ABSTRACT

This project is to design and fabricate the envelope for an indoor airship, paper includes the brief idea about selection of suitable material, deciding and estimating shape and volume of the envelope for an indoor airship with minimum dimension which can lift the required payload.

The methodology adopted here is a systematic collation of various design and approaches and concepts, which were studied during the design. The various shapes have been studied for their different characteristics like surface area, volume, surface area/ volume, lift, length/volume ratio and all the shapes have been compared on above characteristics and a suitable shape have been selected. Also a easy methodology is advised for petal profile generation for the ease of fabrication.

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Chapter 1

Introduction

1.1 What is an Airship?

An airship is a type of lighter–than–air (LTA) aircraft with propulsion and steering systems. It obtains its buoyancy from the presence of a lighter–than–air gas such as H, He, or hot air, based on Archimedes' Principles. The first airship was developed by the French; called a "balloon dirigible", it could be steered and also be flown against the wind, which is not possible with a simple balloon.

Airships are the most suitable aerial platforms for advertising and surveillance, as they offer advantages such as of long endurance, ability to hover with low noise and vibrations levels and low fuel consumption. However, they do suffer from some limitations, such as they can mostly be used in situations in which the flight operations are to be conducted in fair weather conditions and at low speeds, and large size of the platform is not a constraining factor. Several studies are being carried out all over the world related to design, development and flight testing of unmanned, remotely operated and autonomous airships.

1.2Classification of Airship:-

There are three broad categories of an airship:-

1. Rigid Airship:-

As their name implies, rigid airships have an internal frame. The lifting-gas pressure plays no role in maintaining the outer shape of these airships. The Zeppelins and the USS Akron and Macon were famous rigid airships[1]. The rigid structure, traditionally of an aluminium alloy, holds up the form of the airship. In general rigid airships are only efficient when longer than 120 m because a good weight to volume ratio is only achievable for large airships. For a small airship the solid frame would have been too heavy. There is hope that the use of composite materials will change this.

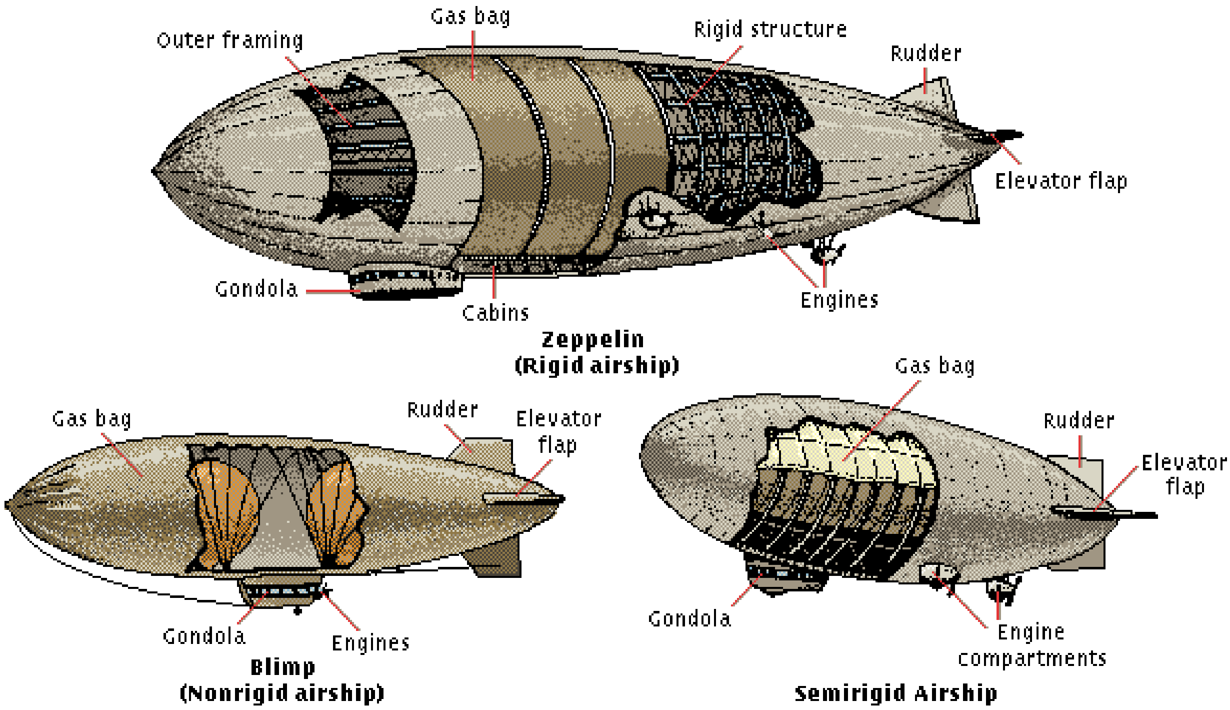

Figure 1.1 Classification of Airship[2]

2. Semi-rigid Airships

Semi-rigid airships were more popular earlier this century. They usually comprise a rigid lower keel construction and a pressurized envelope above that. The rigid keel can be attached directly to the envelope or hung underneath it. This keel is used to share bending loads. The airships of Brazilian aeronaut Alberto Santos-Dumont were semi-rigid. One of the most famous airships of this type was *Italia*, the airship which General Umberto Nobile used on his attempt to reach the North Pole[1].

3. Non-rigid Airships or Blimps

Non-rigid airships, also known as Blimps, are the most common form nowadays. They are basically large gas balloons. Their shape is maintained by their internal overpressure. The only solid parts are the passenger car and the tail fins. All the airships currently flying for publicity use are of that type; the Goodyear Blimps, the Budweiser and the MetLife Blimps in the USA, and the Fuji Blimp in Europe being the examples of the Non-rigid airships[1]. These airships technically referred as 'pressure airships'.

1.3 Applications of Airships

Unlike aircrafts, airships can fly at low altitudes, with low velocities as well as hover in position with very less consumption of fuel. These characteristics make it ideal for numerous applications. A few of them are listed below:-

i. Advertising

The visual appearance of airship has always attracted the attention and the imagination of general public. This fascination with helium- filled airships creates the ultimate advertising vehicle and generates huge amount of money in revenue. As an eye in the sky, the airship provides good camera footage of outdoor events. Under special arrangements with T.V networks and cables, blimps carry the aerial camera without charge and reciprocally receive on air publicity at no cost[3].

Figure 1.2 Airship used for advertising purpose[4]

ii. Tourism

One of the most profitable and growing segments of the market where the need for the airship is more acute is tourism. There is an emerging demand to develop such an airship transport system in the commercial sector and it is considered that such a system could, in many ways, be utilized to stimulate interest in tourism and travel via lighter- than-air vehicles [3].

Figure 1.3 Airship used for tourism purpose[5]

It can be used for scenic excursions exclusively or it can include transportation element, such as flying passengers to many attractive destinations or it could serve as inter island tourist routes, for example between the Hawaiian and Caribbean Islands without affecting the local environment. The impact of this type of travel transcends imagination.

Passengers in helicopters or aircrafts may enjoy comparable views but they will never experience the gentle pace of the airship, nor its spaciousness. Flight characteristics are smooth and unlikely to upset the passengers. Another surprise is the sound, or rather the lack of it. Engines can be cut for gentle and smooth ballooning over special scenic spots.

iii. Other Civil Applications

1) Military Purposes
2) Tourism
3) Air Surveys
4) Advertisement
5) Search and Rescue
6) Coast guard
7) Riot Control
8) Fishery Protection

iv. Military Application

The need for improved surveillance techniques for military, government and scientific applications have increasingly led to the use of airships to meet specialized needs. Examples of operational duties performed by airships include:

1) Command, control and communication Platform
2) Precisely locate friendly and enemy forces
3) Detect targets of an extended battlefield at minimal exposure to the enemy forces
4) Real time targeting
5) Battle management

1.4 Problem definition

It is required to design the envelope for non-rigid airship which can lift the required payload. Also select the suitable material having good strength, ease of adhesion, ease of repair, minimum weight and low cost.

Selecting the shape of envelope which will have minimum surface area to volume ratio in order to minimize the drag force. Deciding the size of envelope to minimize the overall dimension of the airship.

Desired Specifications:-

Table 1.1 Desired specifications for the airship

Property	Value
Payload	500g
Diameter of envelope	1.3m
Length of envelope	4m
Cruising velocity	2-3 m/s
Operating altitude	10m

1.5 Scope of Work:-

The following tasks were carried out in this project:

1. Design and selection of suitable shape of the envelope
2. Selection of material for the envelope
3. Fabrication of the envelope
4. Test of material and sealing
5. Documentation of the problems faced and lessons learnt

The objective of this project is to advice a suitable material for the envelope which have low weight (gsm), low cost, good adhesion property. Select a suitable shape which may give us enough lift to lift the less than 500 gm payload with minimum possible dimension and aerodynamic shape.

Chapter 2

Review of literature

2.1 Background

Till now very few researchers have carried out their work in the area of design of airships. The papers which deal with the present study of interest are discussed below.

Since more than a decade, several airships have been designed, fabricated and field tested by researchers in Lighter-Than-Air systems Laboratory in Aerospace Engineering Department at IIT Bombay under PADD (Program on Airship Design and Development). Three remotely controlled airship developed here, viz., *Micro*, *Mini* and *Macro* are shown in Fig respectively. A brief description of these airships is provided in the sub-sections that follow:

2.1.1 Micro Airship:-

Gawale et al gave the details of the envelope material to be selected along with the stress analysis and the fabrication of the same. *Micro* is non-rigid, Helium filled experimental aerial vehicle with envelope volume of 6.64 m^3 [6].

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Figure 2.1 Micro Airship[7]

The basic purpose of developing the *Micro* airship was to provide a first-hand exposure to issues related to airship design fabrication and operation. The envelope material along with stress analysis and fabrication procedure for the same was considered. The design requirements specified for the *Micro* airship were very modest; it was required to have a payload capacity of 1.0 kg, while operating at a maximum speed of 30 kmph for 20 minutes, using an existing OSMG1415 IC engine, developing 0.41 BHP with a displacement of 2.49 cc. Due to constraints on storage space, it was required to be less than 5.00 m in length [3]

2.1.2 Mini Airship

Subsequent to the successful development and flight demonstrations of Micro airship, the PADD team was invited by the Government of India to showcase their technology to the scientific community of India at a national science congress, and the PADD team developed the *Mini* airship for this purpose, which had an envelope volume of 8.64 m3, resulting in a payload capacity of 3.0 kg, and hence was capable of carrying out various missions, such as aerial surveillance. This airship was subsequently demonstrated at several other places[3].

Figure 2.2 Mini Airship[7]

2.1.3 Macro Airship

Vishal Chaughle[8] et al describes the methodology followed for sizing of the envelope and various key components of airships and the procedure followed for in house fabrication and testing. They also highlighted the major issues that cropped up during the operation of airship in harsh environmental conditions of rain and mild snow as well as at night time. The *Macro* airship was designed and fabricated for flight demonstration at an international symposium on Snow and Avalanches, held at Manali, India in 2009. Also validation of airship design code and testing of video downlink for the recorded video of airship was done for the same.

Figure 2.3 Macro airship[7]

A comparison of the key features of these three airships is provided in below Table

Table 2.1 Comparison table of Micro, mini and macro airship [7]

Parameter	**Micro**	**Mini**	**Macro**
Length (m)	4.99	6.42	8.0
Envelope Volume (m3)	6.8	8.6	26.6
Payload (kg)	1.0	3.0	6.0
Endurance (min)	17	18	25
Max. Speed (m/min)	7.0	10	12
Engine Power (HP)	0.41	0.6	2.0

Rajkumar S. Pant[9] has presented a methodology for arriving at the base specifications of non-rigid airship of conventional configuration. The methodology presented calculates the volume required to carry a user specified payload and also arrives at the mass breakdown. Also the Sensitivity of parameters such as pressure altitude, ambient temperature, cruising speed, helium purity level, engine power, envelope length to diameter ratio etc. to the payload available or envelope volume required using the above methodology is presented.

Gawale[10] et al presented a brief description of a methodology for sizing and baseline design calculations of an RC airship meeting some user specified requirements. The section on design in the paper provides details of the standard envelope profiles for RC airships, types of materials use for envelope and fins and their properties, basic buoyancy and aerodynamic calculations, followed by stabilizer and fin sizing, and description of the propulsion system. The section on fabrication describes the Radio Frequency (RF) sealing method for realizing the envelope and fins, and discusses important issues related to the system integration and testing.

Figure 2.4 KARI VIA-50 Airship[11]

Yung-Gyo Lee[11] et al presented the general plan and approach for developing a 50 m unmanned stratospheric airship system VIA-50 as shown in Fig2.4 to acquire basic technologies required for a station keeping electrical powered high altitude airship.

Looking further beyond, airships are also being considered for the exploration of planetary bodies with an atmosphere. Since 2003, NASA[12] has been designing and testing a robotic lighter-than-air vehicle as depicted in Fig2.5 for the exploration of planets and moons such as Venus, Mars, and Titan.

Figure 2.5 NASA JPL Aerobot[11]

De Paiva[13] et al provided an overview on Project AURORA - Autonomous Unmanned Remote monitoring Robotic Airship, launched in 1998 as depicted in Fig2.6 a research effort that focuses on the development of the technologies required for substantially autonomous robotic airships.

Figure 2.6 AURORA airship[13]

Another important research study related to outdoor autonomous airships is the Lotte Project at University of Stuttgart, Germany in 2002 as shown in Fig2.7 which is a solar powered airship.

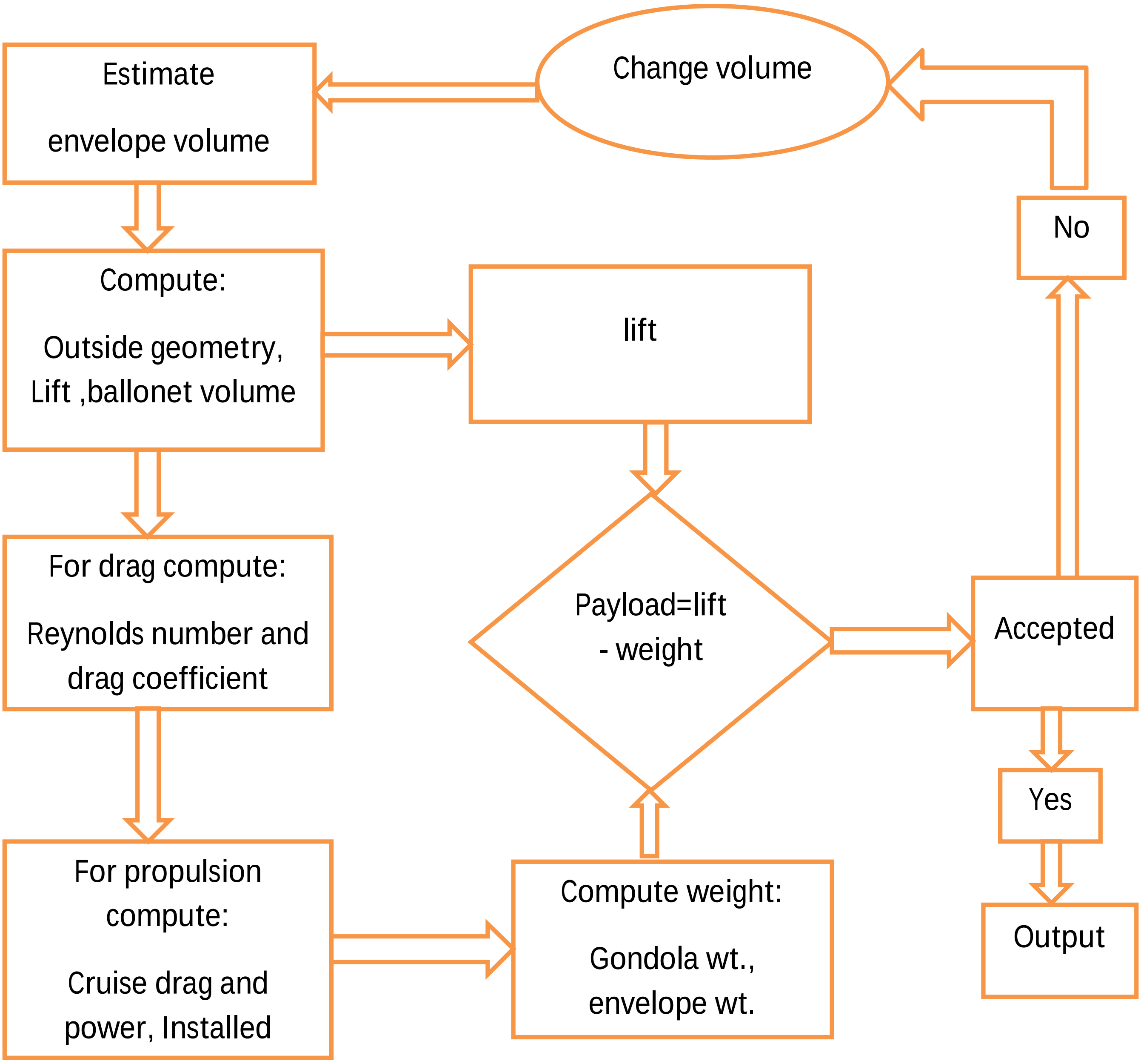
Figure 2.7 Lotte airship[14]

2.2 Methodology to estimate volume

One of the methodology is given by the Prof. R. S. pant IIT Bombay is given as follows:-

Below shown method is based on the fact that once we know the how much load we have to carry i.e. Payload we can estimate the volume of envelope. There is two way to estimate the volume either by feeding the payload and getting the design volume of envelope or initially assuming the volume and calculating the payload. And if that payload is less than the design payload which the airship has to carry then again go to start and increase the volume.

Methodology to estimate the volume



Chapter 3
Components and working principle

3.1 Components of airship

The main components of an airship as shown in Fig3.1

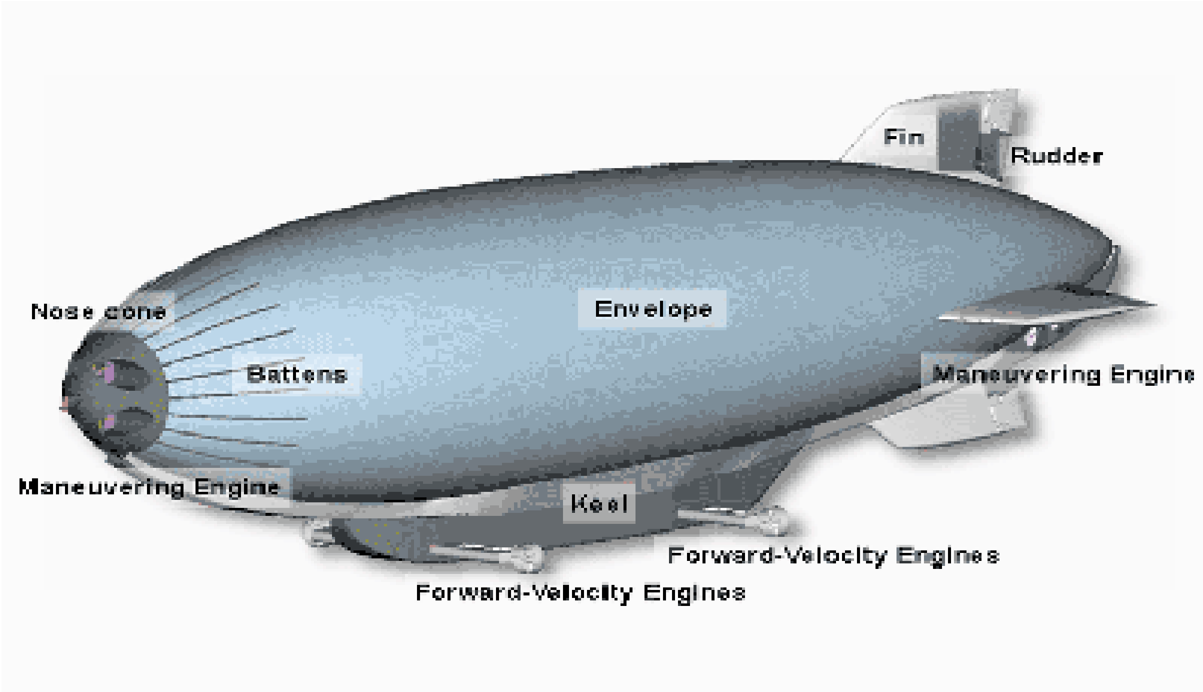


Figure 3.1 Components of Airship[15]

1. Envelope

It is a balloon in which the LTA gas is pressurised. The size of the envelope dictates the lift obtained. Its shape dictates the aerodynamic performance of the airship, and load distribution of the attachments.

