

DTIC FILE

4

MRL-R-1131

AR-005-245



DEPARTMENT OF DEFENCE
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
MATERIALS RESEARCH LABORATORY

MELBOURNE, VICTORIA

REPORT

MRL-R-1131

AD-A207 742

DEVELOPMENT OF A PARACHUTE FOR A SUBMARINE
LAUNCHED PYROTECHNIC SIGNAL

T. Clarke

DTIC
ELECTE
MAY 16 1989
S D
PH

Approved for Public Release



AUGUST 1988

89 5 16 097

**DEPARTMENT OF DEFENCE
MATERIALS RESEARCH LABORATORY**

REPORT

MRL-R-1131

**DEVELOPMENT OF A PARACHUTE FOR A SUBMARINE
LAUNCHED PYROTECHNIC SIGNAL**

T. Clarke

ABSTRACT

This report outlines the development of a parachute required to control the descent of a pyrotechnic flare. The parachute was developed to support a pyrotechnic flare candle with an initial mass of 1 kg for a period which enables an observer to acquire and identify it at a distance of 15 nautical miles (27 kilometres).

Approved for Public Release

© Commonwealth of Australia

POSTAL ADDRESS: Director, Materials Research Laboratory
P.O. Box 50, Ascot Vale, Victoria 3032, Australia

CONTENTS

	Page No.
1. INTRODUCTION	1
2. PERFORMANCE REQUIREMENTS	1
3. PARACHUTE SYSTEM	2
3.1 Design Parameters	2
3.2 Canopy Size	5
3.3 Suspension System	6
3.4 Canopy Manufacture	7
4. TRIALS RESULTS	7
4.1 Parachute Selection	7
4.2 Launch Performance	8
5. DISCUSSION	8
6. CONCLUSIONS	9
7. REFERENCES	10



Accession For	
NTIS Grant	<input checked="" type="checkbox"/>
DTIC Staff	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Classification	
By	
Distribution/	
Availability Codes	
Dist	
A-1	

DEVELOPMENT OF A PARACHUTE FOR A
SUBMARINE LAUNCHED PYROTECHNIC SIGNAL

1. INTRODUCTION

This report outlines the development of a parachute of a relatively simple design and low cost with the capacity of supporting a burning high intensity flare candle during adverse weather conditions.

The Marine Marker Signal is a self-contained pyrotechnic flare suitable for ejection from a submerged submarine. The device was developed for the RAN to overcome the operational deficiencies of visual range and intensity that exist by using a surface smoke candle. Unlike a surface smoke marker this signal, after being ejected from the submarine, floats to the sea surface then using inbuilt sensors initiates the ejection of the payload canister containing the pyrotechnic flare. The payload is propelled to an altitude of approximately 160 metres after which pyrotechnic delays ignite the flare candle. The gas pressure generated by the burning flare candle separates the candle and parachute subassembly from the payload canister. The parachute is deployed by the air stream and controls the descent of the flare candle. The flare payload deployment sequence is shown in figure 1.

2. PERFORMANCE REQUIREMENTS

The parachute system must be capable of controlling the descent of the burning flare candle such that it is visible above the horizon for a period of thirty seconds at a distance of 27 km. The flare candles have typical burning times between 25 to 30 seconds.

After the burning flare candle is ejected from the payload canister near the apogee of flight, the canopy and associated hardware must be capable of withstanding the impulse shock loading produced by the opening parachute.

During the controlled descent the pyrotechnic material is completely consumed causing a change in applied load. The parachute under these conditions must not exhibit excessive oscillatory behaviour or show undue inflight instability.

The parachute system packing volume and mass must be optimized to enable maximum flare payload capability. Figure 2 shows the payload configuration.

The parachute must be of a relatively simple construction, low in manufacturing cost and capable of withstanding the effects of the environment on its performance, storage and handling.

3. PARACHUTE SYSTEM

3.1 Design Parameters

The selection of a parachute system requires the simultaneous evaluation of interrelated variables ie. weight, allowable descent rate, and descent time.

Of the types of parachute available that may be suitable for use with a pyrotechnic signal, there are two main categories.

- (1) Those which fully open at release speed and impose large deceleration forces on the system.
- (2) Those that decelerate the payload appreciably before becoming fully inflated.

In this simple application there is no need to decelerate the payload before the canopy opens fully, so first category may be used.

The development of a suitable parachute system requires the combination of both specific data and empirical details of performance of similar systems before an initial prototype can be obtained. The design can then be tested and refined by experiment.

