appear that the estimates of P_c and P_t should be reduced. However, the parachute attached to the Galileo Probe on its descent must be considered. If the parachute or its attachment cords become coated with aerosols or droplets during the passage through the clouds, the vehicle will intensify the field much more than if the probe descended alone. It will be assumed that the parachute and its attachment cords will be sufficiently conductive to cause field intensification. The length of the probe and parachute is 15 m. Consequently, the Galileo Probe with its parachute will intensify the vertical electric fields about as much as a commercial aircraft and somewhat more than an F-106B. The assumption that the intensification of the field by the probe is the same as that due to a commercial aircrat will tend to overestimate P_c because the horizontal field intensification will be smaller than that caused by the aircraft. However, because $P_c = 3\times10^{-4}$ probably underestimates the results of the commercial airline experience, the two factors will tend to compensate. Similarly, the larger vertical, but smaller horizontal, extent of the probe relative to the F-106B will tend to compensate. Therefore, "ball park" estimates of P_c and P_t will be obtained by setting them equal to those for aircraft flying through terrestrial clouds.

Next P_s will be calculated from P_c and P_t, and the fraction, f, of Jupiter covered by thunderstorms. An examination of the Voyager I images of the dark side of Jupiter shows that approximately 0.2% of the surface is covered with lightning flashes. Because the Voyager camera could detect only the brightest flashes, the total area covered by thunderstorms could be significantly larger.[1] P_s can now be estimated from

$$P_s = f * P_t + (1-f) * P_c * T = 0.002 * 0.42 + 0.998 * 3\times10^{-4} * 1 = 0.001 \quad (1)$$

where T is the flight time through the clouds. Although the duration of the flight between the top of the ammonia clouds and the base of the water clouds is expected to be near 1 h,[10] T could be somewhat less than 1 h if there are clear gaps between the cloud layers.

It is important to recognize the substantial uncertainties involved in each of the steps. The uncertainties arise from our lack of knowledge of the magnitude and extent of electric fields in the Jovian clouds as well as the lack of a validated theory that relates the strike probability to the magnitude of the electric field and the field intensification factor. Although an effort can be made to remedy the latter problem, no measurements of the electric fields in the clouds of Jupiter are available. No electric field measurements will be made by the Galileo probe, and no further missions to Jupiter are planned this century. Hence, a determination of the uncertainty in P_s appears unlikely in the near future. Consequently, P_s should be regarded as a "ball park" estimate with a large uncertainty.

Although the estimate of a strike to the probe is only 0.001, it is about the same as the expected failure rate due to other design factors. Therefore, when entry probes to cloud-covered planets are designed, it seems appropriate to consider measures to protect the vehicle and its payload from lightning activity.

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Effects of an S-Inlet on the Flow in a Dump Combustor

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Introduction

THE design of a combustion chamber involves various studies, of which flowfield analysis is an important part. Some design work is done analytically using computer codes, and detailed testing is done at a later stage. There are complex configurations where a design cannot be accomplished using the available codes. Experiments with either the actual or simulated flow are a reliable means of refining design. The flow in the combustion system can often be studied as an isolated process without heat release. Previous investigations [Ref. (1)] have shown that in certain systems, e.g., the flame holder, the hot (actual) and cold (simulated) flow patterns agree closely.

Swirl is used in some combustion chambers to achieve flame stabilization and improve fuel burning. Swirl can be achieved by: 1) tangential entry of fluid, 2) rotating vanes, or 3) guide vanes. Swirl generation by vanes is most attractive for application in ramjets [Ref. (2)]. That method of swirl was used here.

The different components of the system can have a significant effect on the flow pattern in the burner. Here, the changes in flow pattern that occur due to an S-inlet instead of a straight inlet are studied. They are employed in situations where a conventional straight inlet cannot be used, such as in certerline engine jet aircraft and in cruise missiles. It is conjectured that a nonuniform flow distribution and separation may result when an S-inlet is used.

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