2. Lifting Gas

Lighter than Air gases commonly used are Helium and Hydrogen. Hot air or methane is also used in some airships. Although hydrogen gives a higher specific lift and is cheaper, it is hazardous owing to its explosive nature. Helium, being inert, is safe and thus preferred for use in modern airships.

3. Air ballonets

These are installed within the gas space and connected to external air supply, pressurised to a required differential above atmosphere. When fully distended the ballonets may occupy as much as 40% of the envelope volume but within the altitude range for normal operation, they are partially collapsed and hence free to change their volume[1].

The ballonet volume will fall with decreasing atmosphere pressure and rise with decreasing temperature; for an ascending airship, the former effect without weigh the later, causing the ballonets to shrink as the airship climbs and expand with descent [1].

4. Gondola

The gondola (or car) is an aerodynamically shaped vessel, provided to house the crew, passengers and airship's general system. Depending on overall configuration, the gondola may be designed to carry the propulsion and power unit, fuel, ballast, landing gear, electrical system, etc.

5. Control surfaces

The bare hull of the classic streamline form is directionally unstable, tending always to turn broadside on to the direction of motion. In the horizontal plane this deviation is resisted by fixed vertical tailfins, and in the vertical plane, this deviation is resisted by fixed horizontal tailfins. Intermittent adjustment of rudders and elevators keep the airship on course.

3.2 Working Principle:-

Airships work on the principle of buoyancy. When filled with LTA gas, the envelope of the airship displaces air, and therefore an upward force acts on airship equal to the weight of displaced air. This is nothing but Archimedes Principle.

This upward buoyancy force in case of air can be mathematically expressed as:

$$B = V.\rho_a \qquad (3.1)$$

where,

B is the upward buoyancy force acting on the bod

V is the volume of the body

P_a is the mean density of atmosphere surrounding the body

This buoyancy force acts on all bodies within the atmosphere but is usually negligible compared with the weight of the body itself. If, however, the weight W of the body is less than that of the displaced air, there will be a net upward lift L given by:

$$L = B - W \quad \textit{(3.2)}$$

The obvious case to be considered is that of a balloon incorporating a closed flexible envelope of volume V filled with a gas density ρg which is less than ρa, for example Hydrogen or Helium. The total weight of the system will then be:

$$W = V\,.\rho_g + W_o \quad (3.3)$$

where,

Wo is the weight of the envelope and attachments

The above three equations result in,

$$L_d = V(\rho_a - \rho_g) - W_0 \quad (3.4)$$

$$= L_g - W_0$$

where,

L_d is disposable lift

L_g is gross lift.

Thus, Ld is the weight which an airship can carry. Hence, unlike aeroplanes, airships achieve lift without any external means.

Chapter 4
Design of envelope

4.1 Envelope:

Envelope itself is the outer surface usually surrounding one or More gas bags or ballonets within it. For non-rigid and semi-rigid airships, the envelope is one of the major structural elements. It is, therefore, required that this part of an airship deserves special attention. Materials, design and workmanship must be of the highest standard possible. Additionally, material performance and overall cost need consideration. Since these requirements are in some aspects contradictory, the challenge is to find the best compromise.

The envelope (or hull) is the most critical component of the airship. The design of envelope influences the payload as well as the drag; and thus is most crucial.

Envelope design comprises of the following steps:

1. Finding a suitable material for the envelope
2. Selection of LTA gas
3. Deciding shape and size of the envelope

3.2 Material selection

Materials ideal for use in pressurized non-rigid airship envelopes would have the following properties:

1. High strength: The strength of the material will determine the maximum possible size of the envelope. The airship envelope is subjected to various forms of loading which the material as well as the joints should be able to sustain. The major contributors to load are:

i. Aerodynamic load

ii. Gondola load and fin attachments

iii. Load due to internal over-pressure

2. High strength to weight ratio to minimize the weight of the envelope.

4. High tear resistance to give damage tolerance.

5. Low permeability to minimize gas losses. Gas loss result in increase the operational costs and loss of operational capability due to reduced lift as well as compromised shape.

6. Joining techniques that produce strong and reliable joints, not subject to creep rupture.

7. Low creep to ensure that the envelope shape is maintained throughout its life.

8. Sufficient flexibility to ensure protection against damage due to kinks and folds during operation and storage.

4.2.1 Material Procured

After a through market search, the following materials were obtained and tested:

For convenience: Poly Vinyl Chloride materials shall be classified according to their specific weight and thickness.

a) PVC Material (265 gsm)

b) PVC Material (162 gsm)

c) PVC Material (150 gsm)

d) Aluminium foil (120 gsm)

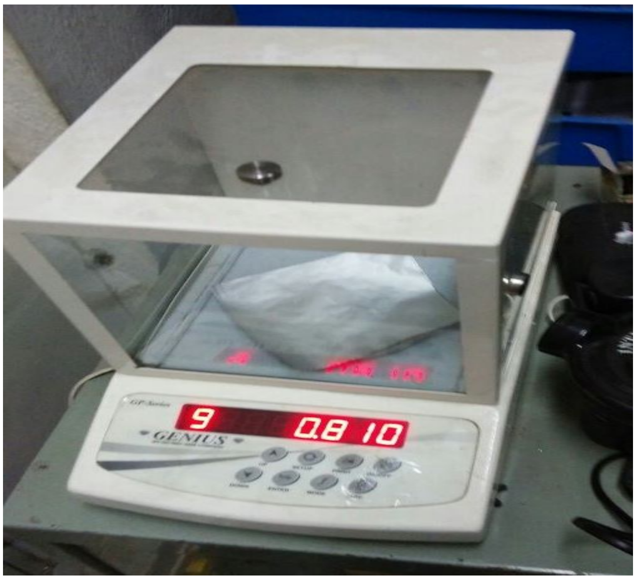
e) Aluminium foil (85 gsm)

4.2.2 Material testing

To find the weight and sealing property of above materials procured different test have been made:-

Weight measurement

Five piece of every sample material is made of dimension 10 cm width and 10 cm height. All the pieces are weighed on electronic weighing machine which give us the weight of each piece on digital screen. Then the five weights are averages out and finally gives the exact weight of the material



4.1 Weight balance machine

Sealing test

Sealing test had been done on the heat sealing machine. Which uses a kenthol metallic strip by using current from the coil to get heated which heats the material and produce the sealing. A digital display is there to adjust the timing which control the heating (over heating).

All the samples have been checked for the sealing by changing the time (at different time of heating). PVC material was not getting seal while the aluminium foil was able to sealed easily.

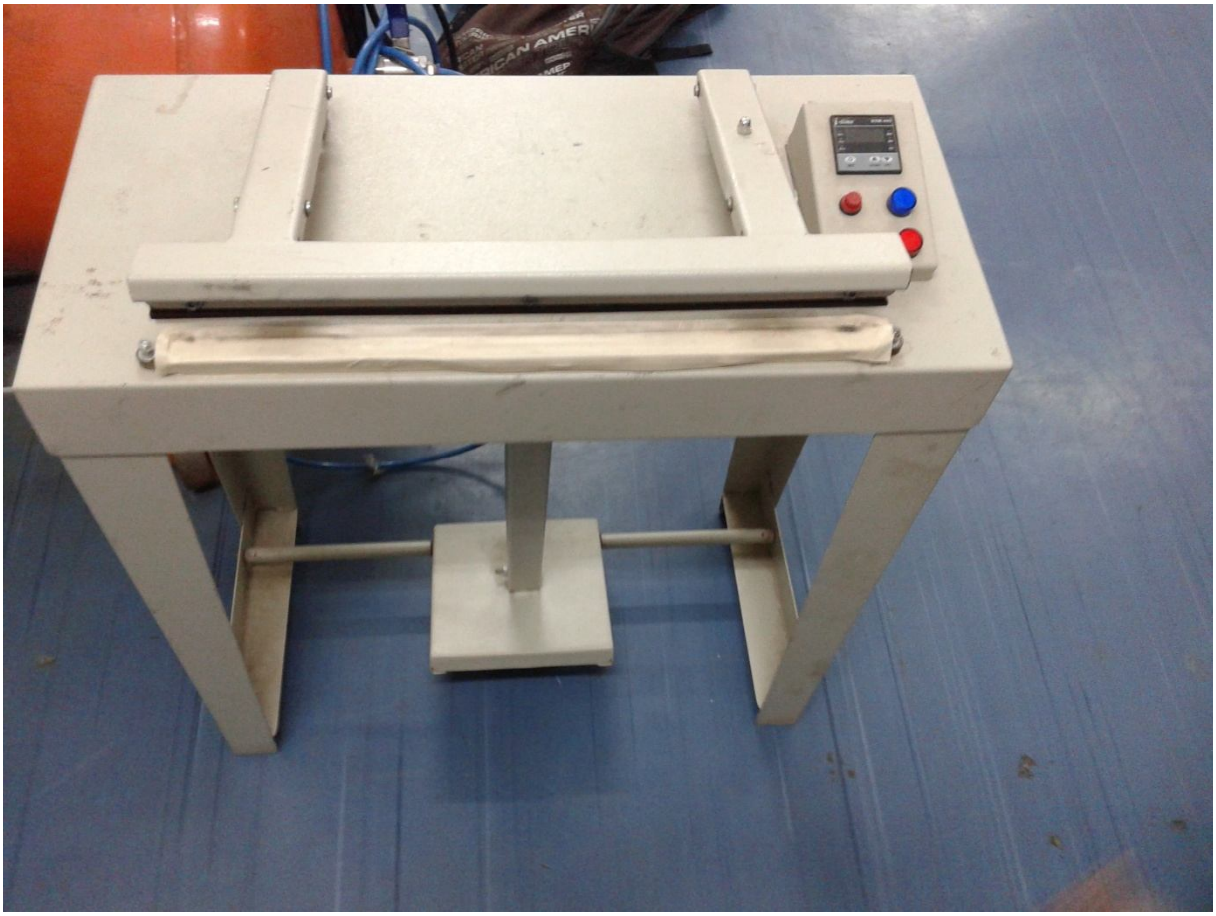


Figure 4.2 Heat sealing machine

Comparison of different material from above test result shown in table below:-

Table 4.1 Comparison of different materials

Materials	Weight(gsm)	Thickness(mm)	Sealing property	Cost (Rs/m^2)
PVC	265	0.15	Poor	75
PVC	162	0.125	Poor	68
PVC	150	0.1	Poor	65
Aluminium foil	120	0.125	Good	120
Aluminium foil	85	0.1	Good	85

First threePVC materials have been analyzed and discarded due to their weight. These three materials have comparatively more specific weight which is not suitable For the airship. Also the adhesion property of these material are not good. Other alluminium foil have good sealing property but it has been discarded due to its high weight.

Finally alluminium foil having least weight (i.e. 85gsm) is selected for the following reason:-

1) Having less weight (85gsm)
2) Good sealing property (heat sealing)
3) Adequate tensile strength (65N) and permeability
4) Low cost (85 Rs./m^2)

4.3 Selection of gas

Table 4.2 Properties of gas

Gas	**Density(kg/m^3)**	**Specific lift(N/m^3)**	**Remark**
Hydrogen	0.085	11.20	Inflammable, relatively cheap
Helium	0.168	10.20	Inert, relatively Expensive
Hot air	0.906	3.14	Inert, very cheap, relatively poor lift
Methane	0.756	4.50	Inflammable, relatively cheap

From above table it can be seen that helium have comparatively low lifting capacity and it is inert gas (safe to handle) but it is costly while hydrogen has high lifting capacity and very cheap and its flammable (hazardous).
Although it is inflammable but due to its high lifting capacity and much lower cost hydrogen gas is preferred for our indoor airship.

4.4 Deciding shape and size of envelope

The first and foremost issue related to envelope design is its shape, which has to meet many conflicting requirements. The shape should result in large volume but low surface area, since the lift producing capacity of an airship envelope is directly proportional to its volume, and its weight is proportional to the surface area. If this was the only consideration, the best shape would have been spherical; however, such a shape would result in large drag and it will not look like an areal vehicle, and hence lead to a much more powerful (and hence heavier) propulsion system.

Design criteria:-

1. Minimum surface area (minimum envelope weight)
2. maximum volume (maximum lift)
3. L/D ratio
4. Surface area/ volume ratio
5. Maximum diameter

As we are designing the indoor airship the main criteria to design the shape is it’s maximum diameter. The maximum diameter should not exceed the average width of the door as we have to carry the shape inside the room . the average width of the door is 1.3 meter. Hence the max diameter of the shape should be 1.3 meter. Inspite of the maximum diameter all other criteria are also important.
A throughout study of various airships which have already been made is done and we have come to know various shapes of envelope. All the shapes have been studied and we have calculated the surface area, volume, L/D ratio and surface area/volume ratio.

4.4.1 Standard shapes of envelope:

1. GNVR

2. NPL

1. GNVR:

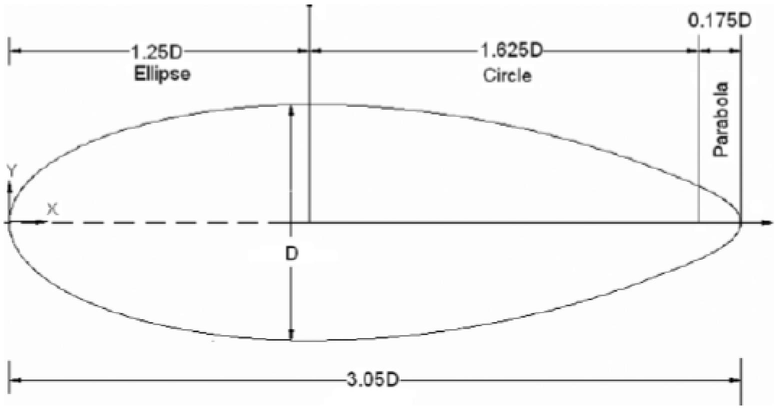


Figure 4.3 GNVR shape envelope[3]

GNVR shape consists of three standard sections, namely ellipse, circle and parabola and its entire geometry is analytically parameterized in terms of its max diameter D as shown if Fig4.3

2. NPL:-

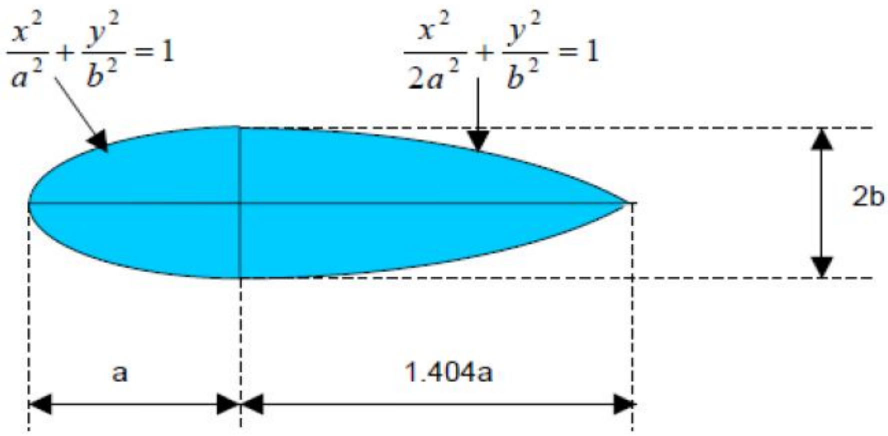


Figure 4.4 NPL shape of envelope[3]

NPL shape is double ellipsoidal shape which consist of two ellipsoid explained by two different equation as shown in fig.4.4.

Curve equation of the above shapes are known hence we calculated the surface area and volume of these shapes from predefined formulae.

We also get some unknown shapes which equation were not known. Hence we adopt a different methodology to calculate the surface area and volume.In this method we grabbed the minimum 500 points on the periphery of the image by using MATLAB @ grabit software. Grabbing points give us the co-ordinates of the all the points. After knowing the co-ordinates by elementary method we have calculated the surface area, volume, L/D ratio.

Some of the shapes and their surface area, volume, L/D ratios are shown below:-

4.5 Different shapes

SHAPE6:-

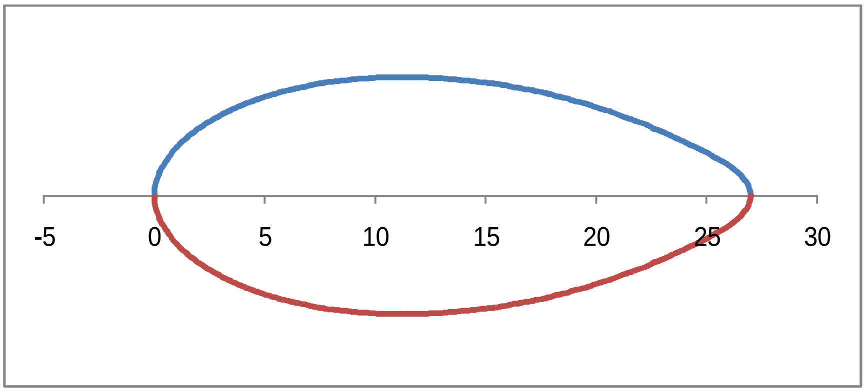


Figure 4.5 SHAPE6

Surface area = 12.74 m^2

Volume = 3.287 m^3

Length= 3.987 m

L/D = 3.067

S.A./Volume = 3.876

SHAPE15

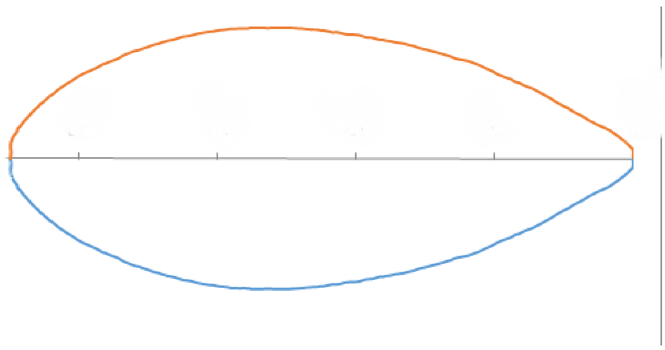


Figure 4.6 SHAPE15

Surface area = 10.072 m^2

Volume = 2.502 m^3

Length= 3.2048 m

L/D = 2.465

S.A./Volume = 4.025

SHAPE16

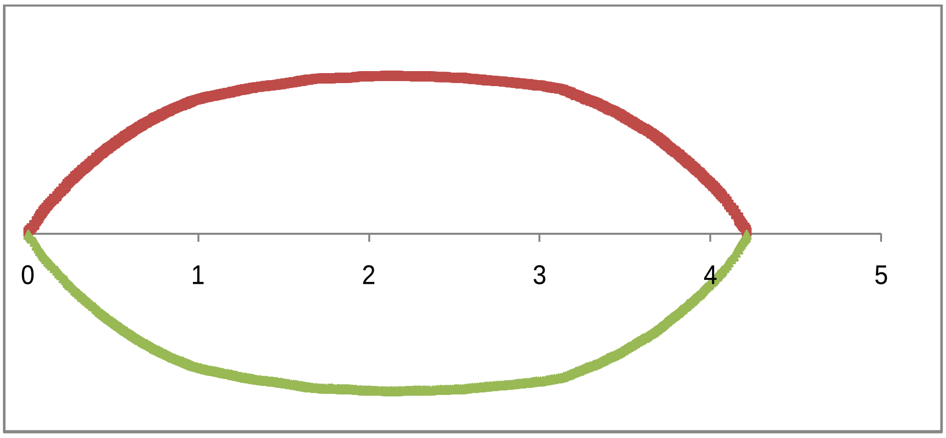


Figure 4.7SHAPE16

Surface area = 13.037 m^2

Volume = 3.487 m^3

Length= 3.708 m

L/D = 2.85

S.A./Volume = 3.73

Comparison of all 16 shapes which have been studied are shown in table below:

4.6 Comparison table of all shapes :

Table 4.3 comparison of all shapes

SHAPE	VOLUME (m^3)	SURFACE AREA (m^2)	SA / Vol	ENVELOPE WEIGHT (kg)	GROSS LIFT (kg)	NET LIFT (kg)	LENGTH (m)	L/D
SHAPE1	2.237	8.904	3.980	0.757	2.503	1.747	2.520	1.938
SHAPE2	2.153	8.796	4.086	0.748	2.409	1.661	2.550	1.961
SHAPE3	2.471	9.949	4.026	0.846	2.765	1.920	3.063	2.356
SHAPE4	2.521	10.182	4.039	0.865	2.821	1.956	3.320	2.554
SHAPE5	1.879	7.827	4.167	0.665	2.102	1.437	2.271	1.747
SHAPE6	3.287	12.744	3.877	1.083	3.678	2.595	3.987	3.067
SHAPE7	1.916	7.880	4.113	0.670	2.144	1.474	2.189	1.684

SHAPE8	2.725	11.141	4.088	0.947	3.049	2.102	3.230	2.485
SHAPE9	2.582	10.229	3.961	0.869	2.890	2.020	3.104	2.388
SHAPE10	3.106	12.443	4.007	1.058	3.475	2.418	3.831	2.947
SHAPE11	2.589	10.248	3.958	0.871	2.898	2.026	3.107	2.390
SHAPE12	2.642	10.563	3.998	0.898	2.956	2.058	3.078	2.367
SHAPE13	2.485	9.970	4.013	0.847	2.780	1.933	3.140	2.416
SHAPE14	2.757	10.747	3.899	0.914	3.085	2.171	3.043	2.341
SHAPE15	2.502	10.073	4.025	0.856	2.800	1.944	3.205	2.465
SHAPE16	3.487	13.037	3.738	1.108	3.902	2.794	3.708	2.853

4.7 Comparison chart:

Graphs showing the comparison of all the shapes on the basis of desired properties as shown in above comparison table:

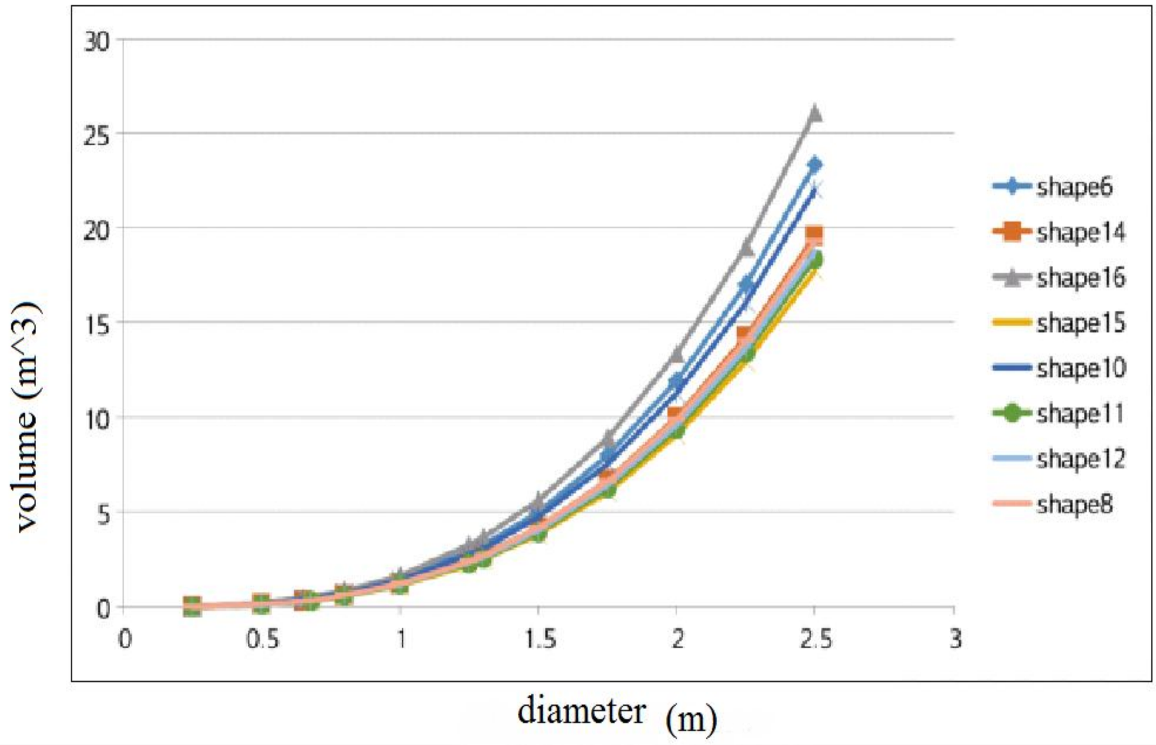


Figure 4.8 diameter v/s volume

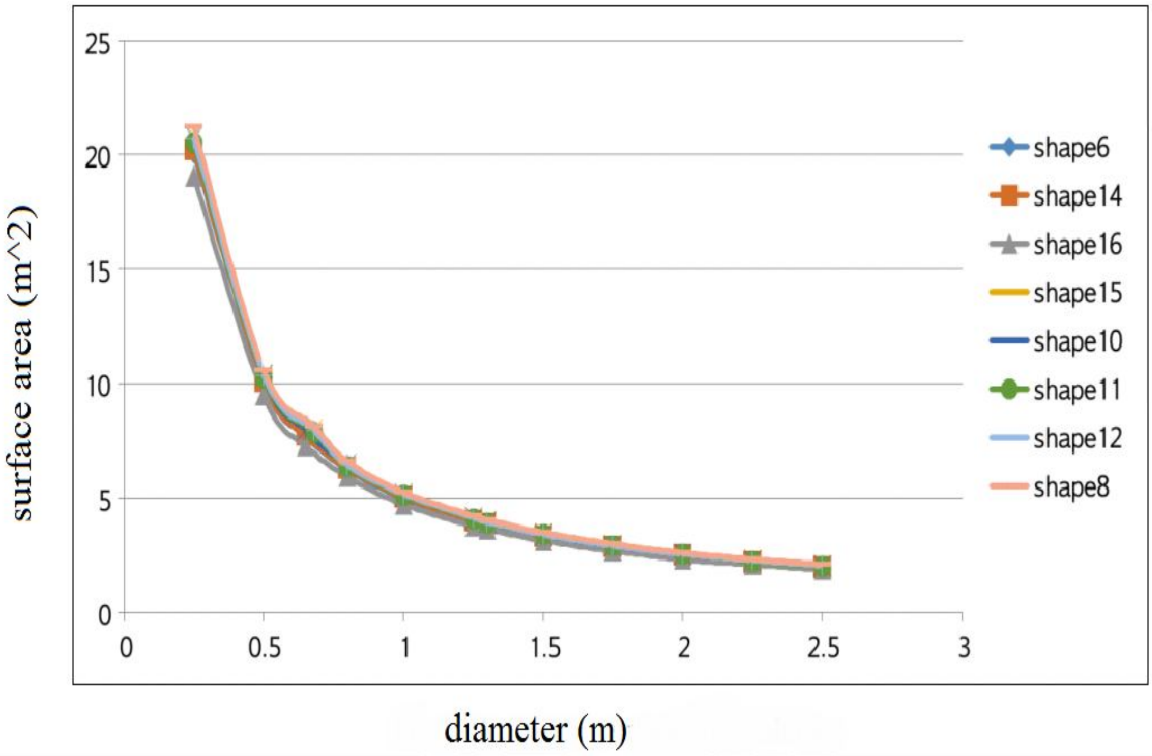


Figure 4.9 diameter v/s surface area

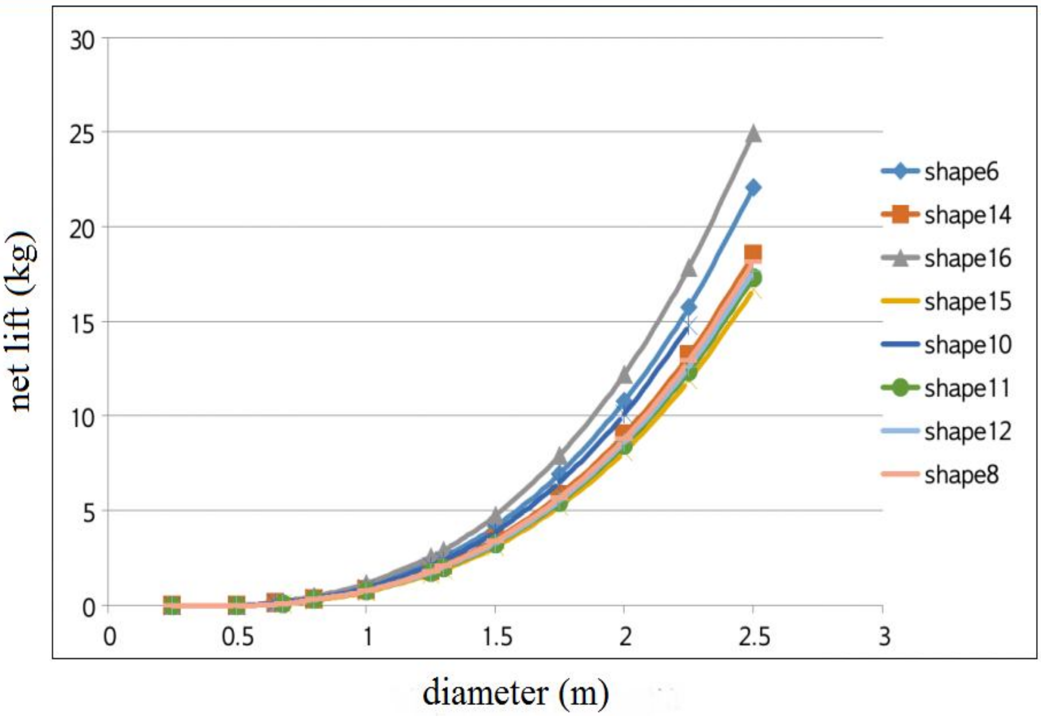


figure: 4.10 diameter v/s net lift

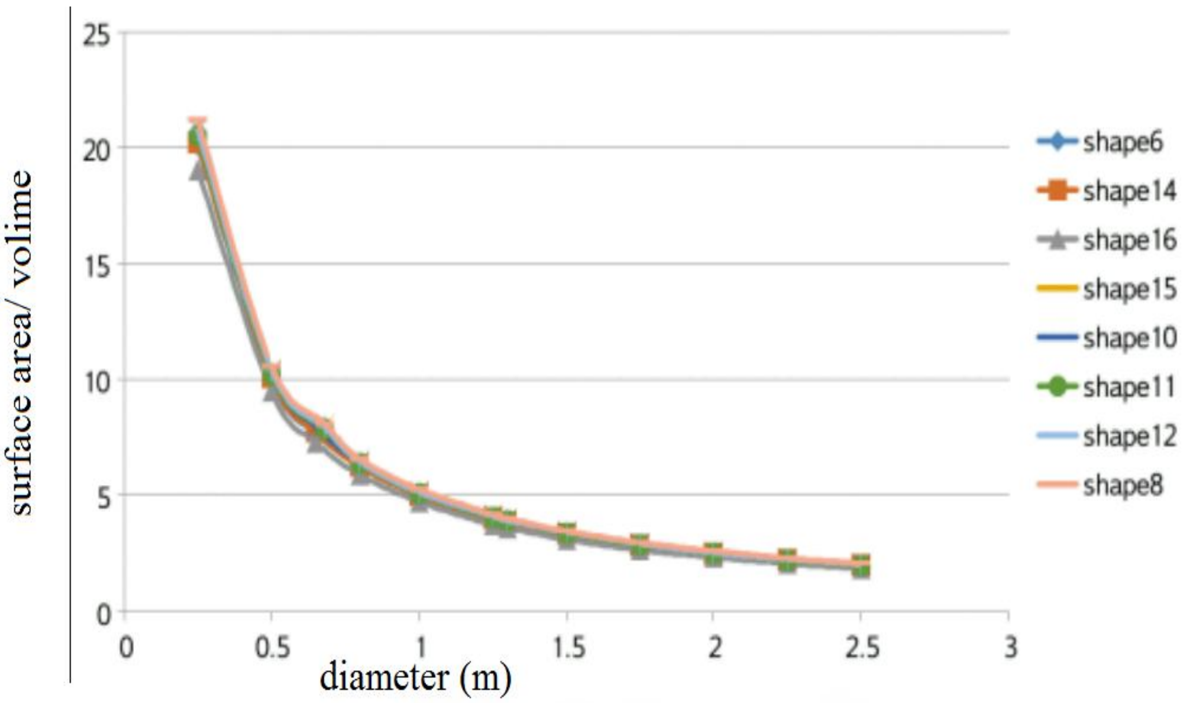


Figure 4.11: diameter v/s surface area/ volume

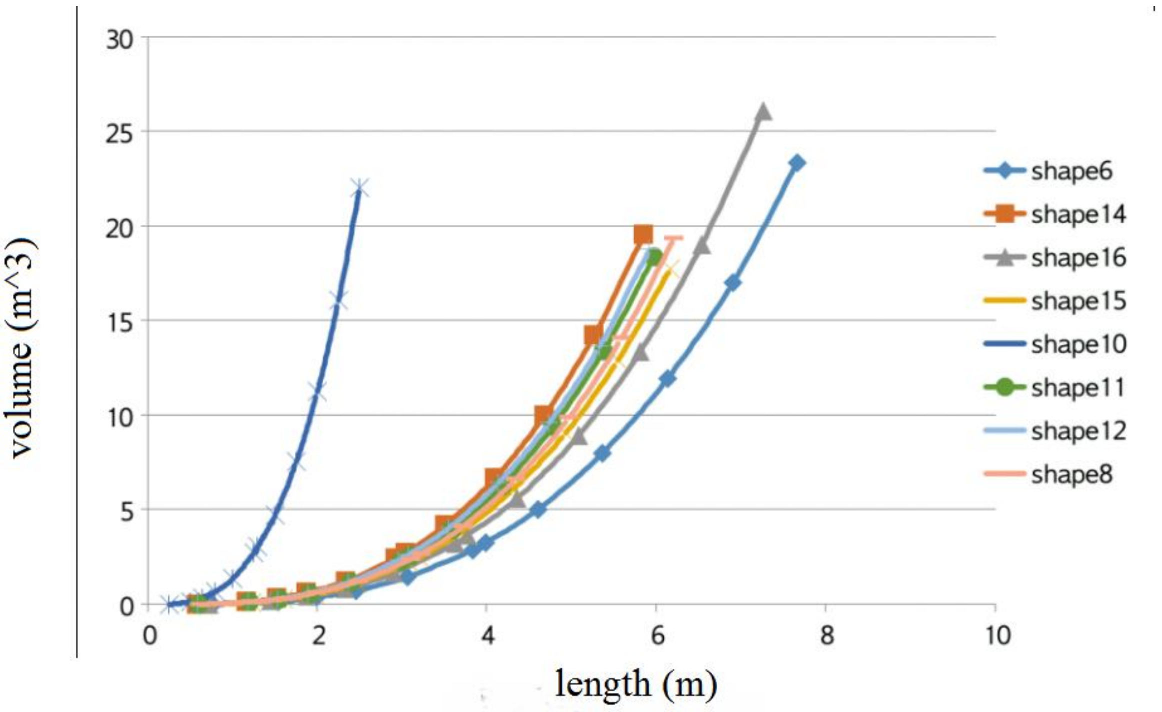


Figure 4.12: length v/s volume

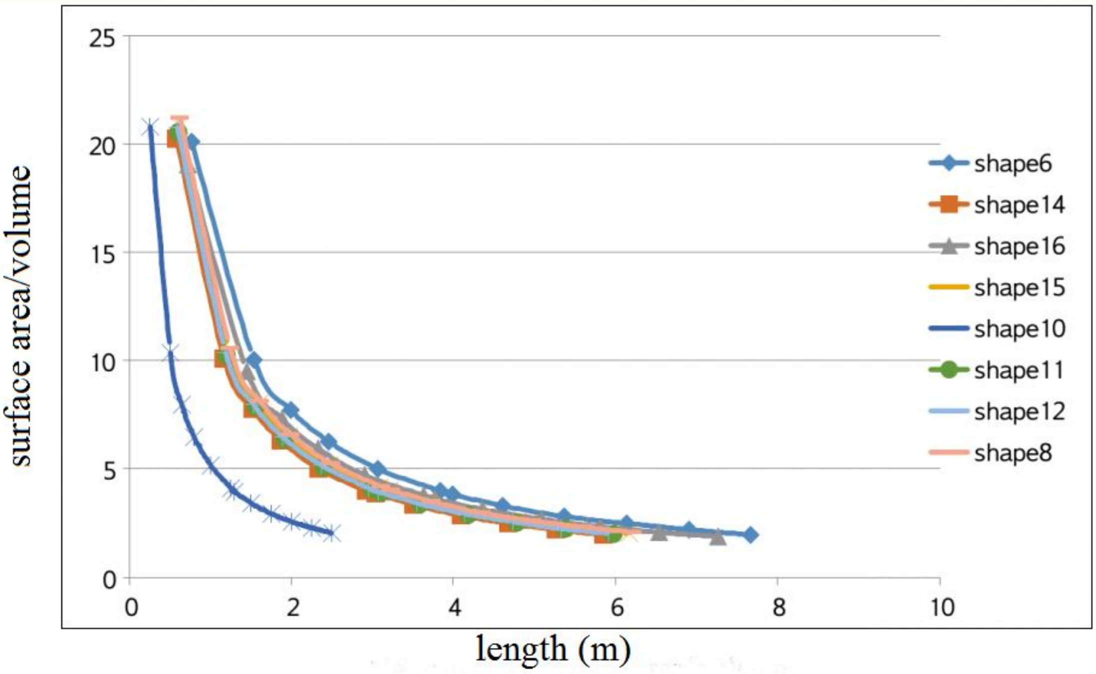


Figure 4.13 length v/s surface area / volume

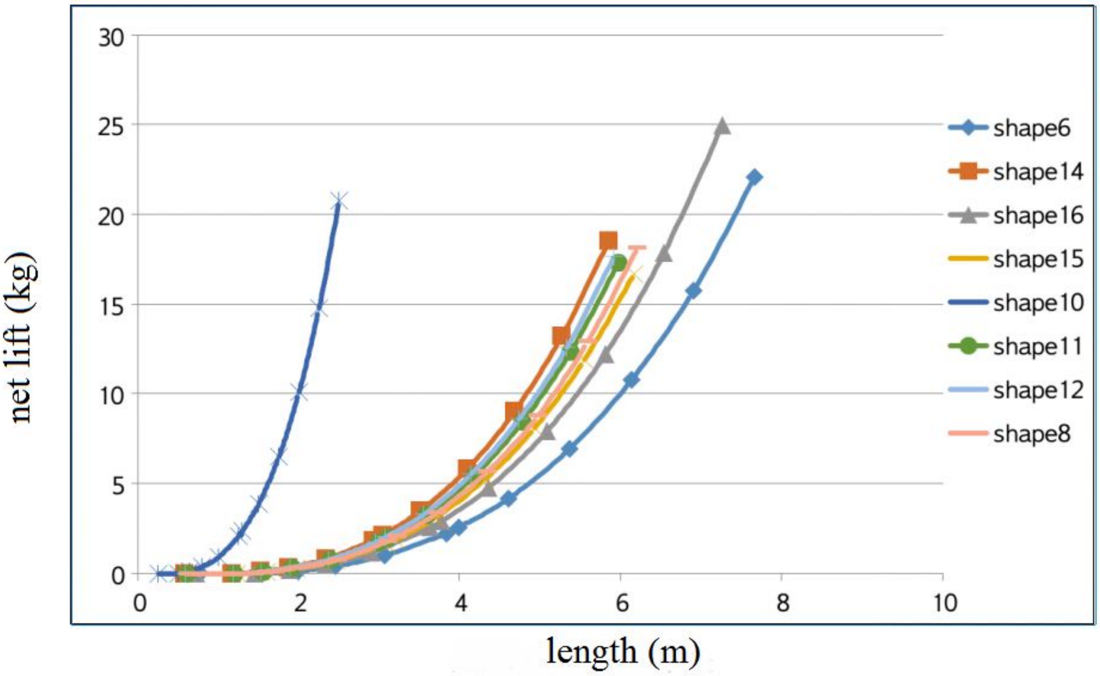


Figure 4.14 length v/s net lift

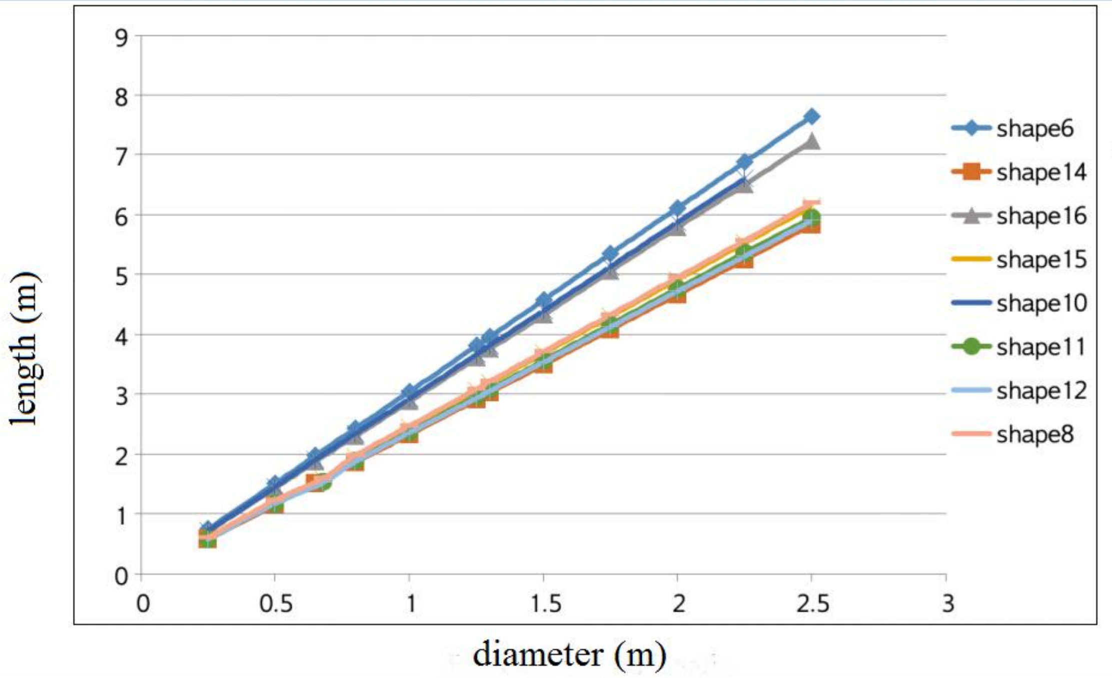


Figure 4.15 diameter v/s length

From above graphs we conclude that the shape 16 is giving maximum lift for 1.3 m diameter also it's surface area/ volume is less.

4.8Selected shape:-

From above table and charts we can see that shape16 is giving large volume, minimum surface area/volume ratio. Hence we have selected shape16 (zeppline) for our indoor airship.

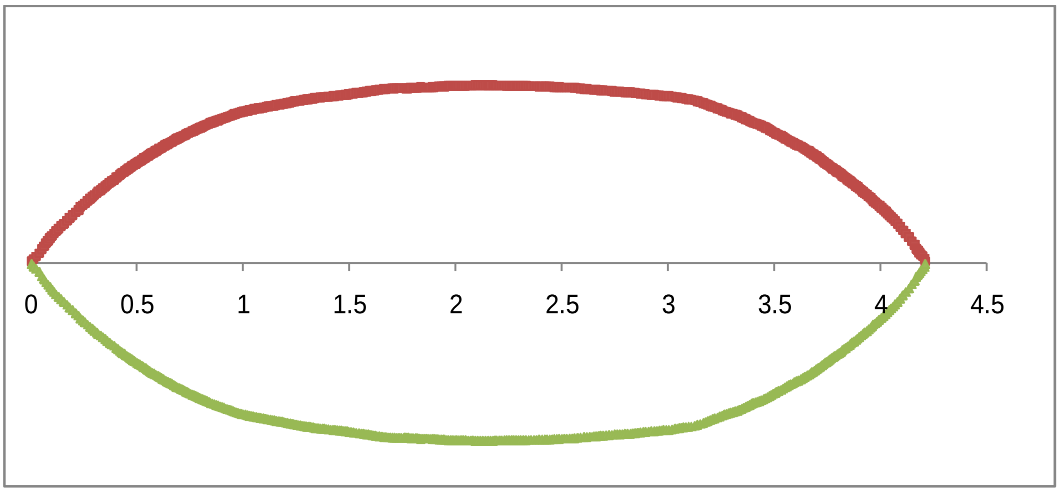


Figure 4.16 selected shape (zeppeline)

4.8.1 Calculation for lift:-

Density of hydrogen= 0.085kg/m^3

Surface area = 13.037m^2

Volume = 3.487m^3

Specific weight of envelope material= 85gsm(grame/sqr meter)

Weight of envelope= surface area×specificweight (4.1)

= 13.037×0.085

= 1.108kg

Gross lift= volume ×(density of air- density of hydrogen (4.2)

= 3.487×(1.204-0.085)

=3.902 kg

Net lift= gross lift- envelope weight (4.3)

=3.902-1.108

=2.795kg

Net lift=2.795kg

Hence it is giving maximum lift in 1.3m diameter.

Chapter 5
Fabrication of envelope

Before starting the fabrication of actual designed envelope a small model is fabricated, To get a brief idea of fabrication of envelope. Also to validate the theoretical lift and volume of selected shape, check the material sealing property and permeability this model is made. Specification of model is shown on following table:

Table 5.1: specification of model

Specification	**Value**
Diameter (m)	0.35
Length (m)	1
Volume (m^3)	0.072
Surface area (m^2)	0.978

Figure 5.1: Fabricated model of envelope

Model of envelope is checked for sealing strength and permeability of the material. Both the property of the material is found out to be excellent. It also validated the petal profile generating method as we got the exact design length of envelope and also the exact shape after fabricating.

The detail method of fabricating the actual envelope is explained in further sections:

After deciding suitable material of envelope and design and selection of shape the next part is fabrication of envelope.

Steps for fabrication of envelope:-

1) Deciding no. of petals
2) Generating petal profile
3) Petal cutting
4) Sealing of patches on the petal
5) Fabrication of nozzle
6) Sealing of petals

5.1 Deciding no. of petals

Number of petals are decided as 8, for the ease of sealing, attaching the gondola at bottom single petal for securing the sealing joints.

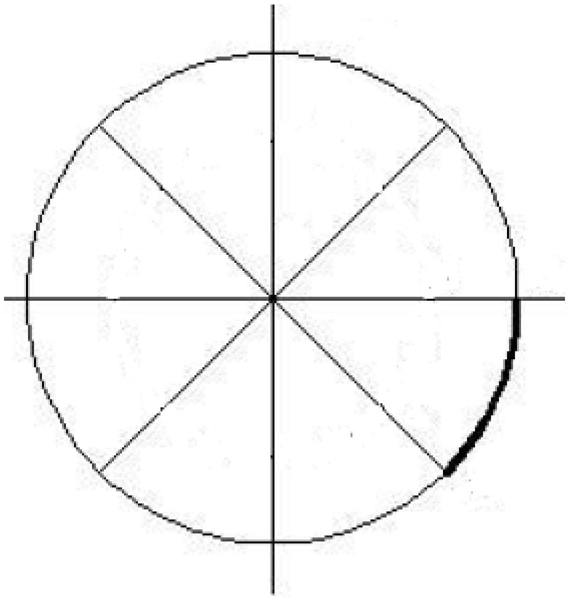


Figure 5.2 Deciding no. of petals

5.2 Generating petal profile

The hull is shown in two views viz. Front View (F.V.) and Side View (S.V.). O-O is the longitudinal axis. Circle B is at the greatest diameter of the hull, and circle A is a circle of any arbitrary diameter. The hull consists of 8petals. Consider the petal shown by bold lines. If the petal is removed from the hull and straightened on a plane, it will appear as shown in the 'Petal Profile', with axis of symmetry O'-O'. 2-2 is the greatest thickness of the petal which is an arc of the circle B (seen in F. V.).

The thickness progressively decreases from cylinder ends, to tip of the petal. To calculate the thickness of the petal at the various points from the centre to the tip, diameters and number of petals (n) is used. At the region of greatest thickness of the petal, i.e. 2-2, the diameter is maximum and corresponds to the diameter of the hull (D). At other points, for example – circle A, the diameter is smaller and a smaller thickness 1'-1' is obtained. The thickness is found out using the formula:

$$\text{Thickness of petal} = \frac{\pi \times d}{n} \tag{5.1}$$

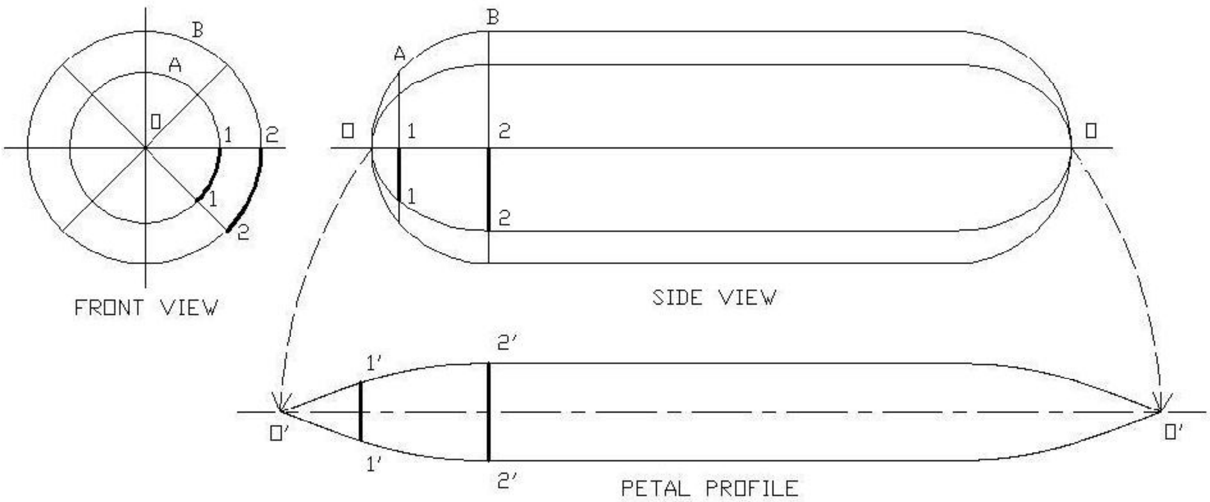


Figure 5.3 Generating petal profile[1]

Thus, various diameters at regular small intervals can be taken from F.V. and corresponding thicknesses can be calculated. A plot of the thicknesses against the length of the petal is taken to obtain the petal profile.

Above method gives the y co-ordinate (i.e. width of the petal).
To calculate the x co-ordinates of the petal, We are considering curve OA as a straight line i.e. diagonal of triangle OA1. That diagonal is calculated by Pythagoras theorem and gives the x co-ordinate of petal profile.

5.2.1 Petal profile:-

Petal profile is generated by calculating the co-ordinates of the petal and is plotted below:

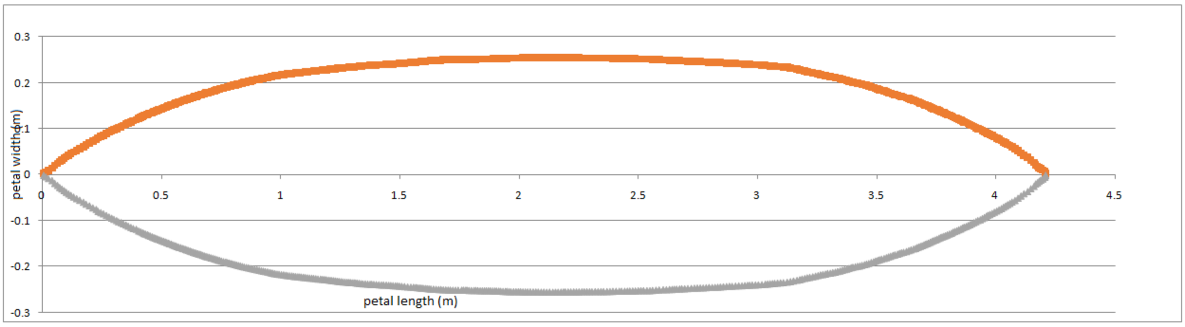


Figure 5.4 Petal profile

5.3 Petal cutting:-

After generating the petal profile 8 petals are cut by giving 1cm margin on both side for sealing.

Figure: 5.5 petal cutting

Figure: 5.6 Petals

5.4 Sealing of patches on petal:-

Number of patches are sealed at specified position for the fin attachment, gondola attachment and nose batton.

Figure: 5.7 Sealed patches on petal

5.5 Fabrication of Nozzle:-

The nozzle is manufactured using the same aluminium foil material. It is manufactured in three stages:

1. A rectangular piece of aluminium foil material is sealed breadth to breadth to forma cylinder. The polymer layer is on the inside, and the metal layer on the outside of this cylinder.
2. The cylinder is physically inverted, thus bringing the polymer layer on the outside.
3. This is sealed between two adjoining petals as shown in figure.

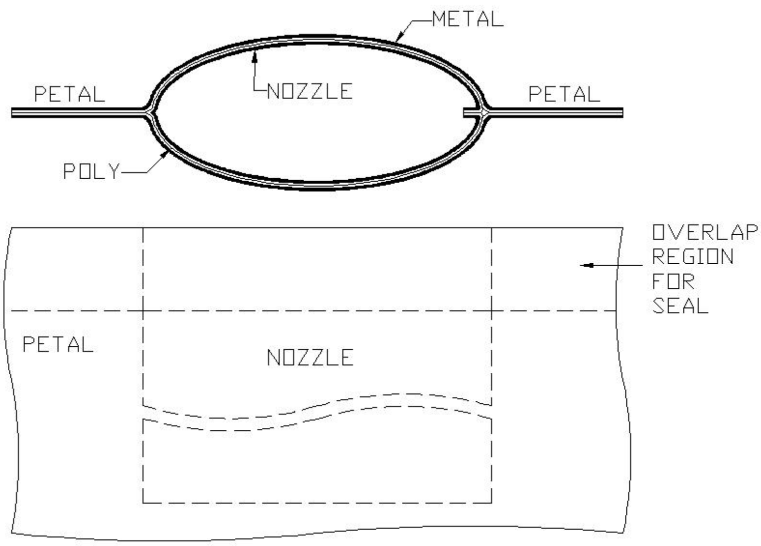


Figure: 5.8 Nozzle design[1]

5.6 Petal sealing:-

Sealing is done on heat sealing machine. For the convenience in sealing first two petals are sealed together to form 4 parts containing two petals. Then the two parts are sealed which form final two parts containing four petals together. Finally the parts containing four petals are sealed together to form final hull profile (envelope).

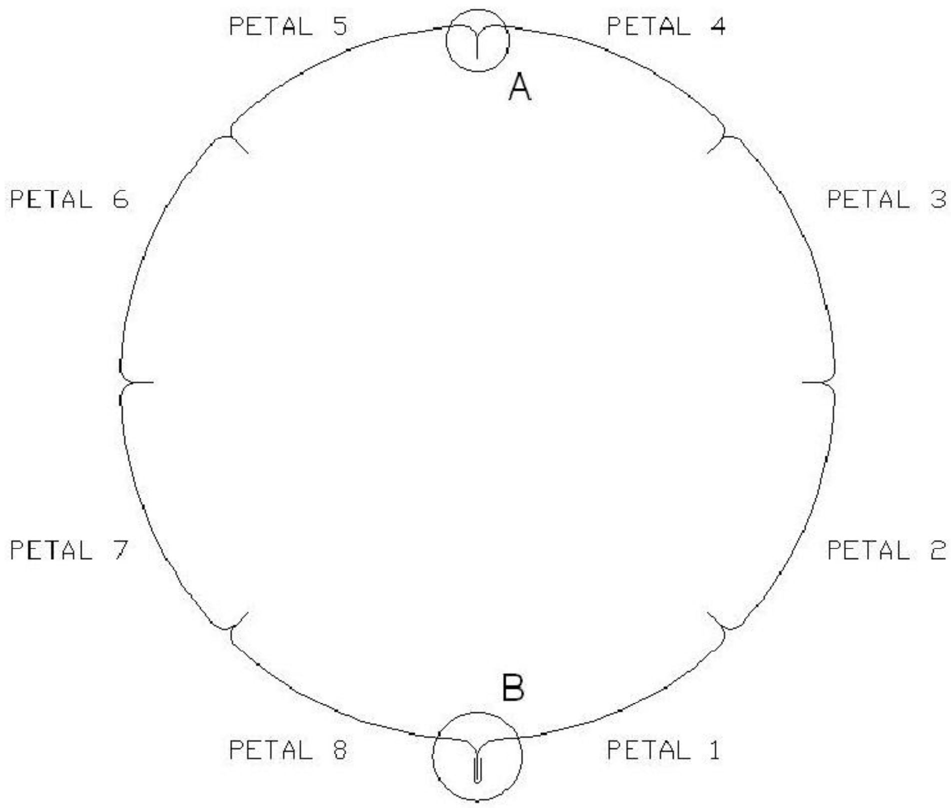


Figure: 5.9 sealing configuration of petal joint[1]

If we go on sealing continuously each petal together then there will be difficulties in sealing and handling the petals while sealing due to the geometry of the sealing machine.

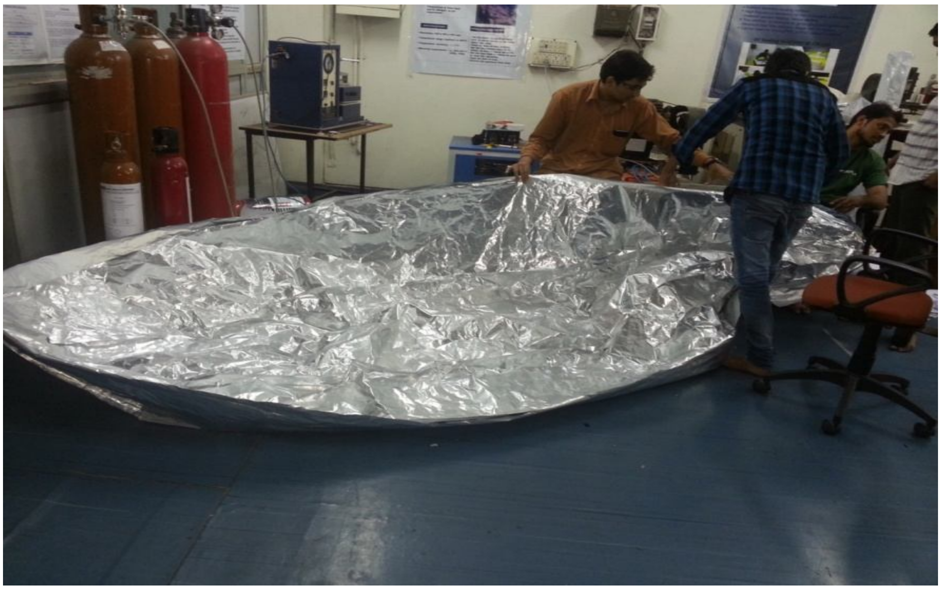


Figure: 5.10 petal sealing

Figure: 5.11 petal sealing

Final fabricated envelope:

Figure: 5.12 sealed envelope

Figure: 5.13 final air filled envelope

Taking precaution while sealing petals:

1. Petals should be sealed carefully to avoid damage of envelope like tearing, pin holes.
2. Not a single point should be left without sealing because it will result in leakage of gas.
3. Petals should be sealed according to the patches provided for the fins and envelope i.e. it should give the exact position of the fins and gondola after sealing the envelope.
4. Nozzle should be sealed between the two petals in such a way that there should not be any leakage because there is 4 layer is going to sealed at one place hence it increases the chances of leakage.
5. Sealing should be perfect at the both noses because at the nose all the petals are being sealed together and also there is not appropriate surface for sealing.

