Table 2 Expected variation from nominal in $v_s t_i/D_0$

Variation from nominal value $v_s t_i/D_0 = 1.75$	Expected frequency of occurrence of a variation larger than in the preceding column
±7.4%	Half of the time
±18.5%	Once in 10 tests
±30.3%	Once in 100 tests
±40.7%	Once in 1000 tests

relationship given in Eq. (4) is not valid for a squidding chute.

Test Data

Berndt's experimental data on the initial phase of inflation for 28 tests are summarized in Table 1. Excluding those four tests in Table 1 with $v_s \geq 300$ ft/sec (because of squidding), the remaining 24 tests give a mean value of 1.75 for the parameter $v_s t_i/D_0$, with a standard error† of ±0.19. That is, from the experimental data it is found that

$$v_s t_i/D_0 = 1.75 \pm 11\% \text{ standard error} \tag{5}$$

As indicated by the data of Table 1 and as known from experience, parachute inflation is a statistical phenomenon. Application of statistics† to the data of Table 1 indicates that one may expect variations in the parameter $v_s t_i/D_0$ in accordance with Table 2.

Summary and Conclusions

To recapitulate, we agree with Berndt[1] that the parachute inflation sequence occurs in two major phases. Elementary considerations show that the dimensionless parameter $v_s t_i/D_0$ should characterize the initial phase of inflation in incompressible flow. With the use of Berndt's data on average skirt inlet area and on canopy volume change during initial inflation, we calculated that one would expect a value of $v_s t_i/D_0 = 1.74$. We then used Berndt's experimental data for initial-phase inflation times and snatch velocities for 24 tests of 28-ft D_0 chutes to calculate that, for those tests, the parameter $v_s t_i/D_0$ actually exhibited an average value of 1.75.

Physically, $v_s t_i/D_0$ is the ratio of distance required for initial-phase inflation to parachute diameter. The results obtained in this paper show that $v_s t_i/D_0$ is constant in incompressible flow. Thus, for a given parachute, the distance for initial-phase inflation is constant, regardless of the velocity or altitude of deployment and regardless of the suspended weight (so long as squidding is not encountered).

It is intuitively evident that $v_s t_i/D_0$ should remain very nearly the same for any flat circular type of chute (e.g., solid, ring-slot, ribbon) if $\hat{c}_v$ remains sensibly constant. We would expect $\hat{c}_v$ to so remain constant as long as the chutes were similar in (suspension line length/diameter) and (number of lines/diameter) ratios.

Berndt correlates his experimental data by presenting empirical curves which permit one to calculate S_p/S_0 vs t/t_f. The empirical curves are entirely adequate for use with a chute for which t_f is known. However, their nature is such that t_i or t_f cannot readily be calculated for given arbitrary values of v_s and D_0. The utility of the dimensionless parameter $v_s t_i/D_0$ developed in this paper is that it allows calculation of t_i for any size chute and any v_s (barring squidding), once the value of $v_s t_i/D_0$ has been established for a particular class or type of chute.

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[2] Daughterty, R. L., *Hydraulics*, 4th ed., McGraw-Hill, New York, 1937, p. 123, Fig. 91-c.

[3] Brown, W. D., *Parachutes*, Pitman & Sons, London, 1951, pp. 67–86 and 100–102.

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† Using statistics of small samples.[4]

A Midair-Deployed Buoyancy Suspension System for the Briteye Battlefield Illumination Flare

Russell A. Pohl*
Raven Industries Inc., Sioux Falls, S. Dak.

VISUAL target illumination for both ground forces and air strikes by combat aircraft employs the use of light emitting pyrotechnic candles. These candles, more commonly called flares, are delivered to the target in two basic modes, ground to ground and air to ground. Ground-to-ground flares are ballistically deployed by various means ranging from hand held signals to large guns (i.e., the 105-mm howitzer) whereas air-to-ground flares are deployed by aircraft. Air-to-ground flares are delivered from external stores on attack aircraft or internal dispensers in cargo aircraft.

Since the basic function of a target illumination flare is to provide visible light in and over an area, it is necessary to maintain the flare in an airborne state during the burn time duration of the flare candle once it has been released from the aircraft. Parachutes of various sizes and design configurations are used to decelerate and provide a slow descent rate to enable a flare to remain airborne during the candle burn duration. The Mark-45 flare, which is a modification of the standard Mark-24, will be the basic flare used by both cargo- and fighter-type aircraft. It is compatible with dispenser and external store carriage and delivery techniques. The Mark-45 aircraft flare has a rated light output of 2 million candle power and a candle burn duration of 2 min. This updated version of the Mark-24 flare will be the primary aircraft delivered flare system used by the Armed Forces.

