

Experimental Study of the Visualization of Vortex Structures Ogives Revolution

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Abstract

A large number of studies of flow visualisations, developed on the upper surface of delta or gothic wings and on that of ogives of revolution, have been carried out in the wind tunnel of the Valenciennes University aerodynamics and hydrodynamics laboratory (LAH). These studies have provided a better understanding of the development and the positioning of vortex structures and have enabled, in particular, the preferential nature of inter vortex angles, thereby defined, to be determined on a wide range of Reynolds. This paper concerns in particular the study by visualisations of the behavioural properties on the upper surface of an ogive of revolution having an apex angle of 68.6° at a low angle of attack and conducted at variable speeds. It has been noted that variations in speed have no influence at all on the behavioural properties of the development of vortex structures whereas, by contrast, changes to the angles of incidence do indeed strongly influence that development. The study of the ascent of the vortex breakdown at high angles of attack has revealed original behavioural properties which find expression notably in the discontinuous evolution, in terms of the apex angle, of those angles of attack which define the beginning and the end of the ascent of this vortex breakdown.

Index terms—

1 Experimental Study of the Visualization of Vortex Structures Ogives Revolution Dr. Abene Abderrahmane

Abstract—A large number of studies of flow visualisations, developed on the upper surface of delta or gothic wings and on that of ogives of revolution, have been carried out in the wind tunnel of the Valenciennes University aerodynamics and hydrodynamics laboratory (LAH). These studies have provided a better understanding of the development and the positioning of vortex structures and have enabled, in particular, the preferential nature of inter vortex angles, thereby defined, to be determined on a wide range of Reynolds. This paper concerns in particular the study by visualisations of the behavioural properties on the upper surface of an ogive of revolution having an apex angle of 68.6° at a low angle of attack and conducted at variable speeds. It has been noted that variations in speed have no influence at all on the behavioural properties of the development of vortex structures whereas, by contrast, changes to the angles of incidence do indeed strongly influence that development. The study of the ascent of the vortex breakdown at high angles of attack has revealed original behavioural properties which find expression notably in the discontinuous evolution, in terms of the apex angle, of those angles of attack which define the beginning and the end of the ascent of this vortex breakdown. These properties undoubtedly reflect those already observed in similar studies carried out on delta and gothic wings and on cones. However, no current theory seems to be able to provide a straightforward explanation of these phenomena.

2 I. CONCLUSION

41 View n° 1 ? = 68.6° i = 8° 19000<Re<80000 View n° 1 : the study to evidence a low incidence of birth vortex
42 structures that will become a stable average impact is concentrated and pass a web structure in the classical.
43 ???2,33and38] View n° 5 ? = 68.6° i = 70° 19000<Re<80000

44 View n° 3 : At 70 ° incidence i, I notice the fusion vortex bursts which are unstable and back to the top of
45 the cone of revolution. the application of this phenomenon of vortex breakdown in the solar collectors has baffles
46 variables [22,33,36,37].

47 Diagram n° 1 1: interior vortex 2: exterior vortex [8,22and 34]

48 2 I. Conclusion

49 While, on a wide range of Reynolds, the preferential nature of the intervortex angles present on the upper surface
50 of delta and gothic wings and of ogives of revolution would seem to be fully catalogued, the very existence of
51 the law of filiation relative to such slender bodies expresses a certain universality of behaviour and reveals the
52 fundamental feature of our study.

53 At the present time, however, no complete theoretical approach would seem to be capable of providing a
54 straightforward explanation of the simplicity of these results. The progressive evolution from elementary vortices
55 of the sheer flow before take-off towards a particularly stable vortex system, wherein spatial positioning reveals
56 an original organisation, still remains today an enigma. It is, of course, difficult to prejudge the lines along which
57 one or more future studies may follow, studies which could lead to a theoretical explanation. However, perhaps
58 we may be permitted to note that the phenomena, in which the sine squared of an angle also plays a part, are
59 created by the simple structures of stationary and unsteady fluid mechanics.

60 It is in this way that the flow -emitted by an ogive of revolution having a demi-span of ? at its summit on a
61 tridimensional dipole with the same axis as that of the cone, or with its summit at the centre of a vortex ring
62 equivalent to the dipole -is proportional to Sin²?. This is how energy -emitted by an oscillating electromagnetic
63 dipole (with properties analogous to those of the oscillating fluid dipole that plays a part in aerodynamics or in
64 hydrodynamics) in a ? direction with regard to the axis of the dipole -is, energy too, proportional to Sin²? or
65 to cos²? = 1-sin²? in the case of the acoustic dipole. It is also a law in Sin²? that gives the dependence, with
66 regard to the angle of attenuation of the second sound thermal waves in liquid helium, by rectilinear vortices
67 which form the ? angle with the direction of the propagation of this wave.

