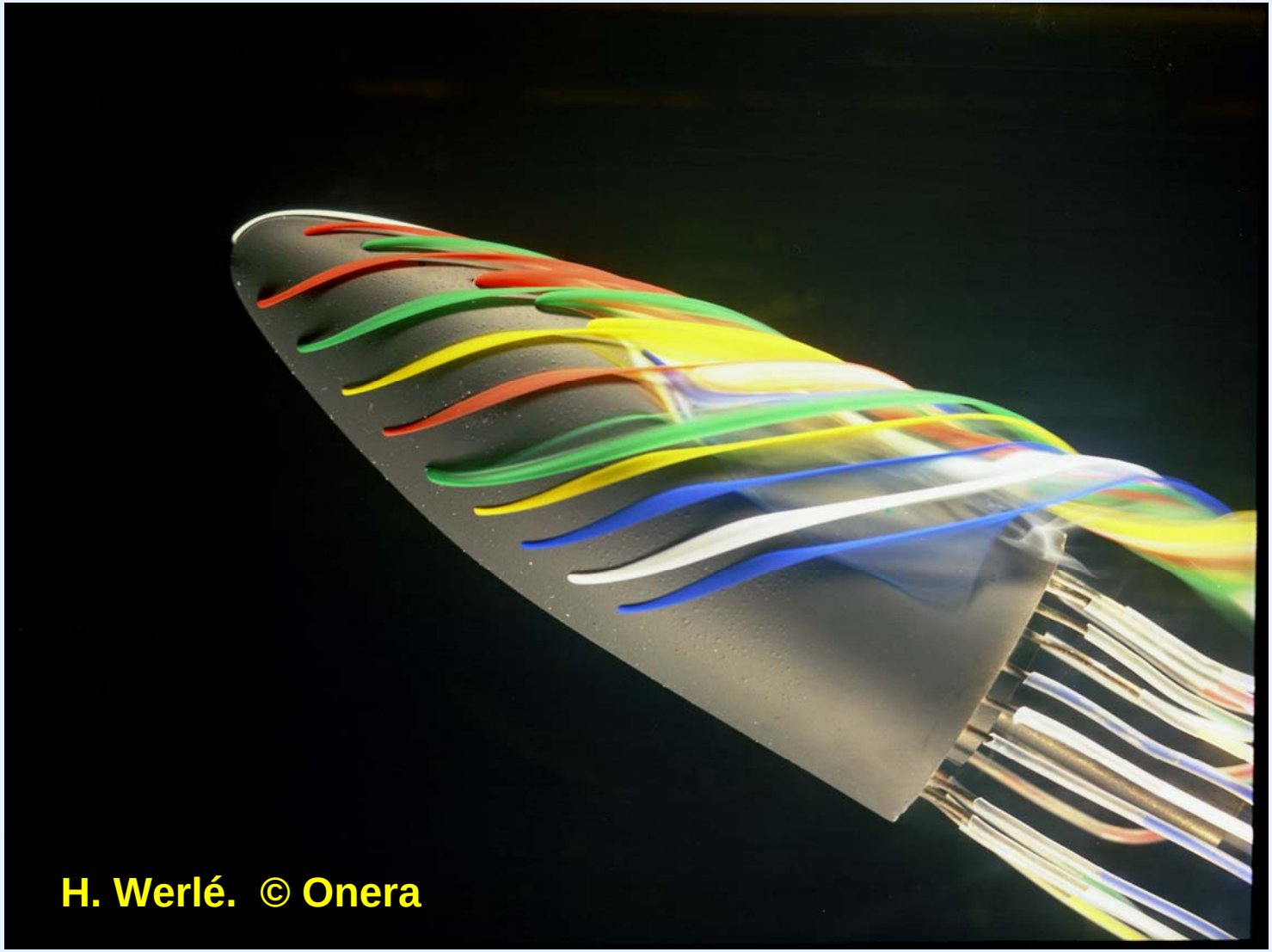
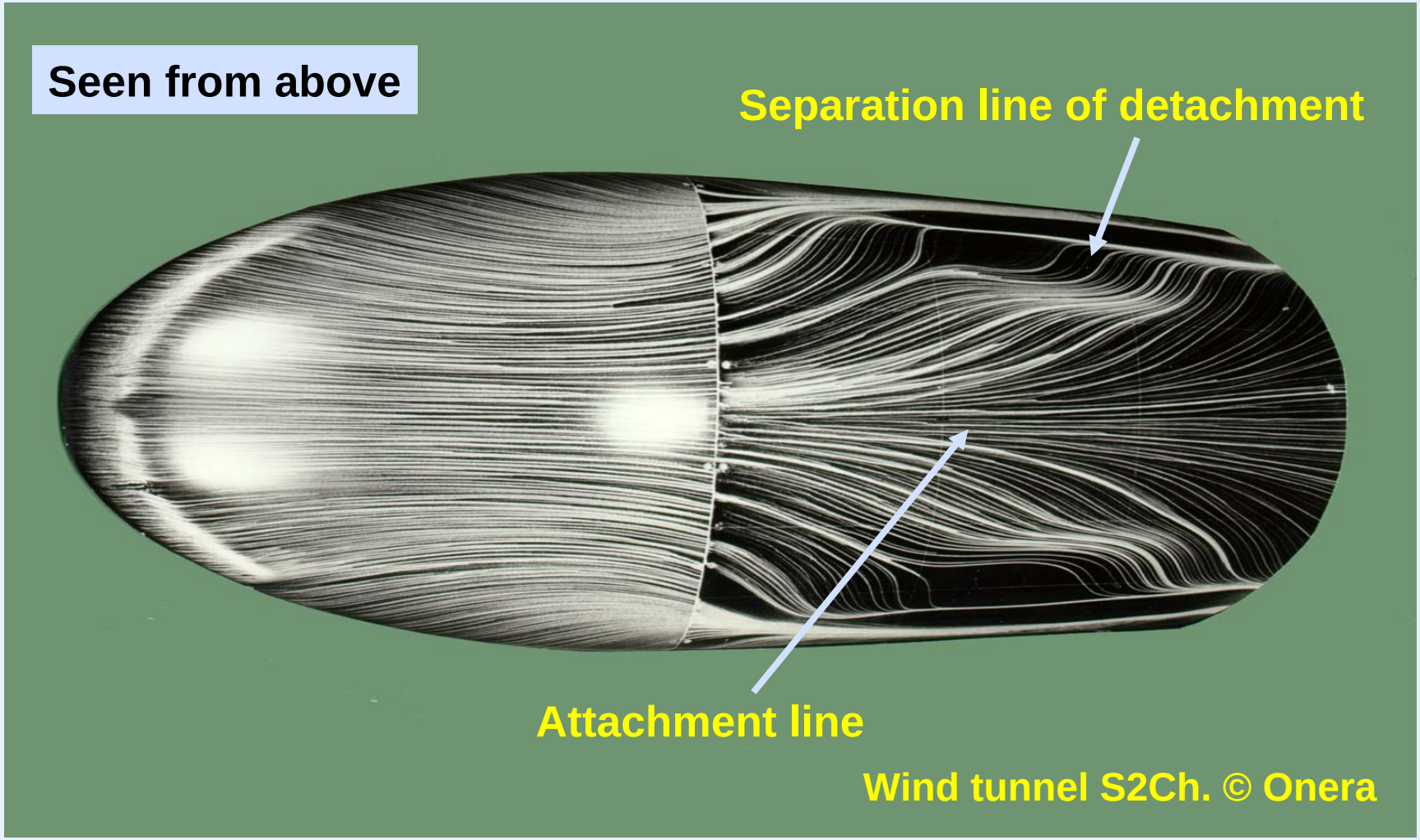
Separation in three-dimensional steady flow

Part 3: TOPOLOGY OF SOME REMARKABLE THREE-DIMENSIONAL FLOWS

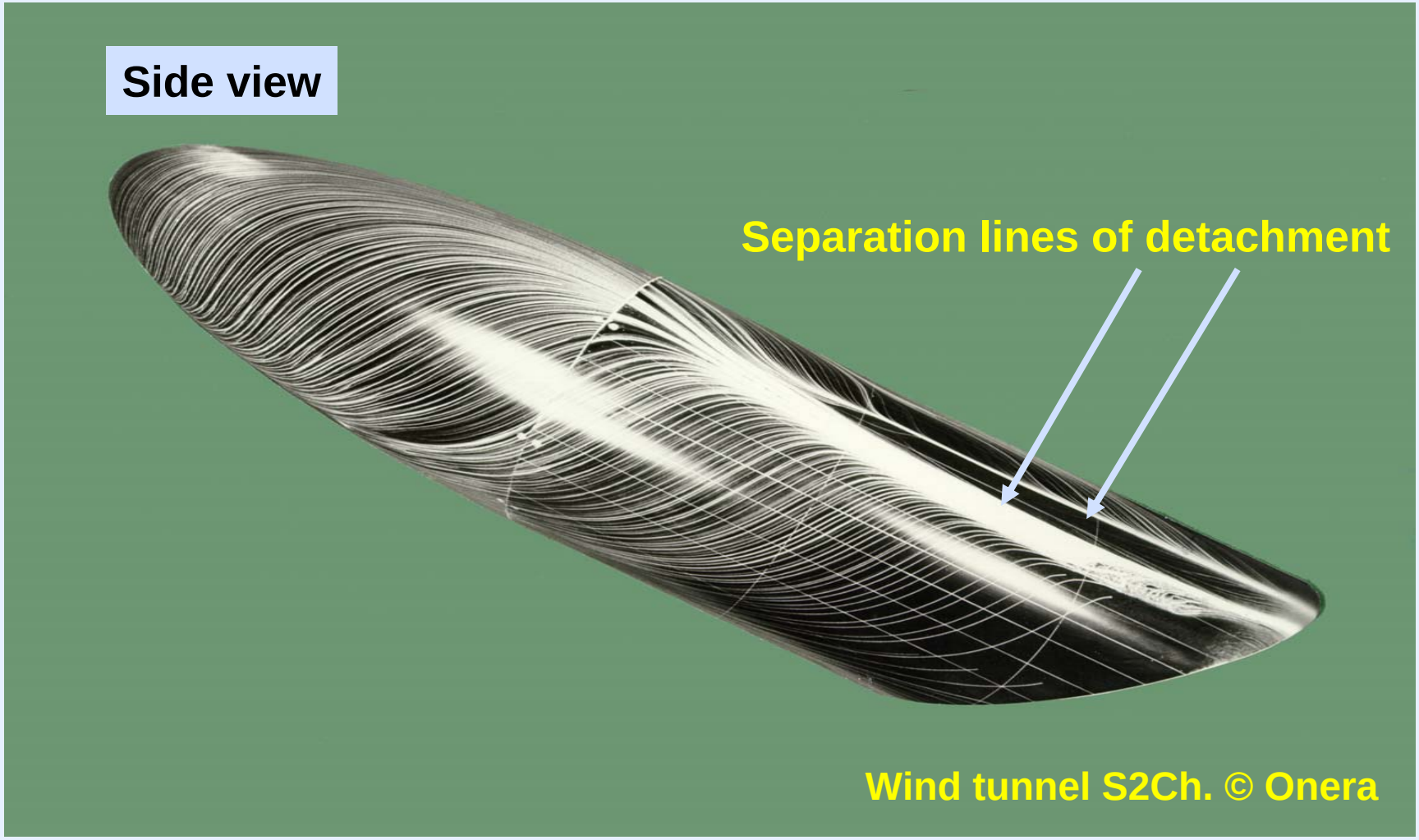
Separation on a blunt body



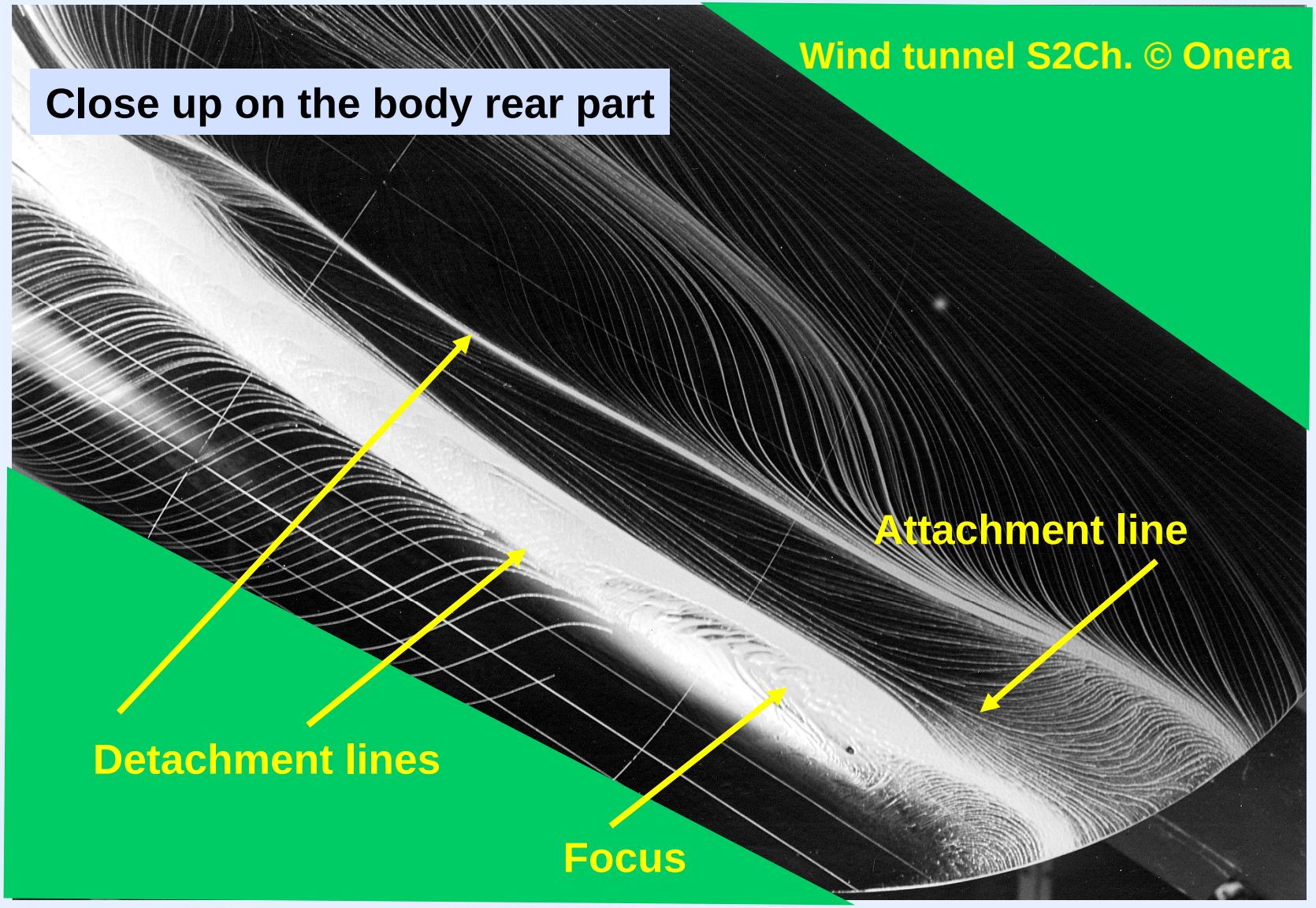
Separation on a blunt body
Two-vortex structure. Skin friction line pattern



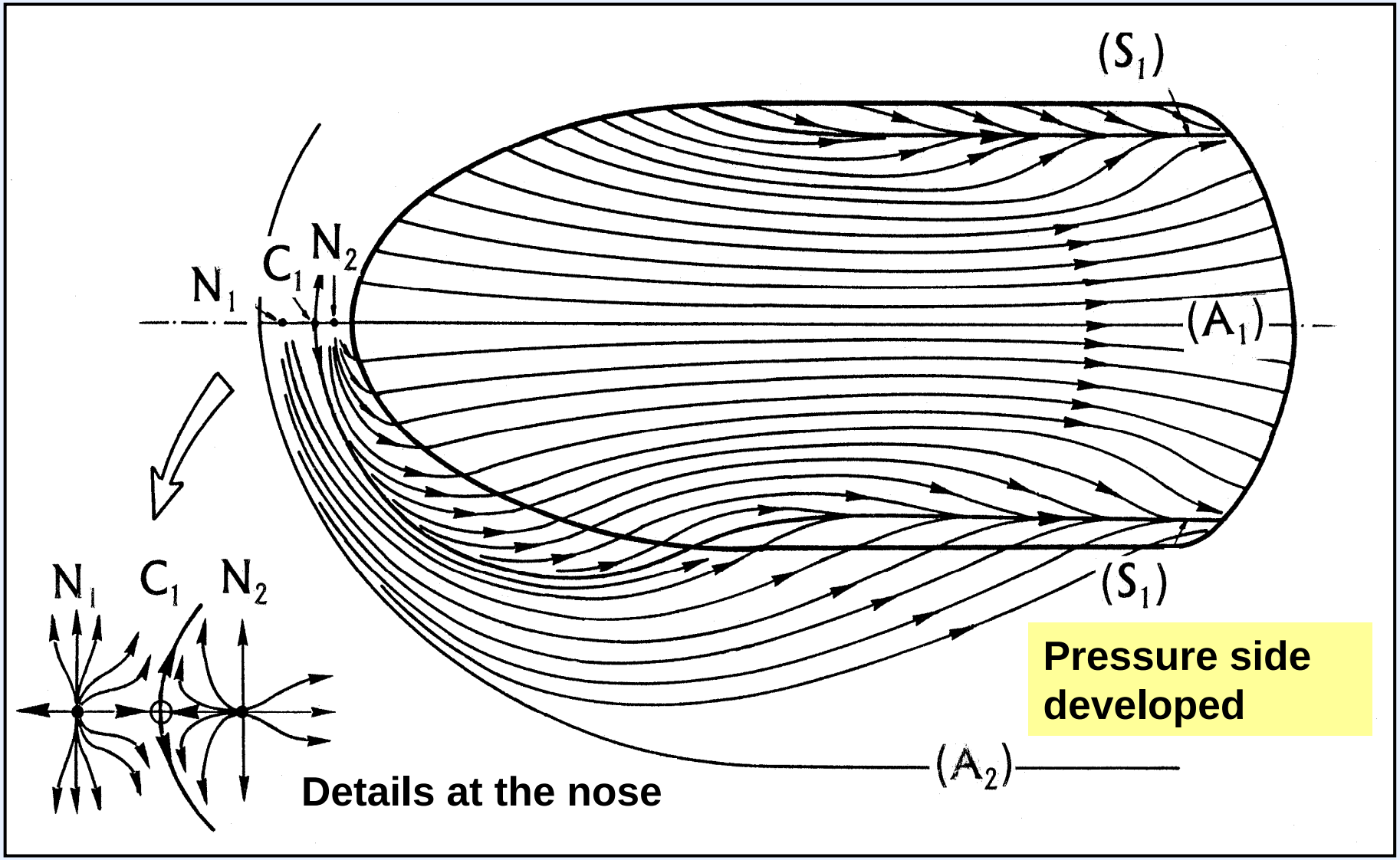
Separation on a blunt body
Two-vortex structure. Skin friction line pattern



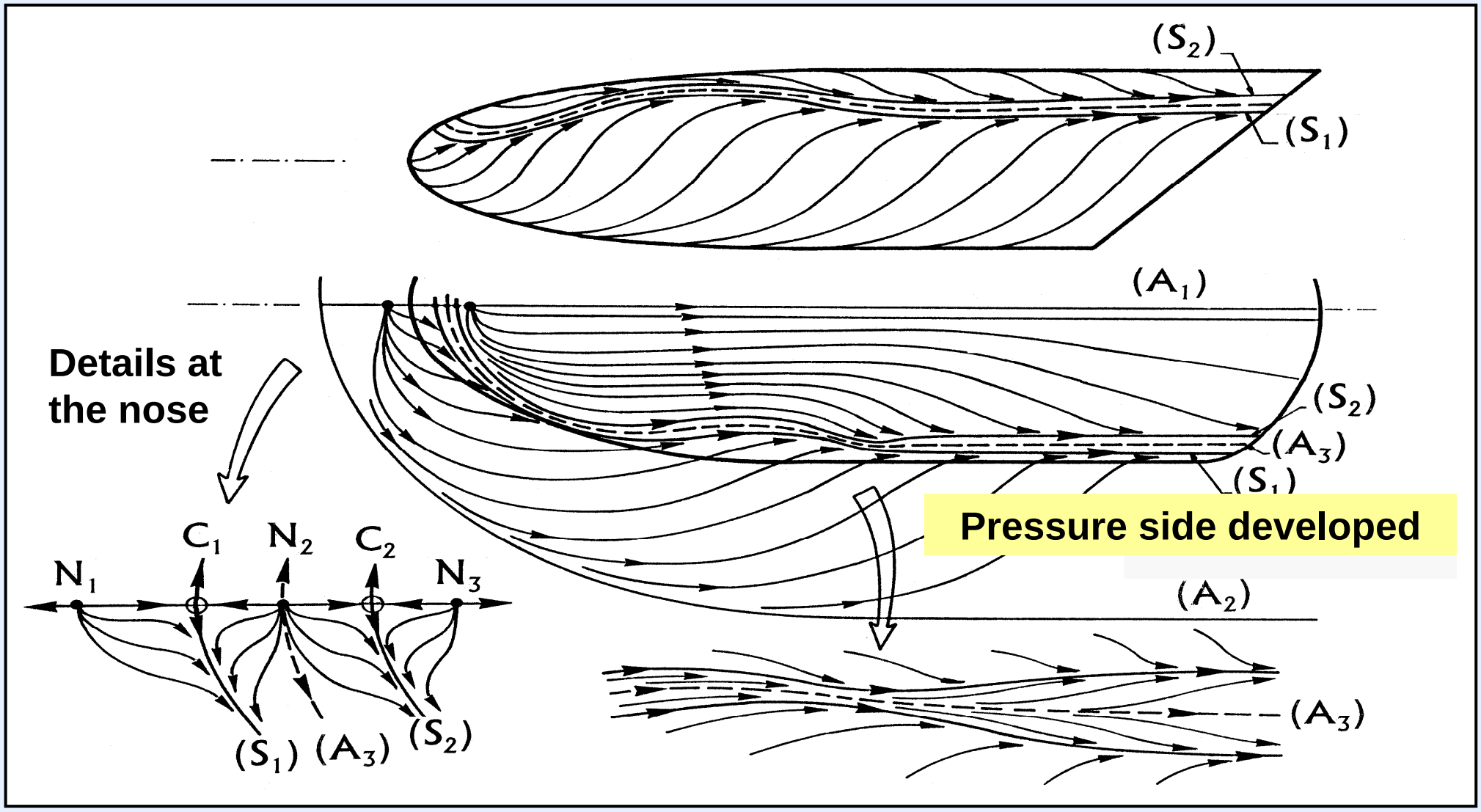
Separation on a blunt body
Two-vortex structure. Skin friction line pattern



Separation on a blunted body
Two-vortex structure. Skin friction line pattern

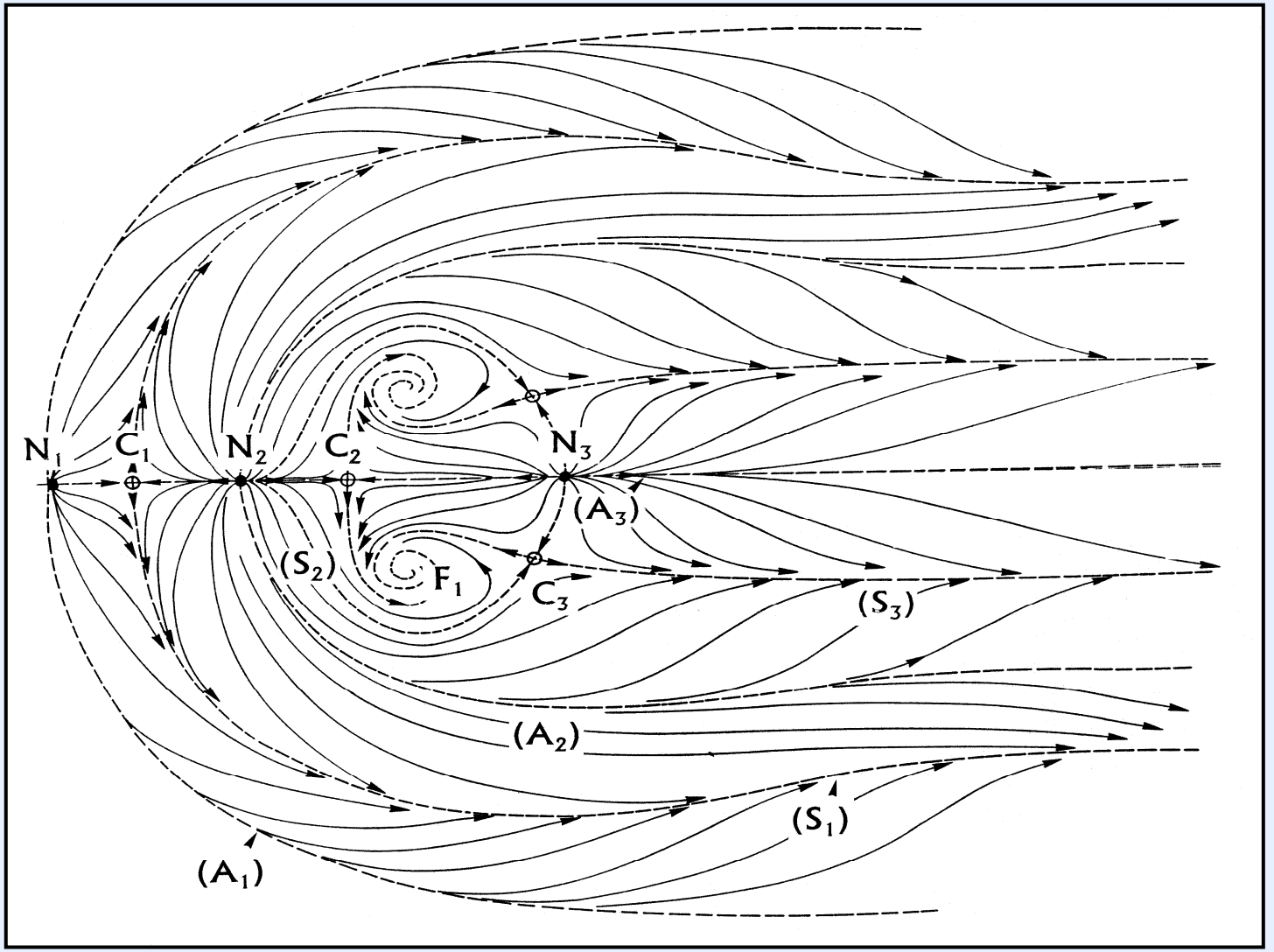


Separation on a blunt body
Two-vortex structure. Skin friction line pattern

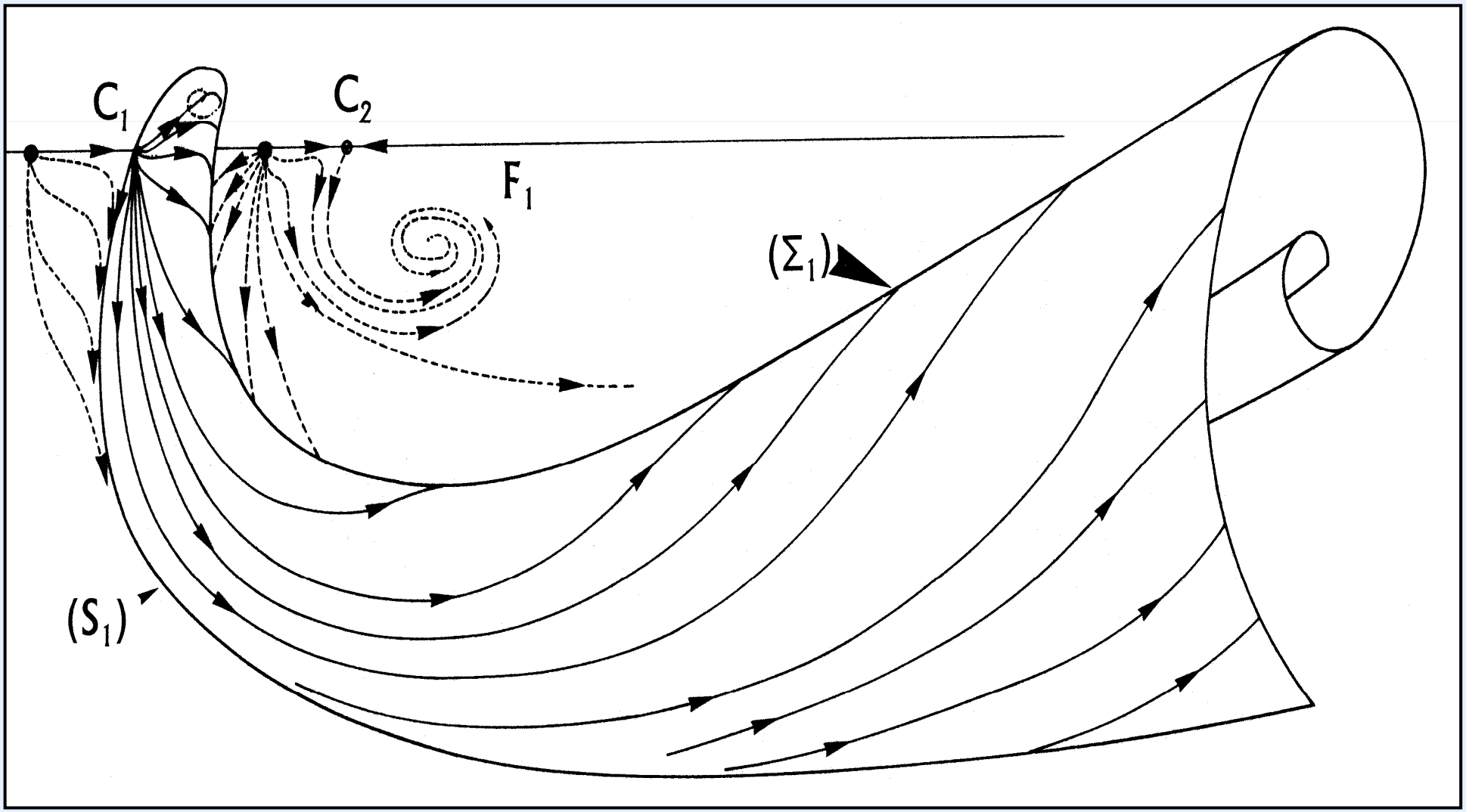


Separation on a blunted body. Skin friction line pattern with two foci. Formation of tornado like vortices

