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Analyzing V-2 Data

By Stanley A. Sojka

My initial interest in rockets (and the very start of my career in chemistry) began when, as a 10 year old boy, I could obtain the ingredients necessary for making my own solid rocket propellants from my local drugstore. It also helped that my nearby Army surplus store had empty shells of various calibers from spent ammunition, and these made for good rocket motor casings (and Vesuvius fountains for the 4th of July). Lucky to have not sustained any debilitating injuries, although experiencing some close calls, I came back to rockets after finishing my adult career to find rocket motors now, a lot safer as well as conveniently commercially available.

I developed a desire to scratch build a rocket, and like many rocket enthusiasts, I chose to model the classic V-2 rocket. The V-2 rocket is probably the most studied design for hobbyist and model manufacturers, because of its unique, well known historic significance, and its appealing aesthetic form which can be easily recognized even by school children.

The V-2 can be regarded as marking if not the very beginning of the space age then certainly of the beginning of the modern guided ballistic missile era. After all, it was the first guided liquid-fueled rocket to actually enter space, which is now considered as the Karman line at an altitude of 100km, or 62mi, above sea level. Unfortunately, this early, rapidly developing, and stunning technological quantum leap was financially supported and usurped by the German Army who turned it into a horrid, terrorizing, and devastating weapon of war. Over 3,000 V-2 rockets where launched against European cities in World War II. In addition to those who died as a direct result of a V-2 attack, we can never forget the thousands of slave laborers who perished by being forced to manufacture those V-2 rounds launched in anger. After the war, the looted V-2 technology, and its captured personnel, provided the basis for both the American and Soviet space programs.

The V-2 rocket on display at the National Air and Space Museum (NASM) of the Smithsonian Institution is shown in **Figure 1**.

Figure 1: The V-2 at the NASM, Washington, D.C.

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Sources of Rocket Dimensions

Rocket dimensions are one of the most critical starting points for the design of your model, and I reasoned that there would be no lack of corroborated dimensional information concerning this well-studied rocket. Little did I realize that my quest to find V-2 dimensions would take me to the NASM in Washington, DC, to see an actual V-2 on display, the NASM Silver Hills, MD archive facility where I viewed reels of microfilm, and to the library at the Naval Research Laboratory.

Sources of rocket dimensions include reference compilations, such as Ref 1 and 12 shown in the Table (**page 9**); original blueprints and drawings, such as Ref 3, 4, 5, 8, 9 and 10; and publications by Experts, such as Ref 2, 6, 7, 11, and 13.

The American army was able to capture sensitive files and hardware as World War II drew to a close. Many of the engineering diagrams were microfilmed and are archived at NASM where a Researcher may examine them and obtain copies. The NASM microfilm Reel# 2559 was an especially rich source of German drawings. The Frames of Reel# 2559 have to be viewed with caution as many drawing are for preliminary designs and prototypes that never became production blueprints. For example, **Figure 2** shows the A-4 drawing from R2559, F117. (A-4 was the name of the rocket before its more recognizable militarized name, V-2)

This early drawing number 4934E is dated August 3rd 1942 and displays a large amount of dimensional information. It certainly helps to know some German language or at least have a

