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AERODYNAMIC DRAG AND STABILITY CHARACTERISTICS OF SOLID AND INFLATABLE DECELERATOR DEVICES AT SUPERSONIC SPEEDS

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ABSTRACT

Experimental drag and stability characteristics of towed decelerators at supersonic speeds are presented in this paper. The decelerators discussed include towed spheres, towed cones (both solid and inflatable), and inflatable towed cone-balloons (both closed pressure and ram-air type devices).

INTRODUCTION

If conventional methods of recovery are to be utilized in the final stage, it is particularly important that the velocity of the payload be gradually reduced as the payload reenters the atmosphere from high-speed high-altitude flight. Investigations have indicated that conventional parachutes are not satisfactory for this first stage deceleration because the parachutes are unable to withstand aerodynamic heating, inflate satisfactorily, and maintain stability under supersonic flow conditions. An initial deceleration system which will reduce the velocity of the payload by substantially decreasing its ballistic coefficient will lessen the initial shock on the payload and on final recovery devices such as parachutes. Spherical balloons and cone devices have been considered as possible decelerators because of their stability and relatively high drag coefficients. Both solid and inflatable decelerators have been investigated and will be discussed in this paper.

Slide I

This slide shows typical examples of the solid and closed pressure vessel inflatable decelerators that were tested.

The 80° cone and sphere shown here were tested both solid and inflatable with very little difference in drag and stability between them. The separation fence shown on some of these configurations is needed for stability at subsonic speeds. The solid models shown here are typical of rigid decelerators at supersonic speeds. They are simple in construction, inherently stable at these speeds, and produce high drag coefficients. The 70° cone balloon (called a ballute) has drag values between the 60° and 80° solid cones. Therefore it would appear that the cone balloon and the cone give similar if not identical results for a given cone angle.

It has been established that the stability of cones decrease with increasing cone angle while drag increases with increasing cone angle in the supersonic speed range and cones with 90° angles were intermittently unstable at these Mach numbers. Although it hasn't been tested it would appear that an 80° cone balloon would be optimum from this investigation from the point of view of drag and stability.

At this stage, a decelerator that had better drag and stability characteristics than a parachute and yet the same storage capability had been developed. However, the problem of having to carry heavy inflation equipment aboard the payload to be recovered still existed. This is where the need for a self-inflating configuration was realized.

Slide 11

This slide shows the development of the ram air ballute from the front inlet to the present side inlet type.

This front inlet configuration was one of the first tries at using the ram air (dynamic pressure) to inflate the decelerator. Many different means of inflating the ballute employing front inlet type configurations were tried; however, there was a mass flow pulsation phenomena in the supersonic speed range which resulted in adverse vibratory fabric loading and subsequent failure of the models. This pulsation problem was solved by placing different percent screens over the inlet; however, this lowered the drag compared to the closed pressure 70° cone balloon or ballute shown in this slide. The side inlet configuration of the 70° cone balloon or ballute was developed as a result of testing at a Mach number of 10. The wake from the forebody did not tend to collapse or recover at any distance aft of the payload that was capable of testing within the tunnel. The core of this wake existed over and outside the ram air inlet diameter; therefore the side inlets were used to feed the ram air into the ballute. This method of extended ram air inlets worked very well.

Essentially what is being developed here is an improved type of high speed parachute that will retain the parachutes weight and packaging features and yet overcome its short comings with respect to supersonic stability and aerodynamic heating resistance.

Slide III

This slide shows a typical plot of drag coefficient versus Mach number. The configurations represented by this figure is the 70^{o} ballute with side inlets and one of the better parachute configurations at a length of tow cable to diameter of forebody ratio of 10. The forebody used in all these tests is shown at the top of the slide. These side inlets fully inflate the model to the same shape as the inflatable closed pressure 70^{o} cone balloon giving approximately the same drag and stability.

Ballutes made of dacron and nylon neoprene have a maximum performance limit of approximately M = 5. Ballutes made of metal fabirc (Rene' 41) coated with a special silicon ceramic elastomer have proved satisfactory at M = 10.

Ballutes have built in "reefing" at all speeds and since parachutes have not been successfully reefed during deployment at high supersonic speeds, it is clear that opening shock loads are higher in parachutes and the result is a heavier cloth structure and subsequent weight penalty. A ballute is a more rigid inflatable structure than a parachute which results in improved stability (less coning).

Slide IV

This slide shows the research areas in which I believe work still needs to be done.

1. reduce internal pressure -

Tests just completed on the 70° ballute with side inlets showed that internal pressures as high as 4 times dynamic pressure were measured. Previous tests showed a pressure equal to dynamic pressure was all that was needed to fully inflate the decelerator. Therefore there still needs to be some development in inflation procedures to reduce the amount of pressure inside the decelerator.