Chapter 6
Inspection of envelope

After fabrication of envelope it must be checked for the leakage and permeability of the material. As we are going to fill inflammable, light weight hydrogen gas hence even a slight leakage is not bearable. Being light than air if hydrogen will find a small pin hole or a way to go out it will leak at very fast rate hence the volume will go on decreasing and will reduce the payload which will require a large propulsion force or else it will not fly. Also being inflammable the leakage may have a very hazardous effect, it may also have chances of catching fire.

Hence the inspection must be done for the leakage in the envelope. To detect the leakage initially the air is filled in the envelope and is left for 24 hours. After filling the air the diameter is measured and volume is calculated. Then after 24 hour again diameter is measured and volume is calculated and finally percentage decrease in volume is calculated. if the decrease in volume is less than 1% then it may be because of the permeability of the material and it is ok. But if it is more then it shows that there is leakages in the envelope and those leakages should be detected and will be covered by applying sealing tapes.

Method to detect the leakages:-

If the reduction in volume is more, Then envelope should be inspected for the leakages. This is done by using a helium detecting machine. A probe which sniffs the helium is being moved on the surface of envelope if there is any leakage it sniffs and the moment it sniffs a alarm ring on the machine which give indication that there is leakage and once knowing the leakage that is sealed by using sealing tape. Initially helium is filled along with the air. Helium being lighter than air it tends to go out before air and get detected by the probe.

Figure 6.1 Leakage testing of envelope

After sealing all the leakages again the same procedure is repeated and the percentage reduction in volume is calculated and if it comes in prescribed limits then the envelope is ready to implement in the airship.

Chapter 7
Result and conclusion

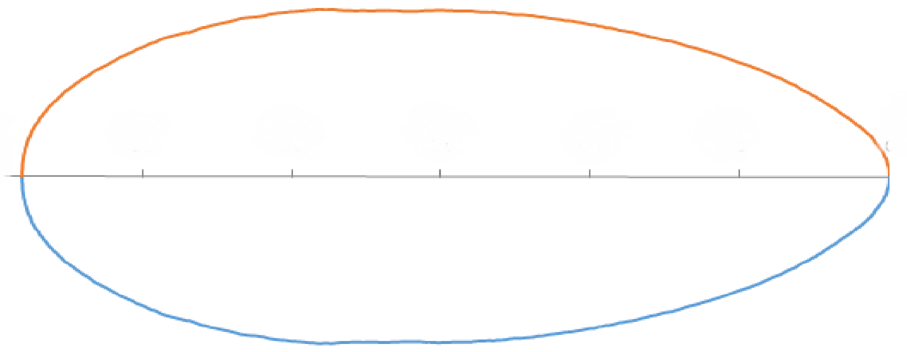
Our material was only one side sealable due to this we had difficulties while sealing the last petal of envelope which may cause leakage at that joint so we sealed that petal carefully After sealing of envelope we filled air in the envelope and we kept for one day after one day we got about 9% of leakage because of which our volume and payload both got reduce so to avoid that we check our envelope by helium testing machine during detection wherever we got leakages we sealed it by sealing tape and kept it again for one day after one day we got only 1% of leakage which was sufficient for our airship to carry payload.

The results obtained by the methodology adopted for designing the envelope are found to be satisfactory. With these observations, envelope for indoor airship is designed and fabricated. A successful flight of this airship, confirmed the design and fabrication methodology adopted for it.