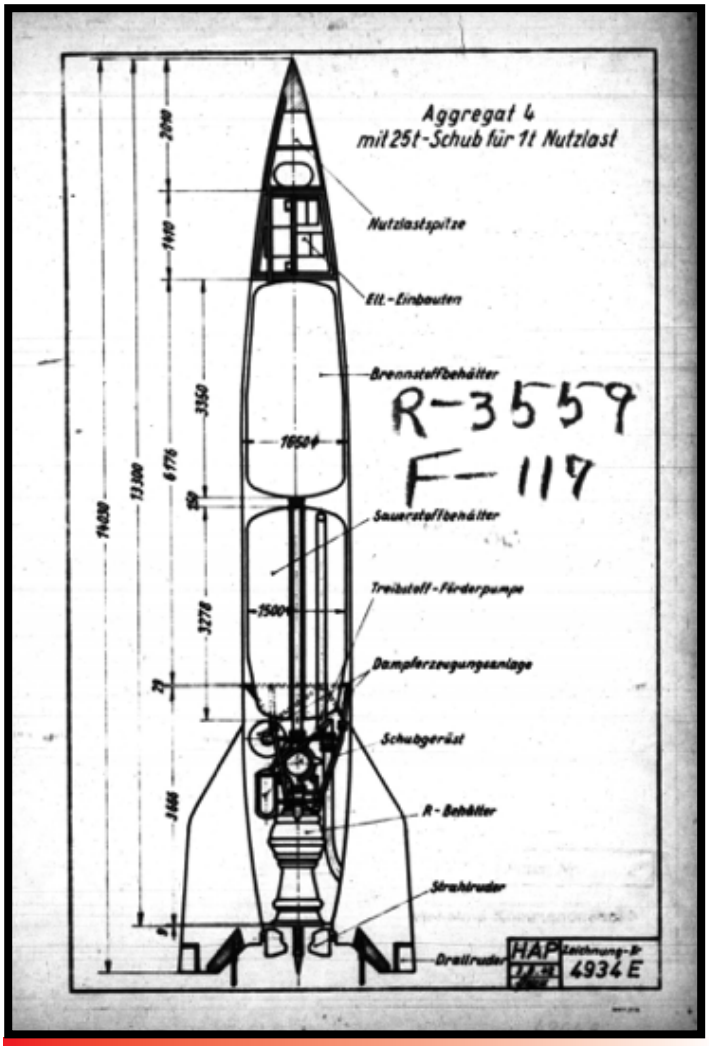

Figure 2: German drawing of the V-2 (A-4) rocket.

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German-English dictionary available. The initials HAP indicate that this drawing originated from Peenemunde, the German rocket development center located on the shores of the Baltic Sea. It should be expected that in order to be substantiated the correct dimensions form a drawing would be repeated in subsequent mechanical drawings and actual production blueprints. This tends to bolster confidence in the dimensions of interest.

Using Dimensions from References

At the beginning of my hunt for dimensional information, I naturally thought that someone else had already done this hard investigative legwork and, thus, this would be a simple task and so I started my quest with the most recent rocket dimension reference compilation, Ref 1. Indeed, the V-2 is well described in Ref 1 and I began to use a drawing program to design my model. (I use AutoSketch 10 from Autodesk).

Soon, however, I ran into pesky annoying difficulties. I had inferred from Ref 1 that the Ogive Length (O.L.), a critical deterministic value for the nose cone, was equal to 5295mm. But using this value in my drawing program gave diameters too large for diameter F1 and diameter F2. The nose cone would be too “fat”. The ogive radius, r, was not given in Ref 1. So, I sought a corroborative reference and obtained Ref 2, which definitively gave the same O.L. value, and also clearly delineated r = 20625mm both for the nose cone and boat tail ogive radii. My thankful relief gradually turned to abject horror as, slowly over a lengthy percolation time, I finally realized that these values of O.L. and r are in conflict and are basically incompatible... a very serious discontinuity.

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The Ogive Family

To be clear and thorough, there are two basic types of ogives: the tangent ogive and the secant ogive. The tangent ogive is illustrated in Figure 3. **Figure 3**.

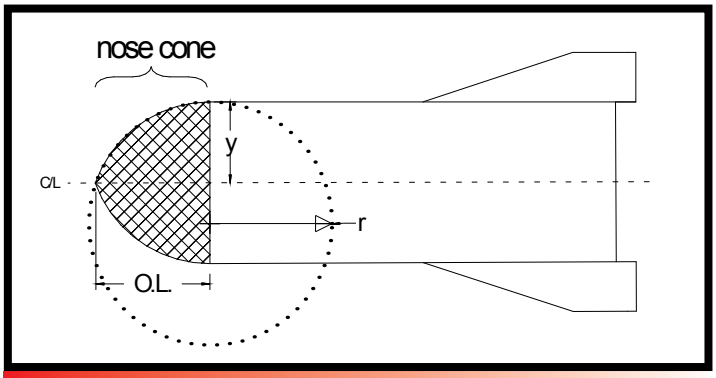

Figure 3: The tangent ogive for a rocket nose cone.