In the early 1960's studies were conducted to determine the illumination requirements for the support of night air attack missions and the capability of existing flares to meet these requirements. These studies, when combined with the operational requirements of the Navy and Air Force, led to the technical development of the Briteye Flare System. The requirements called for a flare system with a light output of 5 million candle power and a burn time duration of 5 min. An average descent rate of 5 fps was also included as an operational characteristic.

Analysis of the decelerator requirements for a long-duration, high-light-output flare indicated that the use of a parachute to provide a descent rate in the 5-fps range would result in critical parachute canopy loading. Preliminary experiments in the use of a balloon-type flare suspension system to provide both initial deceleration and very low terminal descent rates

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* Vice President. Member AIAA.

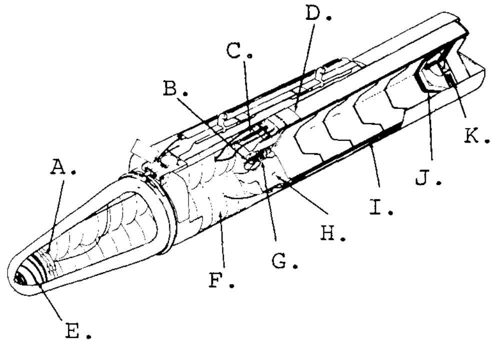

Fig. 1 Briteye Flare configuration: A) drogue chute, B) Y-bridle, C) line cutter, D) fusible joint, E) spring, F) balloon, G) primer igniter, H) heat generator, I) flare candle, J) red flare chemical agent, K) energy absorbing cable.

were investigated in 1963. These early experiments demonstrated that a hot-air balloon design could be used as a decelerator and slow terminal descent rate flare suspension system.

In May of 1964, the Naval Weapons Center of China Lake, California, began engineering development of a battlefield illumination flare with an output of 5 million candle power, a burn duration of 5 min, and a hot-air balloon-type suspension system. The development of the flare has been completed and is presently undergoing final evaluation. It is known as the "Briteye Flare" with a military nomenclature of MLU-32/B99.

The Briteye Flare is packaged as a streamlined external store configuration with an over-all length of 63 in. and external case diameter of 8.25 in. (excluding the strong back) and has a gross weight of 147 lb. It is compatible with all aircraft equipped with standard 14-in. external ordnance racks. The major components, as shown in Fig. 1, consist of an 84-lb magnesium-sodium nitrate-Laminac composition candle, 20-ft-diam balloon and drogue chute suspension system, heat generator, flare ignitor, outer case, strong back, and timer. The rated candle output is 5 million candle power with a 5-min burn duration. A visible red pyrotechnic composition, which serves as a burnout warning to the pilot, is pressed into the candle to provide a color change in the last seconds of candle burn.

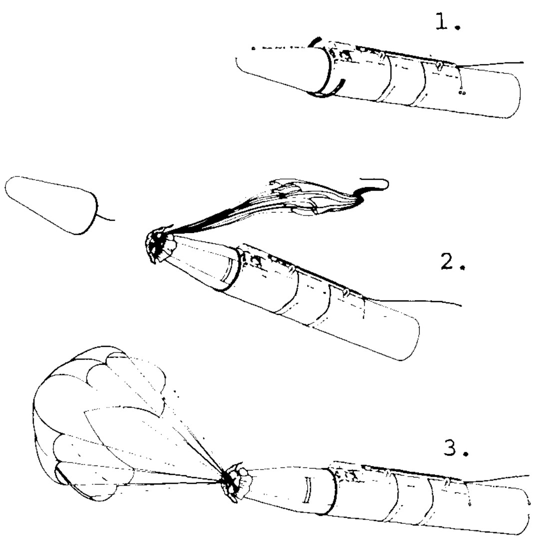

Fig. 2 Initial Briteye Flare sequence of operation: 1) V-band release and nose cone separation begins; 2) nose cone separation and drogue deployment; 3) deceleration stage, drogue chute fully deployed, reefing line cutter initiated.