2. maintain inflation througnout trajectory -

Various techniques for inflating the optimum drag shape should be investigated and should also include a determination for maintaining inflation procedures throughout the descent trajectory down to sea level in order to possibly eliminate the requirement for deployment of a final stage parachute.

3. correlate tunnel results with flight -

To establish more complete data, consideration should be given to perform free flight tests to achieve flight test deployment conditions that can be duplicated in the wind tunnel.

A parametric performance study should be then made in the wind tunnel to ascertain if stability can accurately be determined in wind tunnel testing using an infinite mass relationship.

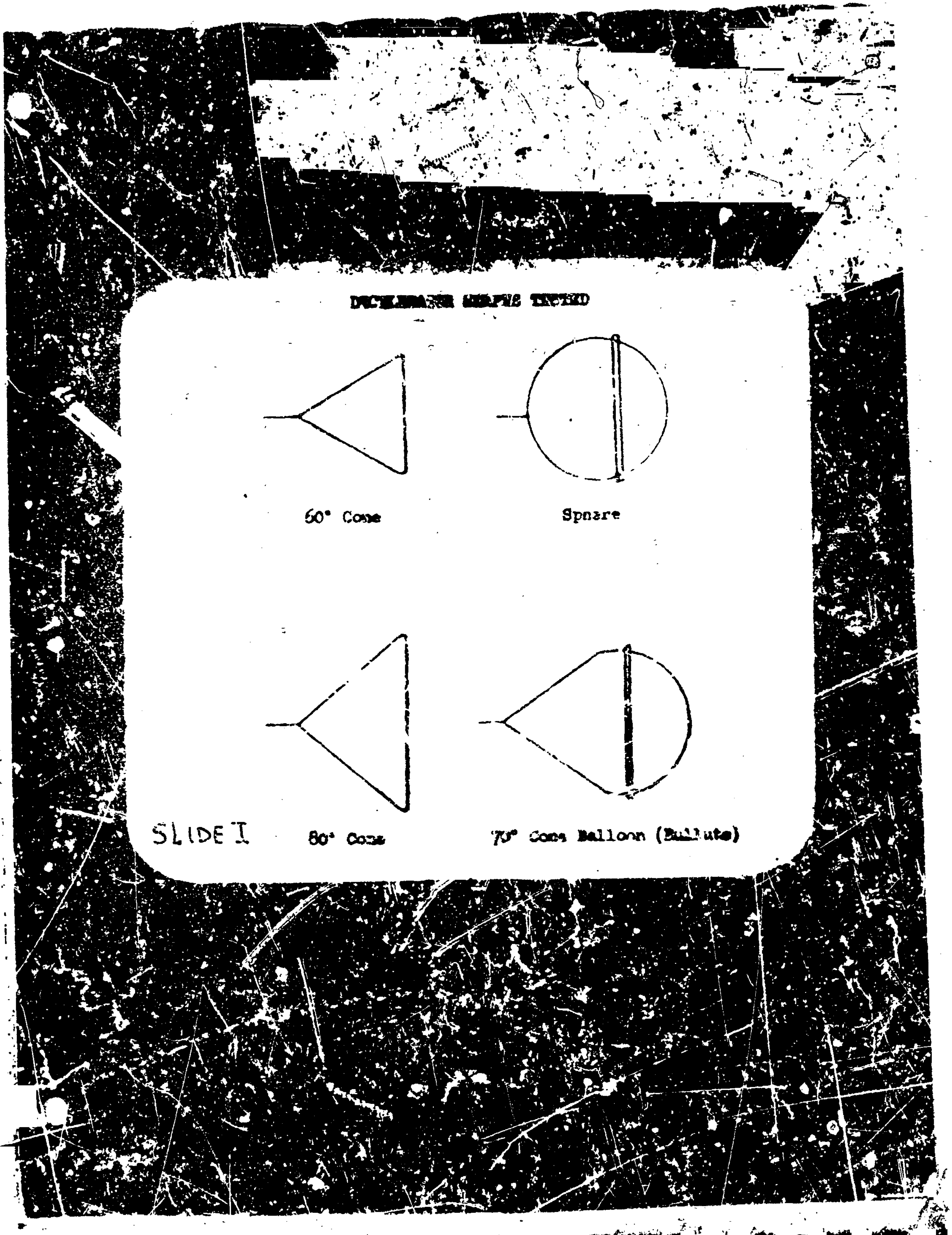
4. extend results to subsonic and hypersonic speed -

Additional wind tunnel testing is also required in the subsonic and hypersonic speed ranges on the basic shapes discussed in this presentation in order to investigate the capabilities of these decelerator systems at speeds up to Mach numbers of 10 and a wide range of dynamic pressures and temperatures that will be encountered in recovery.