In any parachute system physical configuration is likely to involve several trade offs; for example high stability implies a relatively low drag coefficient with the accompanying high descent rate and reduced visible time, a lower descent rate implies a higher drag with a lower stability and larger opening forces on the canopy and may necessitate a high strength parachute system which requires a high cost canopy. (1)(3) The method employed to release the parachute into the air stream and the forces acting to inflate the parachute will influence performance.

In producing a suitable canopy the following factors were of particular importance.

(i) **Opening shock**

The deployment of the parachute is controlled by the pyrotechnic delays which are designed to ignite the flare composition approximately 6.5 s after the payload is ejected from the floating signal canister. At this time the flare is approximately at the apogee of its flight and the velocity of the 1 kg payload is minimal. The parachute is then deployed at a time when the stresses imposed on the system are minimal and the forces at snatch and at full canopy opening are minimized. The respective forces are illustrated in figure 3.

(ii) **Rate of descent**

The rate of descent is determined by the balance of forces acting on the centre of mass of the system. These are the drag force acting upward against the gravitational force acting on the payload canopy system mass, the transient and steady state stresses due to aerodynamic drag, spring, damping and gravity forces during the descent of the parachute system. The governing steady state equation for a descending parachute system is

Ref (1)

$$F = K_D d^2 p v^2 / 2 \quad (1)$$

where

- F = drag force upward, N
- K_D = average drag coefficient, dimensionless
- d = calculated diameter of parachute canopy, m
- p = local air density, kg/m^3
- v = descent velocity, m/s

The drag coefficient is not a constant value and is dependent upon the shape of the canopy and its vertical descent rate. In the case of a flat circular configuration the variation in its value is attributed to the following:

- (a) changes in the projected diameter of the canopy,
- (b) changes in the inflated shape of the canopy,
- (c) the permeability of the canopy material.

All of the above parameters are affected by the pressure differential across the canopy [1].

The nature of the velocity time graph for a Payload canopy system is shown in figure 3 [1].

(iii) Oscillatory behaviour and flight stability

The stability of any fully inflated parachute canopy is affected by a number of interrelated factors, for example canopy shape, line length, fabric permeability and canopy porosity (1). Air which is not able to permeate the canopy fabric is forced to escape by spilling out from underneath the lower edge of the canopy. The spilled air is carried up the outside of the canopy where it attaches itself to the sides of the canopy. The higher local velocity of this air generates a local reduction in air pressure (Bernoulli's Principle), and this pressure differential creates a side force on the canopy pulling it in the direction of the area of lower pressure. Because of the flare's inertia the load on the canopy lags behind this motion causing a tilt of the canopy which results in the canopy spilling the entrapped air on the opposite side. This spilt air attaches itself to the canopy before producing a low pressure region on an other area of the canopy thus pulling the canopy again in the opposite direction. This second swing may be much higher in amplitude than the first. The result is a self perpetuating oscillation where the amplitude increases until the payload and line length act to damp out any further increase.

With flat circular canopies constructed of low permeability fabric the oscillations impressed on the descending motion of the canopy can produce a gliding angle of about 38 degrees.

Improved stability can be achieved by using higher permeability materials, but this increases the descent rate and can also reduce the inflation rate and inflation reliability. An alternative approach is to vent the excess air by cutting equally spaced vents around the periphery of the canopy. This technique aims to permit the venting of just enough air to prevent spilling but should the vents be too large for the load and environmental conditions then the descent rate will increase.

(iv) Environmental Protection

The design of the complete signal offers considerable protection for the parachute canopy from the external environment. It is physically protected by an external casing and by the payload canister. The material recommended for use is ripstop nylon fabric. The material used to make the trials canopies was manufactured by George G. Harris Corp. (USA) to a company specification F 111. The fact that nylon is capable of withstanding temperatures up to 190° C and has a wet strength that is 90% of its dry value enables it to be used as a reliable canopy material [4].

(v) Packing volume and mass

Storage can have quite a substantial effect on the reliability and performance of a parachute deployment system. Any tangling of shroud lines which produces a delay or failure of the parachute to deploy will result in a catastrophic failure of the marker. With advice from a commercial parachute designer and manufacturer a method of folding and packing of the parachute and shroud lines was developed using folding instructions for similar stores.

This procedure involved stretching out the canopy and lines before folding them up in concertina fashion.

(vi) Cost

The parachute is deployed from the payload canister only when the payload is moving at very low speed and the parachute is subjected to low grab and snatch forces by the air stream. This allows the use of cheaper materials and production techniques than are required for parachutes designed for personnel and heavy cargo.