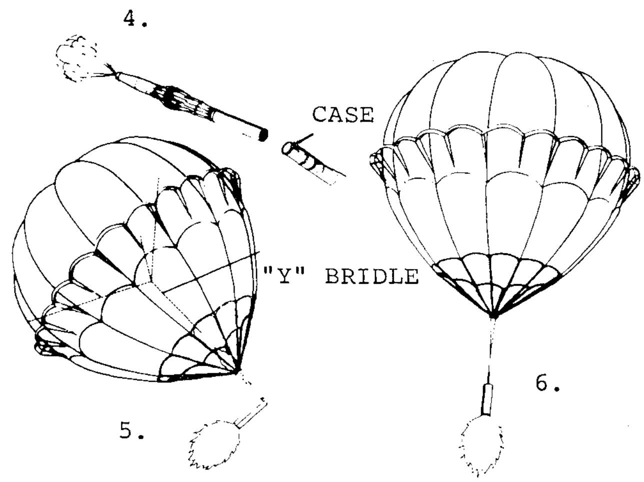

Fig. 3 Second stage Briteye Flare sequence of operation: 4) drogue chute breakaway, balloon deployment, and case separation; 5) ignition of heat generator and candle, and candle tipover; 6) flare cable deployment and flare candle burn.

In operation (Fig. 2-1), the flare is released by the pilot with external rack initiation. The timer, which is preset on the ground, has settings of 2, 5, 10, 15, 20, and 25 sec. Upon release from the aircraft, and integral arming wire is extracted from the timer and the timer is activated. The flare falls free from the aircraft in an unstable end-over-end and/or flat spin. After timer run out, the nose band is released (Fig. 2-2) and the nose cone is ejected by an internal spring contained in the forward end of the nose cone. A 30-in. R-PLUS drogue chute is deployed as the nose is ejected.

The snatch force/opening shock of the drogue chute initiates a retaining cable line cutter that allows the drogue chute to pull the outer bag off the packed balloon (Fig. 2-3). A 3-sec pyrotechnic delay in the line cutter prevents bag release until the store is stabilized. The delayed action vent and destruct system located on the balloon envelope is also initiated at this time.

The balloon is deployed (Fig. 3-4) as the outer bag is pulled away by the drogue chute, the outer case separates from

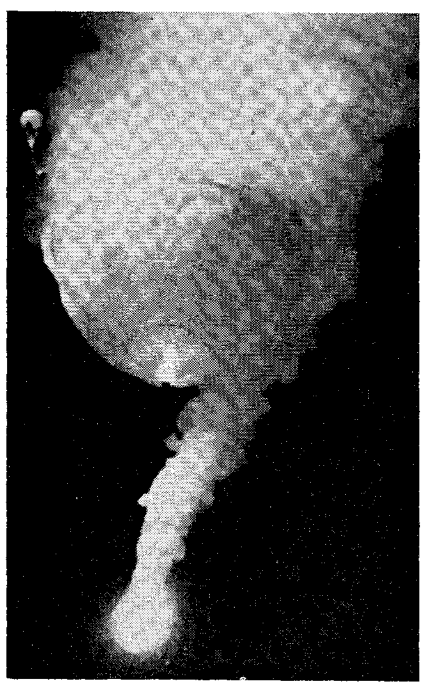

Fig. 4 Briteye system fully deployed in midair mode.

the system and ram air balloon inflation is accomplished through the one-way scoops located circumferentially on the balloon envelope near the balloon equator. A three-dimensional Y-bridle assembly attached to the inside of the balloon at the equator mechanically intiates the flare ignition sequence when the balloon has reached about 90% inflation (Fig. 3-5). This technique of environmental sensing and arming eliminates the need for a safe position on the mechanical timer.

The heat generator, a molded phenolicasbestos case containing a propellant composition, is housed in the interface hardware ahead of the flare candle and is in line with the lower throat of the balloon. The propellant grain is tailored to burn at a rate sufficient to provide a large volume of hot gas to induce the required thermal buoyancy into the balloon. Upon ignition the flare ignitor directs an intense short duration flame on the heat generator and flare candle; thus, both compositions are ignited at the same time. The heat generator output is directed into the balloon, thereby heating and lowering the density of the air in the balloon. The burning flare melts an aluminum separation ring, thus allowing the candle to separate from the interface hardware. As the candle falls the suspension cables, which are joined to a single cable fastened to and stored on the base of the candle, cause the candle to tip over burning face down and arrest the candle 20 ft below the balloon (Fig. 3-6). As the buoyancy increases in the balloon, the downward trajectory is slowed to a mean rate of 5 fps (Fig. 4). This descent rate is maintained by the residual heat in the balloon and the burning flare candle. Although a true hover-type trajectory could be accomplished, a slight downward rate is desirable to keep the dense smoke that is emitted by the burning candle from obscuring the light output.