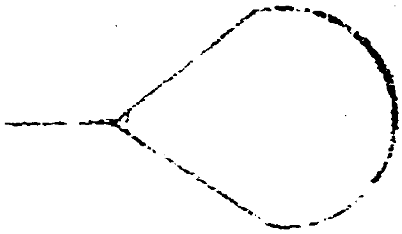
MOVIE

1. This 1st shot shows the 70° cone balloon or ballute with side inlets at a Mach number of 2.5 q = 250 psf. Its drag coefficient of 0.9 was the same as the 70° cone balloon closed pressure inflatable model.

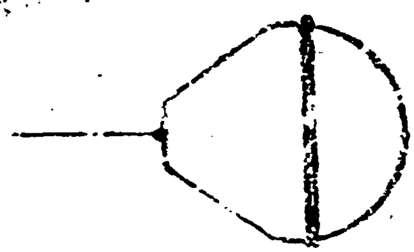
2. This picture shows the towed 80° ram air ballute at a Mach number of 2.75, q = 250 psf This model never fully inflated and it points out the mass flow pulsation phenomena which causes the adverse fabric loading and subsequent failure that existed in many of the front inlet ram air ballutes.


60° Cone
Sphere
SLIDE I
80° Cone
70° Cone Balloon (Ballute)

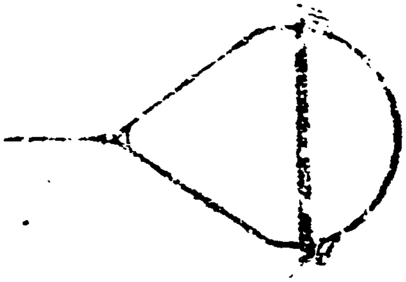
DEVELOPMENT OF THE BALLUTE



70° Cone Ballute

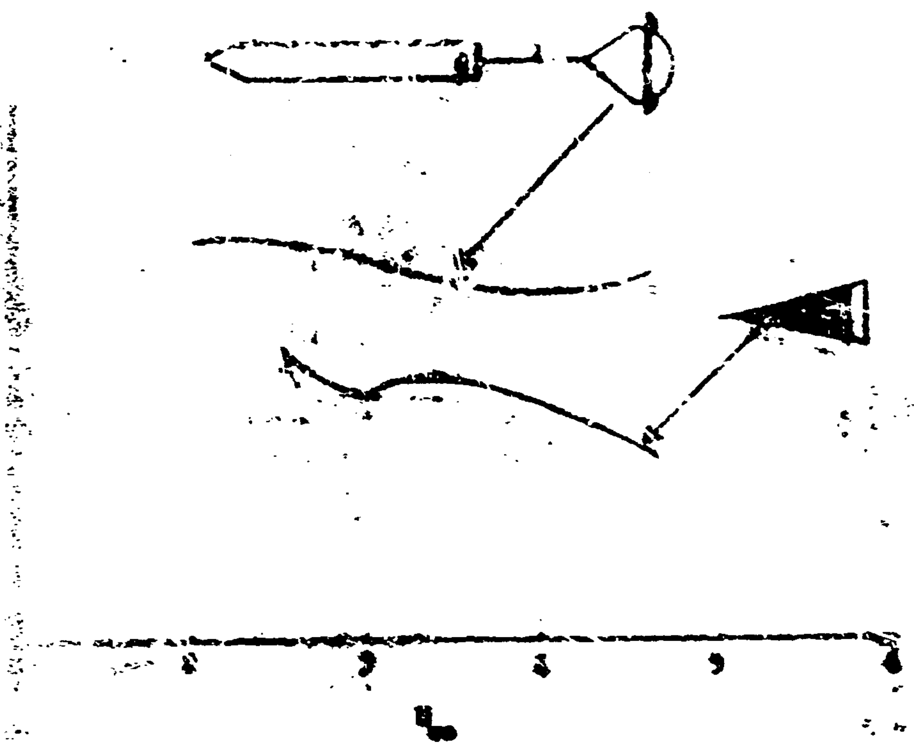


70° Front Inlet Ballute



70° Side Inlet Ballute

SLIDE II



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III

RESEARCH AREAS

1. Reduce internal pressure

2. Maintain inflation throughout trajectory

3. Correlate tunnel results with flight

4. Extend results to subsonic and hypersonic speed

Slide IV