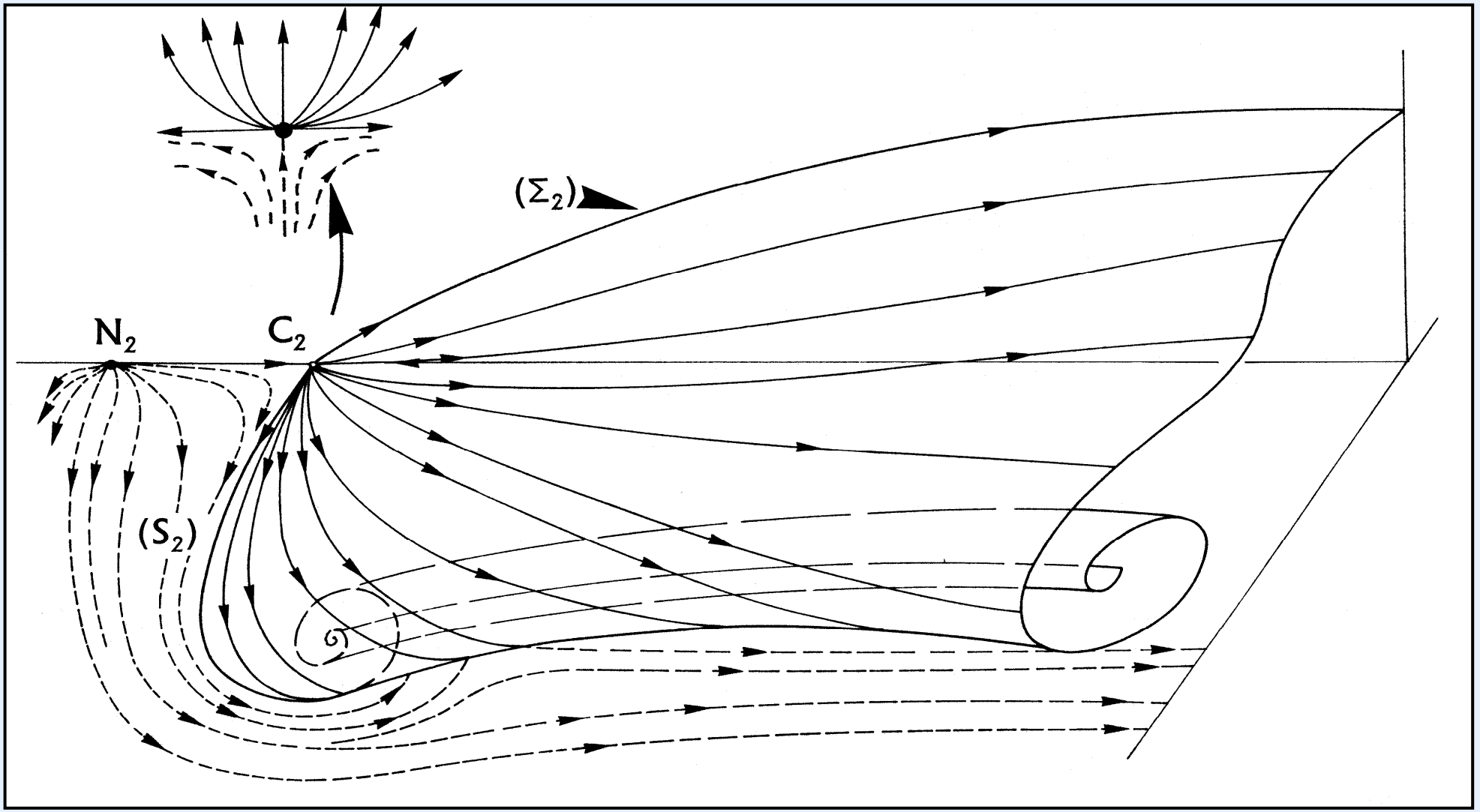
The body surface is dveloped



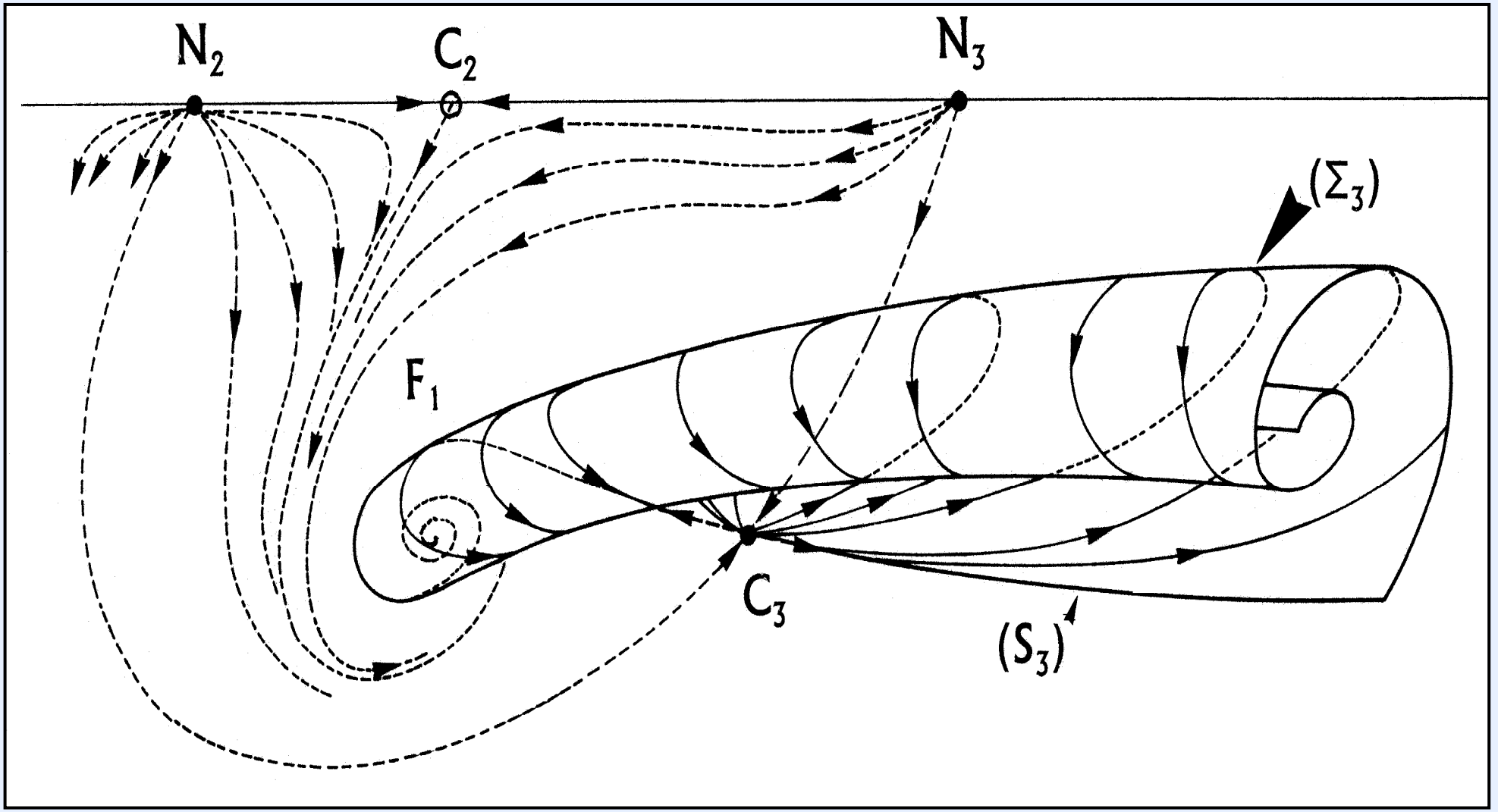
Separation on a blunt body. Structure with two tornado like vortices. First detachment surface



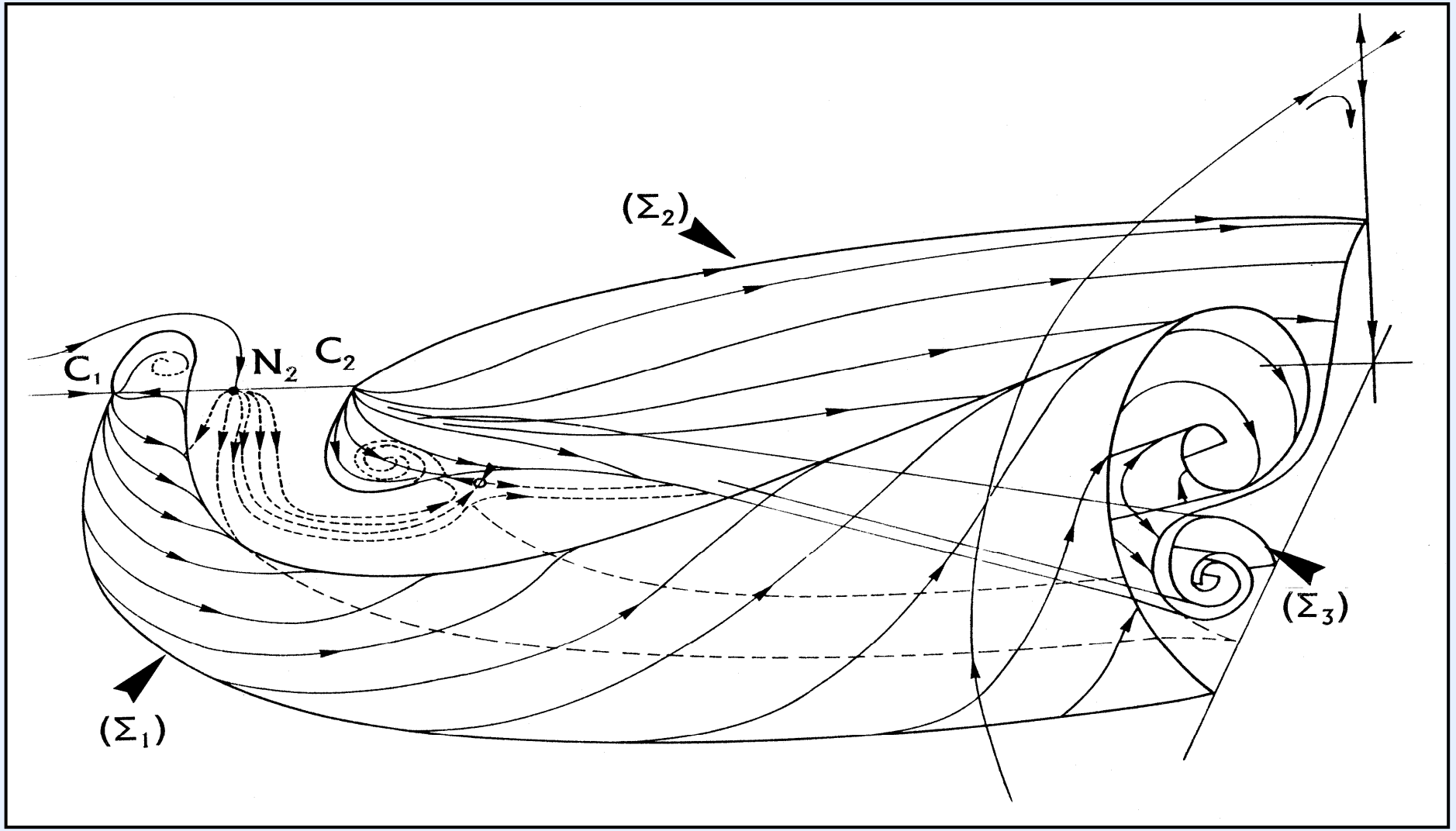
Separation on a blunt body. Structure with two tornado like vortices. Second detachment surface



Separation on a blunt body. Structure with two tornado like vortices. Third detachment surface

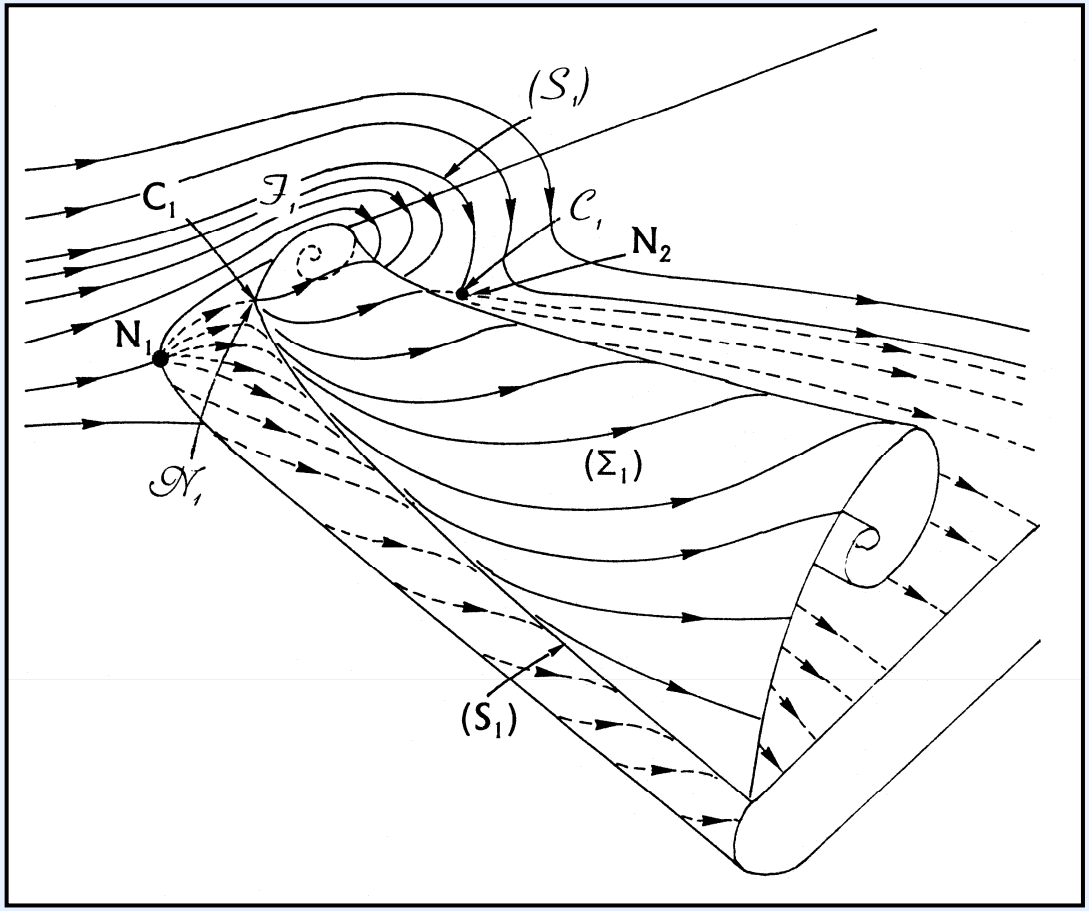


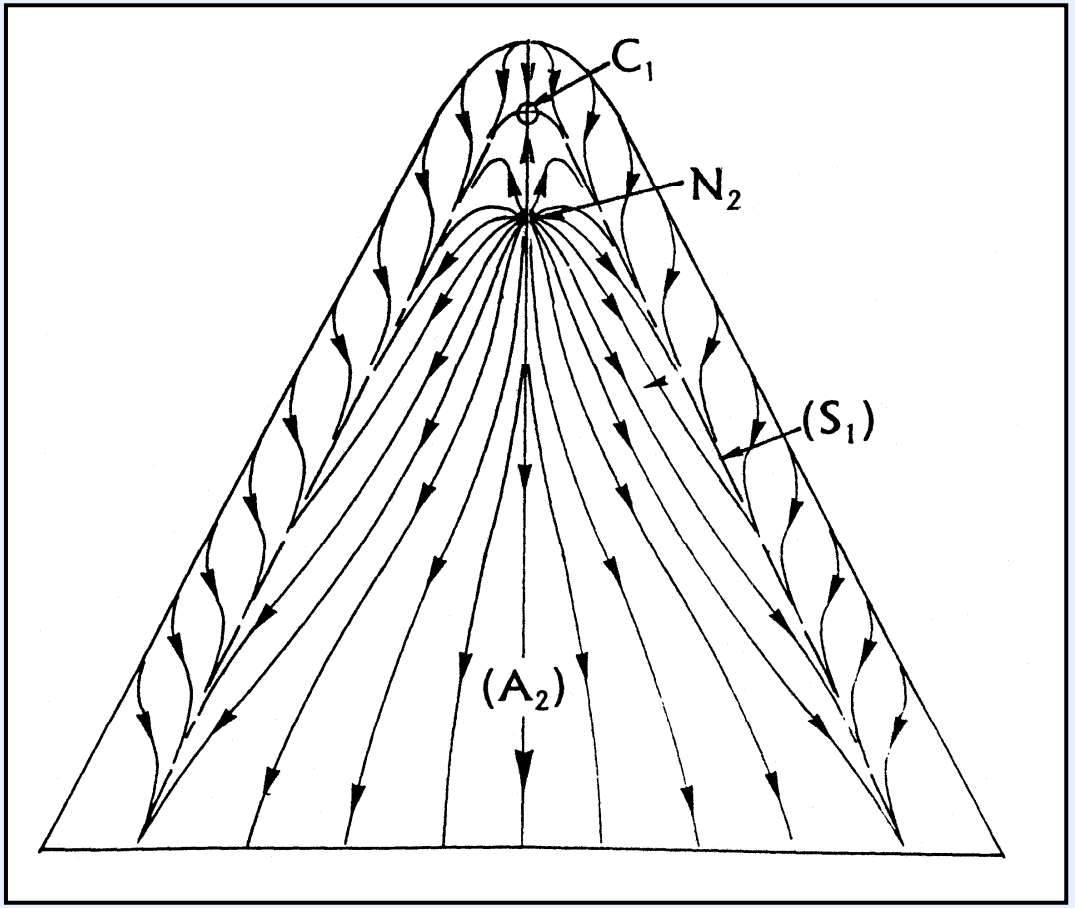
Separation on a blunt body
Assembling of the detachment surfaces



Flow past a delta wing at incidence

Separation on a delta wing at incidence
One-vortex system

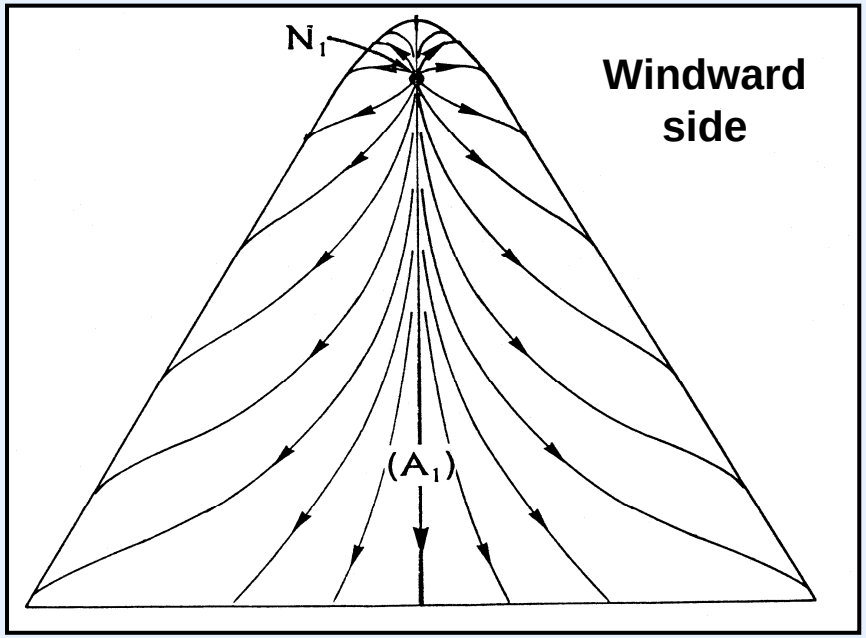


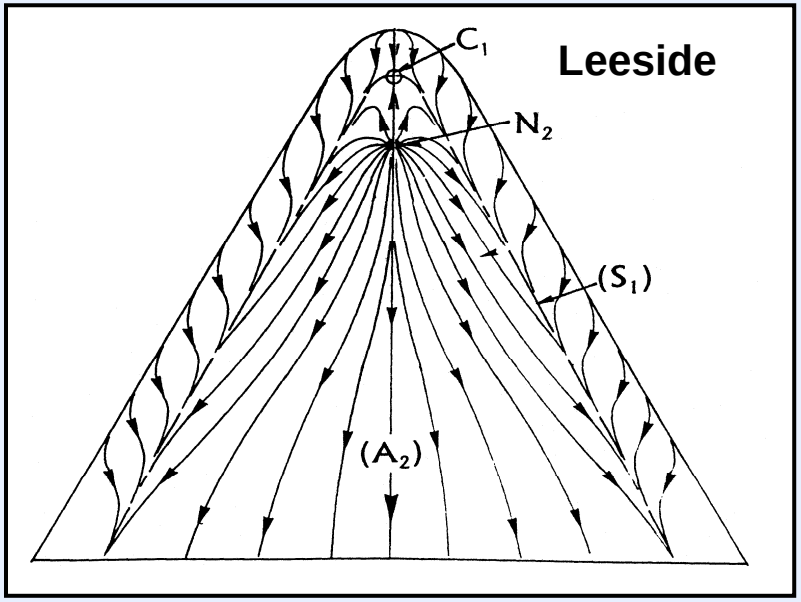


Starting of the primary detachment surface at the wing apex

Skin friction line pattern on the suction side

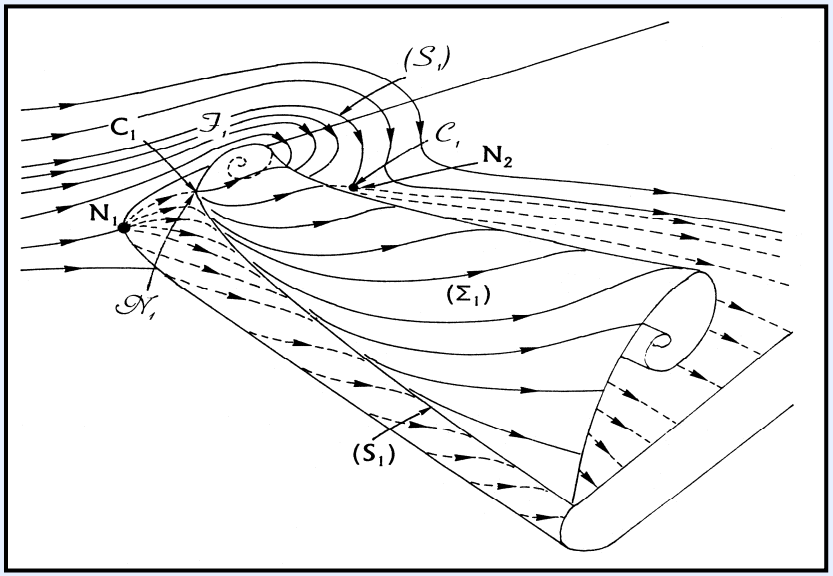
Separation on a delta wing at incidence
One-vortex system