68 It is, moreover, by coupling this law with the concept of that preferential angle, formed by helicoidally vortices
69 with their axes, that the authors of the papers referred to in [1] and [2] interpreted the discontinuous angular
70 behaviour of these vortex systems in liquid helium [1, 2 and 19].

71 Finally, and this ultimate remark is probably not the least important one, the suction force, to which a profile
72 -an infinitely thin and localised plane, let us remember -is subjected in the immediate vicinity of its leading edge,
73 is, that force, too, proportional to the sine squared of an angle, in this case the angle of incidence.

74 As concerns the possible links, of the phenomena we have described, with the properties of an emission or of
75 an absorption of a flow or of a wavewhose source may be dipolar or multipolar -it is perhaps interesting to note
76 that the range of speeds of a tridimensional dipole {characterised by the angle between the radius vector of a
77 point of the fluid and the speed of this fluid} is linked to the angular positioning of this point, with regard to
78 the dipole {characterised by the polar angle between the axis of the dipole and the radius vector}, by a series of
79 striking correspondences between the most simple preferential angles. Moreover, if we now consider the force of
80 interaction between two dipoles of relatively simple orientation -the most simple is one with two parallel dipoles,
81 but numerous other layouts give equally curious results -the range of interaction forces {characterised by the angle
82 between the radius vector joining the two dipoles with this interaction force}, possesses, in its turn, together with
83 the two other ranges of relative positioning and of speeds {characterised as described above}, two new entireties
84 of quite striking correspondences E. TRUCKENBRODT ???24].

85 Where the notable orientations of interaction forces between two parallel dipoles are concerned, and with
86 regard to the common direction of the axes of these dipoles, we have extracted a few particular cases from the
87 general calculations made by W. KÖNIG [25] and from his final result given in J.W-C. RAYLEIGH's very famous
88 book on acoustics [26].

89 These references contain expressions : the components of the force exerted by one sphere on another in the
90 presence of a uniform wind pattern to infinity; where the fluid flow is perfect; the line joining the centres of
91 spheres forming the ? angle with the direction of the wind to infinity -this force is the same as that exerted
92 by one sphere on another when those spheres are moving parallel to each other and at the same speed in an
93 immobile fluid to infinity -but it is known that each of these spheres is equivalent to a tridimensional dipole.

94 The sole particular cases commented on by W. KÖNIG [25] and J.W-C. RAYLEIGH [26] are those where the
95 centres of the spheres are aligned, {i.e. in the direction of the wind}, and where these spheres therefore exert
96 on each other a repulsion force {i.e. perpendicularly to the wind} with, in this case, a gravitational interaction
97 force which explains the formation of very fine powder ridges, perpendicular to the axis of a sound tube, within
98 its antinodes (ventral segments) of vibration.

99 But a whole series of other consequences from the general formulae found in references [25] and [26] seem, they
100 too, to be very significant. One of the most important of these particular cases seems to us to be that where the
101 interaction force between two parallel dipoles is itself parallel to them. Formula n° 4 on page 47 of reference [26]

102 immediately shows that this case corresponds to the θ angle, cancelling the Legendre polynomial $1-5\cos^2\theta$, i.e.
103 at (10) according to the defining formula of preferential angles given at the beginning of this paper.

104 This angle $\theta = 42^\circ = 63.4^\circ$ is, moreover, the angle between the diagonals of the famous "Golden Rectangle"
105 discovered by architects and employed by them from time immemorial [21].

106 In this same train of thought, it is striking to note, in references [27 to 29] the role played systematically by
107 the angle $\theta = 32^\circ = 54.7^\circ$ (cancelling the Legendre polynomial $1-3\cos^2\theta$) in the sound emission of an axisymmetric jet
108 and of two interaction forcing vortex rings or of one forcing vortex ring in the presence of a sphere.

109 In short, many other well-known hydrodynamic and aerodynamic phenomena are rich in preferential angles,
110 the theory of which has at some or other been fully elaborated. This is the case found in the very subtle and
111 elegant theory described in particular in the works of H. LAMB [30] and of J. Lighthill [31]. In the wake,
112 the crests of waves, in a curvilinear triangle form, will in fact each disappear at two counter flow points, the
113 alignment of which, along two right-hand sides, determines a total span of the wake at twice 19.4° here and there
114 of the axis of this wake, axis with which the counterblow tangents, associated with the crests, form an angle of
115 54.7° while also forming with each corresponding edge of the wake an angle of 35.3° {i.e. $54.7^\circ - 19.4^\circ$ }.