Figure 7.1: flying airship

APPENDIX 1

SHAPE 1:-



SHAPE1

Surface area = 8.9036 m^2

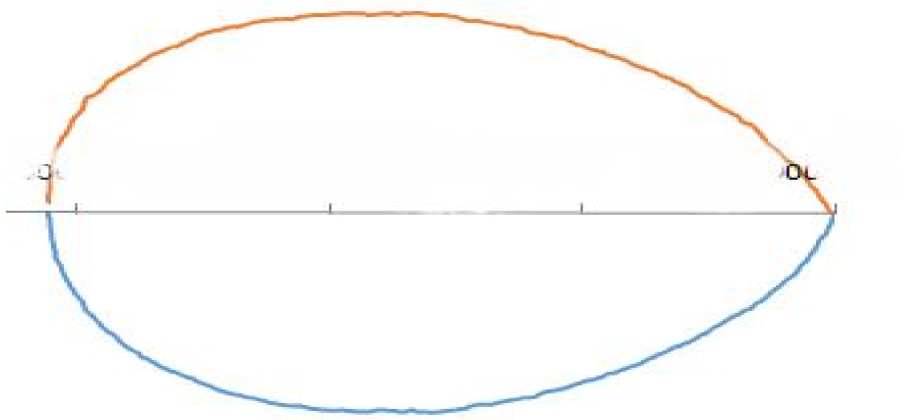
Volume = 2.237 m^3

Length= 2.5197 m

L/D =1.9382

S.A./Volume =3.9798

SHAPE 2:-



SHAPE2

Surface area = 8.7960 m^2

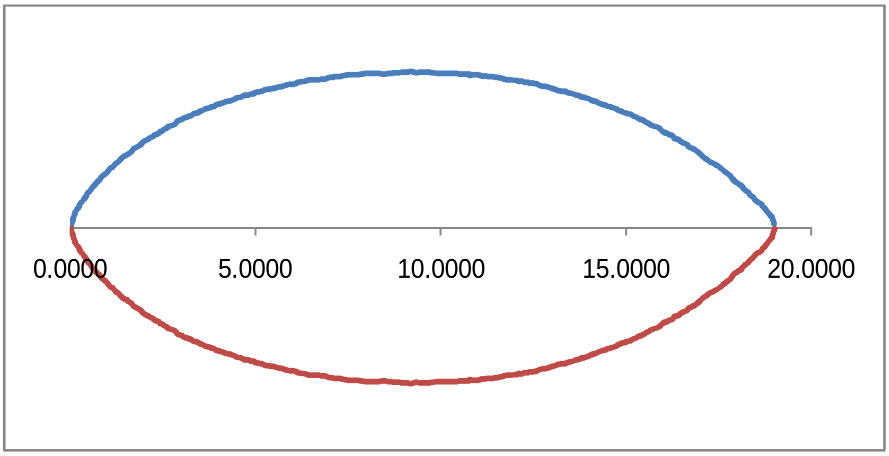
Volume = 2.1525 m3

Length= 2.5496 m

L/D =1.9613

S.A./Volume = 4.0863

SHAPE3:-



SHAPE3

Surface area = 9.9494 m^2

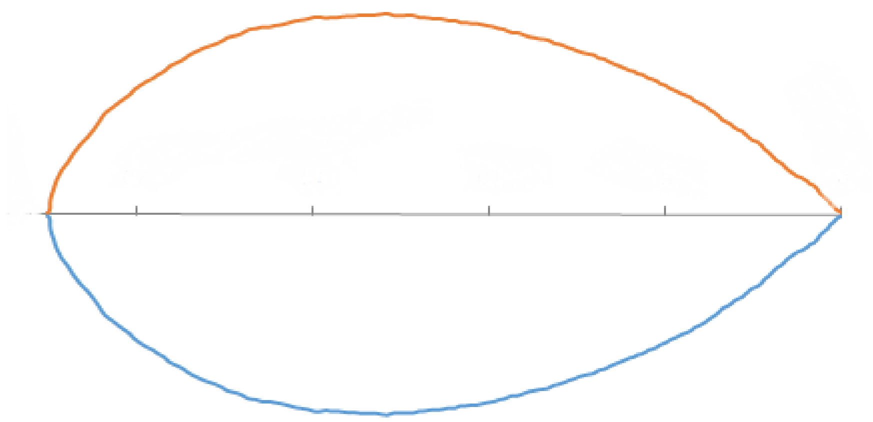
Volume = 2.4711 m^3

Length= 3.063 m

L/D =2.3563

S.A./Volume =4.026

SHAPE4:-



SHAPE 4

Surface area = 10.1822 m^2

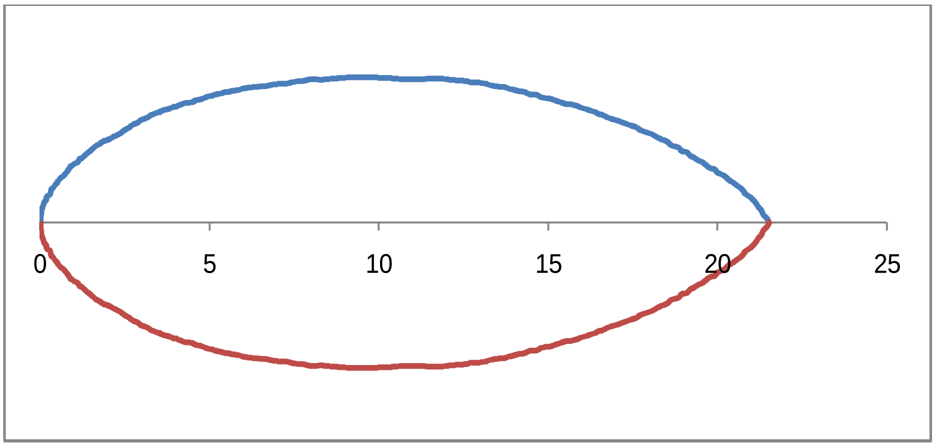
Volume = 2.5212 m^3

Length= 3.3197 m

L/D =2.5536

S.A./Volume = 4.0385

SHAPE5:-



SHAPE5

Surface area = 7.8272 m^2

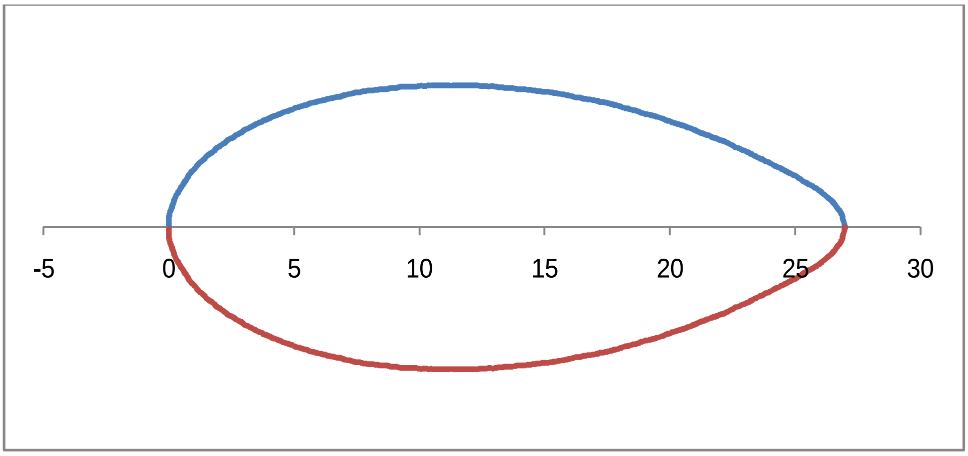
Volume = 1.8785 m^3

Length= 2.2709 m

L/D =1.7469

S.A./Volume = 4.1667

SHAPE6:-



SHAPE6

Surface area = 12.74 m^2

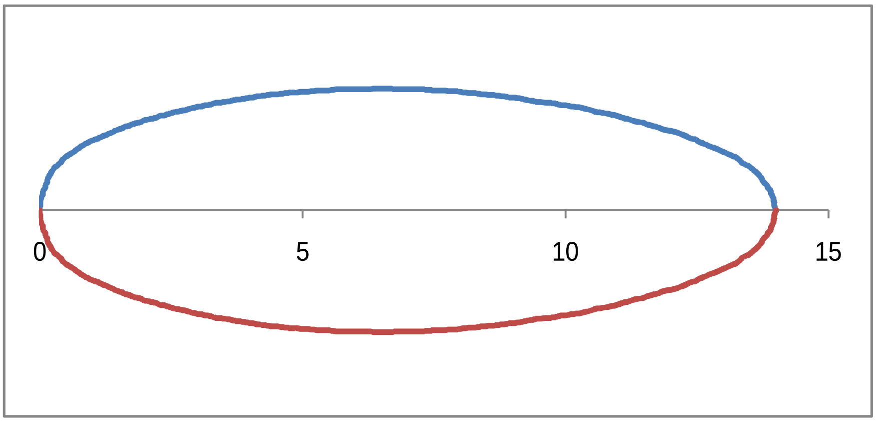
Volume = 3.287 m^3

Length= 3.987 m

L/D = 3.067

S.A./Volume = 3.876

SHAPE 7:-



SHAPE7

Surface area = 7.879 m^2

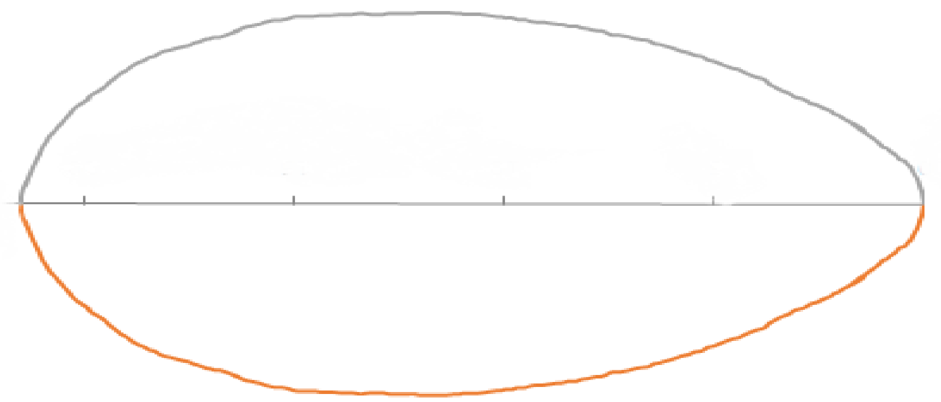
Volume = 1.9159 m^3

Length= 2.189 m

L/D = 1.68

S.A./Volume = 4.112

SHAPE 8:-



SHAPE8

Surface area = 11.11 m^2

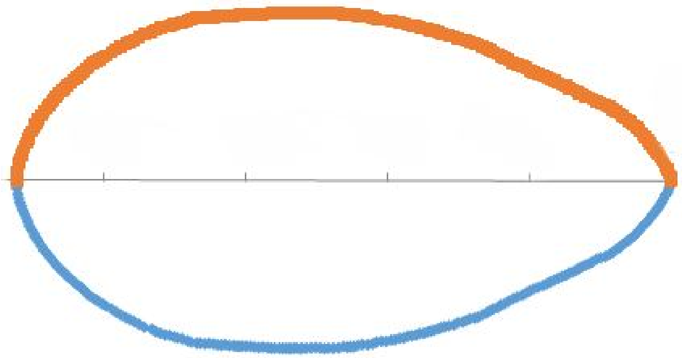
Volume = 2.725 m^3

Length= 3.23 m

L/D = 2.484

S.A./Volume = 4.088

SHAPE 9:-



SHAPE 9

Surface area = 10.229 m^2

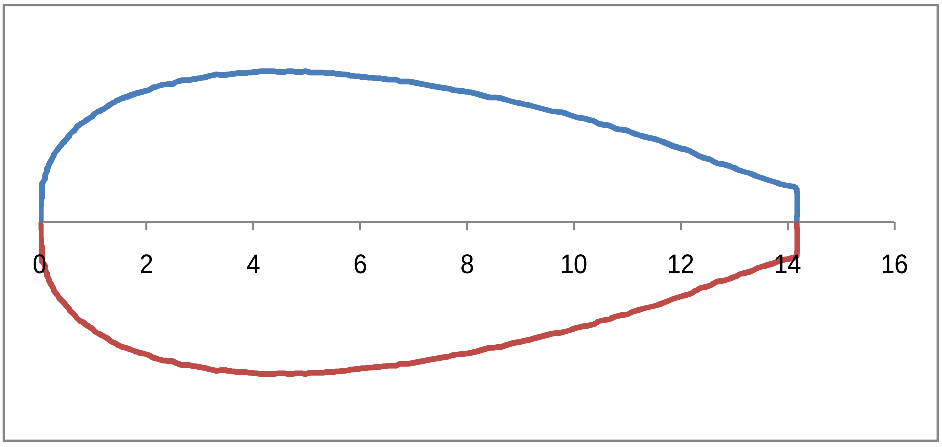
Volume = 2.582 m^3

Length= 3.104 m

L/D = 2.38

S.A./Volume = 3.9611

SHAPE10:-



SHAPE10

Surface area = 12.44 m^2

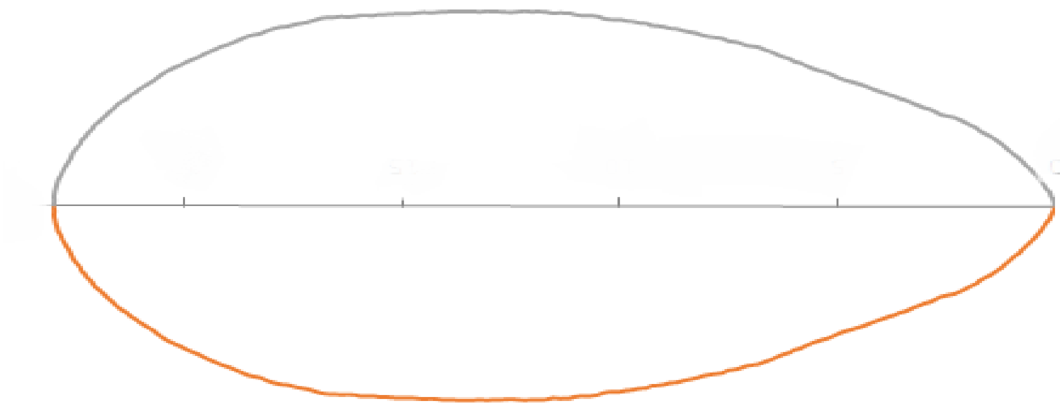
Volume = 3.105 m^3

Length= 3.831 m

L/D = 2.946

S.A./Volume = 4.006

SHAPE 11



SHAPE11

Surface area = 11.02 m^2

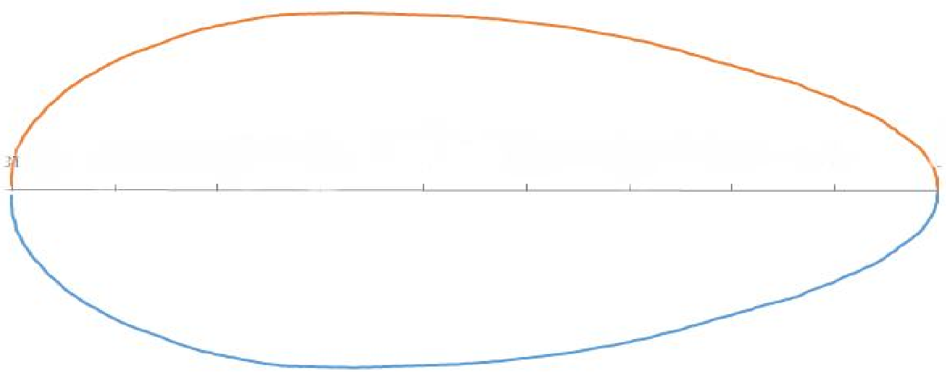
Volume = 2.589 m^3

Length= 3.11 m

L/D = 2.389

S.A./Volume = 3.95

SHAPE12



SHAPE12

Surface area = 10.56 m^2

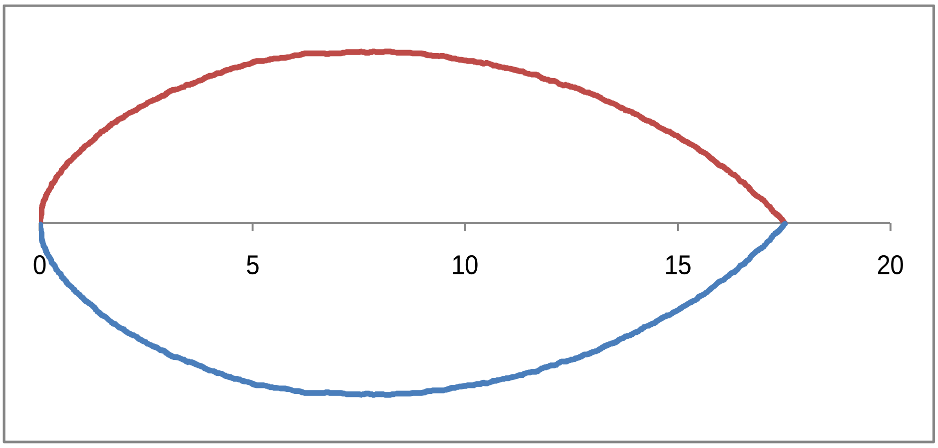
Volume = 2.64 m^3

Length= 3.077 m

L/D = 2.367

S.A./Volume = 3.998

SHAPE13



SHAPE13

Surface area = 9.97 m^2

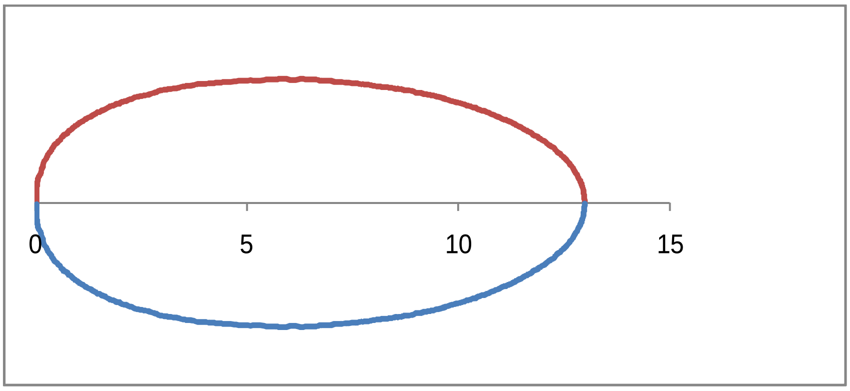
Volume = 2.484 m^3

Length= 3.140 m

L/D = 3.415

S.A./Volume = 4.012

SHAPE14



SHAPE14

Surface area = 10.74 m^2

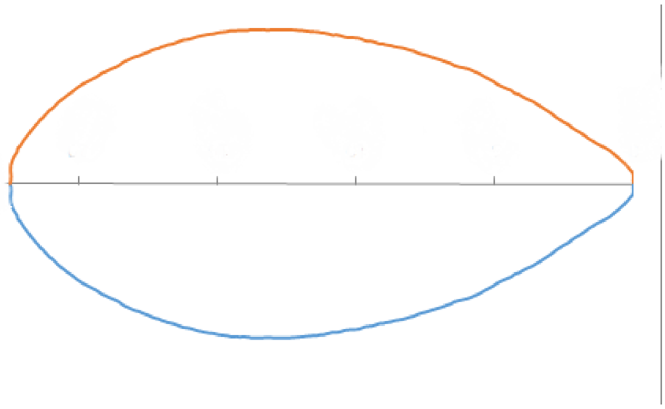
Volume = 2.756 m^3

Length= 3.043 m

L/D = 2.3411

S.A./Volume = 3.8988

SHAPE15



SHAPE15

Surface area = 10.072 m^2

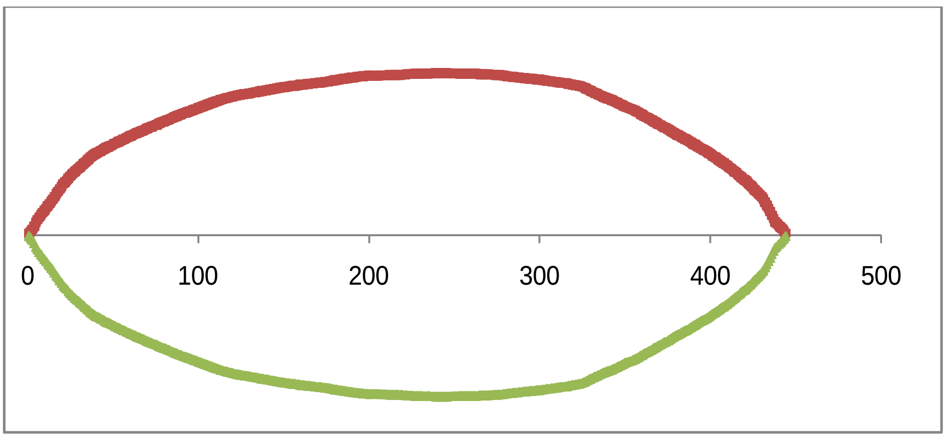
Volume = 2.502 m^3

Length= 3.2048 m

L/D = 2.465

S.A./Volume = 4.025

SHAPE16



SHAPE16

Surface area = 13.037 m^2

Volume = 3.487 m^3

Length= 3.708 m

L/D = 2.85

S.A./Volume = 3.73

APPENDIX II

Calculation for 1.3m diameter of Airship

Sr. no.	X	Y'+	y'-	AREA	VOLUME
1	-0.0003	0.0048	-0.0048	0.0005	0.0000
2	-0.0002	0.0137	-0.0137	0.0010	0.0000
3	-0.0002	0.0226	-0.0226	0.0020	0.0000
4	-0.0001	0.0337	-0.0337	0.0041	0.0000
5	0.0000	0.0493	-0.0493	0.0039	0.0000
6	0.0023	0.0604	-0.0604	0.0047	0.0000
7	0.0046	0.0715	-0.0715	0.0044	0.0000
8	0.0069	0.0803	-0.0803	0.0049	0.0001
9	0.0091	0.0892	-0.0892	0.0054	0.0001
10	0.0114	0.0981	-0.0981	0.0059	0.0001
11	0.0137	0.1070	-0.1070	0.0069	0.0002
12	0.0182	0.1158	-0.1158	0.0075	0.0002
13	0.0227	0.1247	-0.1247	0.0090	0.0004
14	0.0294	0.1335	-0.1335	0.0109	0.0005
15	0.0384	0.1423	-0.1423	0.0120	0.0005
16	0.0451	0.1533	-0.1533	0.0157	0.0009
17	0.0563	0.1643	-0.1643	0.0118	0.0006
18	0.0630	0.1732	-0.1732	0.0159	0.0009
19	0.0719	0.1842	-0.1842	0.0168	0.0012
20	0.0831	0.1930	-0.1930	0.0177	0.0011
21	0.0921	0.2040	-0.2040	0.0104	0.0006
22	0.0965	0.2106	-0.2106	0.0149	0.0013
23	0.1055	0.2172	-0.2172	0.0154	0.0010
24	0.1122	0.2260	-0.2260	0.0182	0.0015
25	0.1211	0.2348	-0.2348	0.0166	0.0016
26	0.1300	0.2414	-0.2414	0.0170	0.0017
27	0.1390	0.2480	-0.2480	0.0149	0.0013
28	0.1457	0.2546	-0.2546	0.0180	0.0019
29	0.1546	0.2612	-0.2612	0.0132	0.0015
30	0.1613	0.2655	-0.2655	0.0187	0.0020
31	0.1702	0.2721	-0.2721	0.0163	0.0016
32	0.1769	0.2787	-0.2787	0.0196	0.0022
33	0.1858	0.2853	-0.2853	0.0171	0.0018
34	0.1925	0.2919	-0.2919	0.0206	0.0024
35	0.2015	0.2985	-0.2985	0.0187	0.0025
36	0.2104	0.3028	-0.3028	0.0242	0.0027
37	0.2193	0.3116	-0.3116	0.0196	0.0028
38	0.2282	0.3160	-0.3160	0.0165	0.0020

39	0.2344	0.3215	-0.3215	0.0163	0.0022
40	0.2411	0.3259	-0.3259	0.0133	0.0019
41	0.2466	0.3291	-0.3291	0.0134	0.0019
42	0.2522	0.3324	-0.3324	0.0168	0.0024
43	0.2589	0.3368	-0.3368	0.0118	0.0016
44	0.2634	0.3401	-0.3401	0.0153	0.0021
45	0.2689	0.3445	-0.3445	0.0174	0.0025
46	0.2756	0.3488	-0.3488	0.0142	0.0022
47	0.2814	0.3516	-0.3516	0.0143	0.0022
48	0.2870	0.3549	-0.3549	0.0124	0.0018
49	0.2915	0.3582	-0.3582	0.0146	0.0023
50	0.2970	0.3615	-0.3615	0.0183	0.0028
51	0.3037	0.3658	-0.3658	0.0172	0.0028
52	0.3104	0.3691	-0.3691	0.0173	0.0029
53	0.3171	0.3724	-0.3724	0.0152	0.0024
54	0.3227	0.3756	-0.3756	0.0153	0.0025
55	0.3282	0.3789	-0.3789	0.0155	0.0025
56	0.3338	0.3822	-0.3822	0.0119	0.0021
57	0.3383	0.3844	-0.3844	0.0172	0.0026
58	0.3439	0.3888	-0.3888	0.0159	0.0027
59	0.3494	0.3920	-0.3920	0.0184	0.0033
60	0.3561	0.3953	-0.3953	0.0138	0.0022
61	0.3606	0.3986	-0.3986	0.0163	0.0028
62	0.3661	0.4019	-0.4019	0.0151	0.0028
63	0.3717	0.4040	-0.4040	0.0204	0.0035
64	0.3784	0.4084	-0.4084	0.0180	0.0035
65	0.3851	0.4106	-0.4106	0.0167	0.0030
66	0.3906	0.4138	-0.4138	0.0194	0.0036
67	0.3973	0.4171	-0.4171	0.0130	0.0024
68	0.4018	0.4193	-0.4193	0.0171	0.0031
69	0.4074	0.4226	-0.4226	0.0172	0.0032
70	0.4129	0.4258	-0.4258	0.0174	0.0032
71	0.4185	0.4291	-0.4291	0.0201	0.0039
72	0.4252	0.4324	-0.4324	0.0163	0.0033
73	0.4307	0.4345	-0.4345	0.0177	0.0033
74	0.4363	0.4378	-0.4378	0.0193	0.0040
75	0.4430	0.4400	-0.4400	0.0165	0.0034
76	0.4486	0.4421	-0.4421	0.0198	0.0035
77	0.4541	0.4465	-0.4465	0.0209	0.0042
78	0.4608	0.4498	-0.4498	0.0211	0.0043
79	0.4675	0.4531	-0.4531	0.0170	0.0036
80	0.4731	0.4552	-0.4552	0.0201	0.0044
81	0.4797	0.4574	-0.4574	0.0214	0.0044

82	0.4864	0.4606	-0.4606	0.0203	0.0045
83	0.4931	0.4628	-0.4628	0.0217	0.0045
84	0.4998	0.4661	-0.4661	0.0219	0.0046
85	0.5065	0.4693	-0.4693	0.0220	0.0047
86	0.5131	0.4726	-0.4726	0.0209	0.0047
87	0.5198	0.4747	-0.4747	0.0193	0.0040
88	0.5254	0.4780	-0.4780	0.0224	0.0048
89	0.5321	0.4813	-0.4813	0.0277	0.0065
90	0.5410	0.4834	-0.4834	0.0289	0.0066
91	0.5499	0.4867	-0.4867	0.0215	0.0050
92	0.5566	0.4888	-0.4888	0.0184	0.0042
93	0.5621	0.4910	-0.4910	0.0217	0.0051
94	0.5688	0.4931	-0.4931	0.0154	0.0034
95	0.5732	0.4953	-0.4953	0.0219	0.0052
96	0.5799	0.4975	-0.4975	0.0233	0.0052
97	0.5866	0.5007	-0.5007	0.0221	0.0053
98	0.5933	0.5029	-0.5029	0.0222	0.0053
99	0.6000	0.5050	-0.5050	0.0237	0.0054
100	0.6066	0.5083	-0.5083	0.0271	0.0064
101	0.6144	0.5115	-0.5115	0.0260	0.0064
102	0.6222	0.5137	-0.5137	0.0296	0.0074
103	0.6311	0.5158	-0.5158	0.0275	0.0066
104	0.6389	0.5191	-0.5191	0.0299	0.0076
105	0.6478	0.5212	-0.5212	0.0277	0.0067
106	0.6556	0.5244	-0.5244	0.0302	0.0077
107	0.6645	0.5266	-0.5266	0.0303	0.0078
108	0.6734	0.5287	-0.5287	0.0316	0.0079
109	0.6823	0.5319	-0.5319	0.0306	0.0079
110	0.6912	0.5341	-0.5341	0.0271	0.0070
111	0.6990	0.5362	-0.5362	0.0273	0.0071
112	0.7067	0.5384	-0.5384	0.0321	0.0082
113	0.7156	0.5416	-0.5416	0.0312	0.0082
114	0.7245	0.5437	-0.5437	0.0240	0.0062
115	0.7312	0.5459	-0.5459	0.0241	0.0063
116	0.7379	0.5480	-0.5480	0.0279	0.0074
117	0.7457	0.5502	-0.5502	0.0310	0.0085
118	0.7546	0.5512	-0.5512	0.0280	0.0075
119	0.7624	0.5533	-0.5533	0.0350	0.0096
120	0.7724	0.5543	-0.5543	0.0319	0.0086
121	0.7812	0.5565	-0.5565	0.0320	0.0087
122	0.7901	0.5586	-0.5586	0.0276	0.0076
123	0.7979	0.5596	-0.5596	0.0315	0.0088
124	0.8068	0.5606	-0.5606	0.0323	0.0088

125	0.8157	0.5628	-0.5628	0.0278	0.0078
126	0.8235	0.5638	-0.5638	0.0278	0.0078
127	0.8313	0.5648	-0.5648	0.0318	0.0089
128	0.8401	0.5658	-0.5658	0.0279	0.0078
129	0.8479	0.5669	-0.5669	0.0241	0.0067
130	0.8546	0.5679	-0.5679	0.0319	0.0090
131	0.8635	0.5689	-0.5689	0.0289	0.0079
132	0.8713	0.5711	-0.5711	0.0321	0.0091
133	0.8801	0.5721	-0.5721	0.0322	0.0092
134	0.8890	0.5731	-0.5731	0.0322	0.0092
135	0.8979	0.5741	-0.5741	0.0283	0.0081
136	0.9057	0.5751	-0.5751	0.0331	0.0093
137	0.9146	0.5773	-0.5773	0.0325	0.0093
138	0.9235	0.5783	-0.5783	0.0406	0.0117
139	0.9346	0.5793	-0.5793	0.0286	0.0082
140	0.9424	0.5803	-0.5803	0.0286	0.0082
141	0.9501	0.5813	-0.5813	0.0295	0.0083
142	0.9579	0.5835	-0.5835	0.0328	0.0095
143	0.9668	0.5845	-0.5845	0.0288	0.0084
144	0.9746	0.5855	-0.5855	0.0248	0.0072
145	0.9813	0.5866	-0.5866	0.0289	0.0084
146	0.9890	0.5876	-0.5876	0.0299	0.0085
147	0.9968	0.5897	-0.5897	0.0291	0.0085
148	1.0046	0.5908	-0.5908	0.0251	0.0073
149	1.0113	0.5918	-0.5918	0.0292	0.0086
150	1.0191	0.5928	-0.5928	0.0292	0.0086
151	1.0268	0.5938	-0.5938	0.0334	0.0099
152	1.0357	0.5949	-0.5949	0.0335	0.0099
153	1.0446	0.5959	-0.5959	0.0294	0.0087
154	1.0524	0.5969	-0.5969	0.0253	0.0075
155	1.0591	0.5979	-0.5979	0.0250	0.0075
156	1.0657	0.5979	-0.5979	0.0295	0.0087
157	1.0735	0.5989	-0.5989	0.0254	0.0075
158	1.0802	0.5999	-0.5999	0.0255	0.0076
159	1.0868	0.6010	-0.6010	0.0305	0.0089
160	1.0946	0.6031	-0.6031	0.0339	0.0102
161	1.1035	0.6041	-0.6041	0.0253	0.0076
162	1.1102	0.6041	-0.6041	0.0382	0.0115
163	1.1202	0.6051	-0.6051	0.0382	0.0115
164	1.1302	0.6061	-0.6061	0.0380	0.0115
165	1.1401	0.6060	-0.6060	0.0257	0.0077
166	1.1468	0.6070	-0.6070	0.0341	0.0103
167	1.1557	0.6080	-0.6080	0.0384	0.0116

168	1.1657	0.6090	-0.6090	0.0427	0.0130
169	1.1768	0.6100	-0.6100	0.0425	0.0130
170	1.1879	0.6099	-0.6099	0.0343	0.0104
171	1.1968	0.6109	-0.6109	0.0428	0.0130
172	1.2079	0.6119	-0.6119	0.0387	0.0118
173	1.2179	0.6129	-0.6129	0.0345	0.0105
174	1.2268	0.6139	-0.6139	0.0345	0.0105
175	1.2357	0.6150	-0.6150	0.0386	0.0119
176	1.2457	0.6148	-0.6148	0.0312	0.0093
177	1.2534	0.6170	-0.6170	0.0347	0.0106
178	1.2623	0.6180	-0.6180	0.0390	0.0120
179	1.2723	0.6190	-0.6190	0.0441	0.0134
180	1.2834	0.6211	-0.6211	0.0522	0.0162
181	1.2968	0.6221	-0.6221	0.0523	0.0162
182	1.3101	0.6230	-0.6230	0.0437	0.0136
183	1.3212	0.6240	-0.6240	0.0351	0.0109
184	1.3301	0.6251	-0.6251	0.0265	0.0082
185	1.3368	0.6261	-0.6261	0.0352	0.0110
186	1.3457	0.6271	-0.6271	0.0309	0.0096
187	1.3534	0.6281	-0.6281	0.0310	0.0097
188	1.3612	0.6292	-0.6292	0.0354	0.0111
189	1.3701	0.6302	-0.6302	0.0311	0.0097
190	1.3779	0.6312	-0.6312	0.0311	0.0098
191	1.3857	0.6322	-0.6322	0.0312	0.0098
192	1.3934	0.6333	-0.6333	0.0444	0.0140
193	1.4045	0.6343	-0.6343	0.0445	0.0141
194	1.4156	0.6353	-0.6353	0.0443	0.0141
195	1.4267	0.6351	-0.6351	0.0366	0.0113
196	1.4356	0.6373	-0.6373	0.0400	0.0127
197	1.4456	0.6372	-0.6372	0.0403	0.0128
198	1.4556	0.6382	-0.6382	0.0401	0.0128
199	1.4656	0.6381	-0.6381	0.0359	0.0114
200	1.4745	0.6391	-0.6391	0.0446	0.0142
201	1.4856	0.6389	-0.6389	0.0446	0.0142
202	1.4967	0.6388	-0.6388	0.0446	0.0142
203	1.5078	0.6387	-0.6387	0.0579	0.0185
204	1.5222	0.6386	-0.6386	0.0312	0.0100
205	1.5300	0.6385	-0.6385	0.0403	0.0128
206	1.5400	0.6395	-0.6395	0.0271	0.0086
207	1.5467	0.6405	-0.6405	0.0268	0.0086
208	1.5533	0.6404	-0.6404	0.0402	0.0129
209	1.5633	0.6403	-0.6403	0.0447	0.0143
210	1.5744	0.6402	-0.6402	0.0316	0.0100