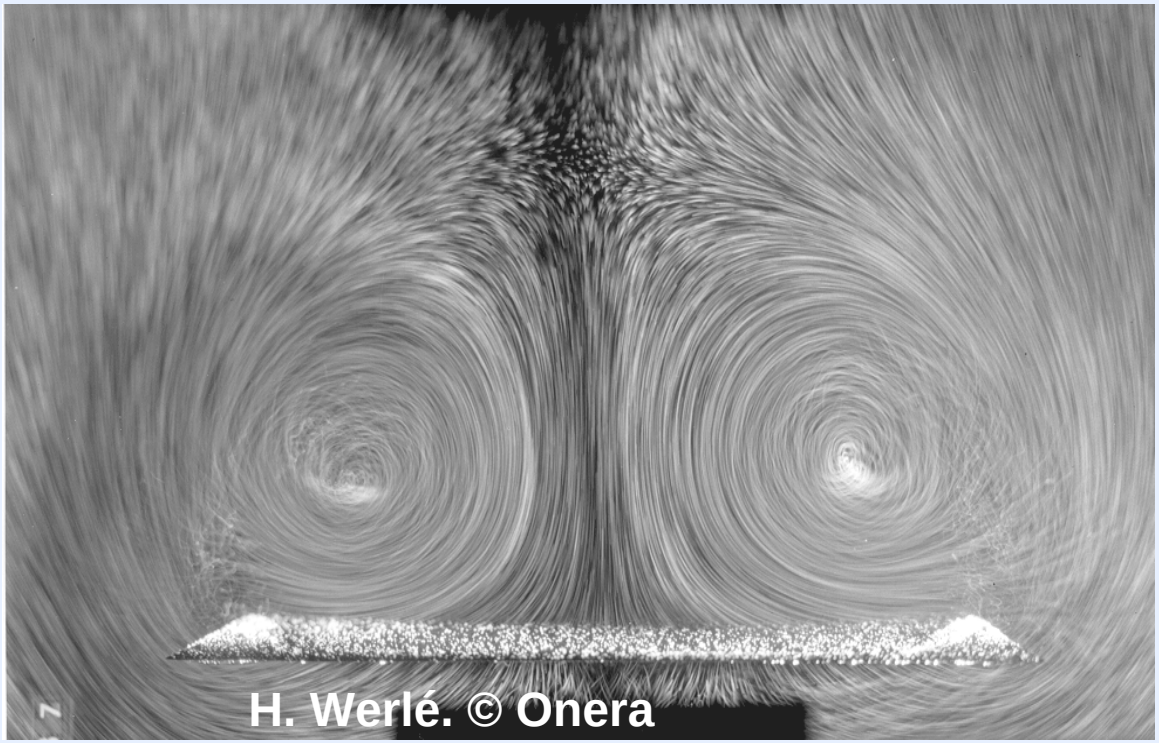


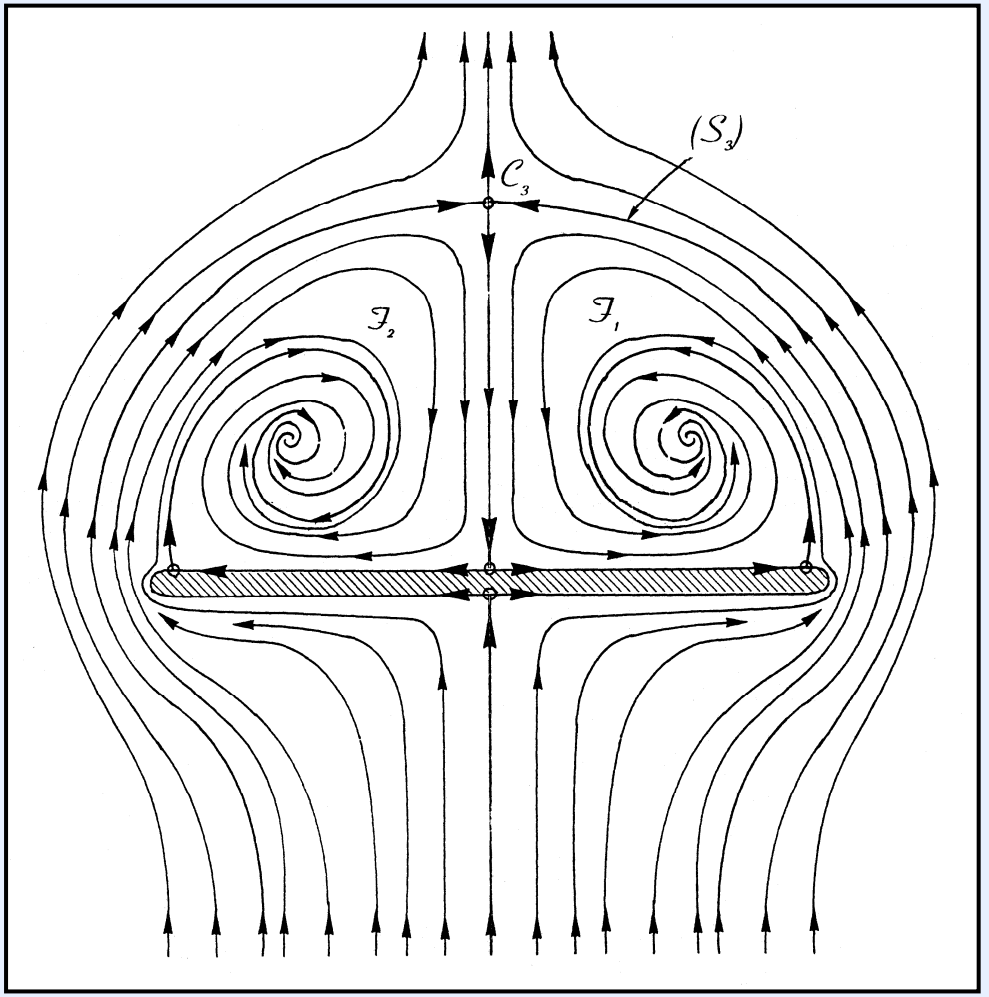
Skin friction line pattern

Starting of the primary detachment surface



Separation on a delta wing at incidence
One-vortex system

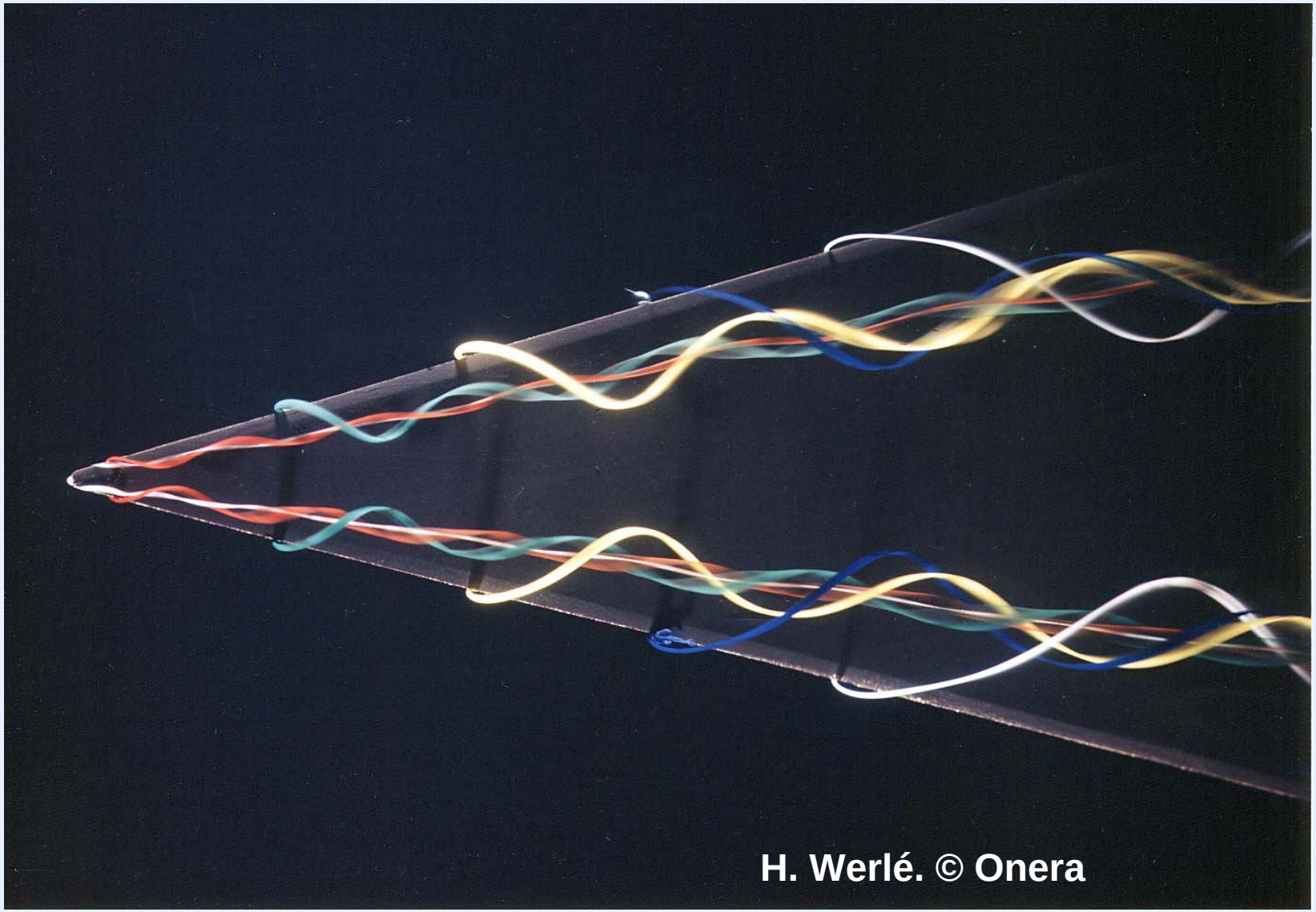




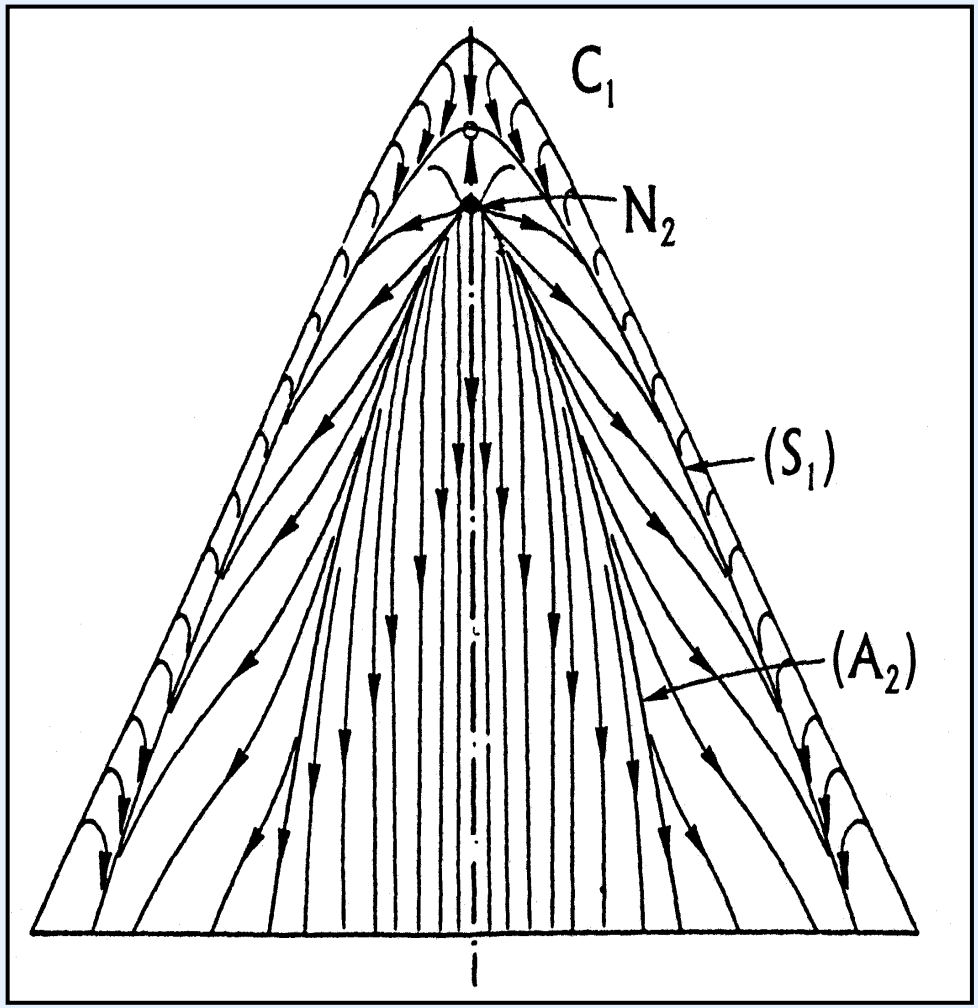
What is seen as two vortices are in fact the traces of the horseshoe vortex forming at the wing apex

Field projected in a plane normal to the wing surface

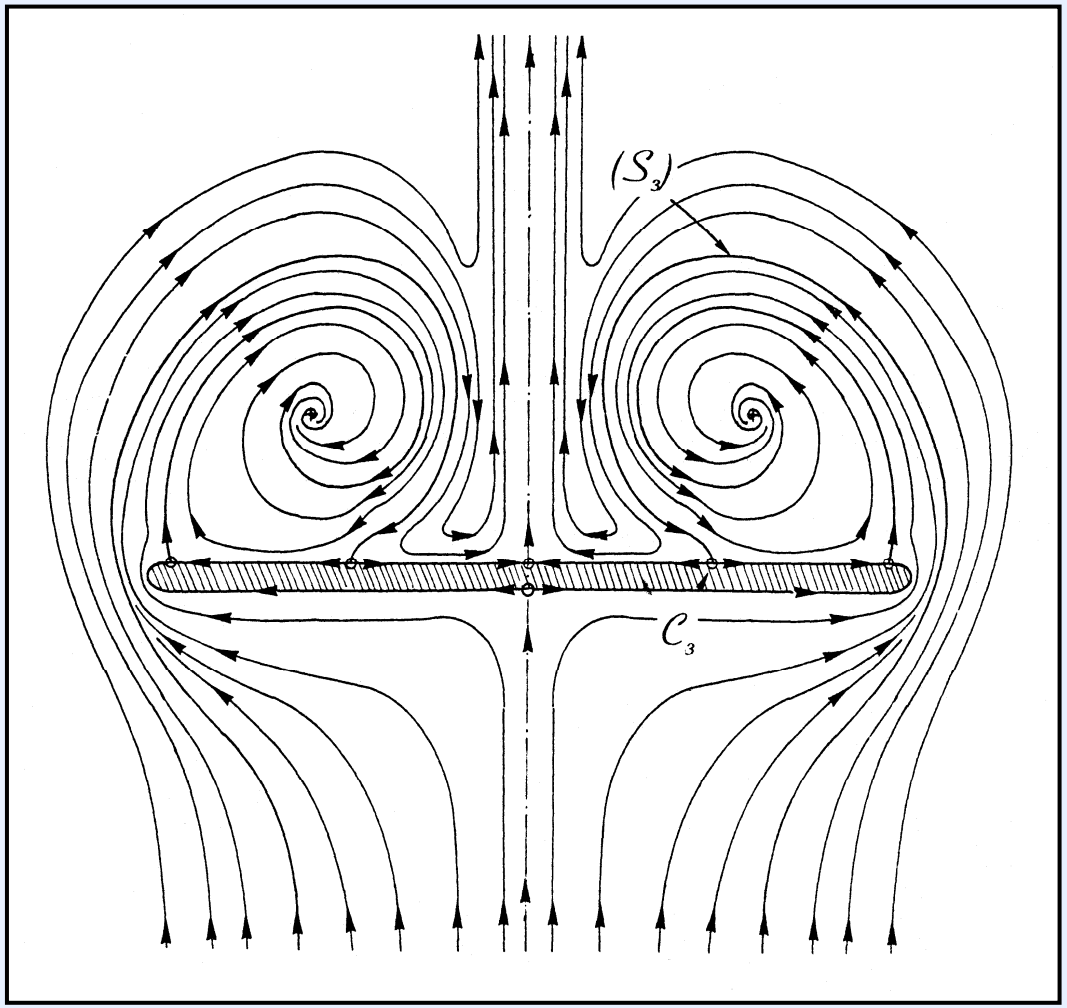
Vortices over a delta wing with a sweep angle of 70°



Separation on a delta wing at incidence
One-vortex system. Other organisation

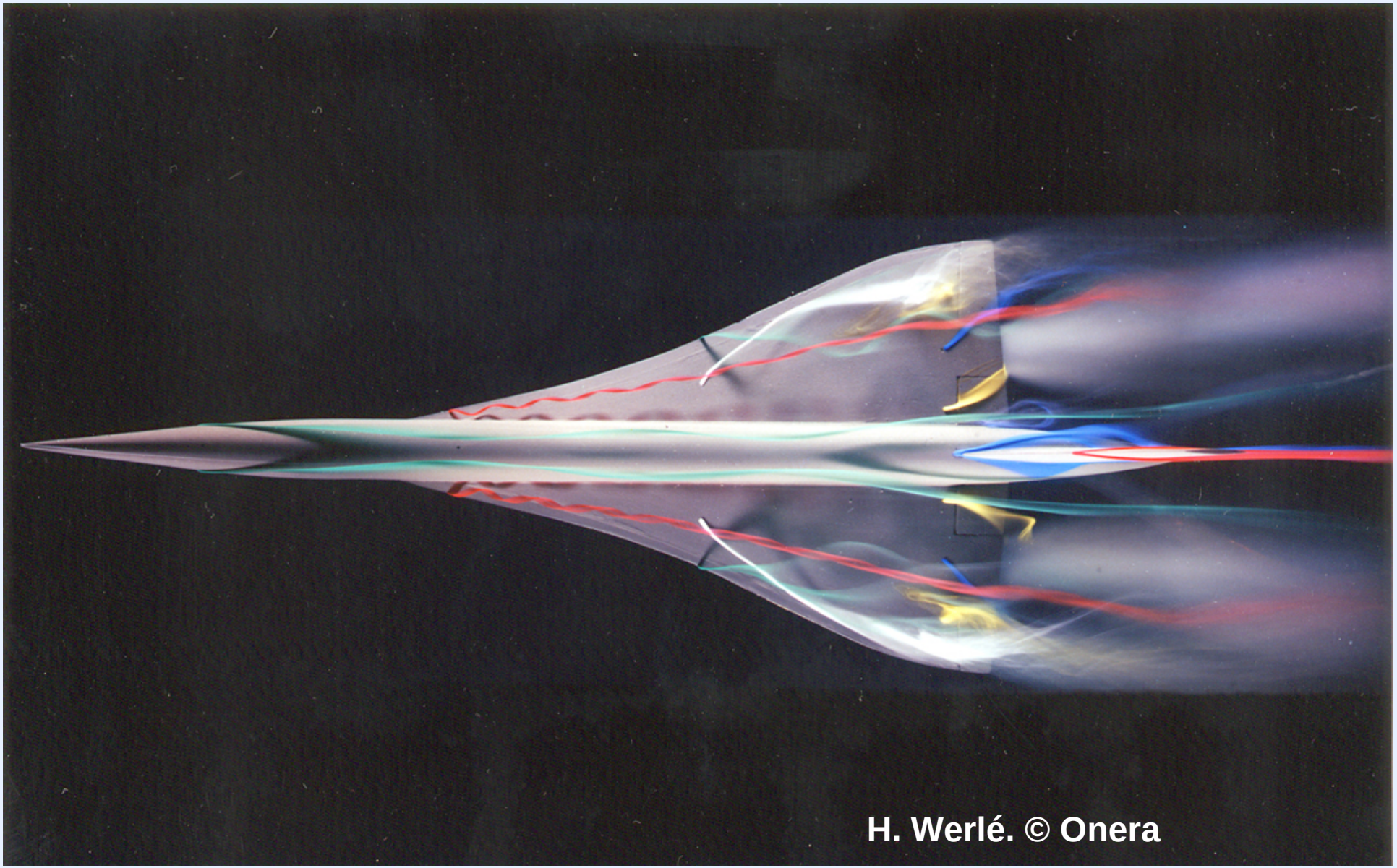


Skin friction line pattern

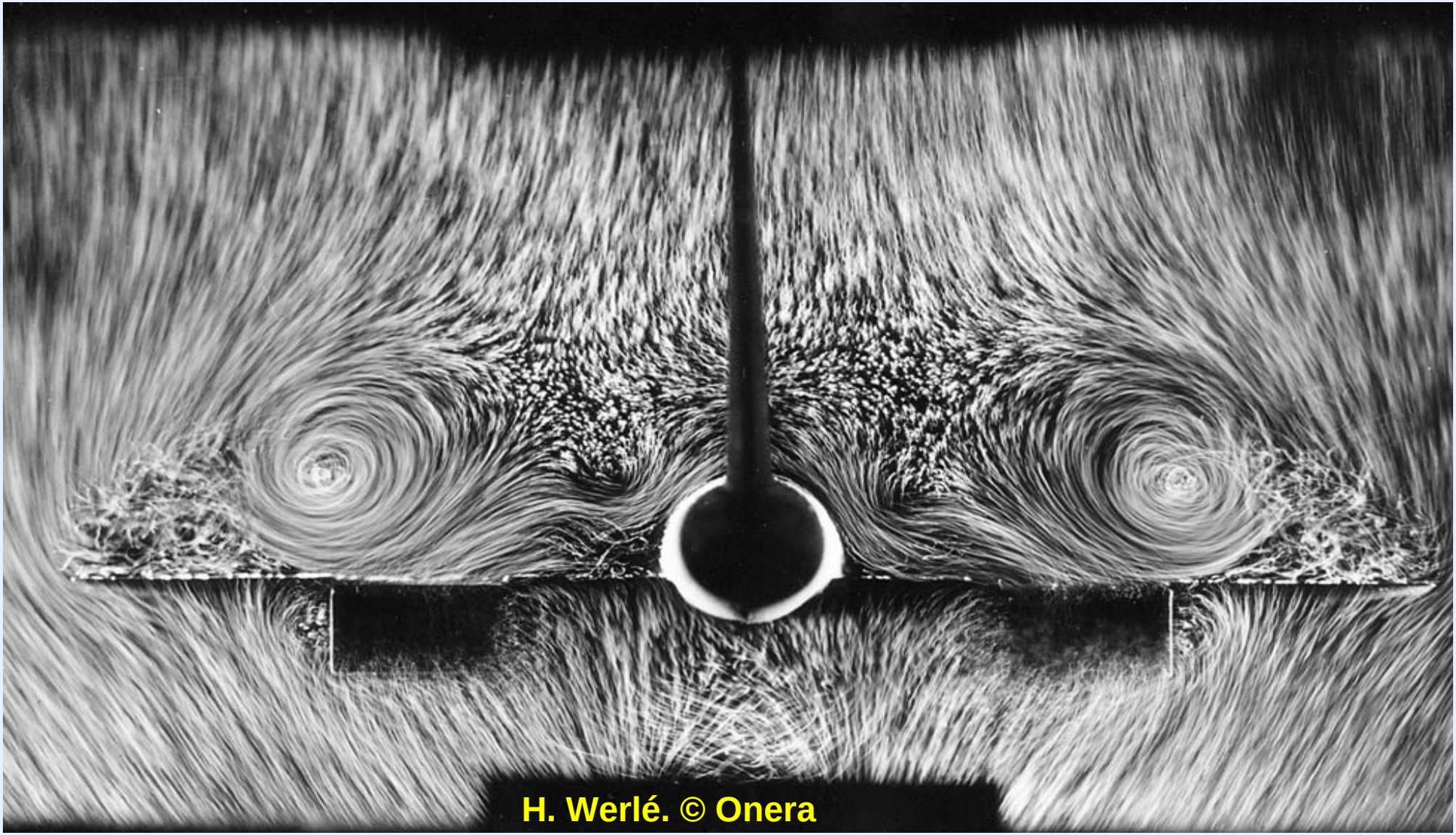


Field projected in a plane normal to the wing surface

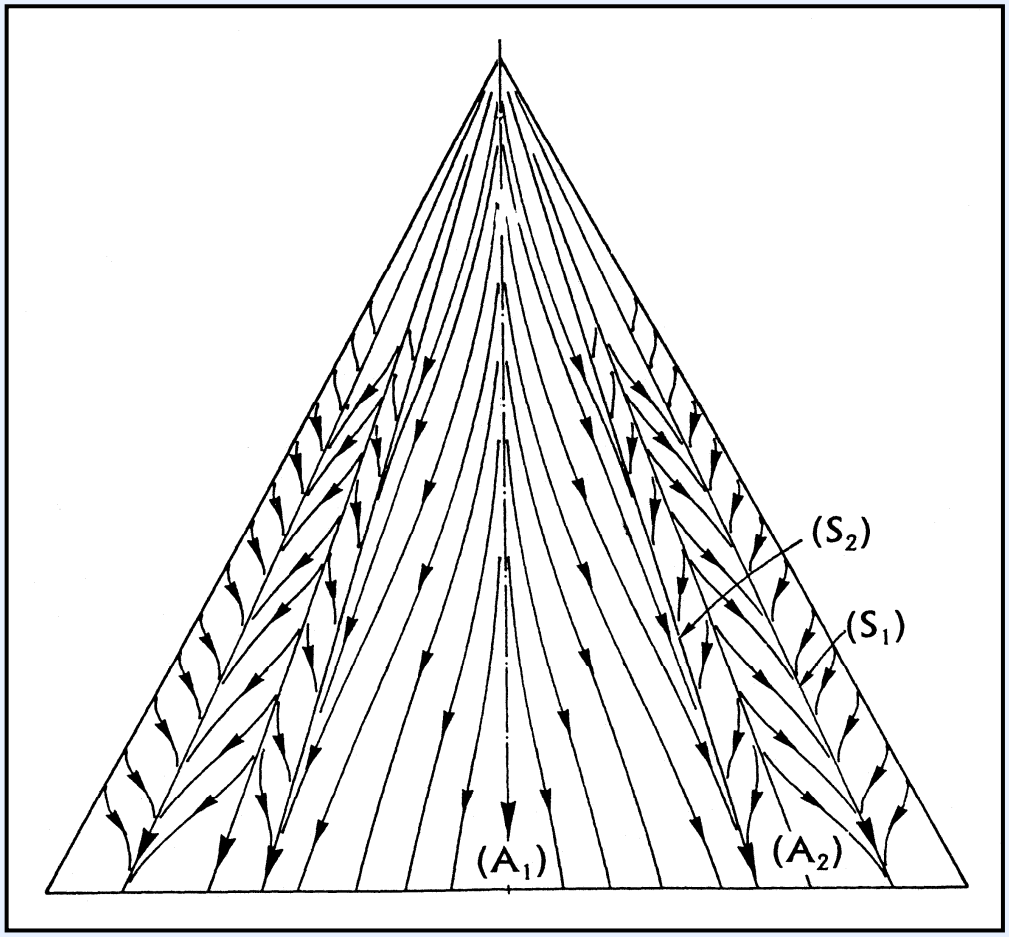
Vortices over the Concorde wing



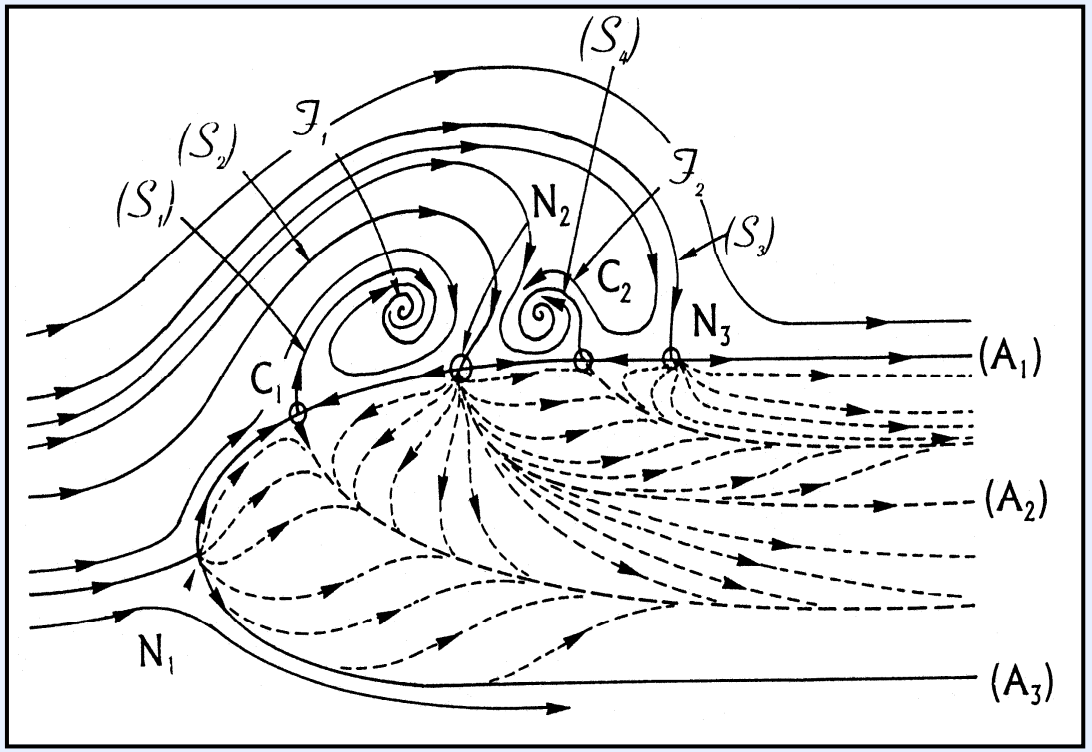
Vortices over a Concorde type wing. Cut by a downstream vertical plane



Separation on a delta wing at incidence
Two-vortex system

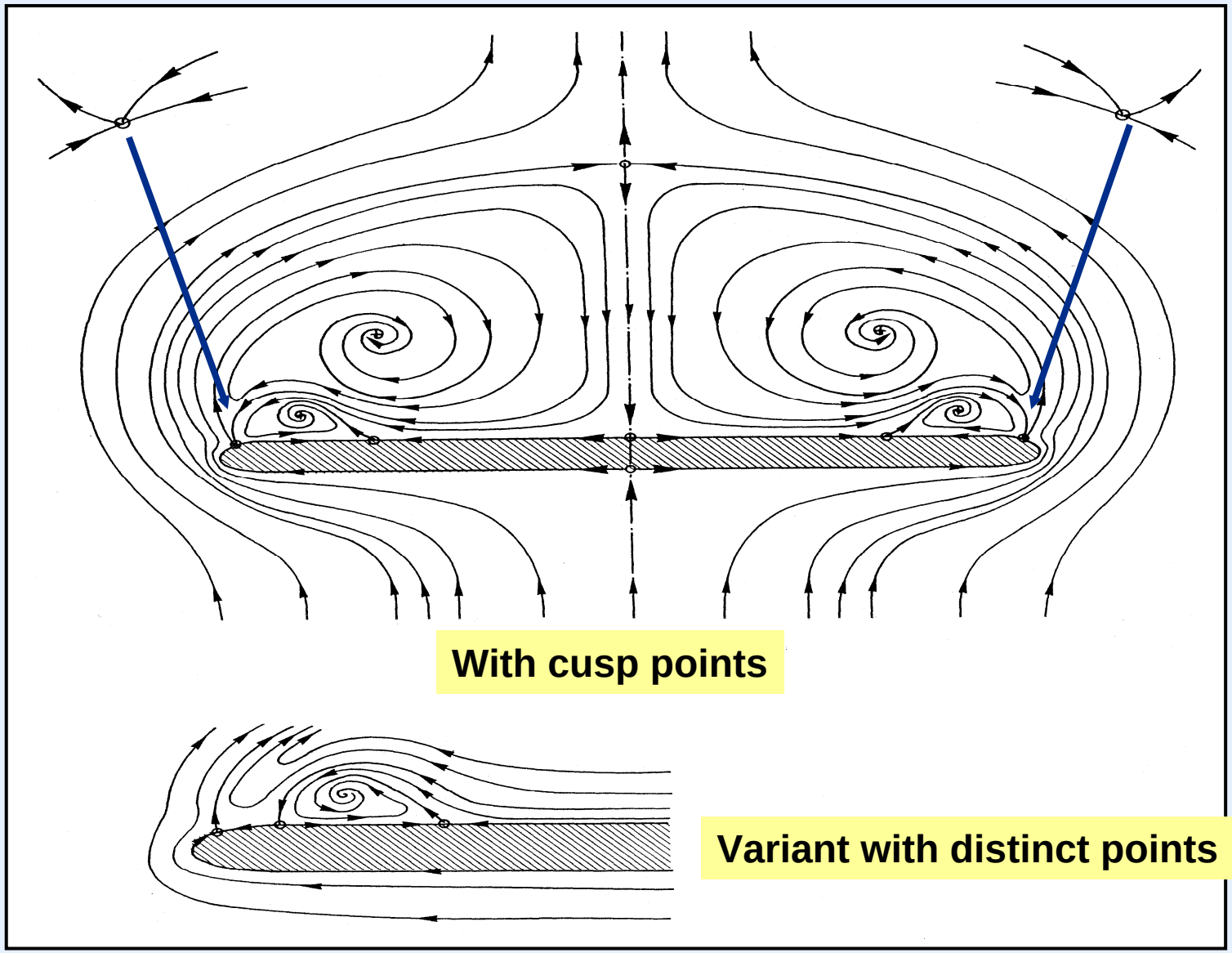


Skin friction line pattern on the wing leeside



Flow in the vicinity of the wing apex

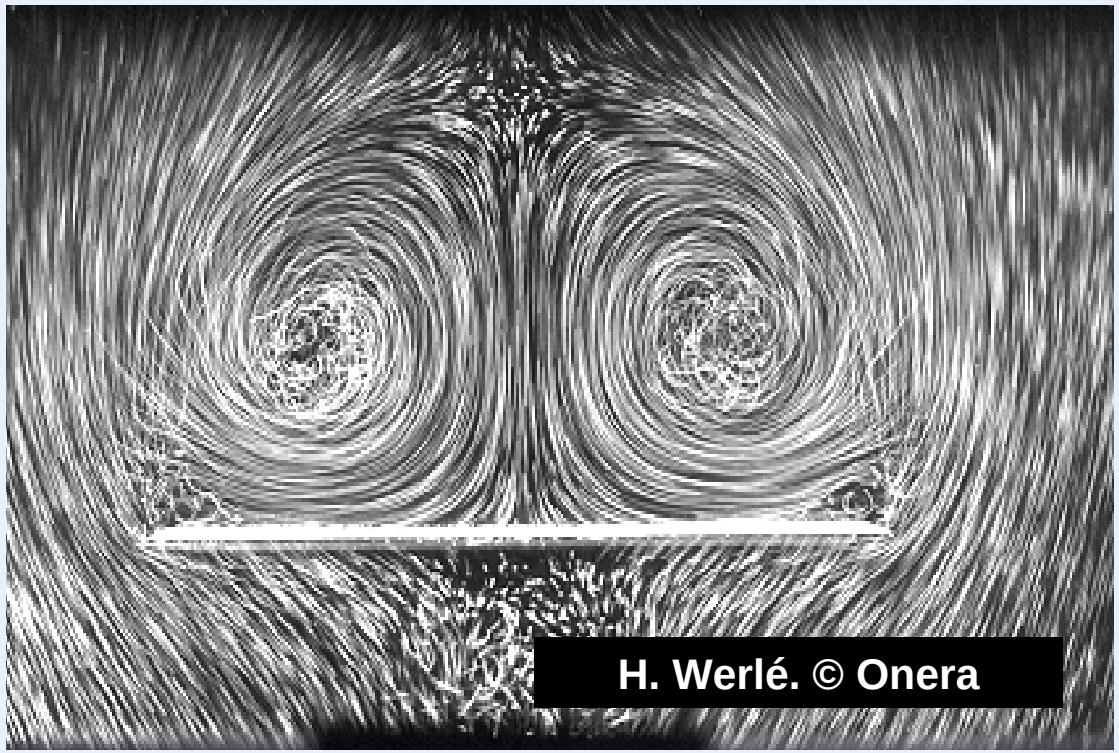
Separation on a delta wing at incidence
Two-vortex system