As the candle burns, its weight loss tends to be compensated for by the loss of heat from the balloon. However, the decrease in weight is greater than the decrease in buoyancy. To compensate for this nonlinear weight-buoyancy phenomenon, a vent is cut in the balloon top 260 sec after drogue chute deployment. The vent increases the balloon heat loss and the mean descent rate of 5 fps is maintained. Some 320 sec after drogue chute deployment the self-destruct system cuts a large opening in the balloon, thus releasing the entrapped hot air. The rapid deflation causes the system to descend to the ground at approximately 20 fps, thereby clearing the airspace of the spent system.

The hot air buoyancy/deceleration design configuration as shown in Fig. 3-6 is a natural shaped hot-air balloon with a maximum inflation diameter of 20 ft. It is packed at a density of 40 lb/ft^3 in a heavy cotton duck deployment bag. A natural-shaped balloon is practically free of circumferential stresses. Almost all the suspended load stresses are meridional. The envelope is constructed of gores sewn together according to basic parachute fabrication techniques. Ram-air-inflation scoops are located near the balloon equator. The lower gores extend on the under side of the upper gores and bear against the lower portion of the upper gore to provide a positive seal when the balloon is fully inflated. Upper gore material is 1.55-oz nylon and lower gore material is 1.30 oz. A calendered and catonic coating process reduces the permeability and enchances the high-density packing properties of the nylon fabric.

Operational conditions of the balloon are in a Reynolds number range of 10^5 to 10^6 and a burble fence is required to prevent coning action of the balloon. A flying fence design was derived to provide uniform flow separation and permit easy packing of the balloon at high density.

The Briteye Flare program has resulted in an advanced design flare system with a light output of 5 million candlepower, burn duration of 5 min, slow terminal descent, and the capability of being carried on external wing racks of high-speed aircraft. Of primary importance in the field of aerodynamic deceleration is the development of a midair-deployed, ram-air-inflated, hot-air buoyancy balloon suspension system. The development of this system has advanced the technology of this type of decelerator/buoyancy aerostat to the point at which computer derived mathematical models of the flight trajectory can be correlated with actual flights. With this understanding this technology can be and is being applied to other applications.

Gust Design Envelope of Interacting Loads

Kenneth L. Roger*
The Boeing Company, Wichita, Kansas

Introduction

When airframe stress is a function of n loads, the critical loading combinations form an n-dimensional surface bordering the design loading region. When the surface is known, techniques are available for computing whether or not the stress will satisfy a random-gust design requirement.[1]

This Note presents an alternate approach wherein the design requirement and the gust load covariances are used to directly define the boundaries of the gust-loading region. This approach is particularly useful to the loads engineer who must specify gust design load envelopes independent of the stress-to-load relationship.

Points on the boundaries of the gust-loading region are defined by a parametric inequality involving the n loads. The design envelope is found by eliminating the parameters. An especially simple analytic solution is found for the design load envelope satisfying the U_σ gust criteria.[2]

Mathematical Definition of the Design Load Envelope

If x, consisting of x_{mean} plus Δx, is the general linear combination of n loads L_i, then, using matrix notation,

$$\Delta x = \{C_i\}^T \{\Delta L_i\} \tag{1}$$

The variances of x and $\dot{x}$ are related to the covariances of $\{\Delta L_i\}$ and $\{\dot{L}_i\}$ (for random-gust inputs) as

$$\sigma_x{}^2 = \{C_i\}^T[\sigma_{L_{ij}}{}^2]\{C_i\} \tag{2}$$

and

$$\sigma_{\dot{x}}{}^2 = \{C_i\}^T[\sigma_{\dot{L}_{ij}}{}^2]\{C_i\} \tag{3}$$

The design region of ΔL, ΔL_2, $\ldots$, ΔL_n includes all points which, for all possible combinations of $C_1, C_2, \ldots, C_n$, satisfy the design criteria inequality. For example, Eqs. (4) and (5) represent the U_σ design gust and an exceedance criteria, respectively, where U_σ and N are specified in the criteria;

$$F_{U\sigma}(\Delta x,\sigma_x) = (\Delta x)^2 - U_\sigma{}^2\sigma_x{}^2 \leq 0 \tag{4}$$

$$F_{\text{exc}}(\Delta x,\sigma_x,\sigma_{\dot{x}}) = (\text{exceedances of } \Delta x) - N \leq 0 \tag{5}$$

Using Eqs. (1–3), the selected design inequality can be written in terms of ΔL_1, ΔL_2, $\ldots$, ΔL_n and the parameters C_1, C_2, $\ldots$, C_n.

The design loads envelope is the boundary of the gust-loading region. It includes all of the potentially critical

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* Structures Engineer, Wichita Division. Member AIAA.