211	1.5822	0.6412	-0.6412	0.0316	0.0101
212	1.5900	0.6423	-0.6423	0.0403	0.0129
213	1.6000	0.6422	-0.6422	0.0358	0.0115
214	1.6089	0.6421	-0.6421	0.0358	0.0115
215	1.6177	0.6420	-0.6420	0.0313	0.0101
216	1.6255	0.6419	-0.6419	0.0358	0.0115
217	1.6344	0.6418	-0.6418	0.0361	0.0115
218	1.6433	0.6428	-0.6428	0.0403	0.0130
219	1.6533	0.6427	-0.6427	0.0362	0.0116
220	1.6621	0.6437	-0.6437	0.0269	0.0087
221	1.6688	0.6436	-0.6436	0.0362	0.0116
222	1.6777	0.6447	-0.6447	0.0318	0.0102
223	1.6855	0.6457	-0.6457	0.0405	0.0131
224	1.6955	0.6456	-0.6456	0.0405	0.0131
225	1.7055	0.6455	-0.6455	0.0274	0.0087
226	1.7121	0.6465	-0.6465	0.0364	0.0117
227	1.7210	0.6475	-0.6475	0.0316	0.0102
228	1.7288	0.6474	-0.6474	0.0452	0.0146
229	1.7399	0.6473	-0.6473	0.0406	0.0131
230	1.7499	0.6472	-0.6472	0.0406	0.0131
231	1.7599	0.6471	-0.6471	0.0364	0.0117
232	1.7687	0.6481	-0.6481	0.0407	0.0132
233	1.7787	0.6480	-0.6480	0.0407	0.0132
234	1.7887	0.6479	-0.6479	0.0407	0.0132
235	1.7987	0.6478	-0.6478	0.0454	0.0147
236	1.8098	0.6488	-0.6488	0.0498	0.0161
237	1.8220	0.6487	-0.6487	0.0452	0.0147
238	1.8331	0.6485	-0.6485	0.0410	0.0132
239	1.8431	0.6495	-0.6495	0.0498	0.0162
240	1.8553	0.6494	-0.6494	0.0455	0.0147
241	1.8665	0.6504	-0.6504	0.0501	0.0162
242	1.8787	0.6492	-0.6492	0.0500	0.0162
243	1.8909	0.6501	-0.6501	0.0544	0.0177
244	1.9042	0.6500	-0.6500	0.0453	0.0147
245	1.9153	0.6499	-0.6499	0.0453	0.0147
246	1.9264	0.6498	-0.6498	0.0500	0.0162
247	1.9386	0.6485	-0.6485	0.0407	0.0132
248	1.9486	0.6484	-0.6484	0.0317	0.0103
249	1.9564	0.6483	-0.6483	0.0497	0.0161
250	1.9686	0.6482	-0.6482	0.0452	0.0146
251	1.9797	0.6481	-0.6481	0.0497	0.0161
252	1.9919	0.6479	-0.6479	0.0452	0.0146
253	2.0030	0.6478	-0.6478	0.0452	0.0146

254	2.0141	0.6477	-0.6477	0.0497	0.0161
255	2.0263	0.6476	-0.6476	0.0406	0.0132
256	2.0363	0.6475	-0.6475	0.0452	0.0146
257	2.0474	0.6473	-0.6473	0.0451	0.0146
258	2.0585	0.6472	-0.6472	0.0406	0.0131
259	2.0685	0.6471	-0.6471	0.0542	0.0175
260	2.0818	0.6470	-0.6470	0.0496	0.0161
261	2.0940	0.6468	-0.6468	0.0496	0.0160
262	2.1062	0.6467	-0.6467	0.0451	0.0146
263	2.1173	0.6466	-0.6466	0.0586	0.0189
264	2.1317	0.6464	-0.6464	0.0498	0.0160
265	2.1439	0.6452	-0.6452	0.0495	0.0160
266	2.1562	0.6451	-0.6451	0.0540	0.0174
267	2.1695	0.6449	-0.6449	0.0540	0.0174
268	2.1828	0.6448	-0.6448	0.0405	0.0130
269	2.1928	0.6447	-0.6447	0.0540	0.0174
270	2.2061	0.6445	-0.6445	0.0452	0.0144
271	2.2172	0.6433	-0.6433	0.0404	0.0130
272	2.2272	0.6432	-0.6432	0.0493	0.0159
273	2.2394	0.6430	-0.6430	0.0451	0.0144
274	2.2505	0.6418	-0.6418	0.0492	0.0158
275	2.2627	0.6417	-0.6417	0.0448	0.0144
276	2.2738	0.6416	-0.6416	0.0447	0.0144
277	2.2849	0.6414	-0.6414	0.0582	0.0186
278	2.2993	0.6413	-0.6413	0.0494	0.0157
279	2.3115	0.6400	-0.6400	0.0448	0.0142
280	2.3226	0.6388	-0.6388	0.0581	0.0185
281	2.3371	0.6375	-0.6375	0.0535	0.0170
282	2.3504	0.6363	-0.6363	0.0666	0.0212
283	2.3670	0.6361	-0.6361	0.0534	0.0169
284	2.3803	0.6348	-0.6348	0.0531	0.0169
285	2.3937	0.6347	-0.6347	0.0445	0.0140
286	2.4047	0.6335	-0.6335	0.0353	0.0112
287	2.4136	0.6334	-0.6334	0.0400	0.0126
288	2.4236	0.6322	-0.6322	0.0487	0.0153
289	2.4358	0.6309	-0.6309	0.0352	0.0111
290	2.4447	0.6308	-0.6308	0.0486	0.0152
291	2.4569	0.6296	-0.6296	0.0527	0.0166
292	2.4702	0.6294	-0.6294	0.0572	0.0179
293	2.4846	0.6282	-0.6282	0.0527	0.0165
294	2.4980	0.6269	-0.6269	0.0481	0.0151
295	2.5102	0.6268	-0.6268	0.0481	0.0151
296	2.5224	0.6266	-0.6266	0.0482	0.0150

297	2.5346	0.6254	-0.6254	0.0482	0.0150
298	2.5468	0.6242	-0.6242	0.0479	0.0149
299	2.5590	0.6240	-0.6240	0.0522	0.0163
300	2.5723	0.6239	-0.6239	0.0480	0.0149
301	2.5845	0.6226	-0.6226	0.0436	0.0135
302	2.5956	0.6214	-0.6214	0.0435	0.0134
303	2.6067	0.6202	-0.6202	0.0477	0.0147
304	2.6189	0.6189	-0.6189	0.0519	0.0160
305	2.6322	0.6177	-0.6177	0.0474	0.0146
306	2.6444	0.6175	-0.6175	0.0433	0.0133
307	2.6555	0.6163	-0.6163	0.0560	0.0172
308	2.6699	0.6150	-0.6150	0.0515	0.0158
309	2.6833	0.6149	-0.6149	0.0516	0.0158
310	2.6966	0.6136	-0.6136	0.0472	0.0144
311	2.7088	0.6124	-0.6124	0.0429	0.0130
312	2.7199	0.6112	-0.6112	0.0344	0.0104
313	2.7287	0.6099	-0.6099	0.0425	0.0130
314	2.7398	0.6098	-0.6098	0.0510	0.0156
315	2.7532	0.6097	-0.6097	0.0469	0.0142
316	2.7654	0.6084	-0.6084	0.0557	0.0167
317	2.7798	0.6061	-0.6061	0.0551	0.0166
318	2.7942	0.6048	-0.6048	0.0382	0.0114
319	2.8042	0.6036	-0.6036	0.0381	0.0114
320	2.8142	0.6024	-0.6024	0.0380	0.0114
321	2.8242	0.6011	-0.6011	0.0338	0.0101
322	2.8330	0.5999	-0.5999	0.0462	0.0138
323	2.8452	0.5987	-0.5987	0.0461	0.0137
324	2.8574	0.5974	-0.5974	0.0465	0.0136
325	2.8696	0.5951	-0.5951	0.0593	0.0172
326	2.8851	0.5916	-0.5916	0.0509	0.0145
327	2.8984	0.5881	-0.5881	0.0467	0.0132
328	2.9106	0.5846	-0.5846	0.0543	0.0154
329	2.9250	0.5811	-0.5811	0.0422	0.0117
330	2.9361	0.5777	-0.5777	0.0344	0.0092
331	2.9450	0.5742	-0.5742	0.0417	0.0114
332	2.9561	0.5708	-0.5708	0.0367	0.0102
333	2.9660	0.5685	-0.5685	0.0376	0.0101
334	2.9760	0.5650	-0.5650	0.0448	0.0121
335	2.9882	0.5615	-0.5615	0.0408	0.0109
336	2.9993	0.5581	-0.5581	0.0369	0.0097
337	3.0092	0.5546	-0.5546	0.0356	0.0096
338	3.0192	0.5523	-0.5523	0.0355	0.0095
339	3.0292	0.5500	-0.5500	0.0363	0.0094

340	3.0392	0.5465	-0.5465	0.0307	0.0083
341	3.0480	0.5453	-0.5453	0.0396	0.0103
342	3.0591	0.5419	-0.5419	0.0348	0.0092
343	3.0691	0.5395	-0.5395	0.0356	0.0091
344	3.0790	0.5361	-0.5361	0.0319	0.0079
345	3.0879	0.5327	-0.5327	0.0352	0.0088
346	3.0979	0.5292	-0.5292	0.0315	0.0077
347	3.1067	0.5258	-0.5258	0.0313	0.0076
348	3.1156	0.5223	-0.5223	0.0311	0.0075
349	3.1244	0.5189	-0.5189	0.0291	0.0065
350	3.1322	0.5144	-0.5144	0.0296	0.0073
351	3.1411	0.5121	-0.5121	0.0226	0.0054
352	3.1477	0.5098	-0.5098	0.0327	0.0081
353	3.1577	0.5074	-0.5074	0.0292	0.0071
354	3.1665	0.5051	-0.5051	0.0300	0.0071
355	3.1754	0.5017	-0.5017	0.0298	0.0070
356	3.1843	0.4982	-0.4982	0.0329	0.0077
357	3.1942	0.4948	-0.4948	0.0262	0.0059
358	3.2020	0.4914	-0.4914	0.0294	0.0058
359	3.2097	0.4857	-0.4857	0.0321	0.0073
360	3.2197	0.4823	-0.4823	0.0300	0.0064
361	3.2285	0.4777	-0.4777	0.0253	0.0055
362	3.2363	0.4743	-0.4743	0.0252	0.0054
363	3.2440	0.4709	-0.4709	0.0220	0.0046
364	3.2507	0.4675	-0.4675	0.0248	0.0053
365	3.2584	0.4641	-0.4641	0.0318	0.0067
366	3.2684	0.4595	-0.4595	0.0286	0.0058
367	3.2772	0.4550	-0.4550	0.0241	0.0050
368	3.2850	0.4516	-0.4516	0.0253	0.0049
369	3.2927	0.4470	-0.4470	0.0266	0.0055
370	3.3016	0.4436	-0.4436	0.0235	0.0048
371	3.3093	0.4402	-0.4402	0.0301	0.0060
372	3.3193	0.4356	-0.4356	0.0231	0.0046
373	3.3270	0.4322	-0.4322	0.0219	0.0045
374	3.3348	0.4299	-0.4299	0.0241	0.0044
375	3.3425	0.4253	-0.4253	0.0318	0.0062
376	3.3536	0.4208	-0.4208	0.0262	0.0049
377	3.3624	0.4162	-0.4162	0.0233	0.0042
378	3.3702	0.4117	-0.4117	0.0272	0.0053
379	3.3801	0.4083	-0.4083	0.0229	0.0040
380	3.3879	0.4037	-0.4037	0.0164	0.0028
381	3.3934	0.4003	-0.4003	0.0163	0.0028
382	3.3989	0.3969	-0.3969	0.0185	0.0033

383	3.4056	0.3935	-0.3935	0.0175	0.0027
384	3.4111	0.3890	-0.3890	0.0182	0.0031
385	3.4177	0.3856	-0.3856	0.0134	0.0020
386	3.4222	0.3822	-0.3822	0.0155	0.0025
387	3.4277	0.3788	-0.3788	0.0149	0.0020
388	3.4321	0.3743	-0.3743	0.0188	0.0029
389	3.4387	0.3698	-0.3698	0.0165	0.0023
390	3.4443	0.3653	-0.3653	0.0148	0.0023
391	3.4498	0.3619	-0.3619	0.0181	0.0027
392	3.4564	0.3574	-0.3574	0.0159	0.0022
393	3.4619	0.3529	-0.3529	0.0177	0.0026
394	3.4686	0.3483	-0.3483	0.0141	0.0021
395	3.4741	0.3450	-0.3450	0.0140	0.0020
396	3.4796	0.3416	-0.3416	0.0159	0.0024
397	3.4863	0.3381	-0.3381	0.0150	0.0020
398	3.4918	0.3336	-0.3336	0.0148	0.0019
399	3.4973	0.3291	-0.3291	0.0184	0.0026
400	3.5050	0.3246	-0.3246	0.0176	0.0022
401	3.5117	0.3190	-0.3190	0.0125	0.0014
402	3.5161	0.3145	-0.3145	0.0147	0.0020
403	3.5227	0.3111	-0.3111	0.0168	0.0020
404	3.5293	0.3054	-0.3054	0.0153	0.0019
405	3.5360	0.3009	-0.3009	0.0163	0.0018
406	3.5426	0.2953	-0.2953	0.0131	0.0015
407	3.5481	0.2908	-0.2908	0.0118	0.0015
408	3.5536	0.2874	-0.2874	0.0155	0.0017
409	3.5603	0.2817	-0.2817	0.0141	0.0016
410	3.5669	0.2772	-0.2772	0.0136	0.0013
411	3.5724	0.2716	-0.2716	0.0133	0.0013
412	3.5779	0.2660	-0.2660	0.0144	0.0014
413	3.5845	0.2603	-0.2603	0.0141	0.0014
414	3.5912	0.2547	-0.2547	0.0127	0.0013
415	3.5978	0.2502	-0.2502	0.0159	0.0015
416	3.6055	0.2434	-0.2434	0.0131	0.0012
417	3.6121	0.2378	-0.2378	0.0128	0.0010
418	3.6176	0.2311	-0.2311	0.0113	0.0009
419	3.6232	0.2254	-0.2254	0.0088	0.0007
420	3.6276	0.2209	-0.2209	0.0119	0.0010
421	3.6342	0.2153	-0.2153	0.0126	0.0009
422	3.6408	0.2086	-0.2086	0.0122	0.0009
423	3.6474	0.2018	-0.2018	0.0128	0.0010
424	3.6551	0.1951	-0.1951	0.0114	0.0008
425	3.6618	0.1883	-0.1883	0.0119	0.0007

426	3.6684	0.1805	-0.1805	0.0097	0.0005
427	3.6739	0.1737	-0.1737	0.0093	0.0005
428	3.6794	0.1670	-0.1670	0.0089	0.0005
429	3.6849	0.1603	-0.1603	0.0088	0.0003
430	3.6893	0.1524	-0.1524	0.0085	0.0001
431	3.6914	0.1435	-0.1435	0.0107	0.0001
432	3.6936	0.1312	-0.1312	0.0098	0.0001
433	3.6957	0.1190	-0.1190	0.0088	0.0001
434	3.6979	0.1067	-0.1067	0.0080	0.0001
435	3.7011	0.0944	-0.0944	0.0085	0.0000
436	3.7021	0.0789	-0.0789	0.0061	0.0000
437	3.7031	0.0655	-0.0655	0.0050	0.0000
438	3.7042	0.0521	-0.0521	0.0021	0.0000
439	3.7052	0.0455	-0.0455	0.0020	0.0000
440	3.7052	0.0377	-0.0377	0.0014	0.0000
441	3.7051	0.0310	-0.0310	0.0012	0.0000
442	3.7062	0.0243	-0.0243	0.0011	0.0000
443	3.7050	0.0154	-0.0154	0.0006	0.0000
444	3.7072	0.0065	-0.0065	0.0001	0.0000
445	3.7083	0.0043	-0.0043	0.0498	-0.0001

APPENDIX III
Calculation of petal profile

	No. of petal		8	
sr. no.	x cord	Width	y+	y-
1	0.004787	0.003753	0.001876	-0.00188
2	0.013686	0.010741	0.005371	-0.00537
3	0.024808	0.01773	0.008865	-0.00886
4	0.04038	0.026465	0.013233	-0.01323
5	0.051713	0.038695	0.019348	-0.01935
6	0.063047	0.047412	0.023706	-0.02371
7	0.072209	0.056129	0.028064	-0.02806
8	0.081371	0.063098	0.031549	-0.03155
9	0.090533	0.070068	0.035034	-0.03503
10	0.099695	0.077038	0.038519	-0.03852
11	0.109623	0.084007	0.042004	-0.042
12	0.119551	0.090958	0.045479	-0.04548
13	0.130644	0.097909	0.048955	-0.04895
14	0.14319	0.104841	0.052421	-0.05242
15	0.156131	0.111754	0.055877	-0.05588
16	0.171813	0.120433	0.060217	-0.06022
17	0.182905	0.129075	0.064537	-0.06454
18	0.19711	0.136007	0.068003	-0.068
19	0.211308	0.144667	0.072334	-0.07233
20	0.225513	0.151562	0.075781	-0.07578
21	0.233513	0.160222	0.080111	-0.08011
22	0.2446	0.165426	0.082713	-0.08271
23	0.255693	0.170592	0.085296	-0.0853
24	0.268238	0.177524	0.088762	-0.08876
25	0.279325	0.184437	0.092218	-0.09222
26	0.290412	0.189603	0.094801	-0.0948
27	0.299821	0.194769	0.097384	-0.09738
28	0.310908	0.199954	0.099977	-0.09998
29	0.318902	0.20512	0.10256	-0.10256
30	0.329989	0.208558	0.104279	-0.10428
31	0.339398	0.213724	0.106862	-0.10686
32	0.350485	0.218909	0.109454	-0.10945
33	0.359894	0.224075	0.112037	-0.11204
34	0.370981	0.22926	0.11463	-0.11463
35	0.380897	0.234426	0.117213	-0.11721
36	0.393443	0.237844	0.118922	-0.11892
37	0.403359	0.244758	0.122379	-0.12238
38	0.411601	0.248177	0.124088	-0.12409