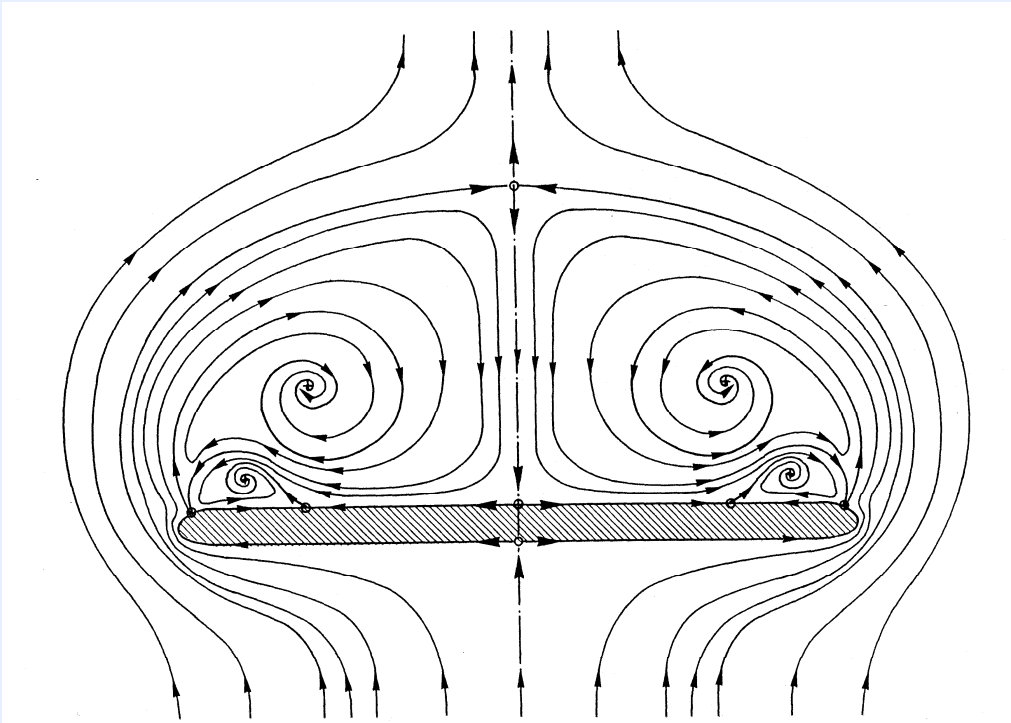
With cusp points

Variant with distinct points

Separation on a delta wing at incidence
Two-vortex system

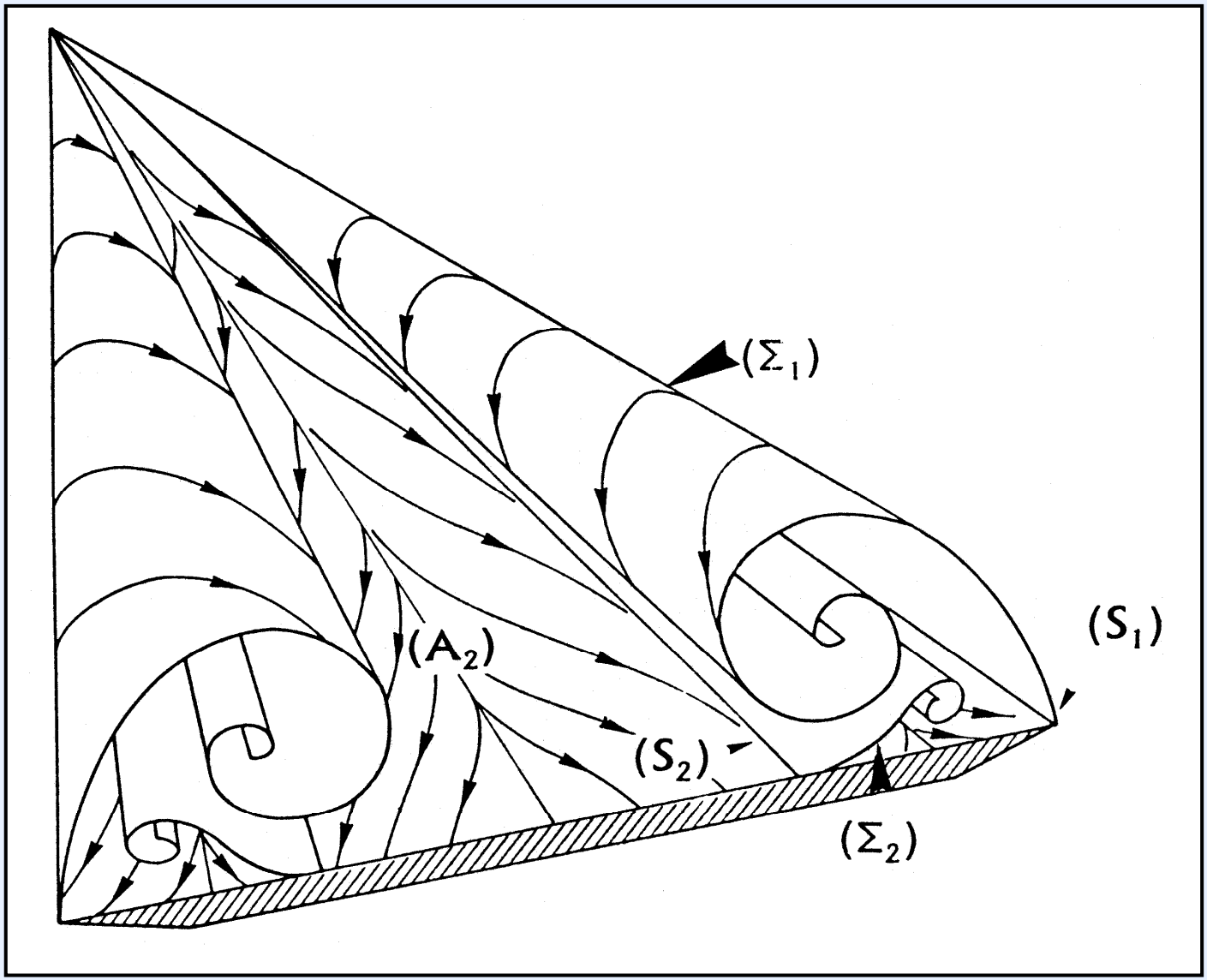


Water tunnel visualization

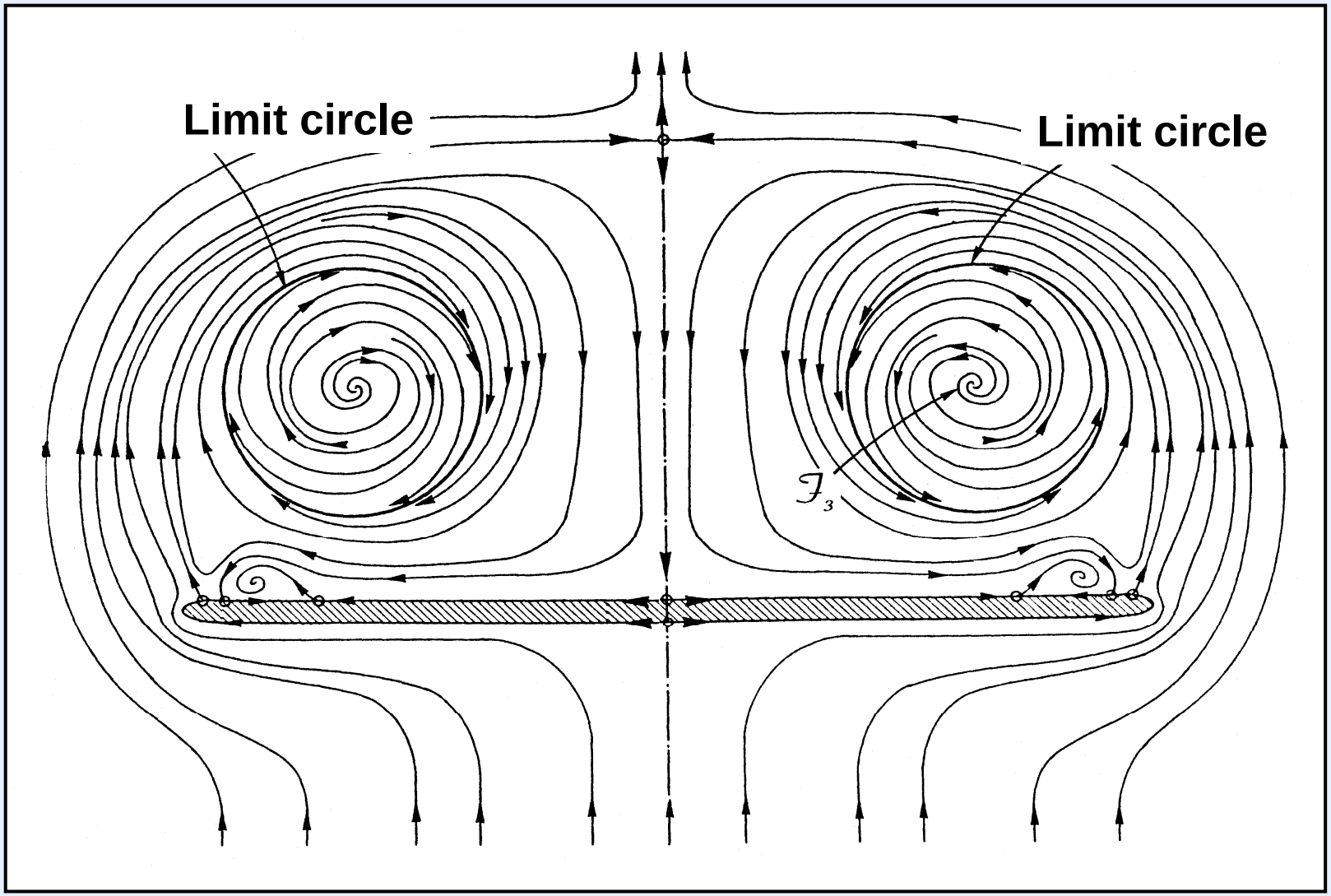


Field projected in a plane normal to the wing surface

Separation on a delta wing at incidence
Two-vortex system

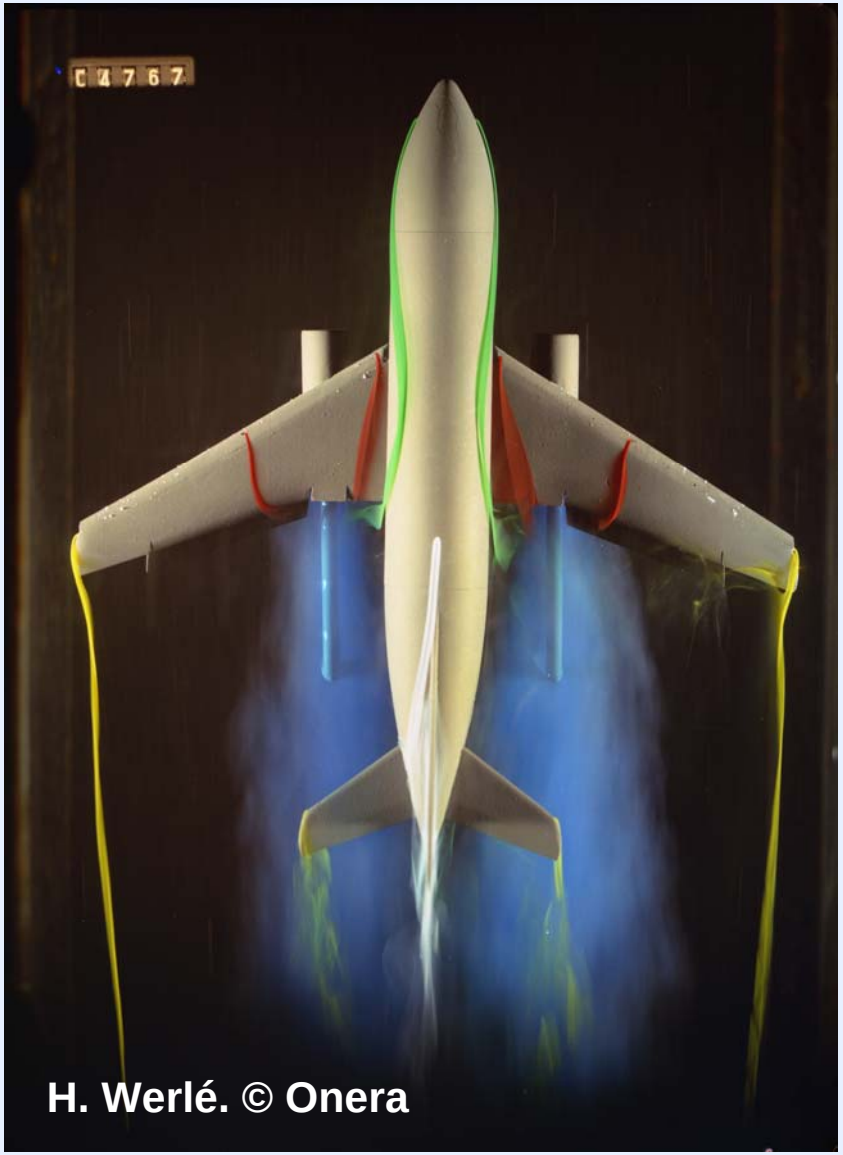


Separation on a delta wing at incidence
Two-vortex system with limit circle



Field projected in a plane normal to the wing surface

Wake vortex of a classical wing

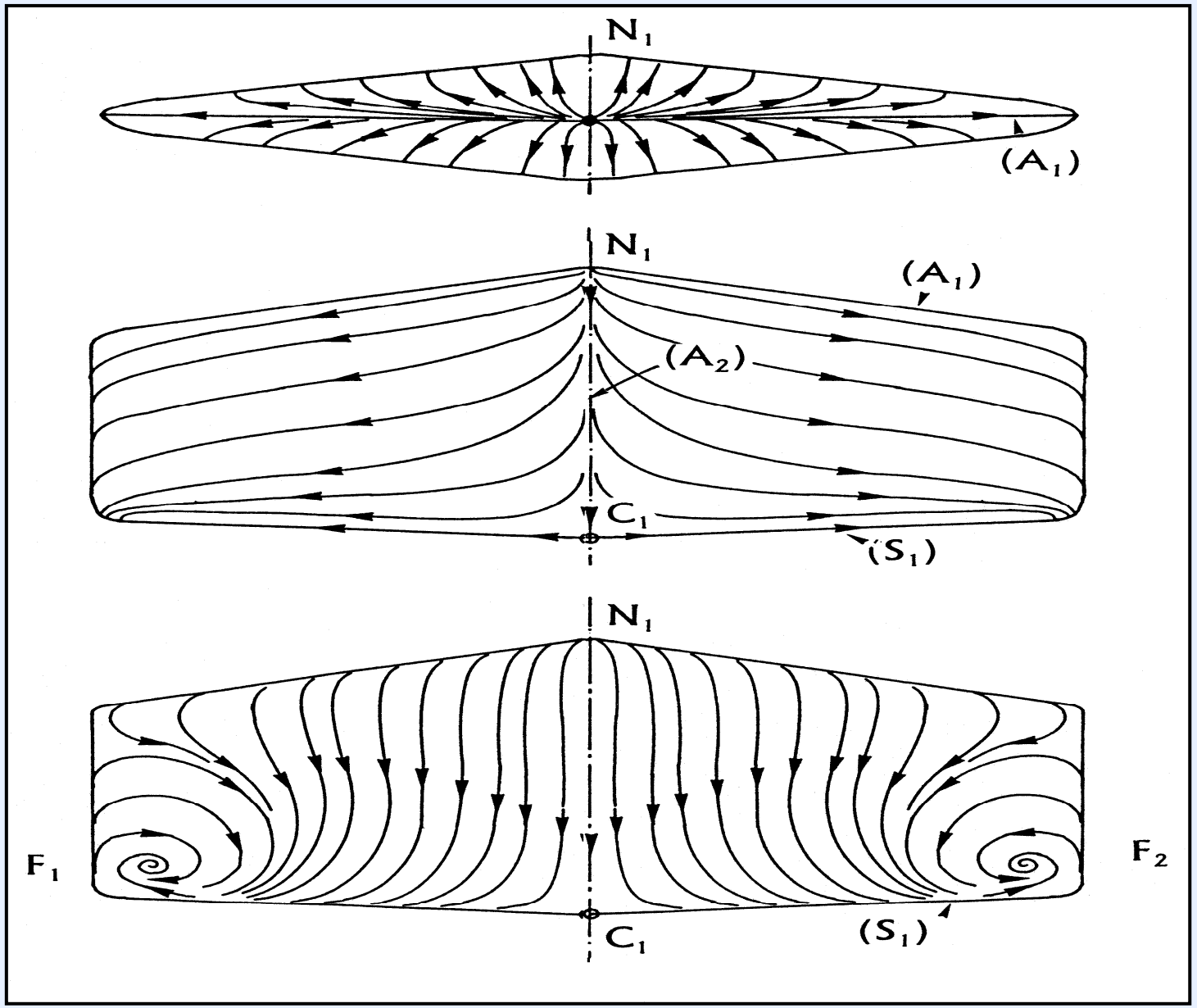


Wake vortex of an isolated classical wing. Skin friction line pattern

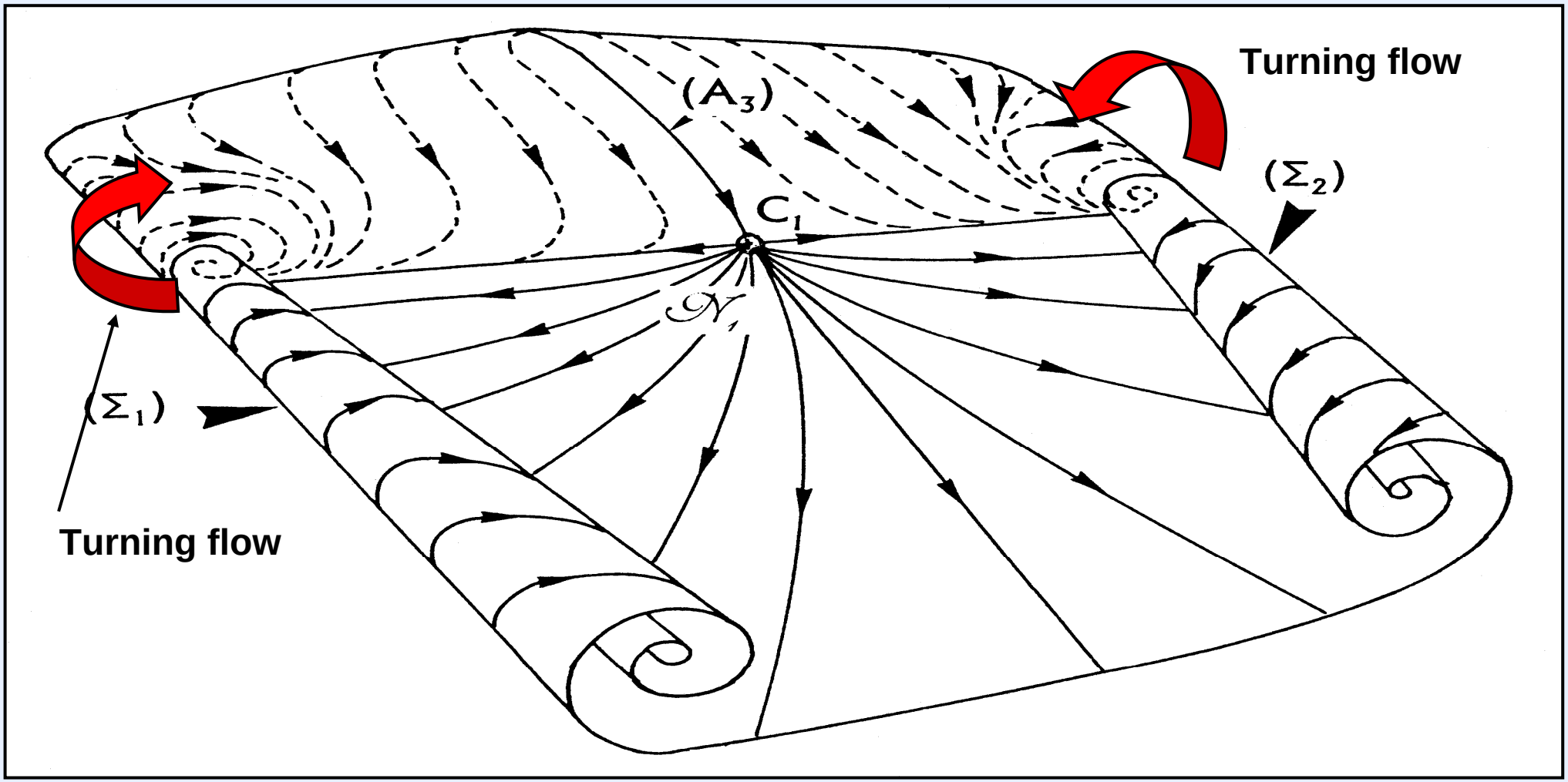
Leading edge region

Pressure side

Suction side

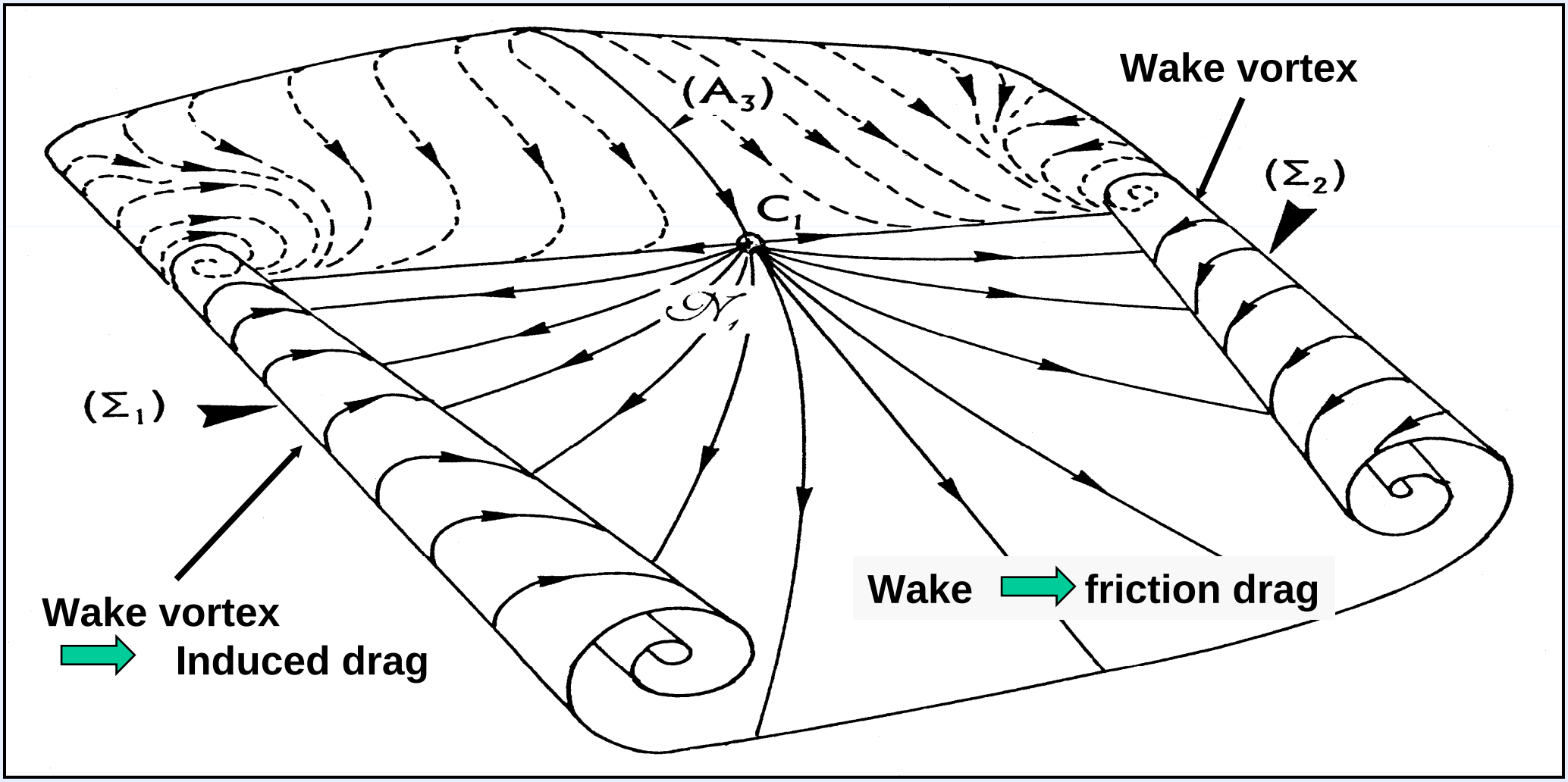


Wake vortex of a classical wing
Detachment surface and vortices



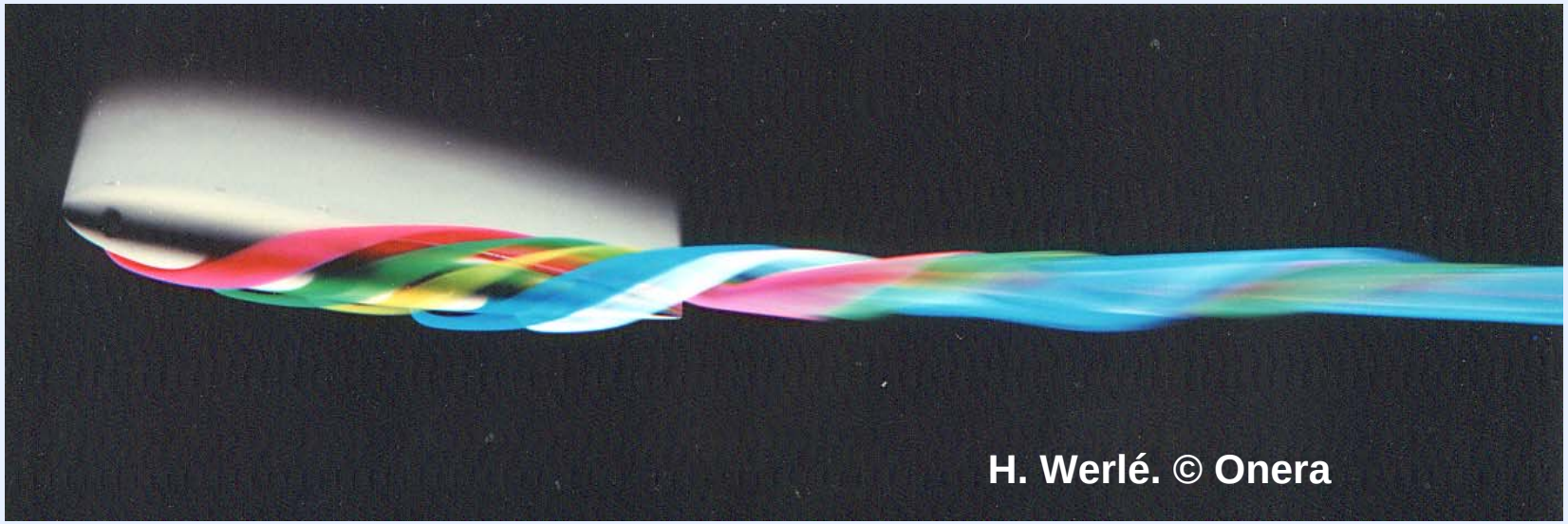
Due to the overpressure on the pressure side, the flow is pushed by the pressure difference and tends to stream on the suction side.