3.2 Canopy Size

The pyrotechnic flare candle is approximately 70 mm in diameter, exhibits a particularly high luminous intensity and flame temperature and burns for a period of not less than 30 seconds.

The estimated total mass of the payload is approximately 1 kg including attached hardware of 0.2 kg.

Consideration of the optimum propulsive loading, launch gas pressure and the space available in the base assembly determined that the payload could be expected to attain an altitude in excess of 165 metres. Using this estimate of payload performance the size of parachute can be calculated.

The load on the parachute is not constant because the mass of the flare decreases as it is consumed. The thermal lifting effect of the burning pyrotechnic materials has not been considered in the calculations. Major perturbations of the descent rate are only dependent upon parachute stability and the prevailing wind conditions and are only noticeable as the load approaches the flare-all-consumed stage.

Assuming a constant supported load, the distance "y" in metres the parachute with canopy area of d_0^2 m² descends in time "t" seconds can be expressed.

$$y = t \sqrt{\frac{2 g m}{d_0^2 p K}} \quad (2)$$

g is the acceleration due to gravity, 9.81 m/s²,
m is the combined mass of parachute, fittings and flare candle, in kg
p and K_D previously defined.

Considering the case when the mass of flare candle is diminishing with time we need to generate a function for descent of the system which is no longer linear with time.

For a burning flare the mass to be decelerated can be expressed as a function of time

$$M(t) = (M_c + M_p) - M_p t/t_p \quad (3)$$

where

M = total mass of the system with respect to time, kg
 Mc = combined mass of the parachute canopy and fittings, kg
 Mp = mass of pyrotechnic, kg
 tp = time to consume pyrotechnic material, s
 t = descent time, s (valid only if t > tp)

Substituting (3) into (2) and integrating between t_1 and t_2

$$y = \sqrt{2g} (d_o^2 p K_D)^{-1/2} \int_{t_2}^{t_1} M(t)^{1/2} dt \quad (4)$$

$$= - \left(\frac{2g}{d_o^2 \rho K_D} \right)^{1/2} \frac{2}{3} \frac{t_p}{M_p} \left[(M_c + M_p) - \frac{M_p}{t_p} t \right]^{2/3} \Big|_{t_1}^{t_2} \quad (5)$$

For our case let

$$d_o^2 = 0.66 \text{ m}^2 \quad \text{Area of circular canopy of 0.915 m diameter}$$

$$p = 1.2372 \text{ kg/m}^3$$

K = 0.75 (This value is only approximate as the drag coefficient is variable dependent on inflated shape and porosity of the canopy but this value is considered average for a flat circular canopy.)

$$M_p = 0.800 \text{ kg}$$

$$M_c = 0.200 \text{ kg}$$

$$t_2 = 30 \text{ s}$$

$$t_1 = 0 \text{ s}$$

$$t_p = 30 \text{ s}$$

Substituting into equation (6) gives the distance the parachute will descend in 30 seconds as 128 metres. This was considered adequate when compared with the ideal value of $165 - 45 = 120$ m as the above calculations do not take into account any lift which would be produced by the burning flare candle and the fact that only the white flare candle in fact has a mass approaching 0.8 kg. The red and green flare candles have masses half that or less of the white candle.

3.3 Suspension System

The suspension system consists of the flare candle, parachute and a suspension cable or riser which is fitted between the parachute suspension lines, shroud lines, and the flare candle. Its purpose is to protect the parachute from the extreme heat produced by the burning flare candle.

For our purposes the riser needs to be able to remain intact despite high temperatures and be flexible enough to allow easy packaging in a confined space.

The riser is constructed from 5/64 inch diameter or 2 mm diameter 304 austenitic stainless steel wire rope of 7 x 9 construction, ie 7 strands 9 wires per strand, 750 mm in length with copper swaged loops at each end. The specified breaking strength of the wire rope is 2258 N.

A tensile test of a sample riser indicated that failure began at a load of 2300 N but outright failure did not occur until 3400 N.

The riser is fitted to the top of the flare candle using a spring pin between two lugs on the flare candle top, at the other end the wire is secured to the parachute by a steel split ring.

3.4 Canopy Manufacture

The canopies prepared for quantitative evaluation were all of parasheet construction (a parasheet is a flat canopy in the shape of a regular polygon (1)) due to the prohibitive cost of manufacturing a segmented parachute. The extra strength of parachute construction with the small increase in performance provided by this parachute configuration is not justifiable on a cost basis.

The canopies produced were as follows.