39	0.419595	0.252493	0.126246	-0.12625
40	0.42606	0.25593	0.127965	-0.12797
41	0.432524	0.258504	0.129252	-0.12925
42	0.440519	0.261078	0.130539	-0.13054
43	0.446062	0.264515	0.132258	-0.13226
44	0.453161	0.267098	0.133549	-0.13355
45	0.461156	0.270546	0.135273	-0.13527
46	0.467594	0.273983	0.136992	-0.13699
47	0.474058	0.276164	0.138082	-0.13808
48	0.479602	0.278737	0.139369	-0.13937
49	0.486066	0.28132	0.14066	-0.14066
50	0.494061	0.283894	0.141947	-0.14195
51	0.501498	0.287332	0.143666	-0.14367
52	0.508935	0.289896	0.144948	-0.14495
53	0.5154	0.29246	0.14623	-0.14623
54	0.521864	0.295034	0.147517	-0.14752
55	0.528329	0.297607	0.148804	-0.1488
56	0.533287	0.300181	0.15009	-0.15009
57	0.540386	0.30189	0.150945	-0.15095
58	0.54685	0.305338	0.152669	-0.15267
59	0.554288	0.307911	0.153956	-0.15396
60	0.559831	0.310475	0.155238	-0.15524
61	0.566295	0.313058	0.156529	-0.15653
62	0.572267	0.315632	0.157816	-0.15782
63	0.580261	0.317332	0.158666	-0.15867
64	0.587275	0.32077	0.160385	-0.16038
65	0.593739	0.32246	0.16123	-0.16123
66	0.601176	0.325034	0.162517	-0.16252
67	0.606135	0.327598	0.163799	-0.1638
68	0.612599	0.329308	0.164654	-0.16465
69	0.619063	0.331881	0.165941	-0.16594
70	0.625528	0.334455	0.167227	-0.16723
71	0.632965	0.337029	0.168514	-0.16851
72	0.638936	0.339593	0.169796	-0.1698
73	0.645401	0.341293	0.170646	-0.17065
74	0.652414	0.343866	0.171933	-0.17193
75	0.658385	0.345557	0.172779	-0.17278
76	0.665485	0.347257	0.173629	-0.17363
77	0.672922	0.350704	0.175352	-0.17535
78	0.680359	0.353268	0.176634	-0.17663
79	0.68633	0.355833	0.177916	-0.17792
80	0.693344	0.357533	0.178766	-0.17877
81	0.700781	0.359223	0.179612	-0.17961

82	0.707795	0.361788	0.180894	-0.18089
83	0.715232	0.363478	0.181739	-0.18174
84	0.722669	0.366042	0.183021	-0.18302
85	0.730107	0.368607	0.184303	-0.1843
86	0.73712	0.371171	0.185585	-0.18559
87	0.743585	0.372861	0.186431	-0.18643
88	0.751022	0.375435	0.187717	-0.18772
89	0.760168	0.377999	0.189	-0.189
90	0.769642	0.379671	0.189835	-0.18984
91	0.776656	0.382216	0.191108	-0.19111
92	0.782627	0.383907	0.191953	-0.19195
93	0.78964	0.385607	0.192804	-0.1928
94	0.794599	0.387298	0.193649	-0.19365
95	0.801612	0.389007	0.194504	-0.1945
96	0.809049	0.390698	0.195349	-0.19535
97	0.816063	0.393262	0.196631	-0.19663
98	0.823077	0.394953	0.197476	-0.19748
99	0.830514	0.396643	0.198322	-0.19832
100	0.838958	0.399207	0.199604	-0.1996
101	0.847032	0.401762	0.200881	-0.20088
102	0.856178	0.403443	0.201722	-0.20172
103	0.864622	0.405115	0.202558	-0.20256
104	0.873769	0.40767	0.203835	-0.20383
105	0.882213	0.409342	0.204671	-0.20467
106	0.891359	0.411897	0.205948	-0.20595
107	0.900505	0.413568	0.206784	-0.20678
108	0.909979	0.41524	0.20762	-0.20762
109	0.919125	0.417786	0.208893	-0.20889
110	0.927199	0.419457	0.209729	-0.20973
111	0.935273	0.421139	0.210569	-0.21057
112	0.944747	0.42282	0.21141	-0.21141
113	0.953894	0.425365	0.212683	-0.21268
114	0.960907	0.427037	0.213518	-0.21352
115	0.967921	0.428728	0.214364	-0.21436
116	0.975995	0.430418	0.215209	-0.21521
117	0.98494	0.432099	0.21605	-0.21605
118	0.993014	0.432898	0.216449	-0.21645
119	1.003062	0.434579	0.217289	-0.21729
120	1.012208	0.435368	0.217684	-0.21768
121	1.021355	0.43704	0.21852	-0.21852
122	1.0292	0.438711	0.219356	-0.21936
123	1.038146	0.439519	0.219759	-0.21976
124	1.047292	0.440317	0.220159	-0.22016

125	1.055137	0.441989	0.220995	-0.22099
126	1.062983	0.442797	0.221398	-0.2214
127	1.071928	0.443604	0.221802	-0.2218
128	1.079773	0.444403	0.222201	-0.2222
129	1.086522	0.44521	0.222605	-0.22261
130	1.095467	0.446027	0.223014	-0.22301
131	1.103541	0.446826	0.223413	-0.22341
132	1.112487	0.448507	0.224253	-0.22425
133	1.121433	0.449305	0.224652	-0.22465
134	1.130378	0.450103	0.225052	-0.22505
135	1.138223	0.450901	0.225451	-0.22545
136	1.14737	0.451709	0.225855	-0.22585
137	1.156315	0.453381	0.22669	-0.22669
138	1.167467	0.454179	0.22709	-0.22709
139	1.175313	0.454959	0.227479	-0.22748
140	1.183158	0.455766	0.227883	-0.22788
141	1.191232	0.456574	0.228287	-0.22829
142	1.200178	0.458255	0.229128	-0.22913
143	1.208023	0.459053	0.229527	-0.22953
144	1.214771	0.459861	0.22993	-0.22993
145	1.222617	0.460678	0.230339	-0.23034
146	1.230691	0.461486	0.230743	-0.23074
147	1.238536	0.463167	0.231583	-0.23158
148	1.245284	0.463975	0.231987	-0.23199
149	1.253129	0.464792	0.232396	-0.2324
150	1.260975	0.465599	0.2328	-0.2328
151	1.26992	0.466407	0.233203	-0.2332
152	1.278866	0.467205	0.233603	-0.2336
153	1.286711	0.468003	0.234002	-0.234
154	1.29346	0.468811	0.234406	-0.23441
155	1.30012	0.469628	0.234814	-0.23481
156	1.307966	0.469572	0.234786	-0.23479
157	1.314714	0.470379	0.23519	-0.23519
158	1.321462	0.471196	0.235598	-0.2356
159	1.329536	0.472013	0.236007	-0.23601
160	1.338482	0.473695	0.236847	-0.23685
161	1.345142	0.474493	0.237246	-0.23725
162	1.35519	0.474436	0.237218	-0.23722
163	1.365238	0.475225	0.237613	-0.23761
164	1.375229	0.476014	0.238007	-0.23801
165	1.381978	0.475929	0.237965	-0.23796
166	1.390923	0.476746	0.238373	-0.23837
167	1.400971	0.477545	0.238772	-0.23877

168	1.412123	0.478333	0.239167	-0.23917
169	1.423224	0.479113	0.239556	-0.23956
170	1.43217	0.479019	0.239509	-0.23951
171	1.443322	0.479817	0.239908	-0.23991
172	1.45337	0.480596	0.240298	-0.2403
173	1.462315	0.481385	0.240693	-0.24069
174	1.471261	0.482183	0.241092	-0.24109
175	1.481252	0.482982	0.241491	-0.24149
176	1.489326	0.482897	0.241448	-0.24145
177	1.498272	0.484578	0.242289	-0.24229
178	1.50832	0.485376	0.242688	-0.24269
179	1.519632	0.486165	0.243083	-0.24308
180	1.532995	0.487818	0.243909	-0.24391
181	1.546358	0.488579	0.244289	-0.24429
182	1.55751	0.489339	0.24467	-0.24467
183	1.566456	0.490119	0.245059	-0.24506
184	1.573204	0.490917	0.245458	-0.24546
185	1.58215	0.491734	0.245867	-0.24587
186	1.589995	0.492532	0.246266	-0.24627
187	1.59784	0.49334	0.24667	-0.24667
188	1.606786	0.494148	0.247074	-0.24707
189	1.614631	0.494946	0.247473	-0.24747
190	1.622477	0.495753	0.247877	-0.24788
191	1.630322	0.496561	0.248281	-0.24828
192	1.641474	0.497369	0.248684	-0.24868
193	1.652626	0.498148	0.249074	-0.24907
194	1.663727	0.498928	0.249464	-0.24946
195	1.672873	0.498833	0.249417	-0.24942
196	1.682864	0.500505	0.250253	-0.25025
197	1.692912	0.50042	0.25021	-0.25021
198	1.702903	0.501209	0.250605	-0.2506
199	1.711849	0.501125	0.250562	-0.25056
200	1.72295	0.501923	0.250961	-0.25096
201	1.734051	0.501829	0.250914	-0.25091
202	1.745152	0.501734	0.250867	-0.25087
203	1.759583	0.50164	0.25082	-0.25082
204	1.767354	0.501518	0.250759	-0.25076
205	1.777402	0.501452	0.250726	-0.25073
206	1.78415	0.502241	0.25112	-0.25112
207	1.790811	0.503058	0.251529	-0.25153
208	1.800801	0.503001	0.251501	-0.2515
209	1.811902	0.502917	0.251458	-0.25146
210	1.819748	0.502822	0.251411	-0.25141

211	1.827593	0.50363	0.251815	-0.25182
212	1.837584	0.504438	0.252219	-0.25222
213	1.846465	0.504353	0.252177	-0.25218
214	1.855346	0.504278	0.252139	-0.25214
215	1.863116	0.504202	0.252101	-0.2521
216	1.871997	0.504137	0.252068	-0.25207
217	1.880943	0.504061	0.252031	-0.25203
218	1.890934	0.504859	0.25243	-0.25243
219	1.899879	0.504775	0.252387	-0.25239
220	1.90654	0.505573	0.252786	-0.25279
221	1.915485	0.505516	0.252758	-0.25276
222	1.923331	0.506315	0.253157	-0.25316
223	1.933322	0.507122	0.253561	-0.25356
224	1.943313	0.507038	0.253519	-0.25352
225	1.950061	0.506953	0.253476	-0.25348
226	1.959007	0.50777	0.253885	-0.25388
227	1.966777	0.508568	0.254284	-0.25428
228	1.977878	0.508502	0.254251	-0.25425
229	1.987869	0.508408	0.254204	-0.2542
230	1.99786	0.508323	0.254162	-0.25416
231	2.006806	0.508239	0.254119	-0.25412
232	2.016797	0.509037	0.254518	-0.25452
233	2.026787	0.508952	0.254476	-0.25448
234	2.036778	0.508867	0.254434	-0.25443
235	2.04793	0.508783	0.254391	-0.25439
236	2.060141	0.509562	0.254781	-0.25478
237	2.071242	0.509458	0.254729	-0.25473
238	2.08129	0.509364	0.254682	-0.25468
239	2.093502	0.510153	0.255077	-0.25508
240	2.104654	0.51005	0.255025	-0.25502
241	2.11692	0.510829	0.255414	-0.25541
242	2.129177	0.509852	0.254926	-0.25493
243	2.142498	0.510622	0.255311	-0.25531
244	2.153599	0.510509	0.255254	-0.25525
245	2.1647	0.510415	0.255207	-0.25521
246	2.176966	0.51032	0.25516	-0.25516
247	2.186957	0.509343	0.254672	-0.25467
248	2.194728	0.509259	0.254629	-0.25463
249	2.206939	0.509193	0.254596	-0.2546
250	2.21804	0.509089	0.254545	-0.25454
251	2.230251	0.508995	0.254497	-0.2545
252	2.241352	0.508891	0.254446	-0.25445
253	2.252453	0.508797	0.254399	-0.2544

254	2.264664	0.508703	0.254352	-0.25435
255	2.274655	0.5086	0.2543	-0.2543
256	2.285756	0.508515	0.254257	-0.25426
257	2.296857	0.508421	0.25421	-0.25421
258	2.306848	0.508326	0.254163	-0.25416
259	2.320169	0.508242	0.254121	-0.25412
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265	2.394601	0.506728	0.253364	-0.25336
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268	2.431234	0.506398	0.253199	-0.2532
269	2.444556	0.506314	0.253157	-0.25316
270	2.455717	0.506201	0.2531	-0.2531
271	2.465708	0.505233	0.252616	-0.25262
272	2.477919	0.505148	0.252574	-0.25257
273	2.48908	0.505045	0.252522	-0.25252
274	2.501291	0.504077	0.252038	-0.25204
275	2.512392	0.503973	0.251987	-0.25199
276	2.523493	0.503879	0.25194	-0.25194
277	2.537924	0.503785	0.251892	-0.25189
278	2.550191	0.503663	0.251831	-0.25183
279	2.561352	0.502685	0.251343	-0.25134
280	2.575831	0.501718	0.250859	-0.25086
281	2.589203	0.500722	0.250361	-0.25036
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283	2.619226	0.499594	0.249797	-0.2498
284	2.632548	0.498607	0.249304	-0.2493
285	2.643709	0.498494	0.249247	-0.24925
286	2.652589	0.497527	0.248763	-0.24876
287	2.662647	0.497451	0.248726	-0.24873
288	2.674913	0.496493	0.248247	-0.24825
289	2.683794	0.495516	0.247758	-0.24776
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291	2.709381	0.494463	0.247232	-0.24723
292	2.72386	0.49435	0.247175	-0.24718
293	2.737232	0.493355	0.246677	-0.24668
294	2.749443	0.492368	0.246184	-0.24618
295	2.761654	0.492264	0.246132	-0.24613
296	2.773921	0.492161	0.24608	-0.24608

297	2.786187	0.491184	0.245592	-0.24559
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299	2.811719	0.490103	0.245051	-0.24505
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301	2.835146	0.489013	0.244506	-0.24451
302	2.846308	0.488045	0.244023	-0.24402
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307	2.909797	0.484042	0.242021	-0.24202
308	2.923118	0.483046	0.241523	-0.24152
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310	2.948757	0.481947	0.240973	-0.24097
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315	3.005561	0.478846	0.239423	-0.23942
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317	3.034651	0.475999	0.238	-0.238
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319	3.054765	0.474045	0.237023	-0.23702
320	3.064822	0.473087	0.236543	-0.23654
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322	3.086043	0.47118	0.23559	-0.23559
323	3.098309	0.470202	0.235101	-0.2351
324	3.110731	0.469225	0.234613	-0.23461
325	3.12664	0.467375	0.233687	-0.23369
326	3.140386	0.464622	0.232311	-0.23231
327	3.153058	0.461888	0.230944	-0.23094
328	3.167884	0.459164	0.229582	-0.22958
329	3.179488	0.456421	0.228211	-0.22821
330	3.188988	0.453706	0.226853	-0.22685
331	3.200593	0.45101	0.225505	-0.22551
332	3.210838	0.448295	0.224148	-0.22415
333	3.221384	0.446464	0.223232	-0.22323
334	3.234057	0.443758	0.221879	-0.22188
335	3.245661	0.441034	0.220517	-0.22052
336	3.256208	0.438319	0.219159	-0.21916
337	3.266453	0.435614	0.217807	-0.21781
338	3.276697	0.433782	0.216891	-0.21689
339	3.287244	0.43195	0.215975	-0.21597

340	3.296198	0.429244	0.214622	-0.21462
341	3.307803	0.428296	0.214148	-0.21415
342	3.318048	0.425581	0.21279	-0.21279
343	3.328594	0.423749	0.211874	-0.21187
344	3.338094	0.421043	0.210522	-0.21052
345	3.348641	0.418347	0.209174	-0.20917
346	3.358141	0.415642	0.207821	-0.20782
347	3.367641	0.412946	0.206473	-0.20647
348	3.377141	0.41025	0.205125	-0.20512
349	3.386111	0.407554	0.203777	-0.20378
350	3.395275	0.403994	0.201997	-0.202
351	3.402306	0.402171	0.201086	-0.20109
352	3.412551	0.400368	0.200184	-0.20018
353	3.421715	0.398536	0.199268	-0.19927
354	3.431215	0.396713	0.198357	-0.19836
355	3.440715	0.394017	0.197009	-0.19701
356	3.451261	0.391321	0.195661	-0.19566
357	3.459731	0.388616	0.194308	-0.19431
358	3.469305	0.385929	0.192965	-0.19296
359	3.479852	0.381496	0.190748	-0.19075
360	3.489801	0.37879	0.189395	-0.1894
361	3.498271	0.375221	0.18761	-0.18761
362	3.50674	0.372534	0.186267	-0.18627
363	3.514202	0.369847	0.184924	-0.18492
364	3.522672	0.36717	0.183585	-0.18359
365	3.533625	0.364484	0.182242	-0.18224
366	3.543575	0.360905	0.180452	-0.18045
367	3.552044	0.357335	0.178667	-0.17867
368	3.561015	0.354648	0.177324	-0.17732
369	3.570515	0.351088	0.175544	-0.17554
370	3.578984	0.348392	0.174196	-0.1742
371	3.589938	0.345706	0.172853	-0.17285
372	3.598407	0.342127	0.171063	-0.17106
373	3.606499	0.33944	0.16972	-0.16972
374	3.615469	0.337627	0.168813	-0.16881
375	3.627446	0.334067	0.167033	-0.16703
376	3.637395	0.330478	0.165239	-0.16524
377	3.646365	0.326909	0.163454	-0.16345
378	3.656912	0.323349	0.161674	-0.16167
379	3.665882	0.320643	0.160322	-0.16032
380	3.67237	0.317083	0.158542	-0.15854
381	3.678859	0.314415	0.157208	-0.15721
382	3.686321	0.311747	0.155874	-0.15587

383	3.693449	0.30907	0.154535	-0.15454
384	3.700911	0.305529	0.152764	-0.15276
385	3.706476	0.302852	0.151426	-0.15143
386	3.712964	0.300193	0.150097	-0.1501
387	3.719263	0.297526	0.148763	-0.14876
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390	3.740904	0.286902	0.143451	-0.14345
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393	3.764083	0.277142	0.138571	-0.13857
394	3.770571	0.273591	0.136796	-0.1368
395	3.777059	0.270923	0.135462	-0.13546
396	3.784521	0.268256	0.134128	-0.13413
397	3.791649	0.265578	0.132789	-0.13279
398	3.798777	0.262037	0.131019	-0.13102
399	3.807747	0.258496	0.129248	-0.12925
400	3.816442	0.254936	0.127468	-0.12747
401	3.822741	0.250511	0.125256	-0.12526
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404	3.846923	0.239878	0.119939	-0.11994
405	3.855618	0.236327	0.118164	-0.11816
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409	3.885954	0.221269	0.110635	-0.11063
410	3.893828	0.217719	0.108859	-0.10886
411	3.901701	0.213304	0.106652	-0.10665
412	3.910396	0.208889	0.104444	-0.10444
413	3.919091	0.204464	0.102232	-0.10223
414	3.927116	0.20004	0.10002	-0.10002
415	3.93738	0.196489	0.098245	-0.09824
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417	3.954773	0.186758	0.093379	-0.09338
418	3.962646	0.181469	0.090735	-0.09073
419	3.968945	0.177054	0.088527	-0.08853
420	3.97764	0.173523	0.086761	-0.08676
421	3.987088	0.169098	0.084549	-0.08455
422	3.996537	0.1638	0.0819	-0.0819
423	4.006801	0.158502	0.079251	-0.07925
424	4.016249	0.153195	0.076598	-0.0766
425	4.026516	0.147897	0.073949	-0.07395

426	4.035214	0.141726	0.070863	-0.07086
427	4.043912	0.136437	0.068219	-0.06822
428	4.05261	0.131149	0.065574	-0.06557
429	4.061589	0.125861	0.06293	-0.06293
430	4.070769	0.119708	0.059854	-0.05985
431	4.083213	0.112701	0.05635	-0.05635
432	4.095657	0.103073	0.051536	-0.05154
433	4.108101	0.093445	0.046722	-0.04672
434	4.120794	0.083816	0.041908	-0.04191
435	4.13641	0.074179	0.03709	-0.03709
436	4.149808	0.06194	0.03097	-0.03097
437	4.163206	0.051448	0.025724	-0.02572
438	4.169976	0.040955	0.020478	-0.02048
439	4.177762	0.035705	0.017852	-0.01785
440	4.184436	0.02959	0.014795	-0.01479
441	4.191206	0.024348	0.012174	-0.01217
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443	4.209349	0.012118	0.006059	-0.00606
444	4.211839	0.005111	0.002556	-0.00256

Length of petal= 4.21m

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