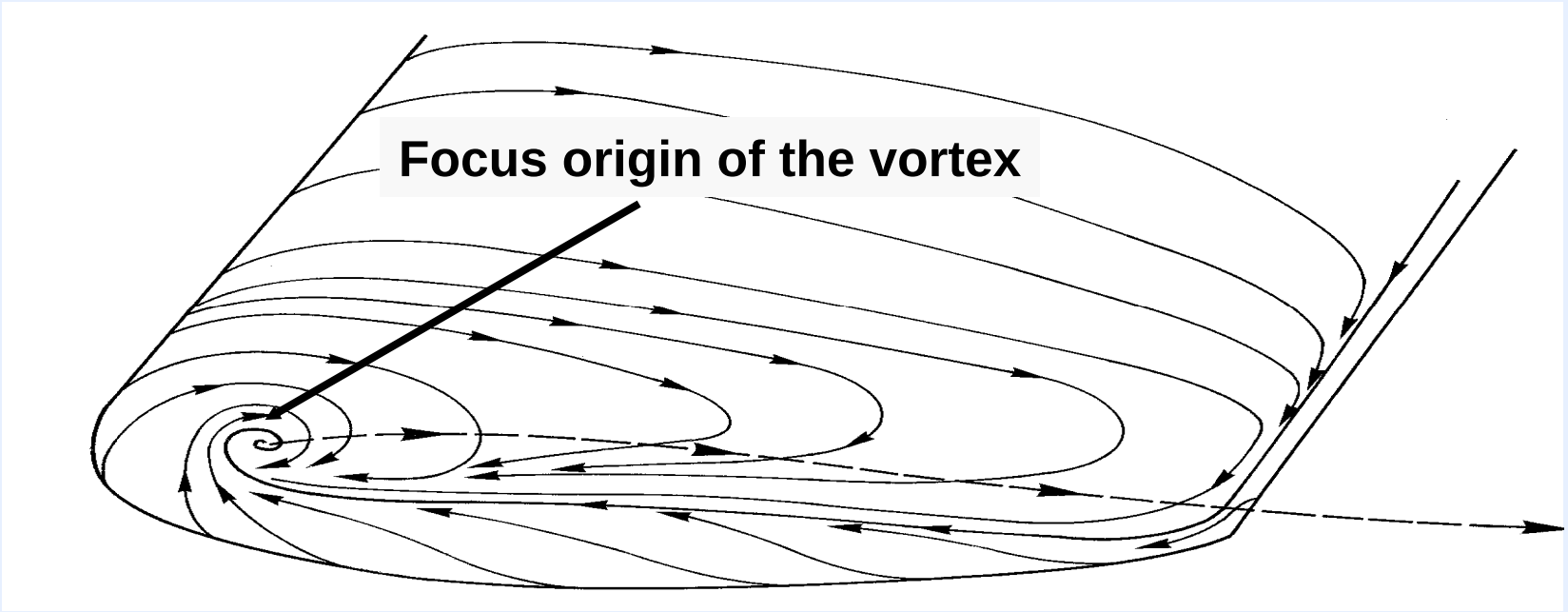
Wake vortex of a classical wing
Detachment surface and vortices



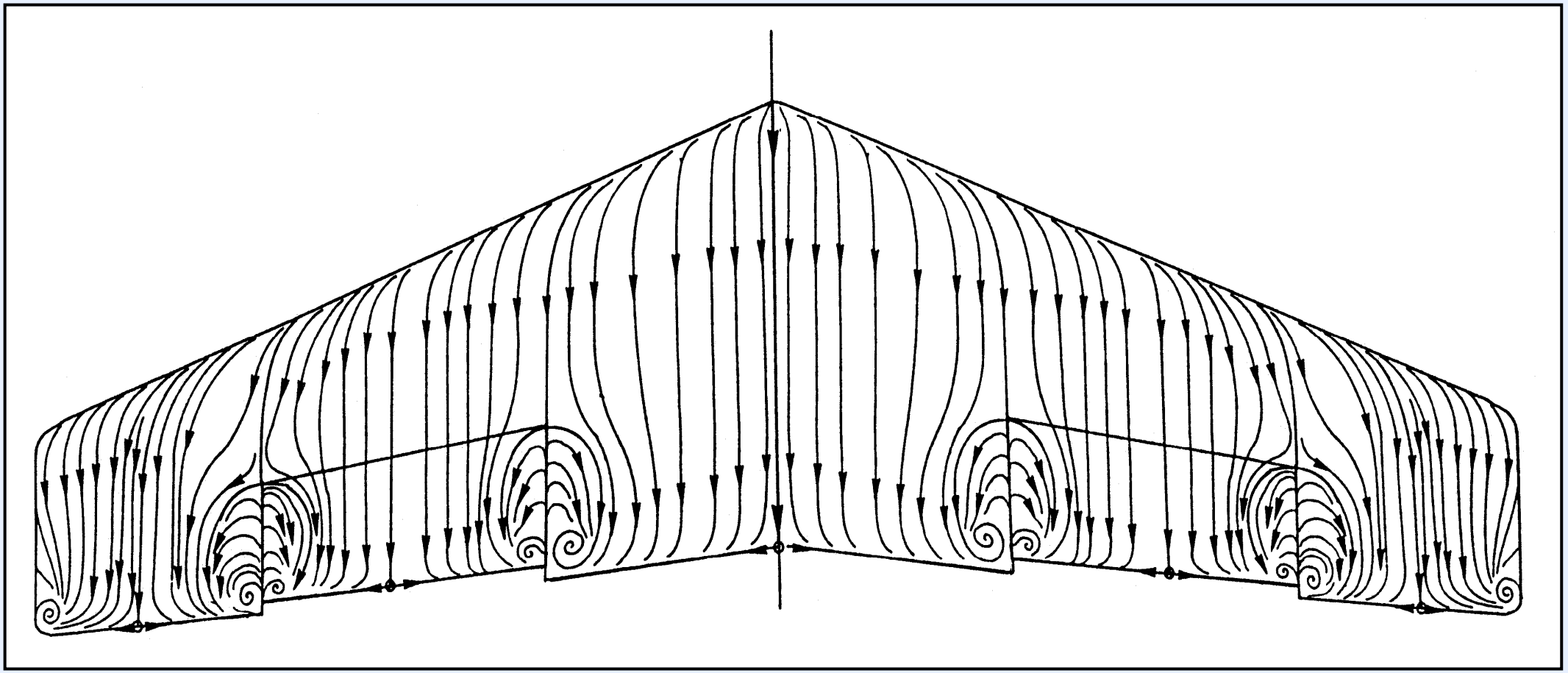
Vorticity (entropy) produced in the boundary layers is concentrated in the two tip vortices

Formation of a wing tip vortex

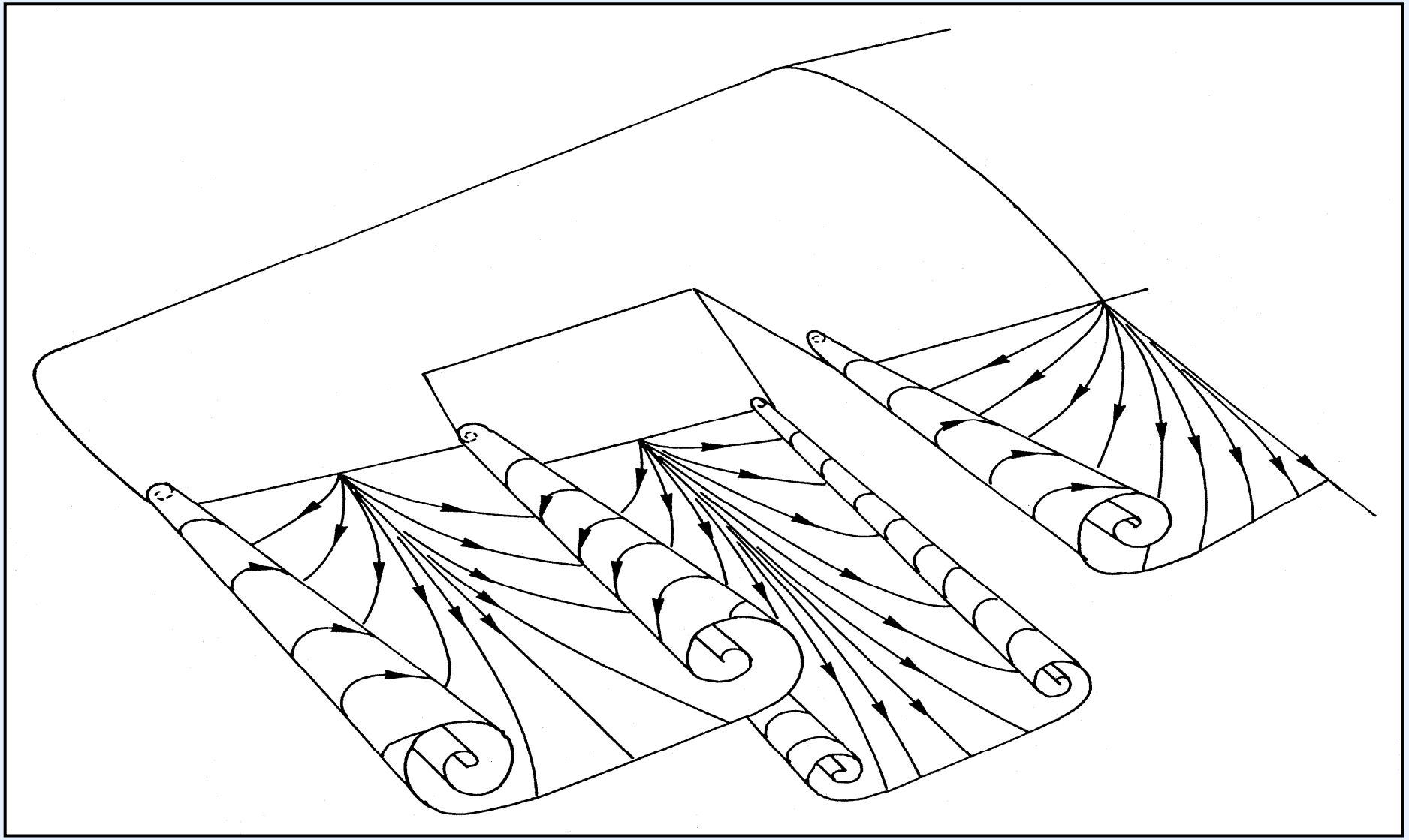




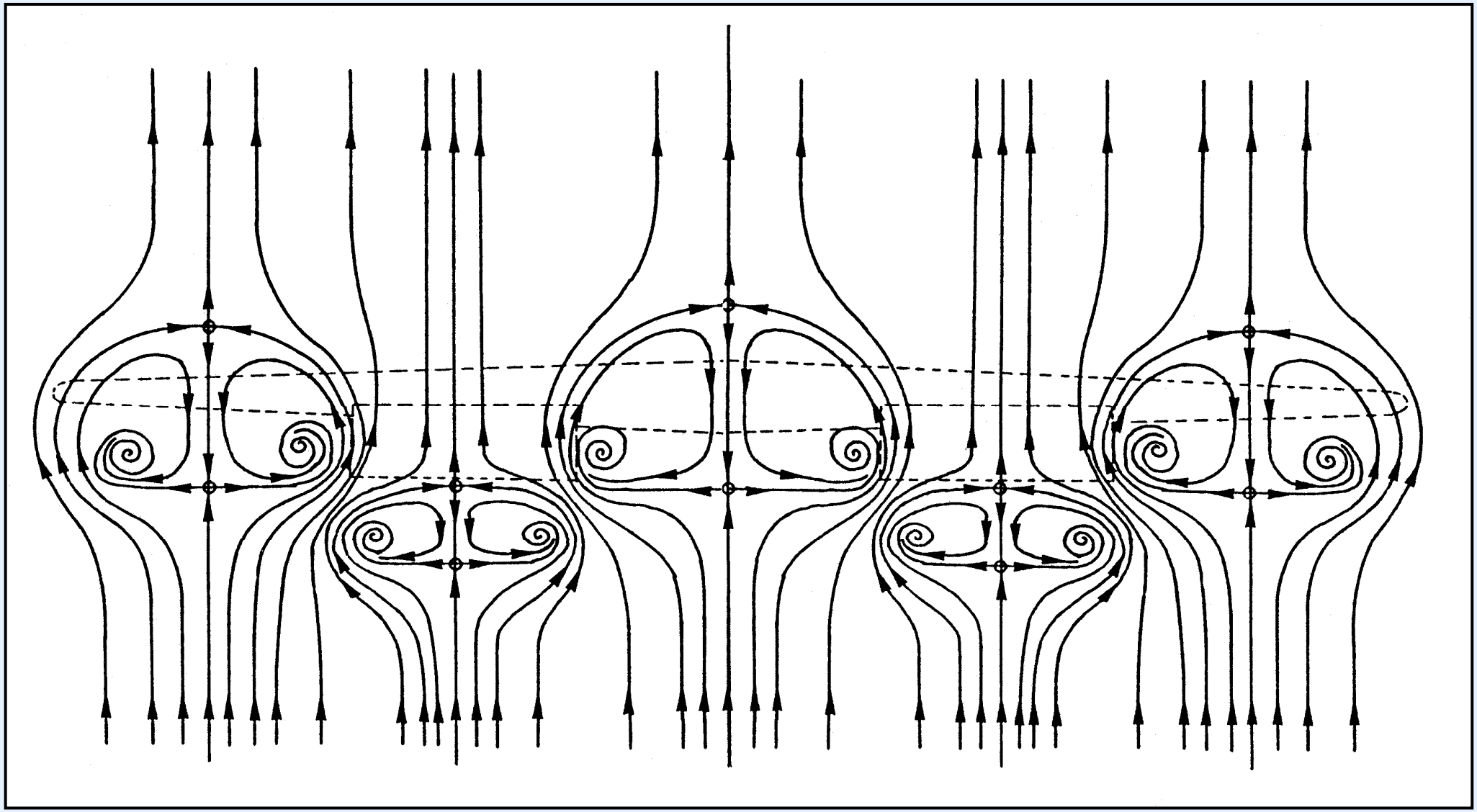
Wake vortex of a wing with control surfaces
Skin friction line pattern on the suction side



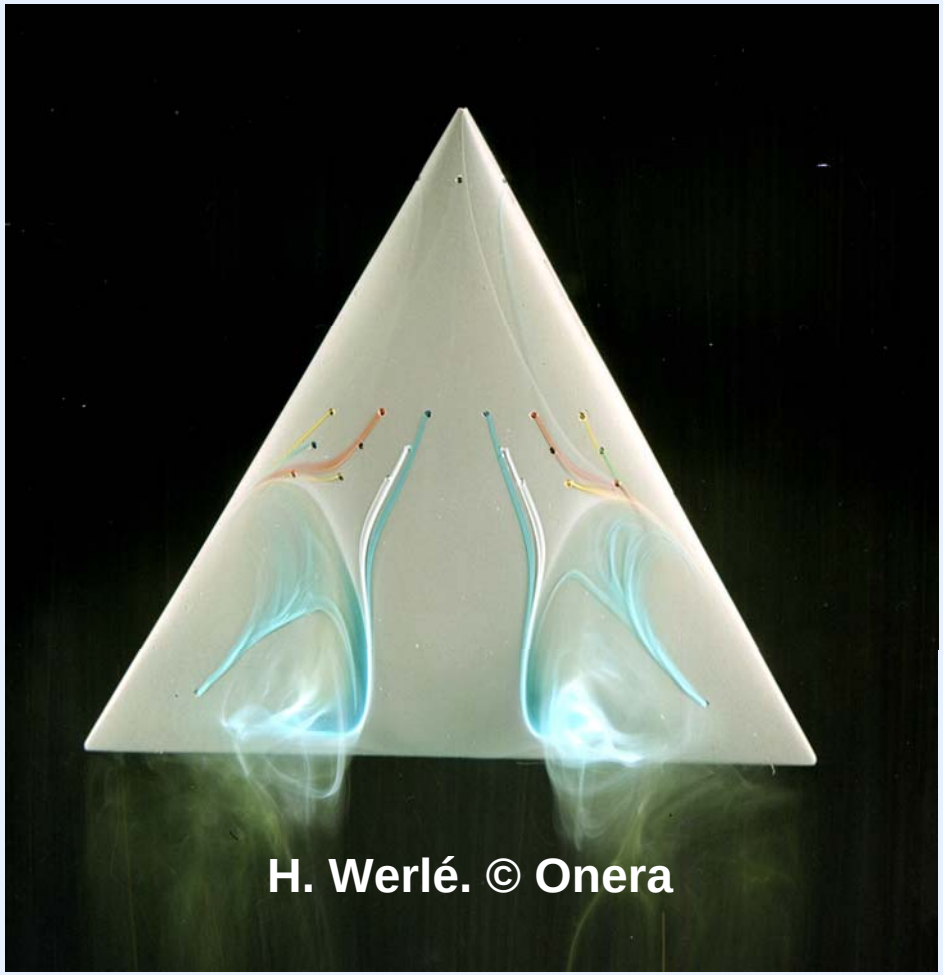
Wake vortex of a wing with control surfaces
Vortices emitted by tips of wing and control surfaces

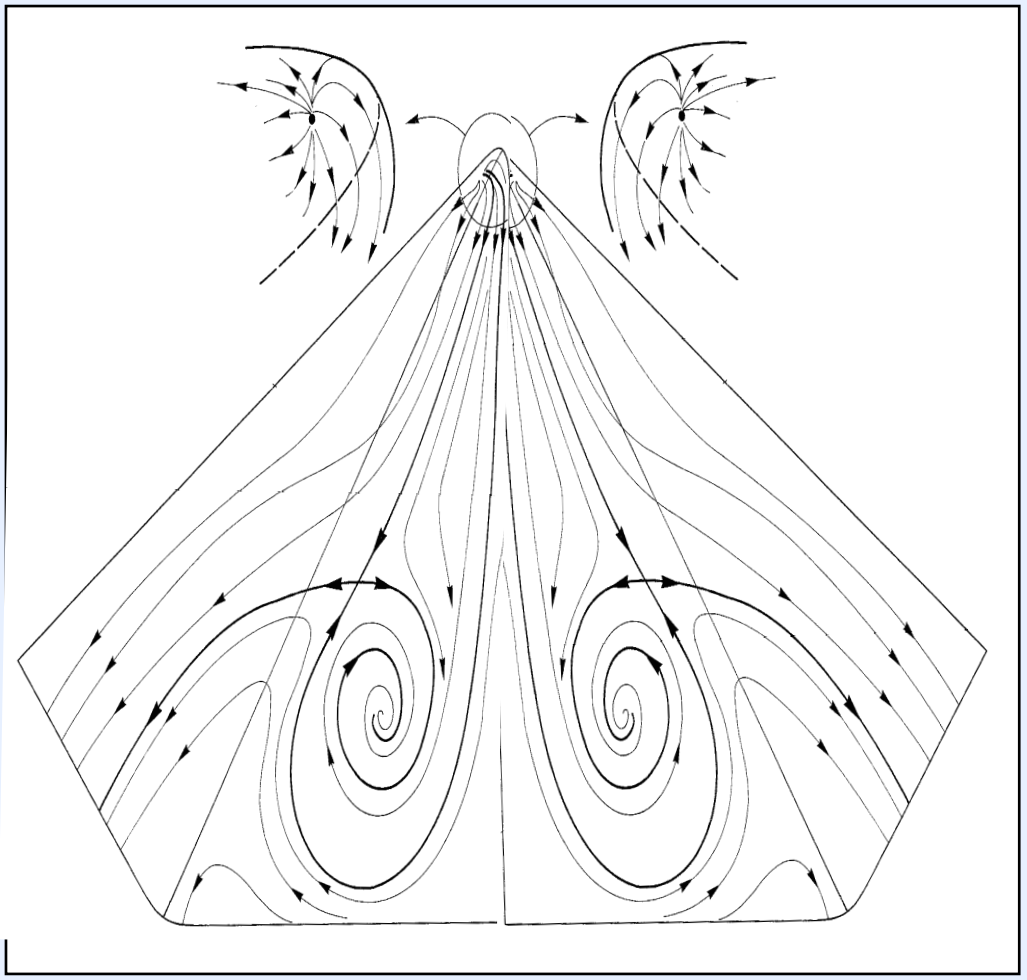


Wake vortex of a wing with control surfaces
Field projected in a downstream plane



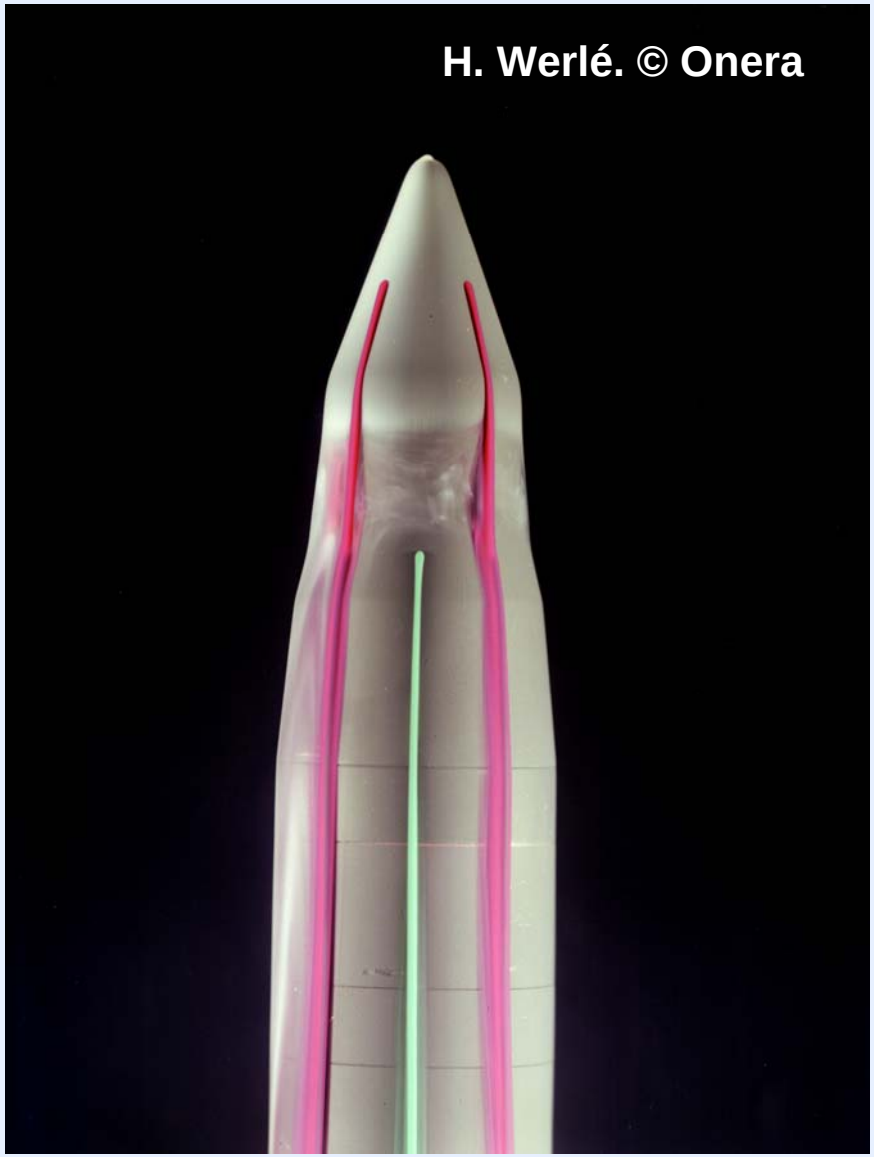
Separation on a delta wing at very low Reynolds number