- (i) Two flat circular parachutes one 915 mm diameter and the other 1067 mm in diameter. Figure 4 shows details of the construction of the 915 mm diameter circular parasheet. The 1067 mm diameter parasheet is a scaled up version.
- (ii) Two cruciform parasheets, (figure 5) were also prepared. This type of canopy is inexpensive to manufacture and is more stable than circular types typically having oscillations of only ± 3 degrees and being inherently stable (5).

4. TRIALS RESULTS

A series of development trials were conducted to determine the most appropriate configuration to satisfy the operational requirements. These were as follows.

4.1 Parachute Selection

This trial was conducted to determine the most suitable parasheet from four candidate models. Inert payloads representing various loads that occur through the flare

burning range were used as loads for each of the configurations of parachute. The parasheet, support and load were packed into a canister similar to that intended for use in the payload of the marine signal. The parachutes were released into the air stream at an altitude of 120 metres from a tethered helium filled balloon. Their free fall times were recorded.

The results are tabulated in table 1 and a graph of Average Descent Rate vs Supported Mass plotted (figure 6). As might be expected the larger 1066 mm diameter canopy has the lowest descent rate. However being a larger canopy it also occupies a larger volume and reliable packing into the canister was difficult. All the canopies performed reasonably well but in the tests the cruciform parasheets had the higher average descent rates. This was because they had less surface area than either of the circular canopies.

4.2 Launch Performance

On the basis of tests conducted the 915 mm diameter circular parasheet was chosen for the testing of the completed prototype at sea.

The trial was conducted in fine weather with the sea state varying between smooth and sea state 2, visibility was assessed as greater than 20 km. In these weather conditions it was not possible to evaluate the performance of the canopy in a high wind conditions. Of the six experimental models successfully ejected from a submerged submarine, only four signals successfully launched a payload after reaching the sea surface.

With each of the successful payload launches the parachute and flare candle were correctly ejected from the payload carrier near the apogee of their flight. As predicted, the relatively low velocity enabled the correct streaming of the parachute and flare candle permitting the canopy to unfurl and fill with air. The burning candle very quickly aligned itself below the centre of the canopy and no substantial flight instabilities were recorded. Video records of the trial confirm that stability of the system is dependent on the mass of the payload and as the flare is consumed and the load on the parachute approaches zero, system oscillations were recorded but did not reach an unacceptable level. Video records of the burning flare candle indicate that a peak amplitude of oscillation of about ± 45 degrees occurred near burn out of the flare.

5. DISCUSSION

Although the cost of the parachute was small by comparison to some multigore parachutes (a multigore parachute is one made up of multiple pieces of shaped fabric sewn together) found in other pyrotechnic stores, it may still be feasible to further reduce the cost of the parachute. With this application we are dealing with relatively low grab and snatch forces which indicate that less specialised materials and production techniques may produce a parachute at lower cost.

Because of the limited volume available in the payload canister and the support tube running through the parachute stowage area it is difficult to achieve proper stowage of the parachute. Although these difficulties did not affect the performance or reliability of any of the experimental devices, it is an area which should be addressed in any future development. Possible remedies involve changes to extend the length of the payload or changes to the payload design to eliminate the need of the central support column.

In the trials and selection of the canopy, descent rate and stability are considered to be the more important of the performance criteria. Although the canopy performed well in keeping the flare aloft for periods exceeding the specified time required during sea trials of experimental devices, video records show that at low payload masses when the candle is exhausted, severe oscillations and instability were observed.

The design of the suspension system may be improved by the following.

(i) Venting of the parachute canopy

Venting of the canopy, apart from increasing the critical opening velocity can also be used to improve canopy stability and distribution of opening forces (3). This can be achieved by cutting equally spaced holes around the skirt of the canopy to vent the excess air which at some times seemed to build up in the canopy and spill out setting up unwanted oscillation of the canopy. Another method of improving stability may be to construct canopies of more porous materials.

(ii) Riser lengths

Line length also influence stability of the system (3). By shortening the lines the dynamic stability of the system is improved, however the current lines are only 762 mm in length, which is already less than the normal practice of having the line lengths just longer than the open diameter. It would not be wise to further restrict the open diameter of the canopy by shortening the suspension lines. It may however be quite possible to reduce from 750 mm the length of the riser or suspension cable without exposure of the parachute to any further risk of being burnt by the flare candle.

6. CONCLUSIONS

Theoretical and experimental work carried out resulted in the development of a "parasheet" of circular configuration. The canopy flat diameter is 914 mm and the material is ripstop nylon fabric.

A number of these canopies were tested by drops from a tethered helium balloon and by ground based firings of development marker prototypes. In all cases the canopy provided the required descent rate for the payload, that is, the flare was above the required minimum altitude for the specified period of 30 seconds.