The hatched area is the nose cone profile and it is a segment of the circle (dotted line used for the circle) of radius r, also called the ogive radius. The rocket body is tangent to the curve of the nose cone at the nose cone base, that is, the line, y, lies on a radius and it is tangent, or 90°, to the rocket body precisely at the point where the nose cone base, y, meets the rocket body. The O.L. lies along the centerline, C/L, of the rocket, and the nose cone base, y, is perpendicular to it. For the tangent ogive, there is a strict, simple, and handy mathematical relationship among the O.L., r, and y derived from the Pythagorean Theorem. This relationship is shown in Eq(1)

Eq(1) $$r = (y^2 + (O.L.)^2)/2y$$

We shall use this equation to help us resolve our dimension discrepancy.

The other kind of ogive is the secant ogive, and one type of secant ogive is illustrated in **Figure 4**.

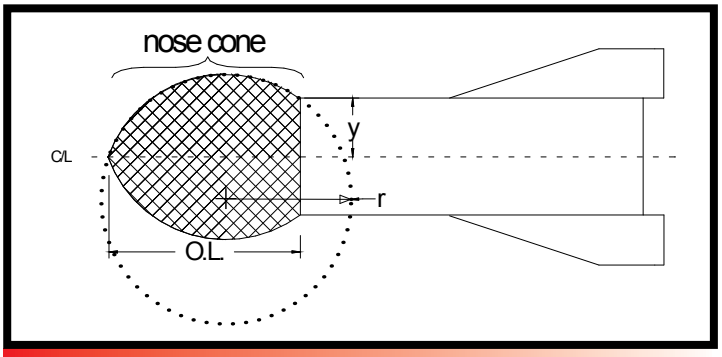

Figure 4: Example of a secant ogive for a rocket nose cone.

In the secant ogive in **Figure 4**, the base of the nose cone, y, does not lie on a radius, and the rocket body will not be tangent, or be 90° to the curve at its intersection with the nose cone base. Instead, the nose cone bulges out to a diameter larger than the rocket diameter. A well-known example of this situation is the secant ogive nose cone of the Honest John rocket. The base of the nose cone, y, will still be perpendicular to the rocket centerline. Think of the secant ogive as derived from any line through the circle, except a diameter, but still perpendicular to the rocket centerline. For the secant ogive, there are no simple and easy to use mathematical relationships among O.L., r, and y.

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Results from Using the Tangent Ogive Equation

We can now use the **Eq(1)** relating the tangent ogive elements to perform some calculations and help us resolve our dimension discrepancy. Thus, using the value of O.L. as 5295mm, which was given in Ref 1-2, and y as 825.5mm, which is one-half of the established V-2 diameter, F3, one calculates r as 17395mm. This value for r is, significantly, 16% smaller than the 20625mm given in Ref 2.

We now have a gross discrepancy with these two reference values.

Which r value is correct? What is the real O.L.? How do we decide?

To proceed, we can see what happens to the O.L. by algebraically rearranging Eq(1) to Eq(2).

Eq(2) O.L. =

By using **Eq(2)**, we can calculate O.L. with y as 825.5mm and r as the 20625mm. This gives a value for O.L of 5776.7mm, which we can round off to 5777mm.

Thus, if the German rocket designers meant to use a tangent ogive, which I believe they did, then, by strict mathematics, the O.L. must be 5777mm and r must be 20625mm.

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On the other hand, if they intended to use a secant ogive, then the base of the nose cone would be slightly larger than the rocket diameter, and this arrangement has no appealing virtues. Furthermore, the nose cone would be "fat". This can be illustrated by the **Figure 5**, which was obtained from my drawing program and shows the two different ogive nose cone profiles superimposed on one another.

The solid curve is when O.L = 5777mm giving r = 20625mm. Most importantly, notice that this curve nicely intersects the given values for diameter F1 and diameter F2. The curve perfectly meets diameter F1 at the well reported and corroborated value of 956mm. And it meets diameter F2 at the not well reported value of 1381mm. On the other hand, the dashed curve is when O.L. = 5295mm giving r = 17395mm. This curve is noticeably bulging and, moreover, does not intersect diameter F1 and diameter F2. In fact, F1 would have to be 7.2% larger, and F2 would need to be 4.9% larger to intersect the dashed curve.