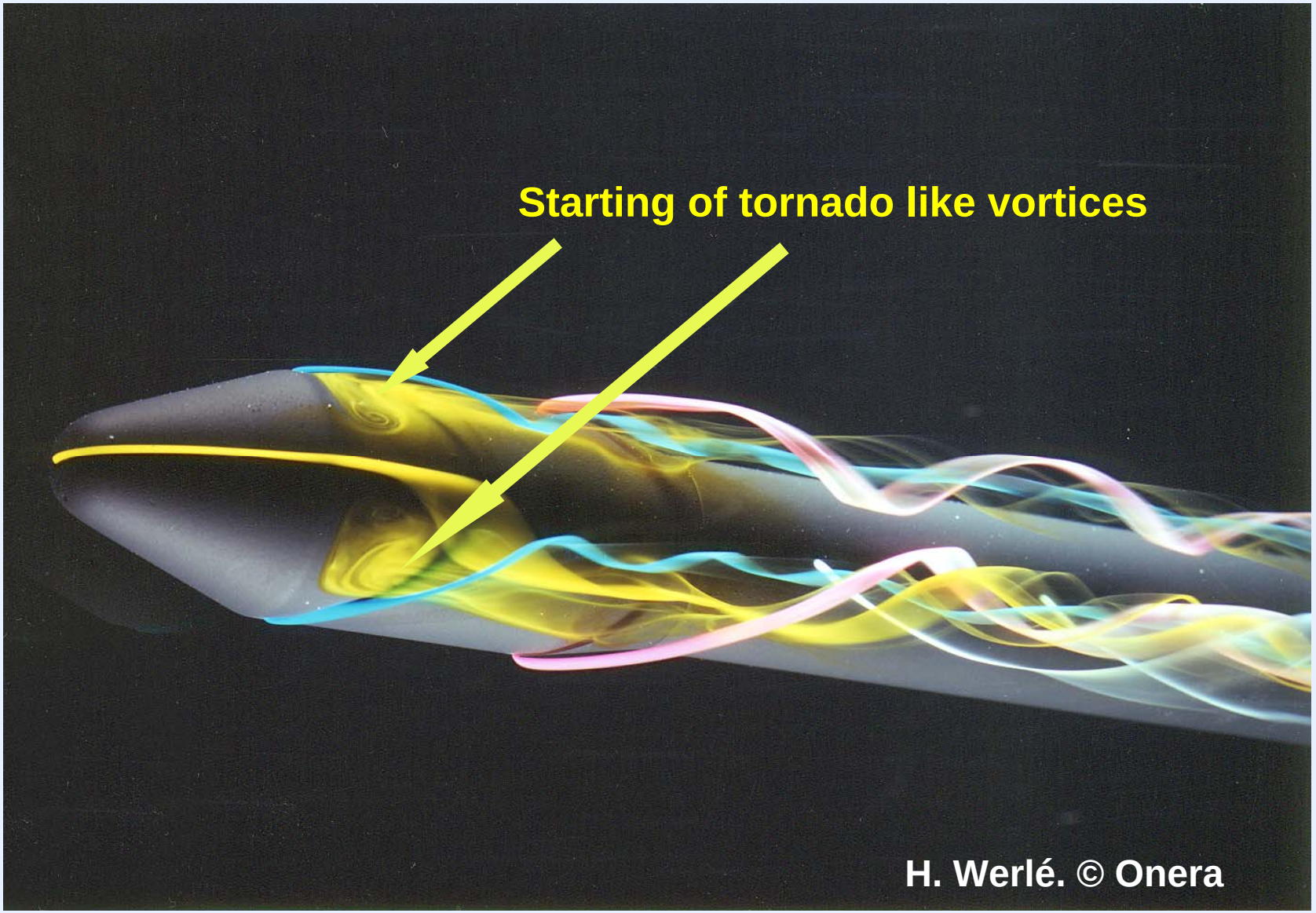


Vortices emanate from foci distinct from the wing apex

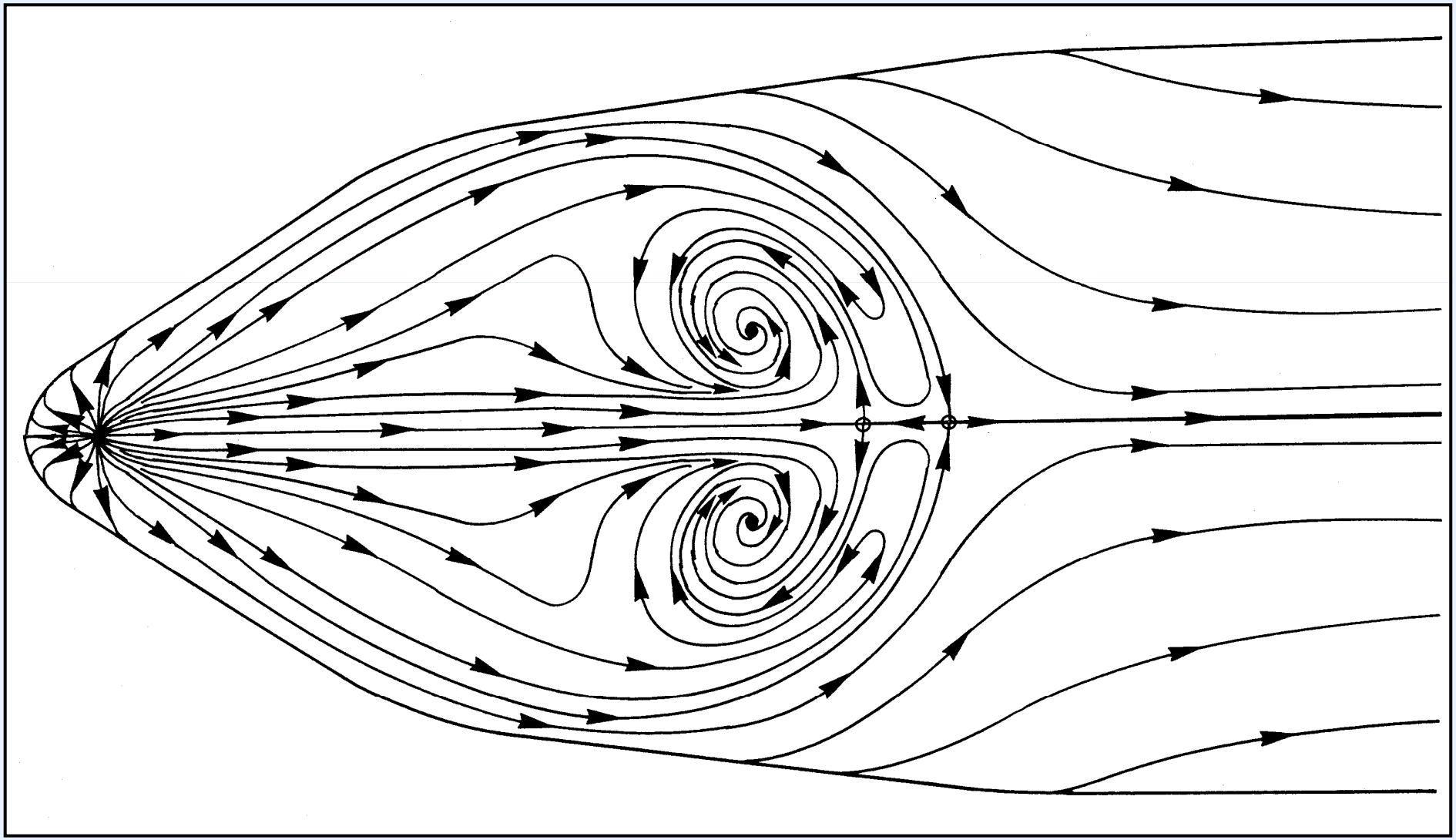
Separation on a slender body



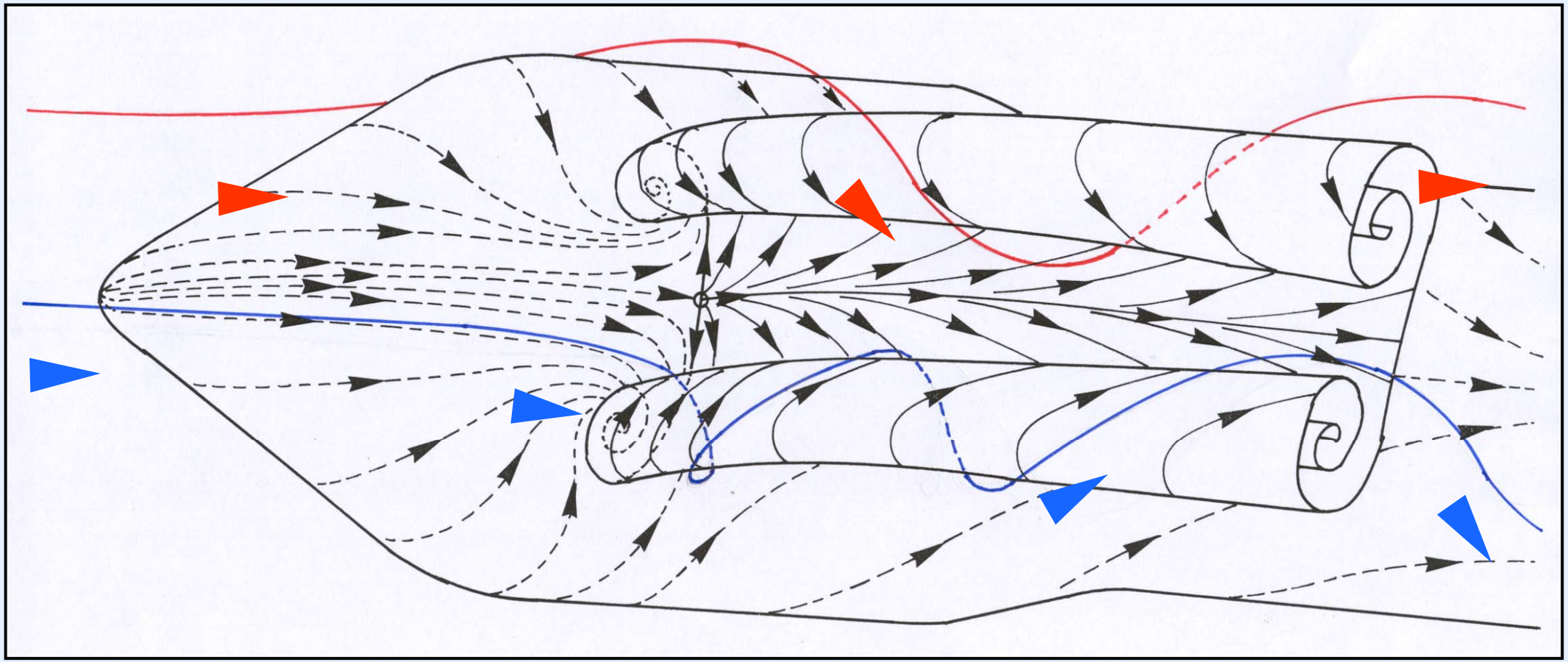
Separation on a space launcher ogive



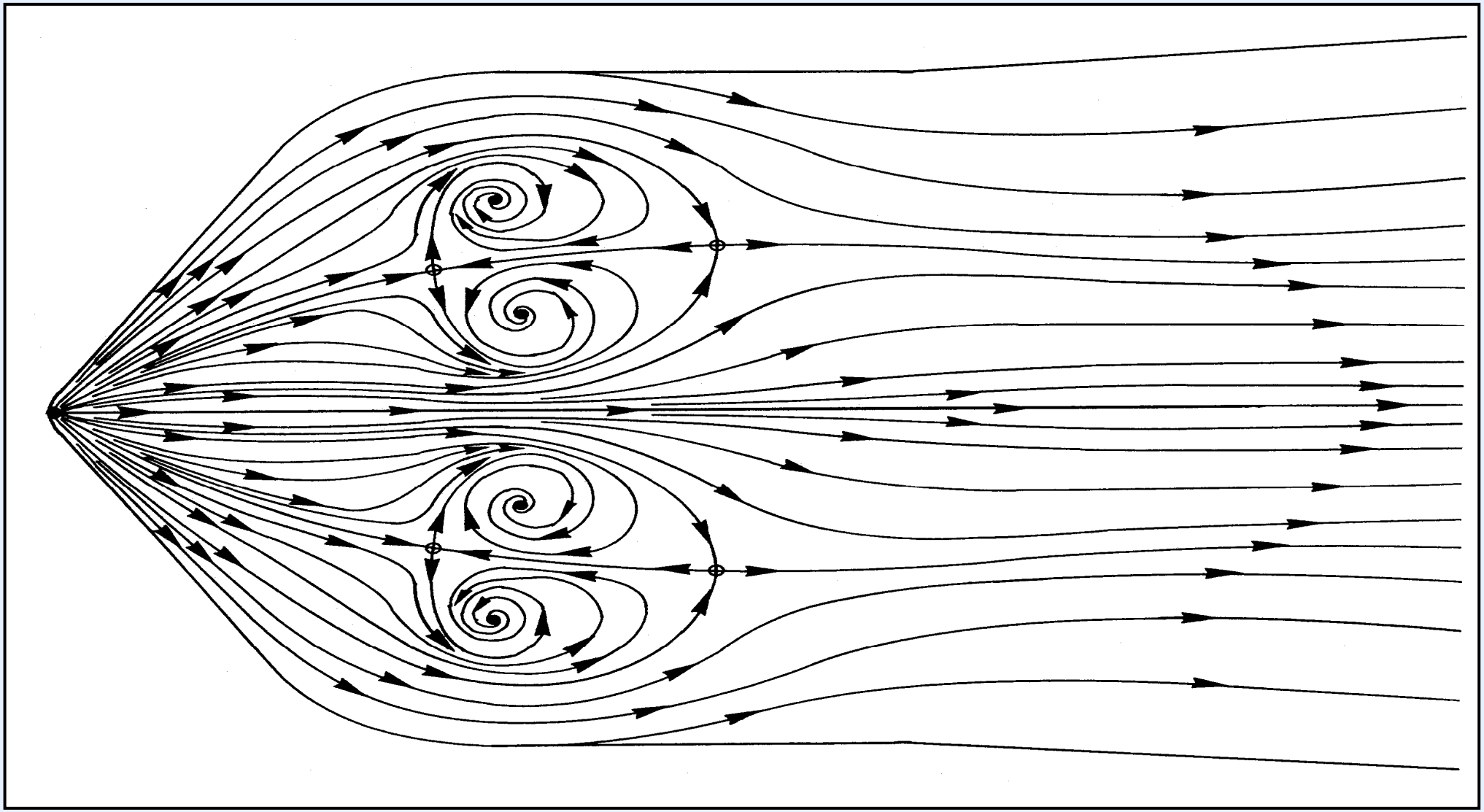
Separation on a blunted slender body
Separation with two tornado like vortices. Skin friction line pattern.



Separation on a blunted slender body
Separation with two tornado like vortices. Detachment surfaces



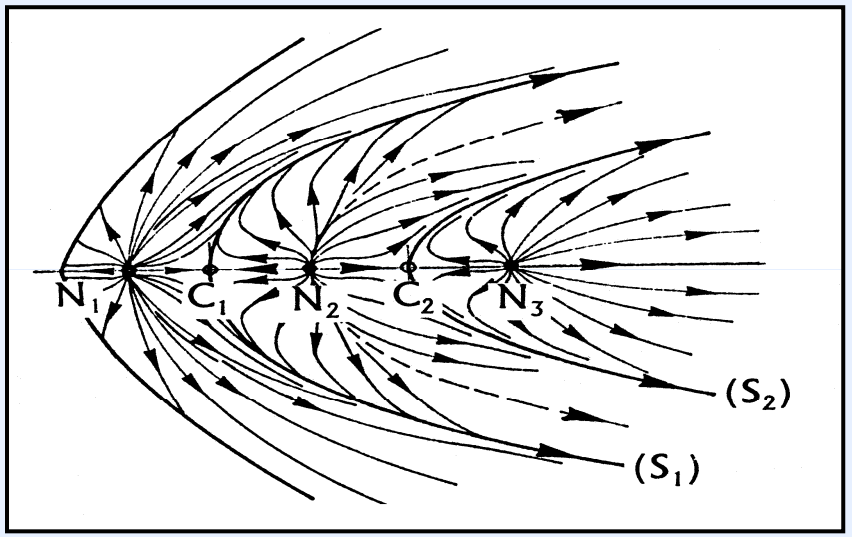
Detachment on a missile ogive with flat faces
Separation with four tornado like vortices



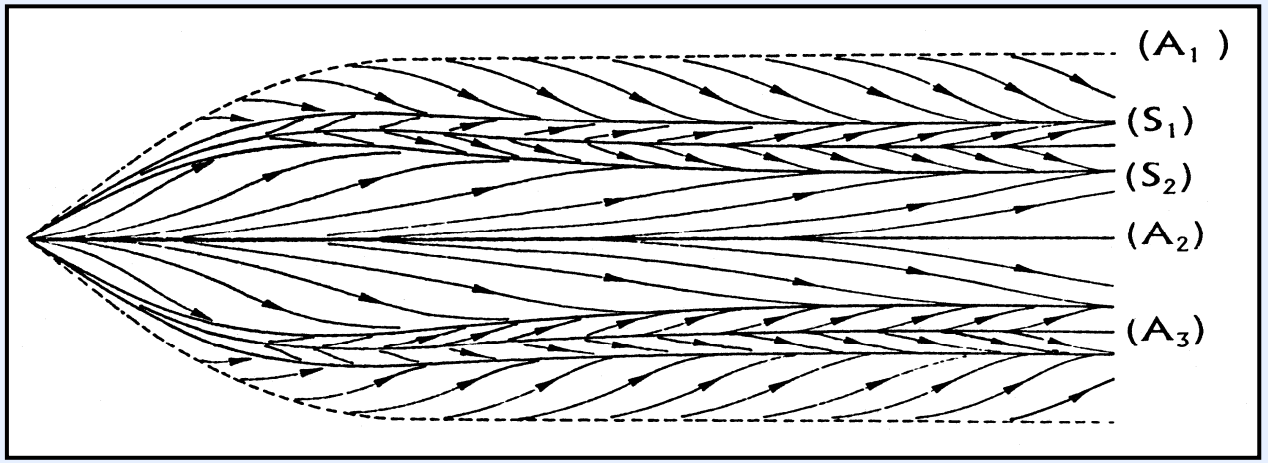
Separation on a sharp slender body

Skin friction line pattern

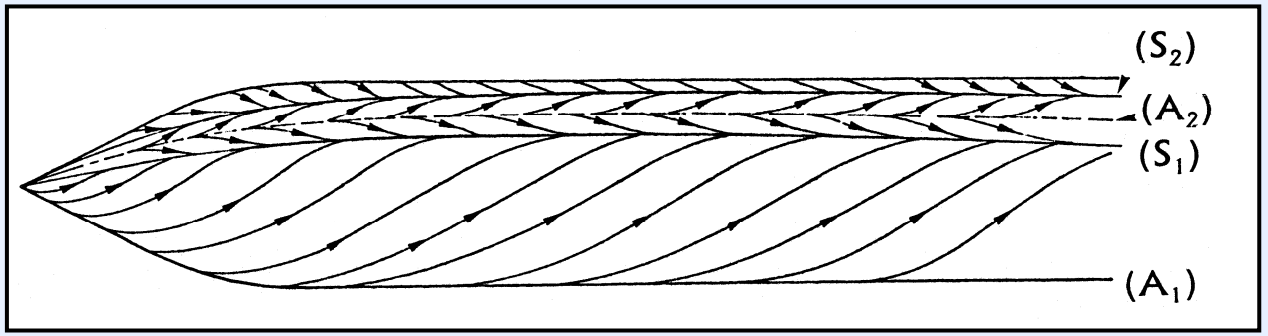
Details near the apex



View from above
(body surface developed)

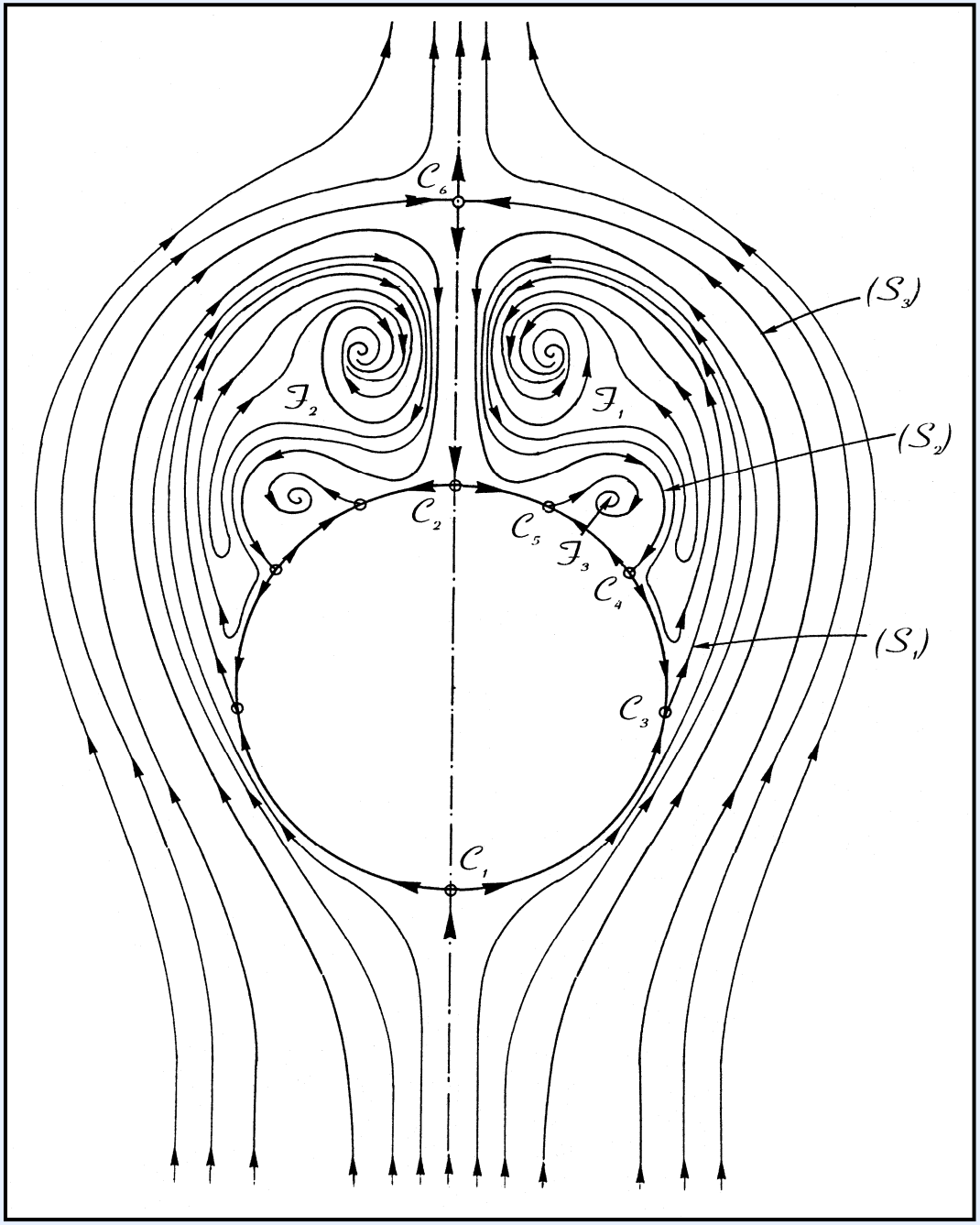


Side view



Separation on a sharp slender body

Two-vortex system

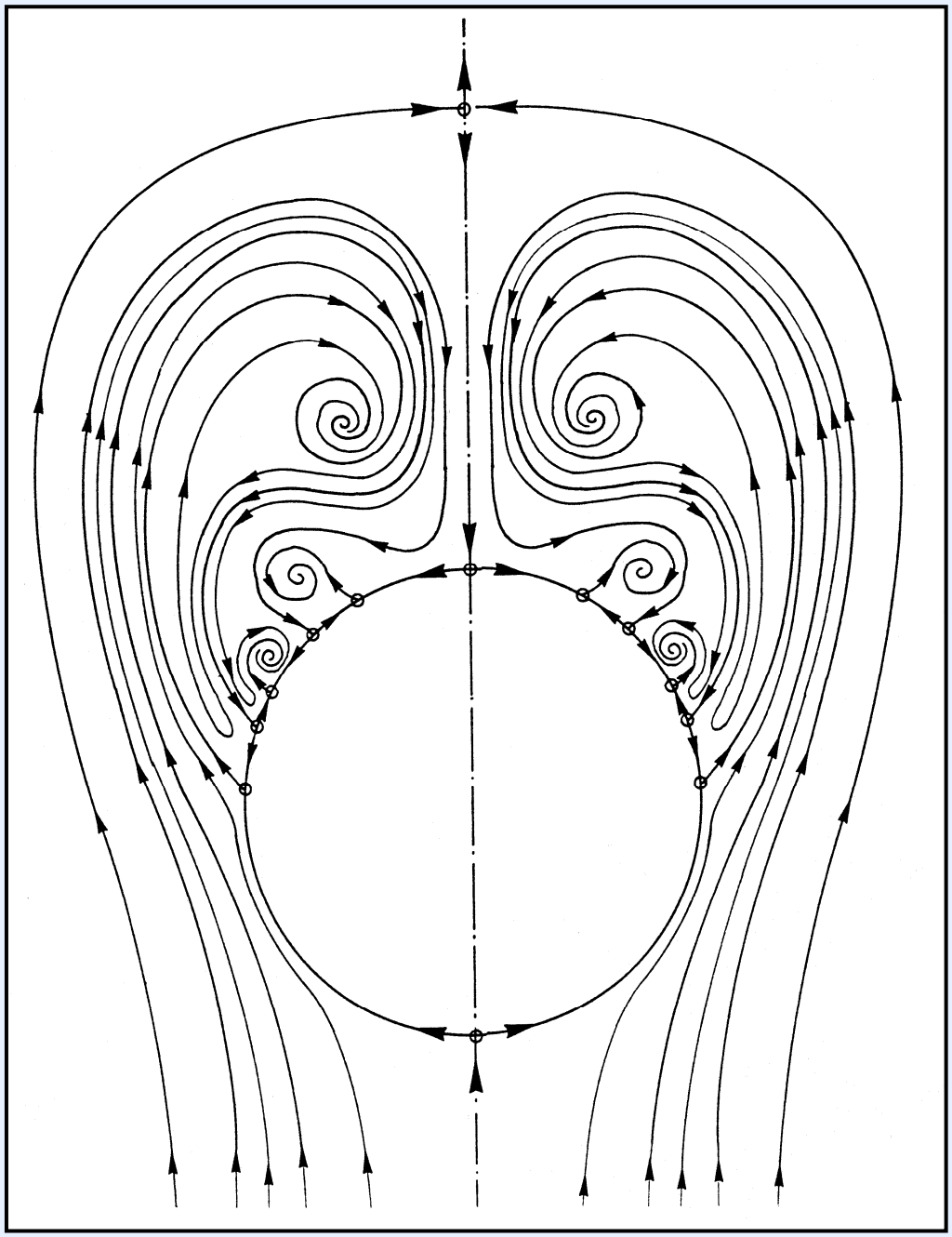


Field projected in a plane normal to the body axis

Separation on a sharp slender body

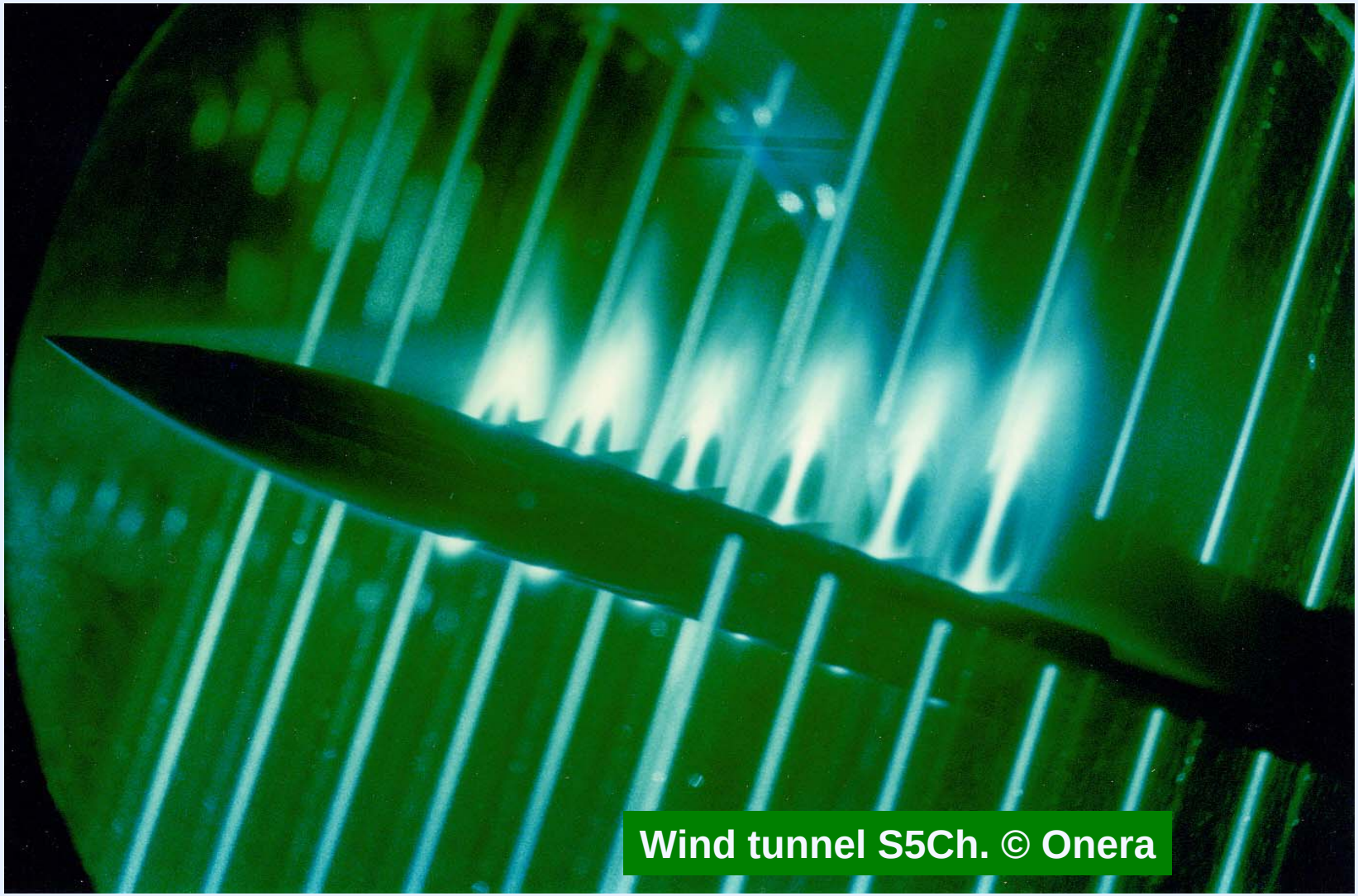
Separation on a sharp slender body

Three-vortex system



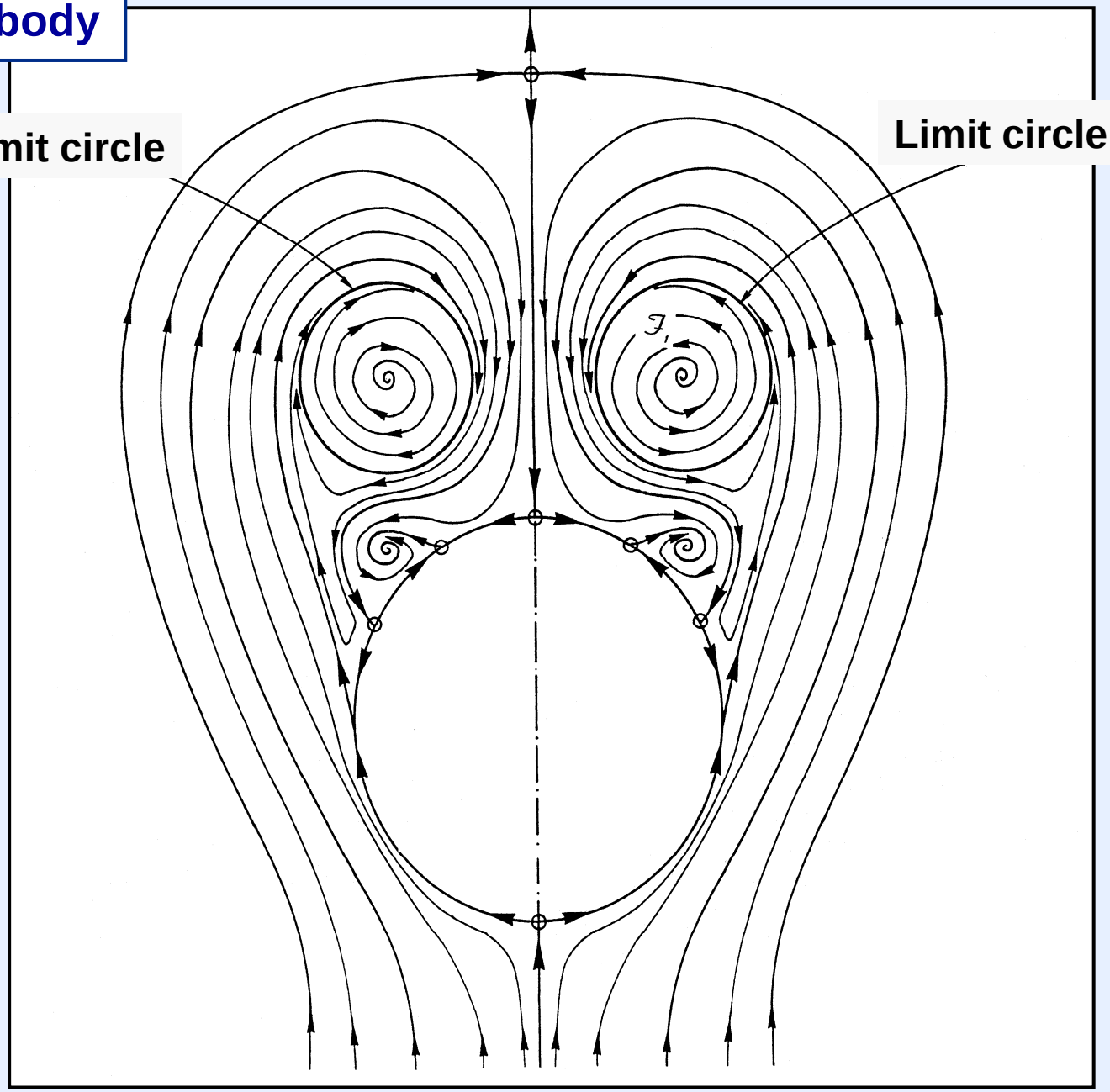
Field projected in a plane normal to the body axis