The preliminary results were confirmed by firings of development prototype markers from a submerged submarine.

7. REFERENCES

1. AMC Pamphlet 706-188 (1974). Engineering Design Handbook Military Pyrotechnics Series Part Four, Design of Ammunition for Pyrotechnic Effects.
2. Hoerner, Sighard F. (1958). Fluid-Dynamic Drag published by the author 1958.
3. Poynter, Danial F. (1972). The Parachute Manual, MRL-629.136.1/POV (DRN 7621-06802-9).
4. Engineering Properties, and Applications of Plastics (1957). Kinney, Gilbert Ford, John Wiley & Sons Inc.
5. Recovery Systems Design Guide, Air Force Flight Dynamics Laboratory, Ewig, E.G. : Bixby, H.W., AFFDL-TR-78-151 (DRN 8011-08856-0).

TABLE 1**Results of Canopy Selection Trial**

Parachute Type	Supported Mass	0.70 kg	0.35 kg	0.10 kg
CIRCULAR				
915 mm dia		4.65	2.84	-
1066 mm dia	Average Descent Rate m/s	4.29	2.47	-
CRUCIFORM				
Type A		5.05	3.50	-
Type B		5.30	3.55	2.20

Note: When a 0.10 kg mass is attached to the canopy the system becomes so unstable that no meaningful results are obtained. This indicated that the behaviour of the flare at end of burn could not be predicted.