With the agreement amongst O.L, r, and y mathematically satisfied for the tangent ogive, I searched the references for a confirmation that the O.L. = 5777mm. interestingly, a primary source for the O.L. was difficult to corroborate in all the sources examined, but it became apparent and was verified by studying Ref 3.

Conclusions

As shown in the attached Table, when I used O.L = 5777mm, I generated a circle with nose cone ogive r1 = 20625mm with my drawing program. I used r2 = 20625mm for the boat tail ogive radius, assuming r1 = r2. This appeared to be a reasonable assumption because when I folded all blueprints and drawings by bringing the nose over the tail, the nose cone and boat tail curves could be made to exactly overlap.

There is generally good agreement among the sources for dimensions A – O and diameters F1, F3, F5, F6, F8, and F9.

The most glaring discrepancy is the ogive length, O.L., and corresponding ogive radius, r, discussed in detail above.

The overall length of the rocket from nose to end-of-fin, dimension O, is 14026mm. There is a support beam extension, dimension J, of 10mm which one could add to the overall length. I chose not to add this in my

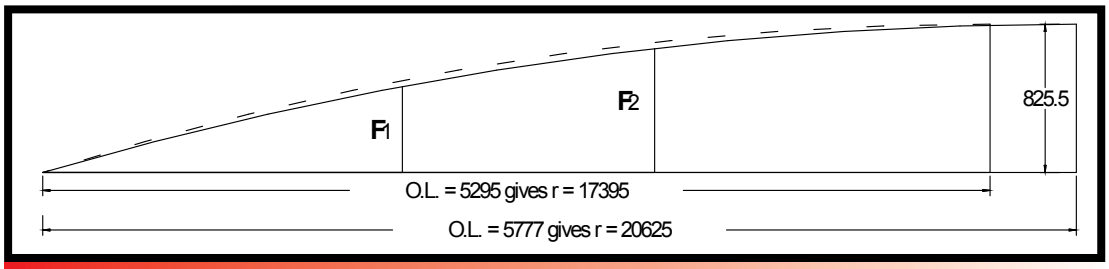

Figure 5: Comparison of the two different ogive nose cone profiles(dimensions in mm).

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V-2 rocket design. The support beam is inside the wing and is parallel to the rocket body. This is where the structural weight of the rocket resided and also represents the four support points on which the erect rocket stood.

Diameter F2 is under-reported and I used a value of 1381mm, which intersects the new ogive curve. Likewise, diameter F4 is not found, but I needed it for my design (and you may too) and I calculated a value of 1323mm, again consistent with intersection of the ogive curve. Curiously, the radius of F5 is reported as 1650+/-10mm. This is the only dimension I found with these variance limits, and it is attributable to the fact that this intersection is intended to be rounded rather than coming to a sharp point. Finally, diameter F7 is under-reported and I used a value of 1704mm as this would make a clean 45° angle for the connection line between the circular planes defined by diameter F7 and F8.

Summary

Although sources abound for the dimensions of the V-2, I found discrepancies among the sources. The Table shows my compilation of key dimensions from various sources (dimensions in mm).

Dimensional discrepancies can be due to authors looking at different V-2 (A-4) drawings and blueprints, the actual examination of different V-2 rockets, and the reporting on modified V-2 rockets. The latter is especially true of the NRL documentation as significant changes were made to the nose of the rocket to accommodate different experiments.

Finally, I recommend all Rocketeers seeking to model the V-2 rocket to use the ogive length, O.L. = 5777mm, corresponding to an ogive radius of r = 20625mm for both the nose cone and boat tail. This means that the nose cone will be 9.1% longer and the cylindrical body shorter when compared to the smaller erroneous value of O.L = 5295mm. This may not be noticeable on small models but will become apparent the larger the model becomes. The true scale modelers among us, whom are purists at heart, will want to use this newly determined O.L. value for the absolute accuracy and precision demanded by scale building requirements.

For the convenience to all model Rocketeers, the last column of the Table contains my best dimension values for the V-2 rocket.

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Trying to find accurate dimensions for this well-known rocket was an interesting journey. It taught me to challenge everything and to relentlessly pursue verifiable sources primarily. A little application of math helps a lot. Now that I have completed all the hard investigative legwork for you, I hope you will enjoy the building of your very own V-2 rocket. For now, I am well on my way to building my own version of this infamous and historic rocket which left forever an indelible mark on the face of the 20th Century.