Separation on a sharp slender body in a Mach 2 flow
Laser sheet visualization



Separation on a sharp slender body

Existence of a limit circle



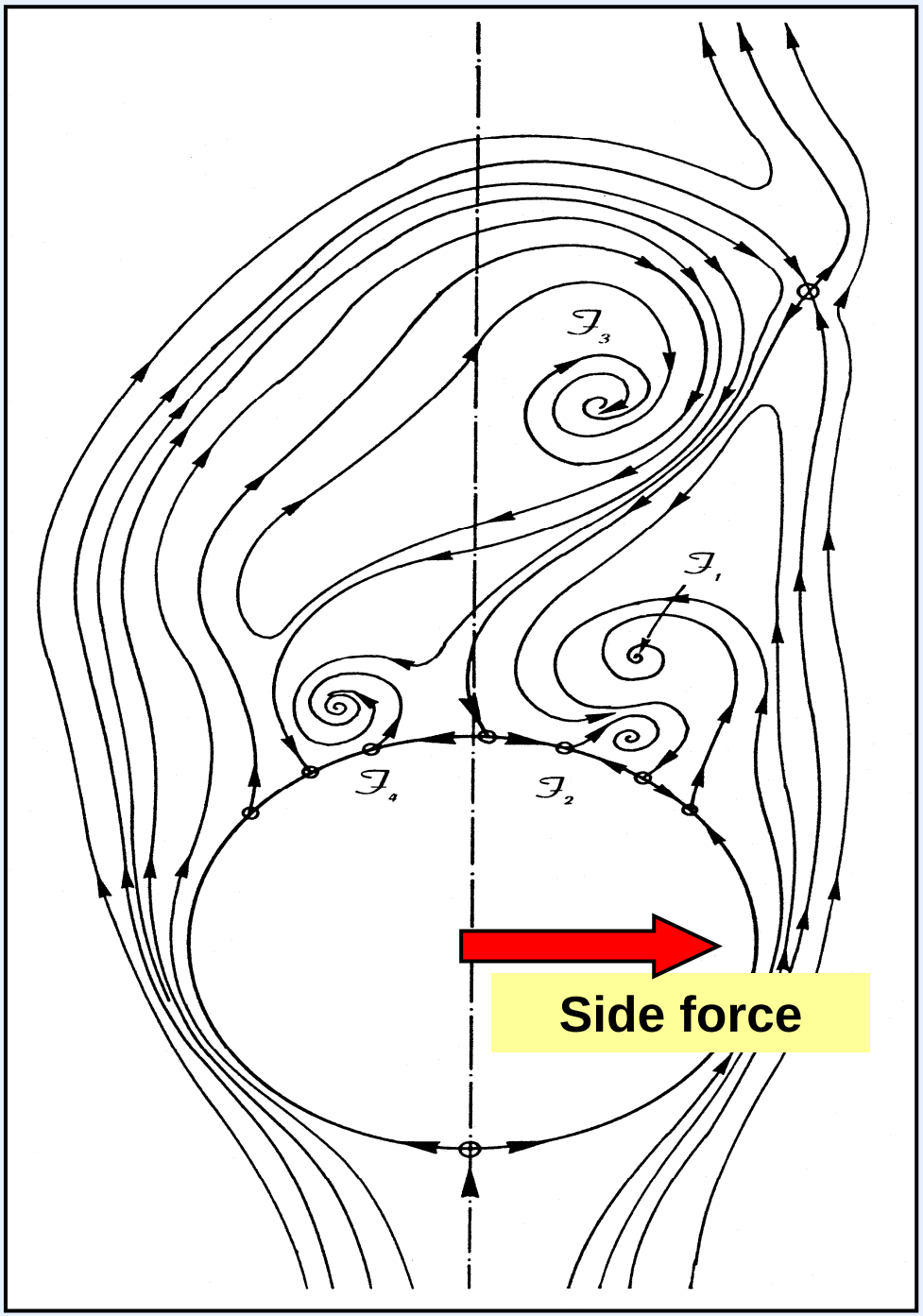
Field projected in a plane normal to the body axis

Separation on a sharp slender body

Asymmetric configuration and side force

Interaction between the two vortices may lead to a loss of symmetry for the system

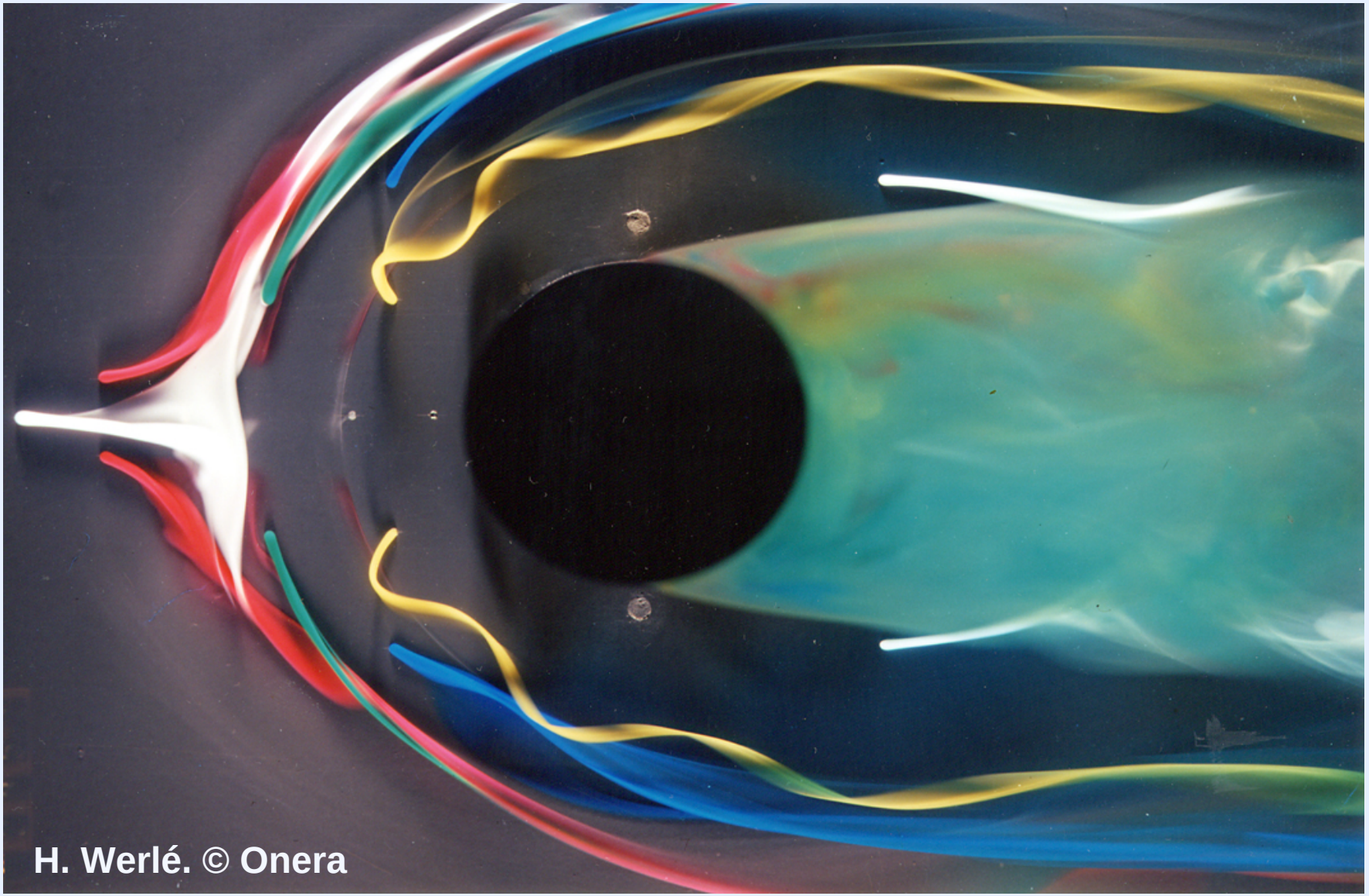
This occurs in a well defined range of angle of incidence. Asymmetry entails existence of a side force



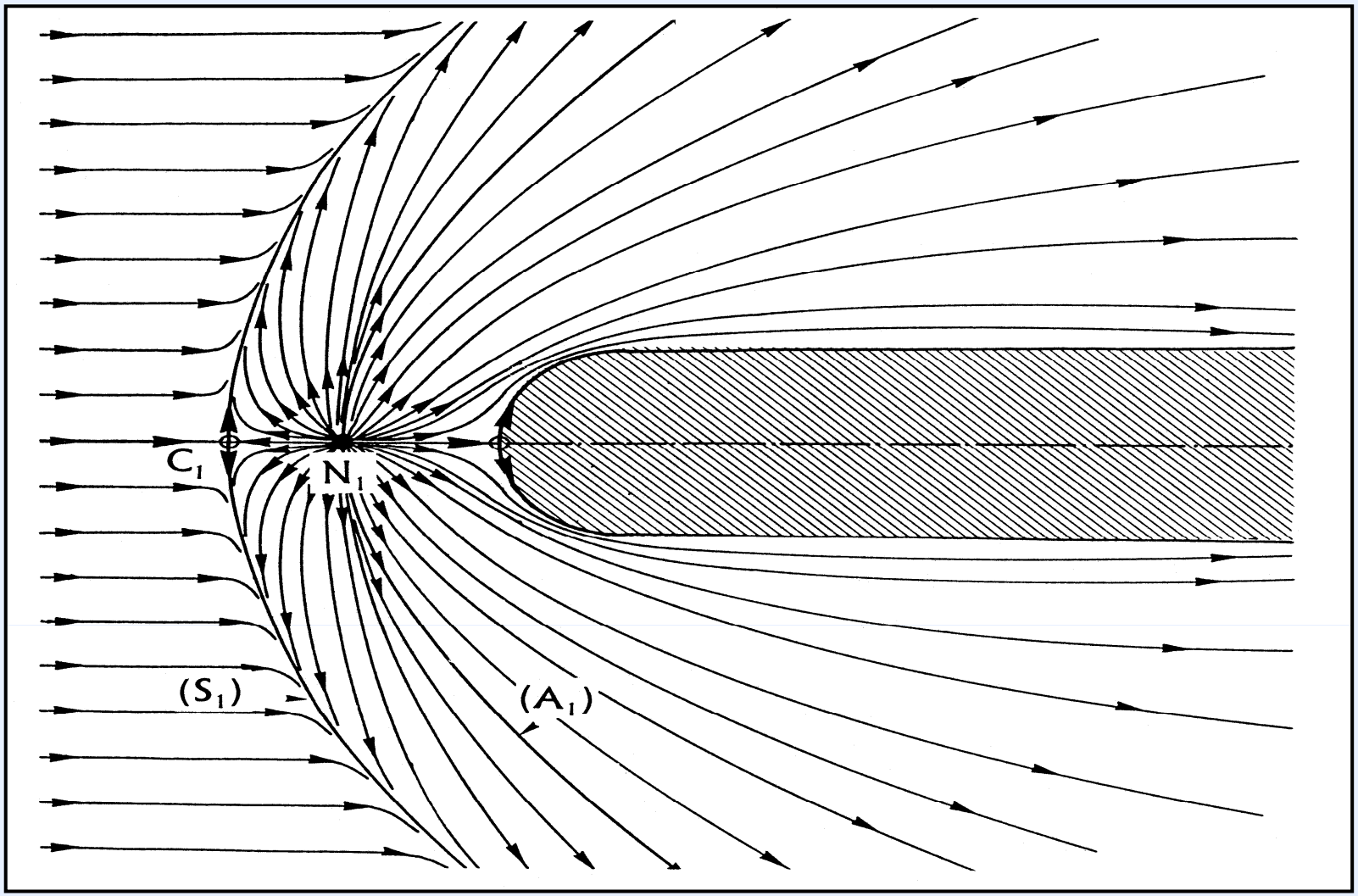
Field projected in a plane normal to the body axis