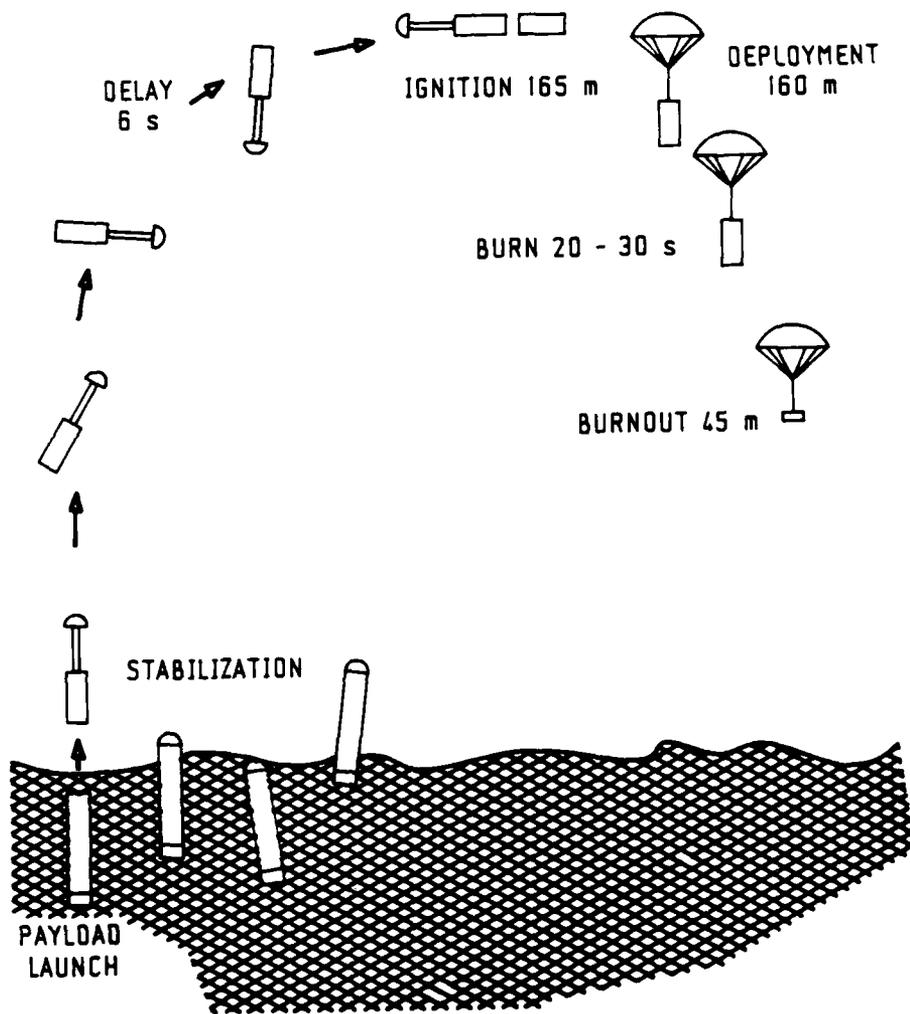


FIGURE 1 Parachute Deployment Sequence

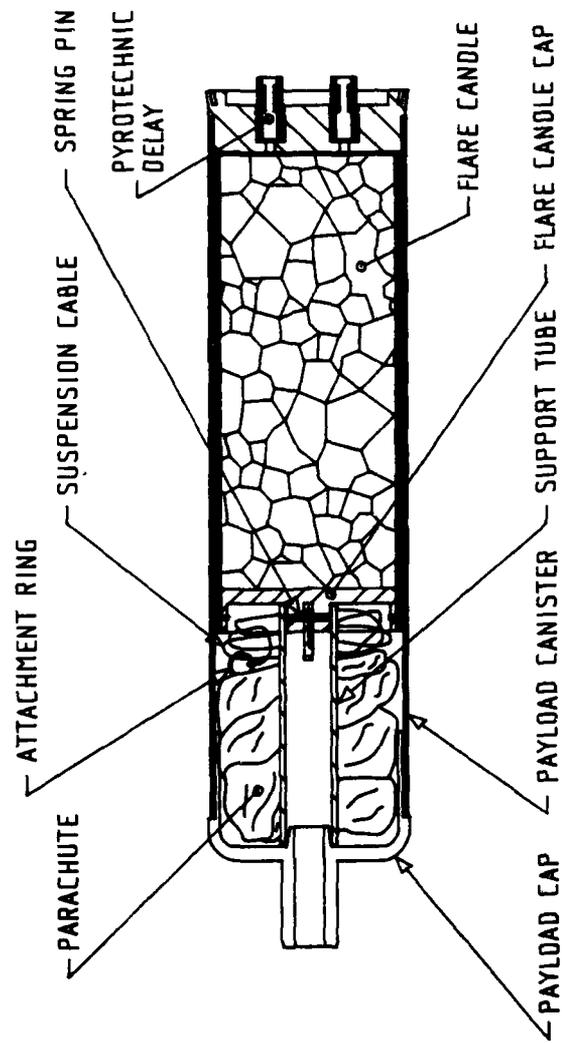


FIGURE 2 Payload Assembly

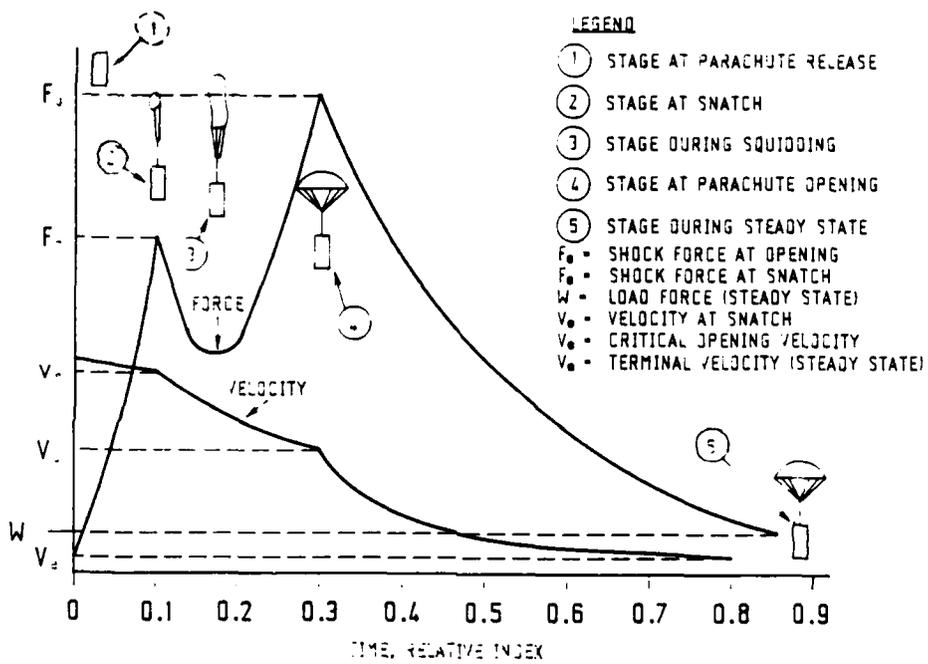