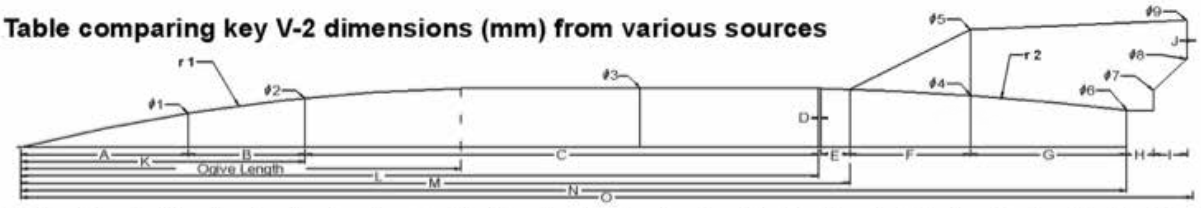
Acknowledgements

I wish to express my gratitude to the very able assistance of the Staff at the NASM Silver Hills, MD archive facility, the NASM in Washington D.C., and at the Naval Research Laboratory. Special thanks to Michael J. Neufeld of the Smithsonian Institution for his constructive comments and cogent advice freely given.

About the Author

Stan Sojka finished a 25 year career as an industrial chemist and is now back to building rockets. In addition to being a consultant to the chemical industry, he is an Adjunct Professor of Chemistry at Mount St. Mary's University, Emmitsburg, MD.

Table comparing key V-2 dimensions (mm) from various sources



Ref	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	2010	2010	2010	2010	2010	2285	-	2007	-	-	2007	1829	1803	2010
B	1410	1410	1410	1410	1410	1400	-	1397	1397	-	1397	1463	1422	1410
C	6176	6176	6176	6215	6176	6225	-	6223	-	-	-	6187	6185	6176
D	29	29	-	5	29	-	-	-	-	-	-	-	-	29
E	345	345	-	451	345	-	-	-	-	-	-	-	-	345
F	1449	1449	-	-	-	-	-	-	-	-	-	-	-	1449
G	1881	-	-	-	-	-	-	-	-	-	-	-	-	1881
H	325	325	-	-	-	-	-	-	-	-	-	-	-	325
I	401	-	-	-	-	-	-	-	-	-	-	-	-	401
J	11	10	-	-	10	-	-	-	-	-	-	-	-	10
K	3420	3420	-	-	3420	-	-	-	-	-	-	-	-	3420
L	9596	9596	-	-	9596	-	-	-	-	-	-	-	-	9596
M	9970	9970	-	-	9970	-	-	-	-	-	-	-	-	9970
N	13300	13300	-	-	13300	-	-	-	-	-	-	-	-	13300
O	14026	14026	-	14036	14026	14300	14000	14021	-	14030	-	14021	-	14026
O.L.	5295	5295	5777	-	-	-	-	-	-	-	-	-	-	5777
ϕ1	956	-	-	-	-	-	-	956	965	-	956	-	-	956
ϕ2	-	-	-	-	-	-	-	-	1372	-	-	-	-	1381
ϕ3	1651	1651	-	-	-	1650	1650	1651	1651	-	-	1646	1657	1651
ϕ4	-	-	-	-	-	-	-	-	-	-	-	-	-	1323
ϕ5	3300	3300	-	-	-	-	-	-	-	-	-	-	-	3300
ϕ6	1040	1040	-	-	-	-	-	-	-	-	-	-	-	1040
ϕ7	1800	-	-	-	-	-	-	-	-	-	-	-	-	1704
ϕ8	2506	2506	-	-	-	-	-	-	-	-	-	-	-	2506
ϕ9	3564	3564	-	3564	-	-	-	3556	3556	-	-	3597	3556	3564
r1	-	20625	20625	-	-	-	-	-	-	-	-	-	-	20625
r2	-	20625	-	-	-	-	-	-	-	-	-	-	-	20625

[1] *Rockets of the World*, 3rd ediiton, Peter Alway
[2] *Model Rocketeer*, June 1976, *The A-4*, Gregory P. Kennedy
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[14] Recommended dimensions for all V-2 models