116 It is there where the following relation is to be found, never interpreted before now, in terms of preferential
117 angles :

118 The link between the wake of a ship, being the result of the combination of bidimensional surface waves shed
119 in various directions, and the phenomena described above may appear at first sight to be very mysterious. We
120 may, however, be permitted to reason that the paper by E. LEVI [32] under the title "An oscillating approach to
121 turbulence", so suggestively illustrated by figure n° 1 on page 352 of his study {an illustration which represents
122 the frontier of a wake or of a maximum layer as a swell induced by the emission of vortices} perhaps provides
123 the starting point of a profitable line of further research which could lead to a better understanding of the
124 omnipresence of preferential angles and of their filiations in tridimensional flows, and in particular in those
125 developed around slender bodies.

126 The essential question to be pursued, and one which remains as yet to be entirely addressed, seems to us
127 primarily to lie with structures and wave propagation. What is required is the explanation of the link between
128 those preferential angles, which appear in structures exterior to the borderline layer, and structures, which would
129 also probably need to be termed preferential angles, to be found in the forms and modes of wave propagation. The
130 latter have recently been the subject in a close study of "the coherent structures of turbulence", structures that
131 are, in particular, present in laminar-turbulent transition zones or in zones of anisotropic turbulence, especially
132 where they relate to layers.

133 3 Bibliography



Figure 1:

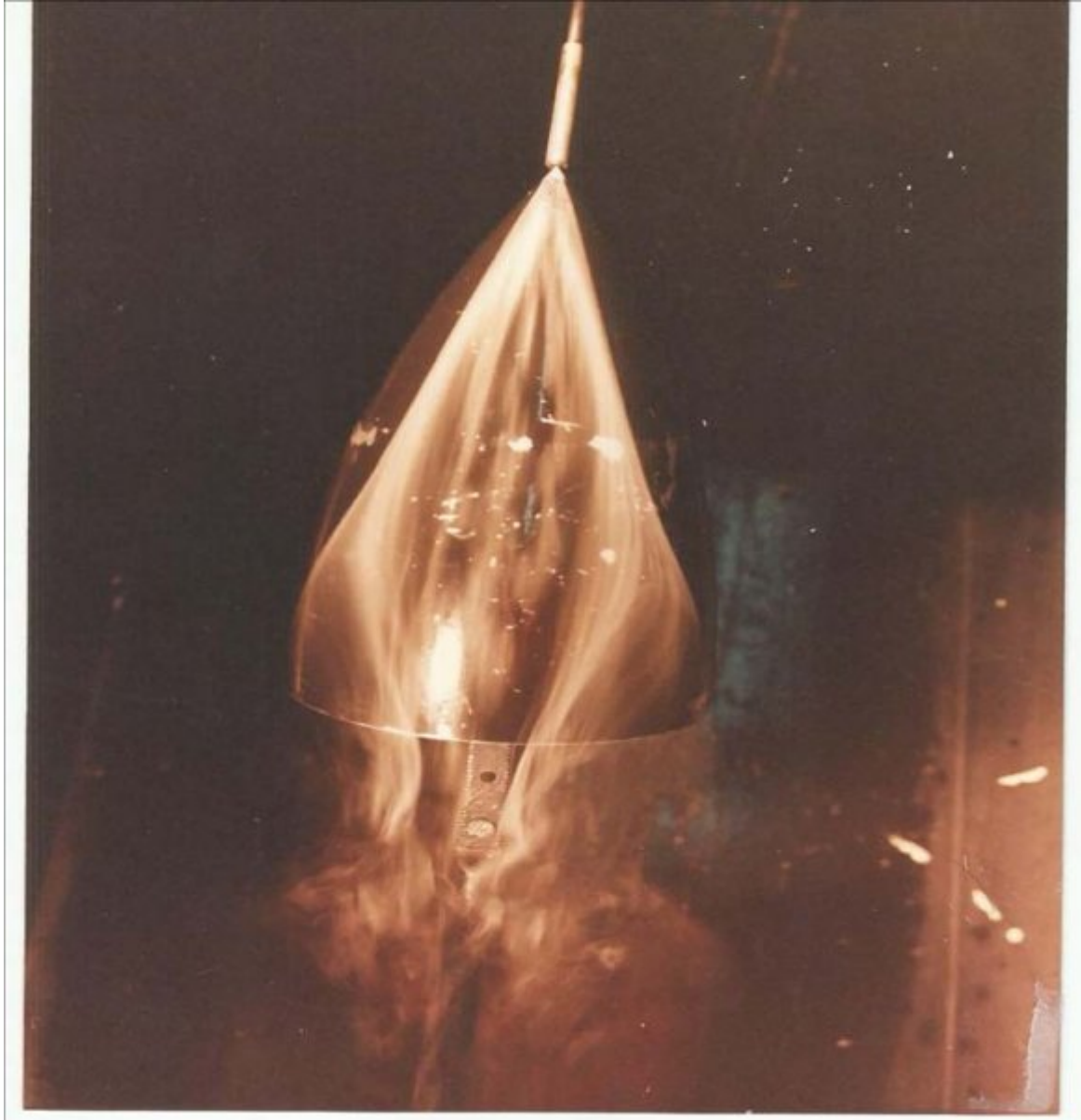


Figure 2:

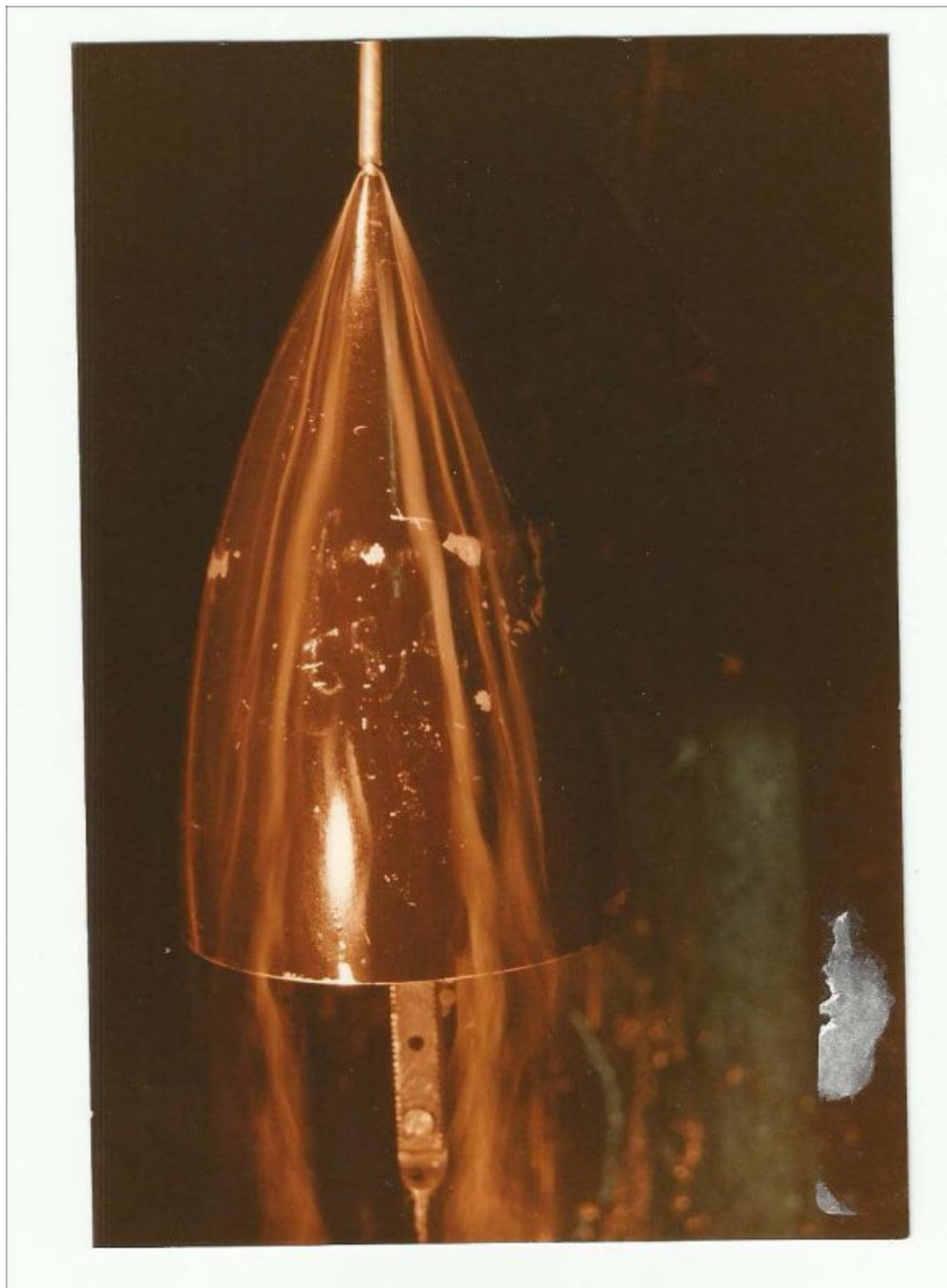


Figure 3:

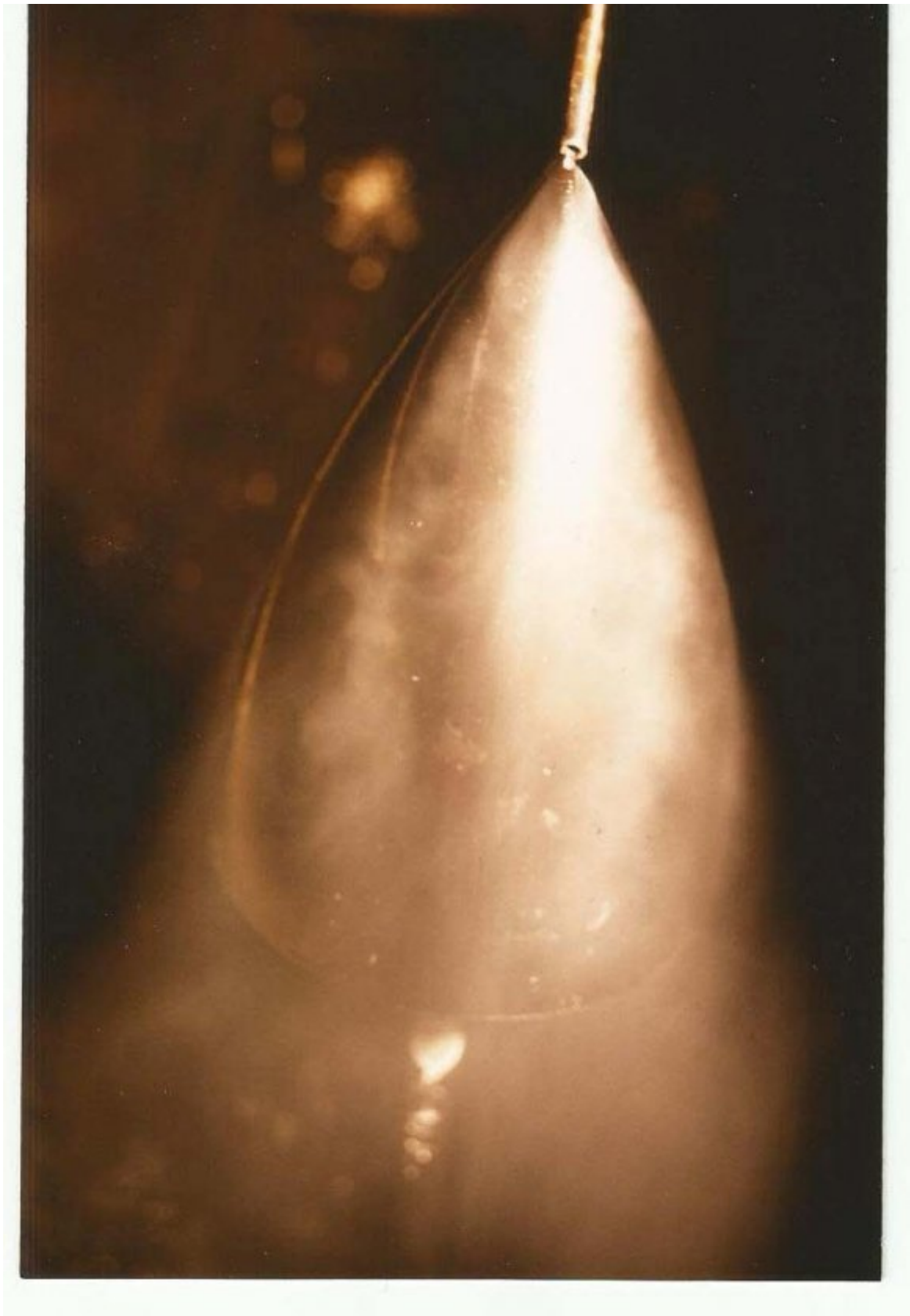


Figure 4:

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