FIGURE 3 Force vs Time Graph of Parachute Suspension System

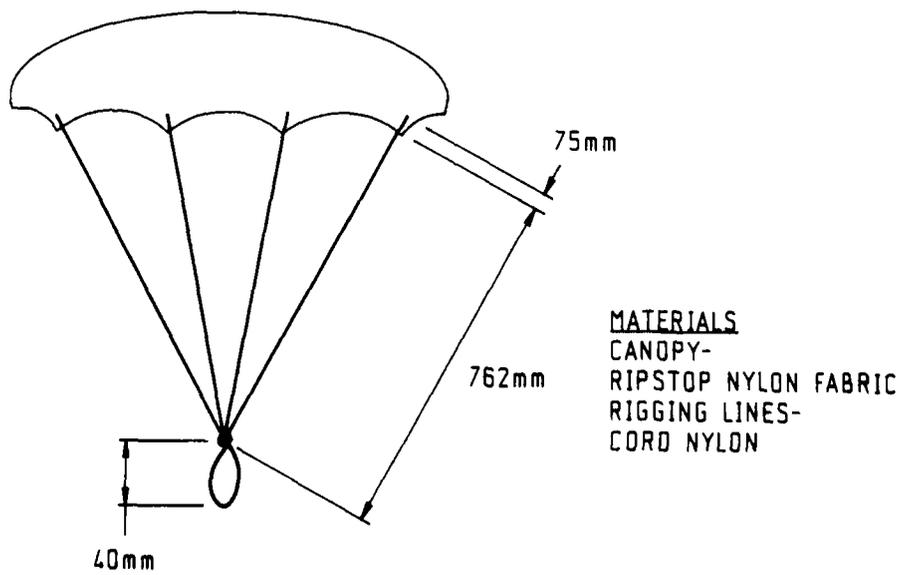
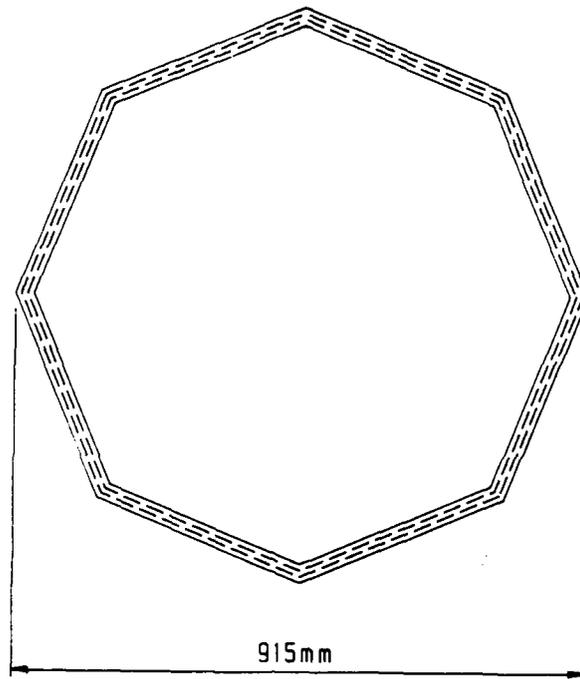
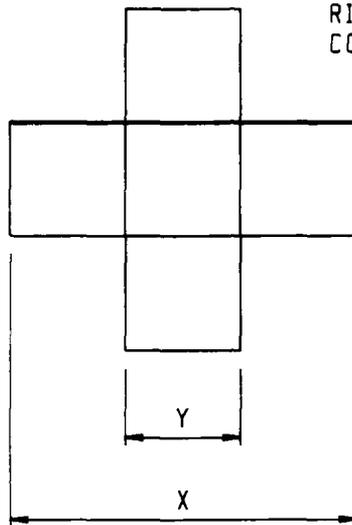


FIGURE 4 Signal Flare Parasheet

MATERIALS
CANOPY-
RIPSTOP NYLON FABRIC
RIGGING LINES-
CORD NYLON



CANOPY TYPE A X = 1200mm
Y = 350mm
CANOPY TYPE B X = 1100mm
Y = 350mm

FIGURE 5 Cruciform Parasheets

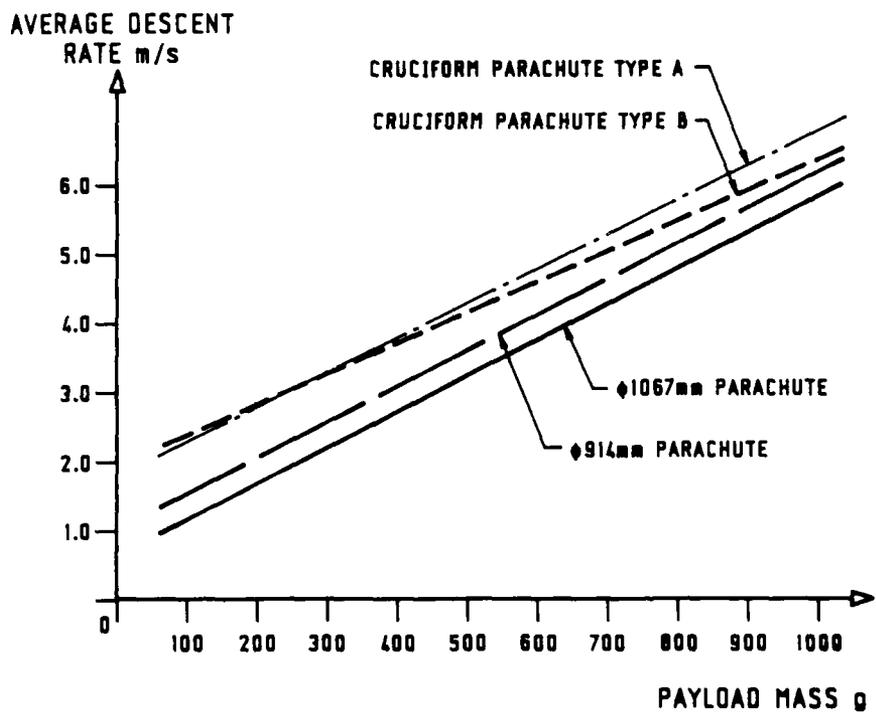


FIGURE 6 Descent Rate vs Mass

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

DOCUMENT CONTROL DATA SHEET

REPORT NO.
MRL-R-1131

AR NO.
AR-005-245

REPORT SECURITY CLASSIFICATION
Unclassified

TITLE

Development of a parachute for a submarine launched
pyrotechnic signal

AUTHOR(S)

T. Clarke

CORPORATE AUTHOR

Materials Research Laboratory
Defence Science & Technology Organisation
PO Box 50
Ascot Vale Victoria 3032

REPORT DATE
August 1988

TASK NO.
NAV 83/137

SPONSOR
RAN

FILE NO.
G6/4/8-3165

REFERENCES
5

PAGES
20

CLASSIFICATION/LIMITATION REVIEW DATE

CLASSIFICATION/RELEASE AUTHORITY
Chief, Explosives Division MRL

SECONDARY DISTRIBUTION

Approved for Public Release

ANNOUNCEMENT

Announcement of this report is unlimited

KEYWORDS

Parachute flares

Submarine launched

SUBJECT GROUPS 0079A

ABSTRACT

This report outlines the development of a parachute required to control the descent of a pyrotechnic flare. The parachute was developed to support a pyrotechnic flare candle with an initial mass of 1 kg for a period which enables an observer to acquire and identify it at a distance of 15 nautical miles (27 kilometres).

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

(MRL-R-1131)

DISTRIBUTION LIST

Director, MRL
Chief, Explosives Division
Dr B.W. Thorpe
Mr T. Clarke
MRL Information Services

Chief Defence Scientist (for CDS/ACDSO,ACDSP)
Director, Weapons Systems Research Laboratory
Director, Surveillance Research Laboratory
Director, Aeronautical Research Laboratory
Director, Electronics Research Laboratory
Counsellor, Defence Science, Embassy of Australia - data sheet only
Counsellor, Defence Science, Australian High Commission - data sheet only
Scientific Adviser to DSTC, c/- Defence Adviser - data sheet only
Scientific Adviser to MRDC, c/- Defence Attache - data sheet only
DDSTI Joint Intelligence Organisation
OIC, Technical Reports Centre, Defence Central Library
Officer in Charge, Document Exchange Centre, DSTO (17 copies)
Army Scientific Adviser, Russell Offices
Air Force Scientific Adviser, Russell Offices
Navy Scientific Adviser, Russell Offices
Librarian, Bridges Memorial Library, Australian Defence Force Academy
Senior Librarian, DSTO Salisbury
Librarian, H Block
UK/USA/CAN/NZ ABCA Armies Standardisation Rep., c/- DGAD(NSO)
Head of Staff, British Defence Research & Supply Staff (Australia)
NASA Senior Scientific Representative in Australia

INSPEC: Acquisitions Section Institution of Electrical Engineers
Chief Librarian, Central Library, CSIRO
Head Librarian, Australian Nuclear Science & Technology Organisation
State Librarian, State Library of New South Wales
Senior Librarian, University of Tasmania
Library - Exchange Desk, National Bureau of Standards
Exchange Section, British Library Document Supply Centre
Periodicals Recording Section, Science Reference & Information Service
Library, Chemical Abstracts Reference Service
Engineering Societies Library
Documents Librarian, The Center for Research Libraries
Resources Librarian, Dept. of Scientific and Industrial Research