Separation on a sharp slender body
Symmetrical and asymmetrical configurations

Separation induced by a blunt obstacle

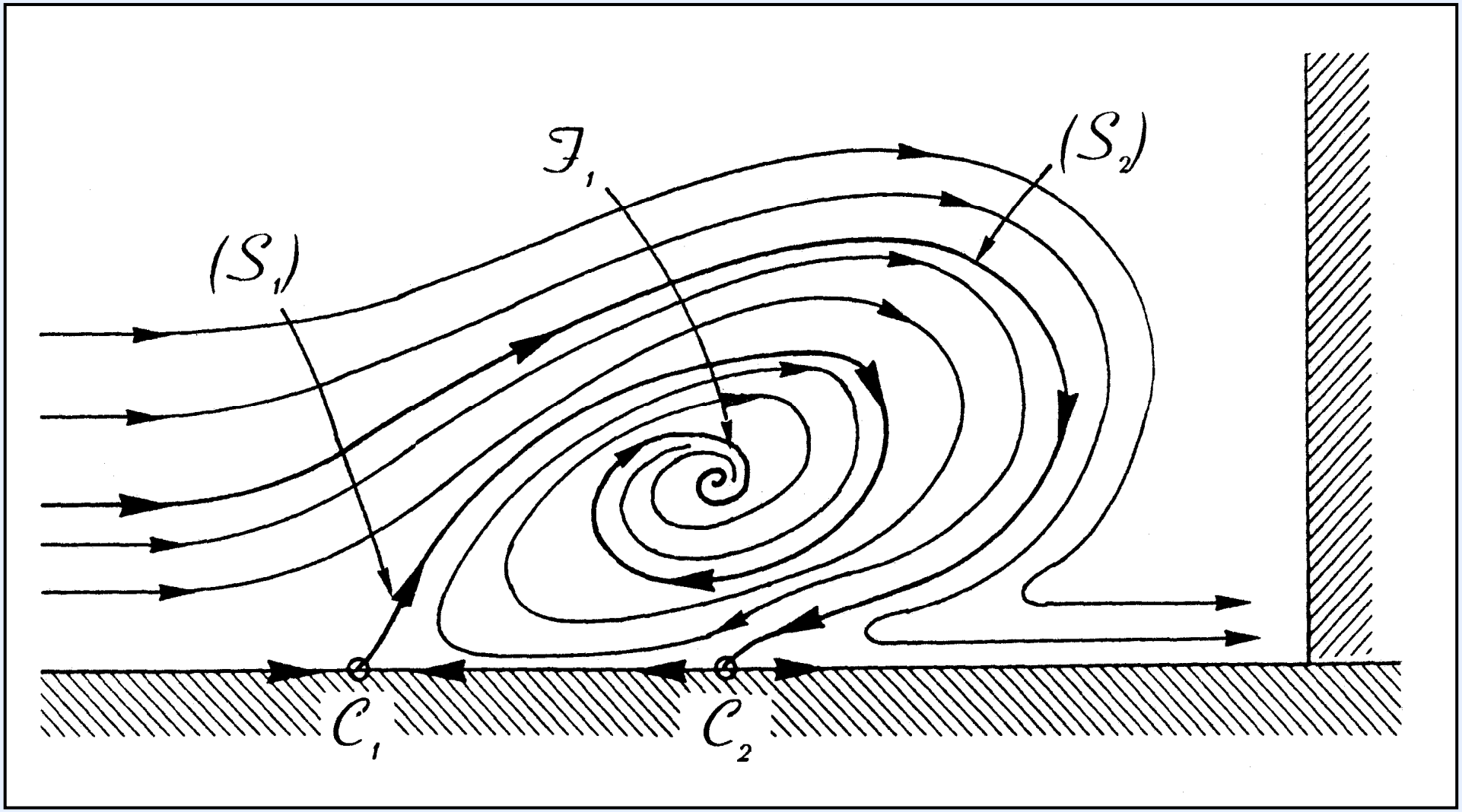


Separation induced by a blunt obstacle
Skin friction line pattern



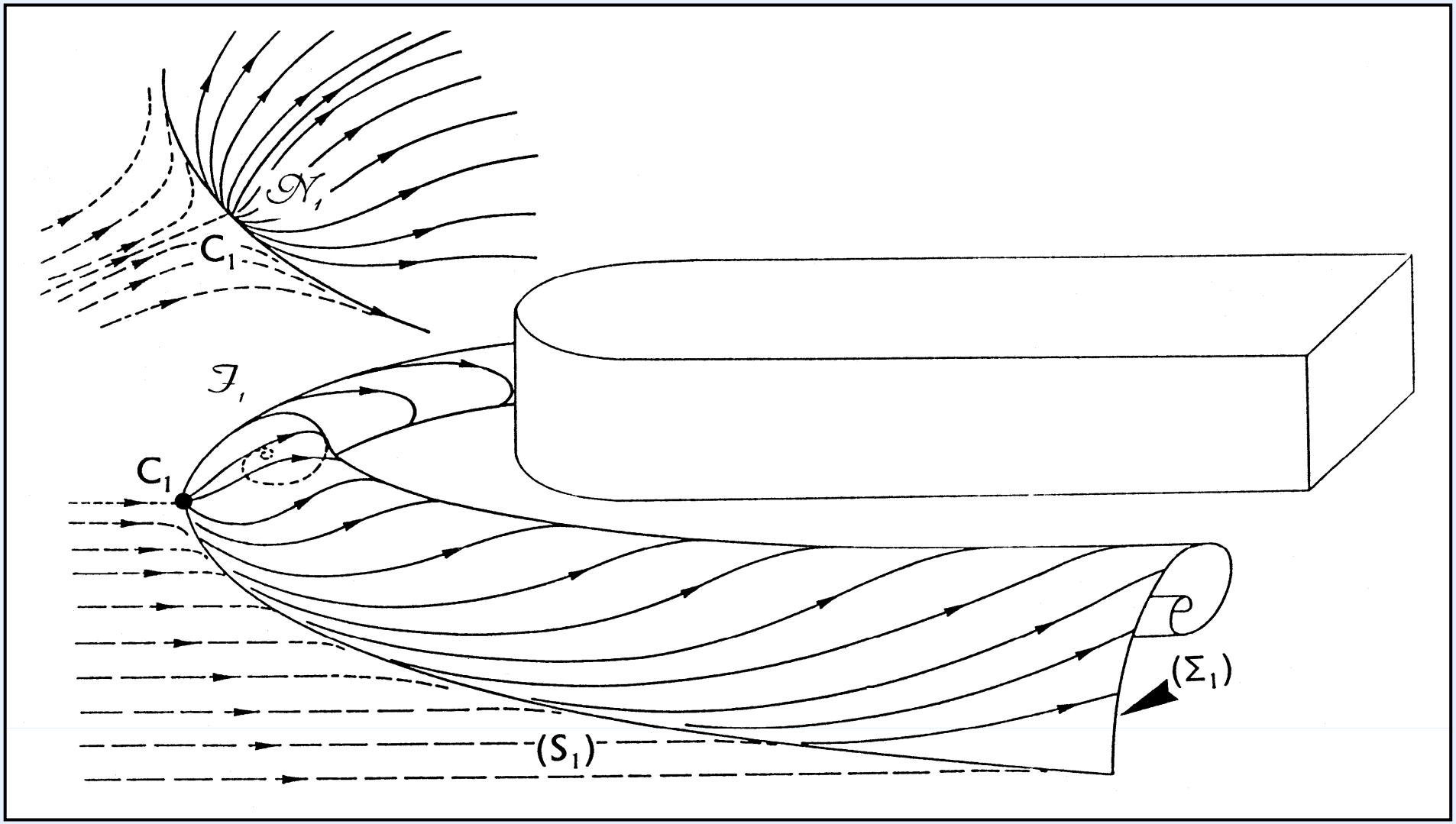
One-vortex system

Separation induced by a blunt obstacle
Flow in the symmetry plane



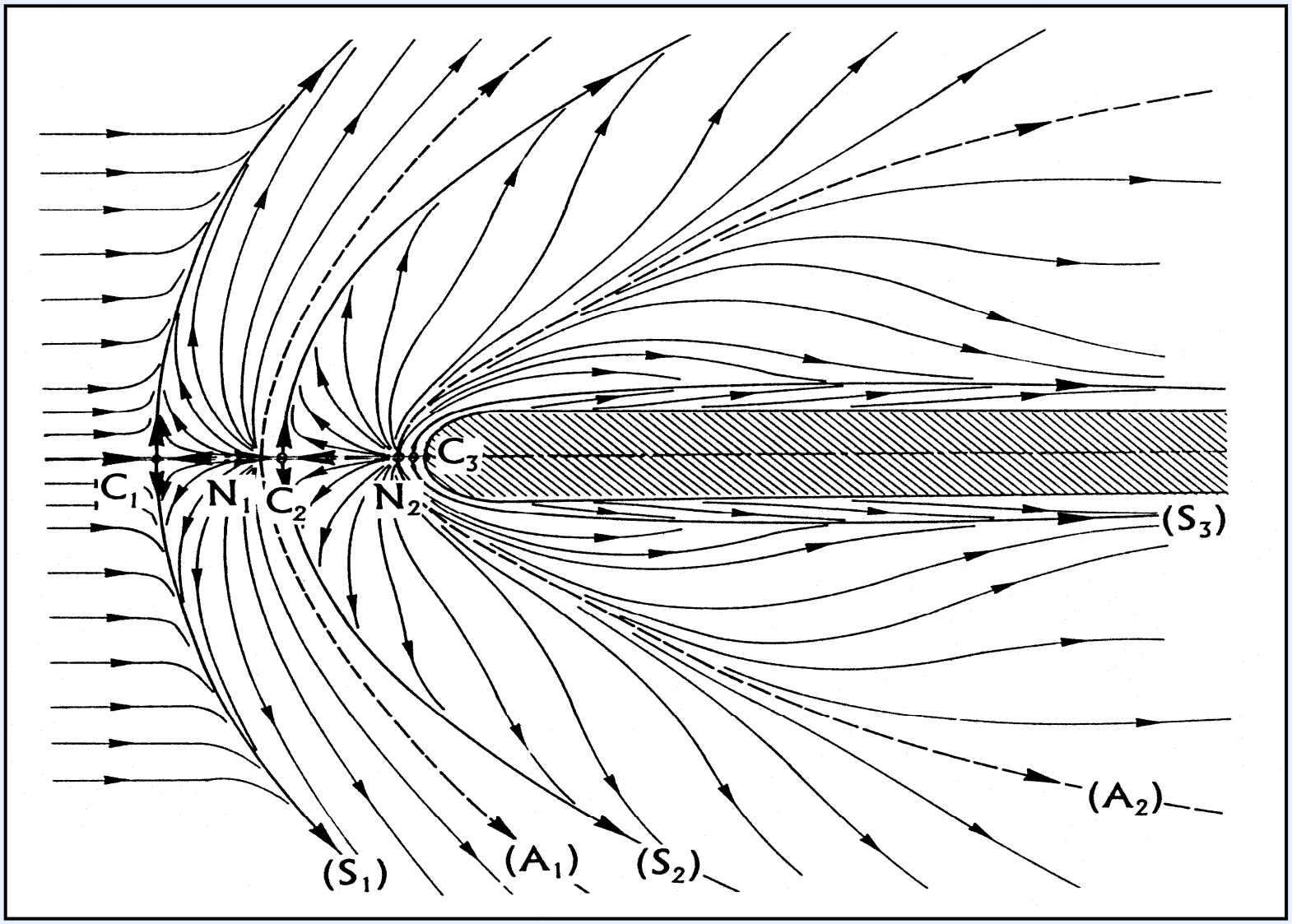
One-vortex system

Separation induced by a blunt obstacle
Detachment surface



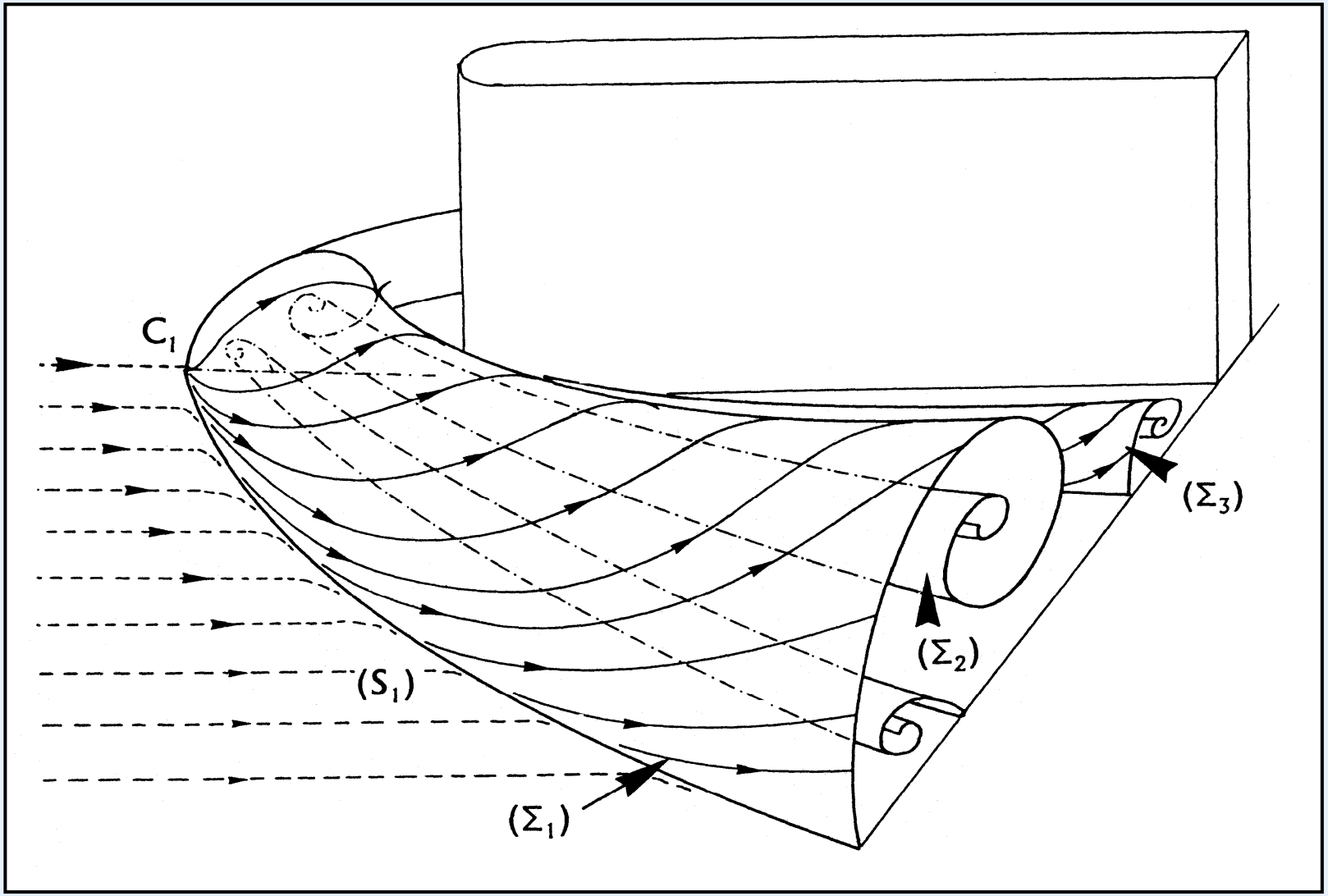
One-vortex system

Separation induced by a blunt obstacle
Skin friction line pattern



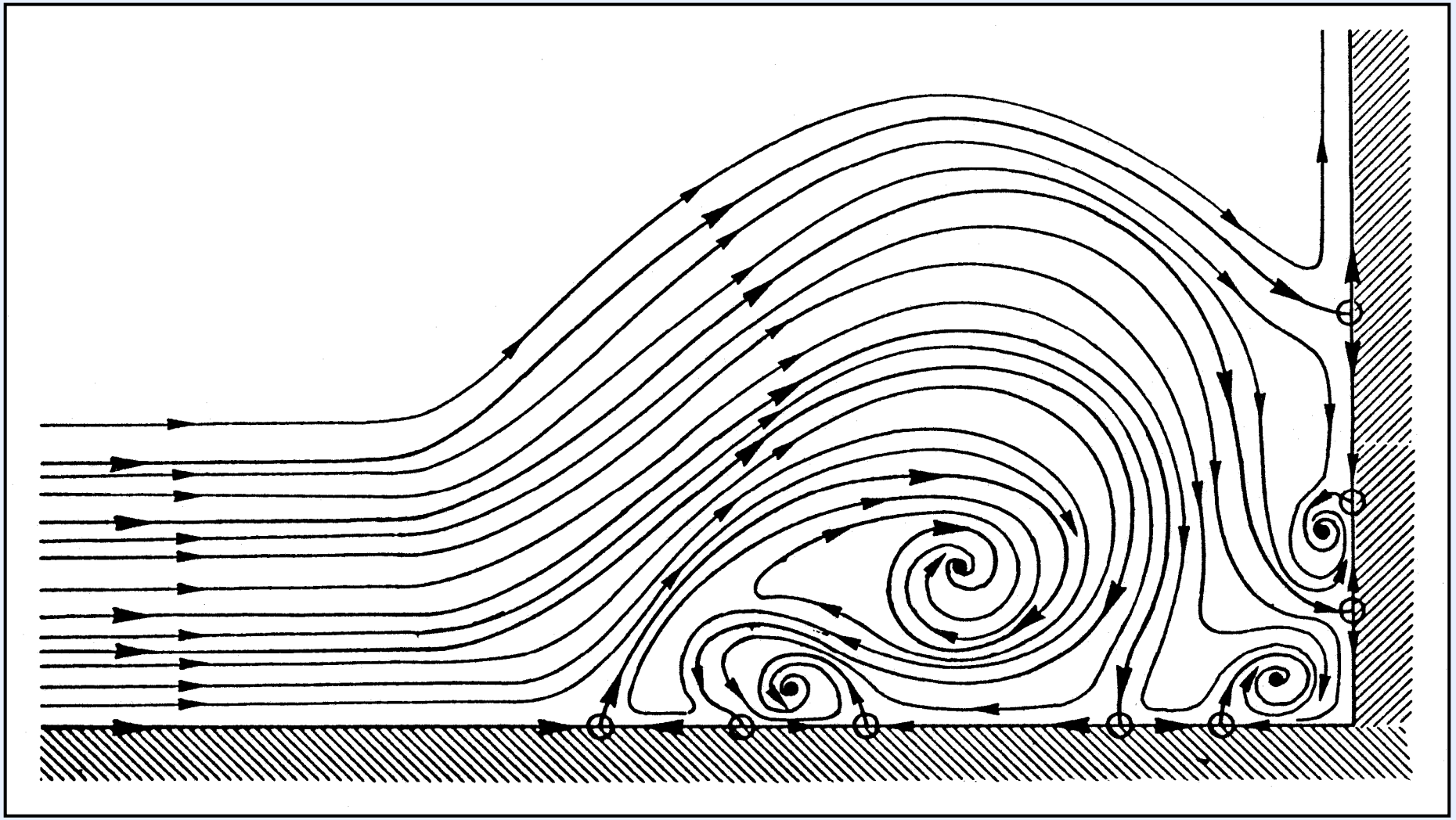
Three-vortex system

Separation induced by a blunt obstacle
Detachment surface



Three-vortex system

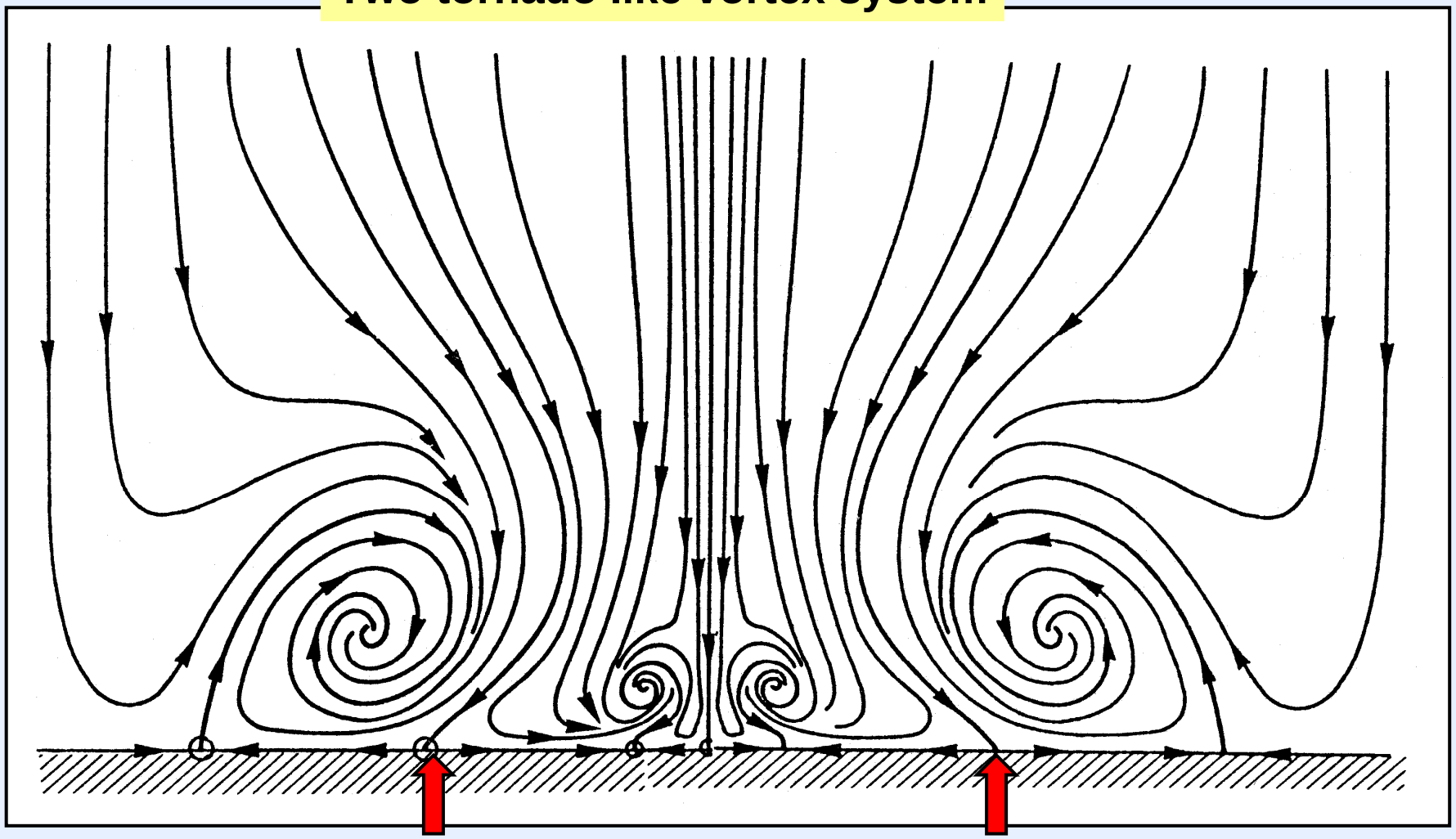
Separation induced by a blunt obstacle
Flow in the symmetry plane



Four-vortex system

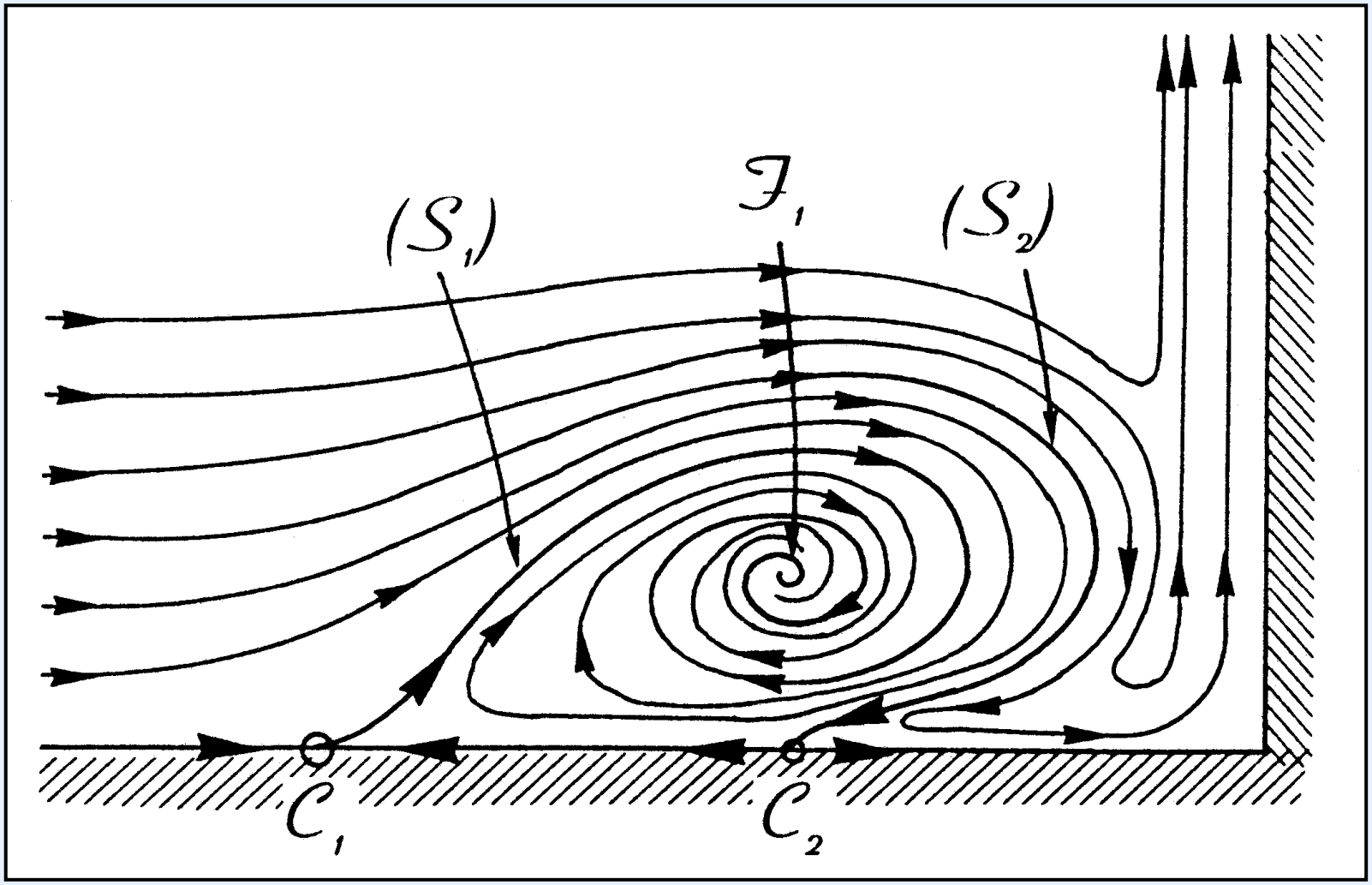
Separation induced by a blunt obstacle
Field in a downstream vertical plane

Two tornado like vortex system



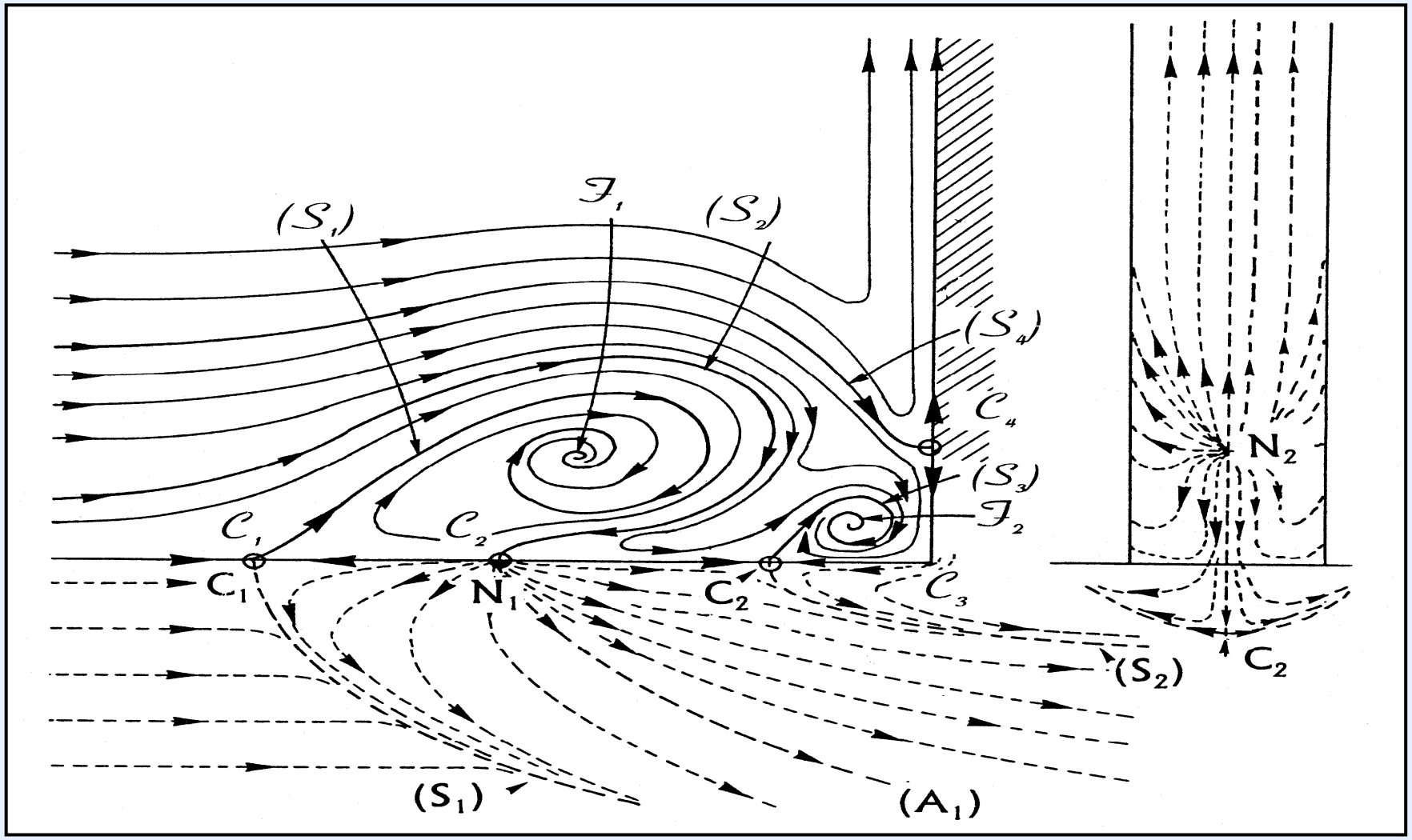
Impact regions : pressure and heat transfer peaks

Separation induced by a blunt obstacle
Flow in the symmetry plane. Variant



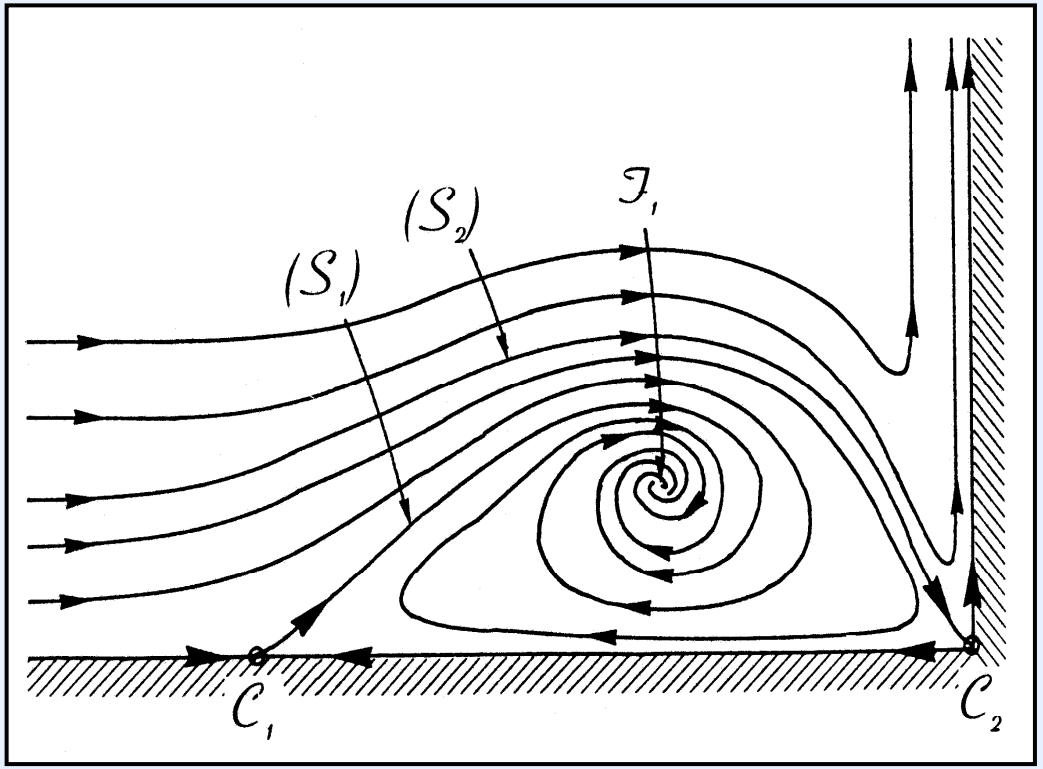
Structure with one detachment

Separation induced by a blunt obstacle
Flow in the symmetry plane. Variant

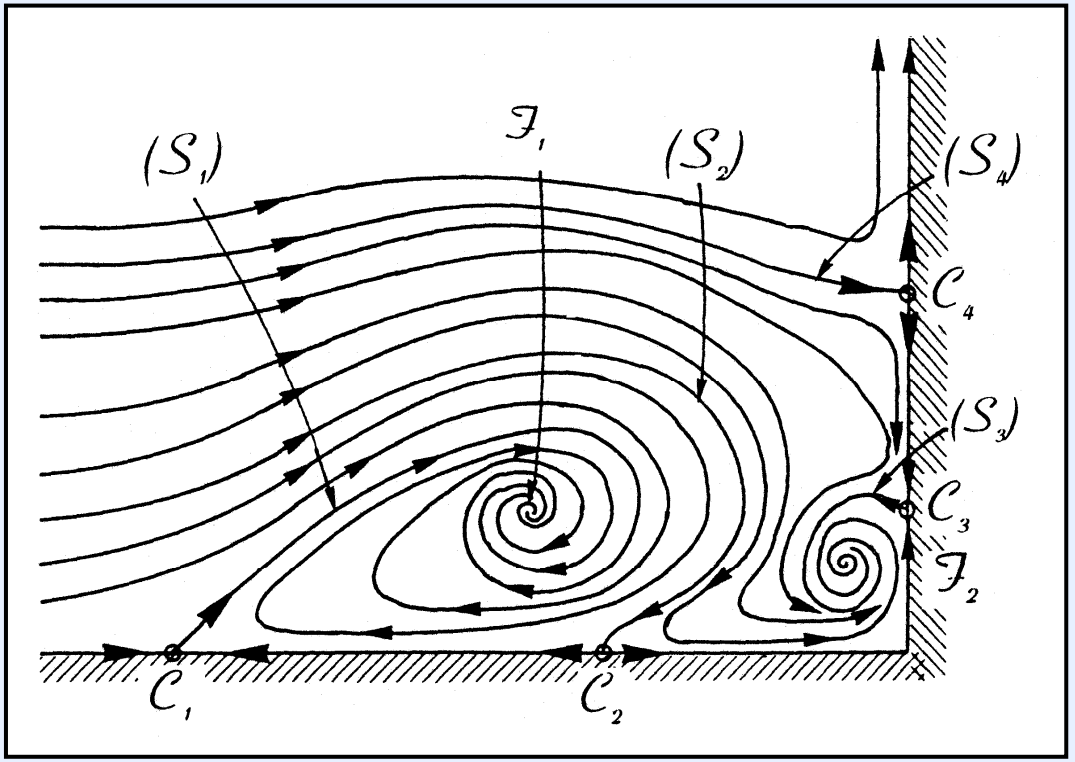


Structure with two detachments

Separation induced by a blunt obstacle
Flow in the symmetry plane. Variants

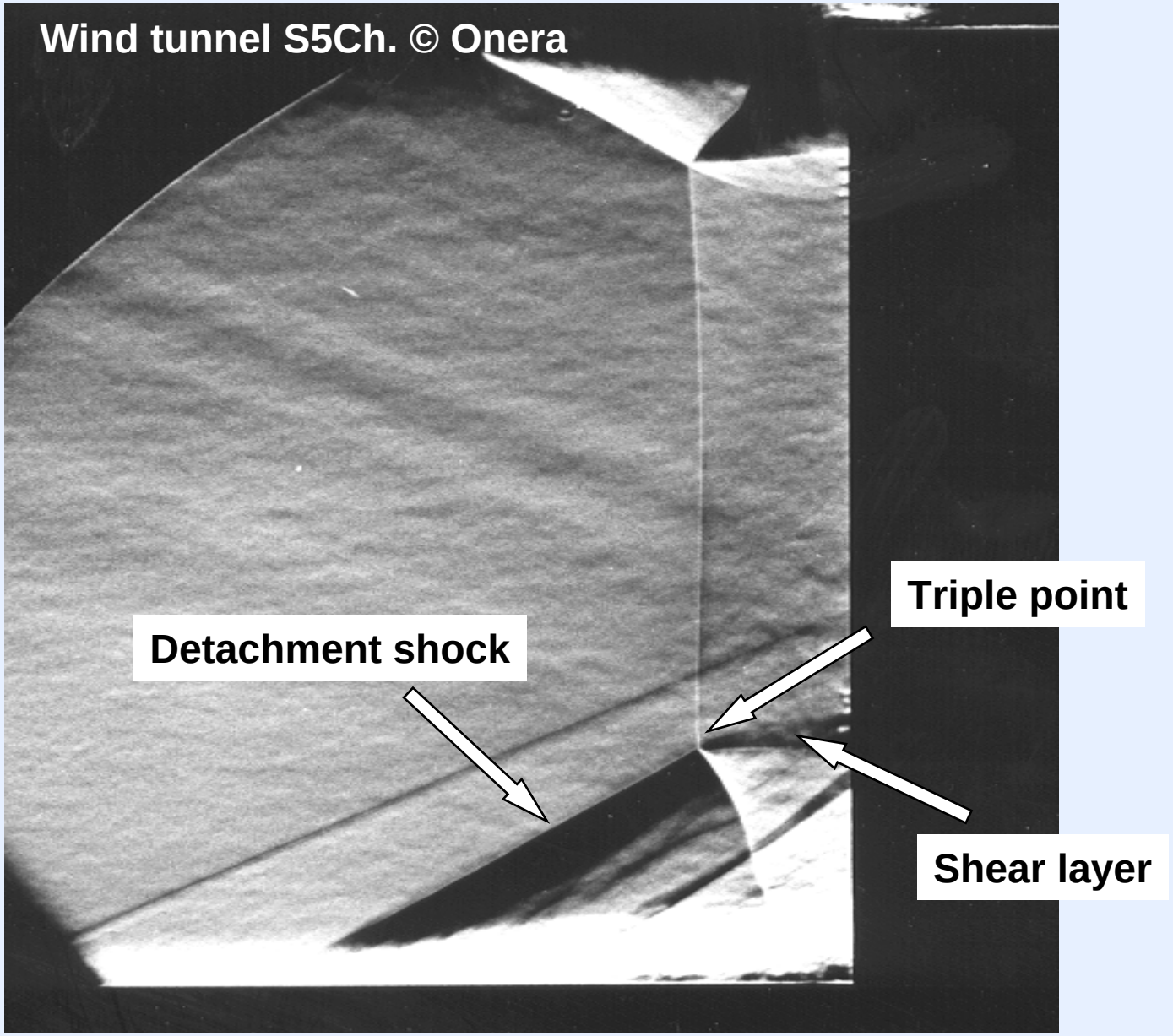


Attachment at the obstacle foot

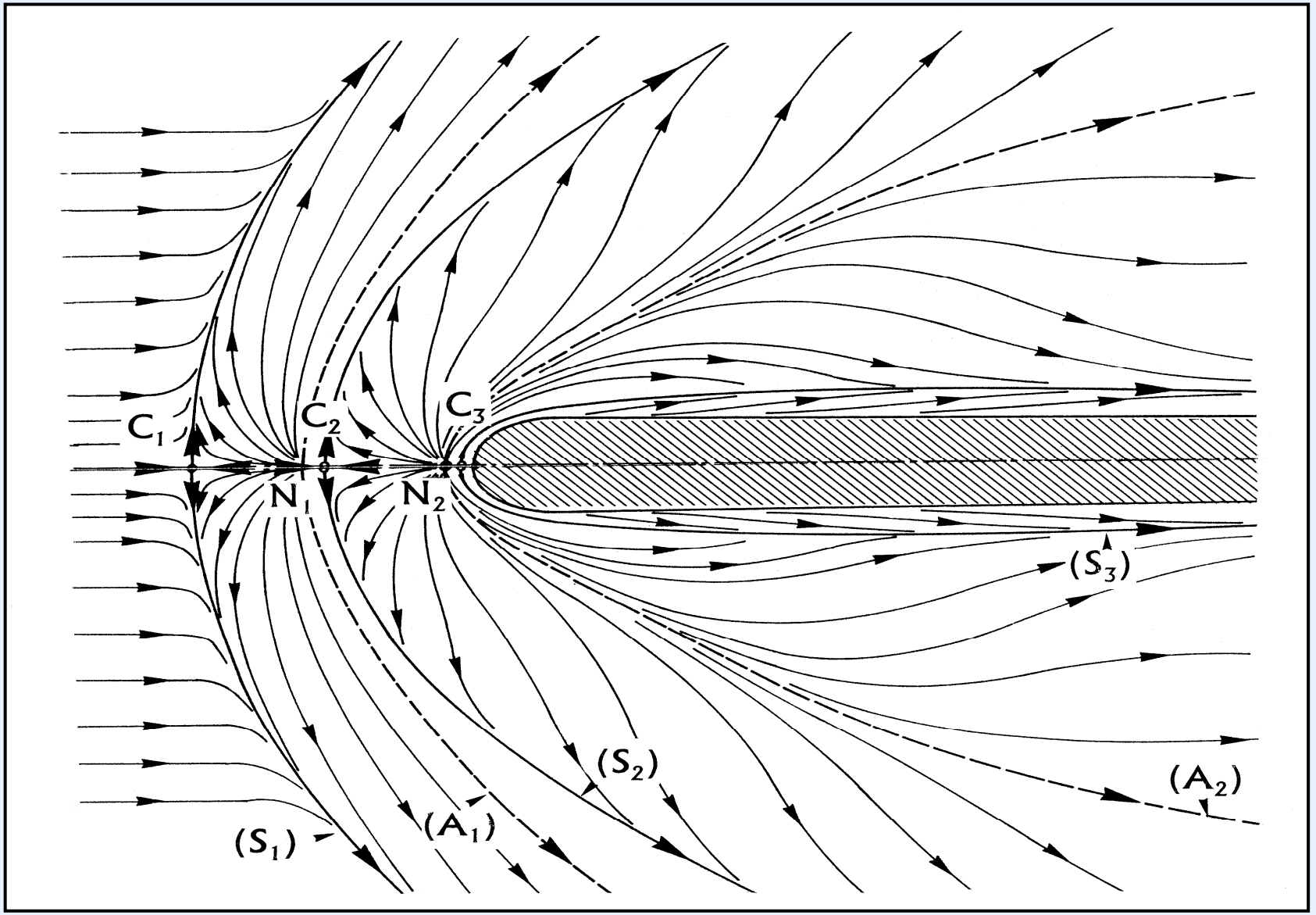


Detachment on the obstacle

Detachment induced by an obstacle in supersonic flow

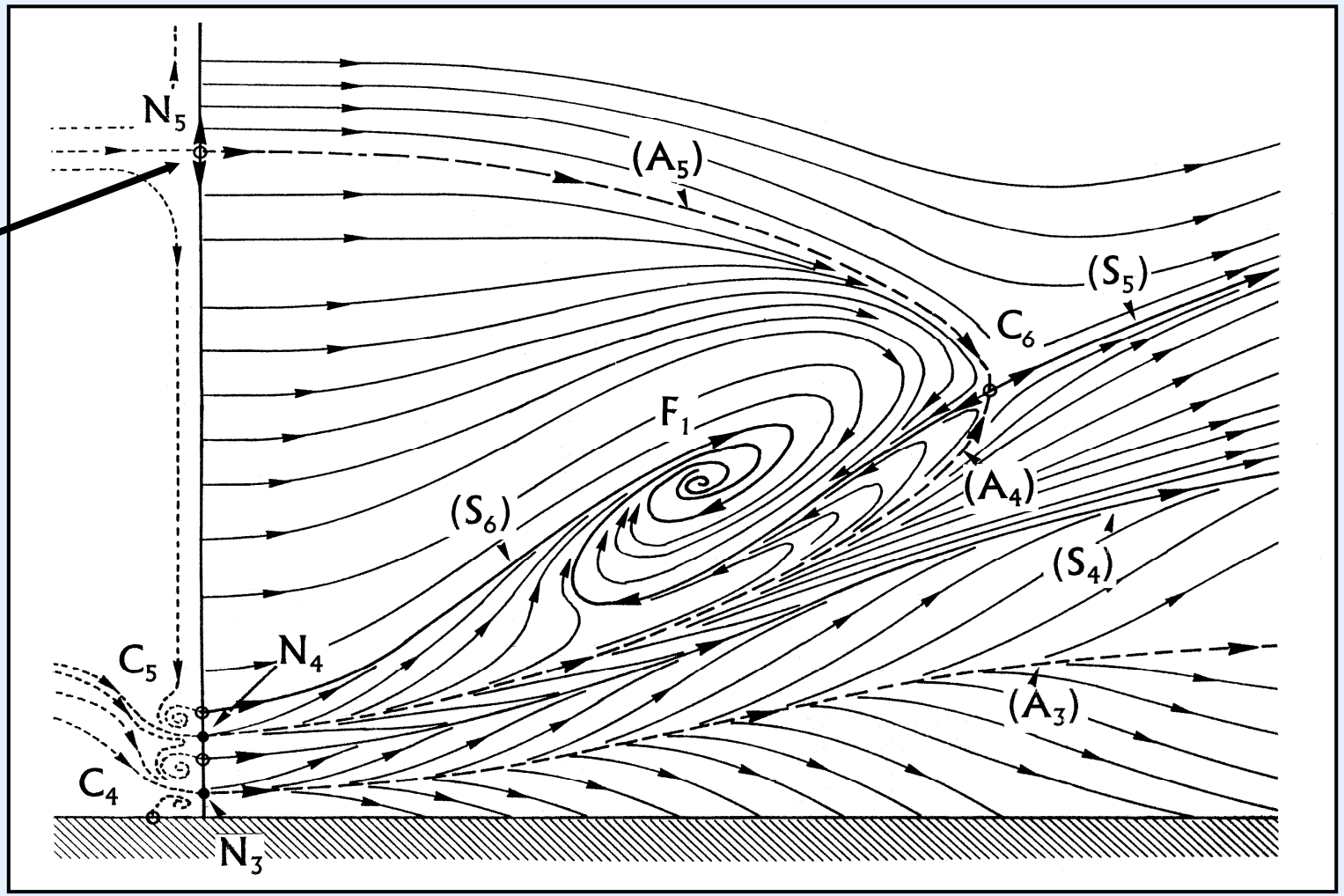


Detachment induced by an obstacle in supersonic flow
Skin friction line pattern on the horizontal floor

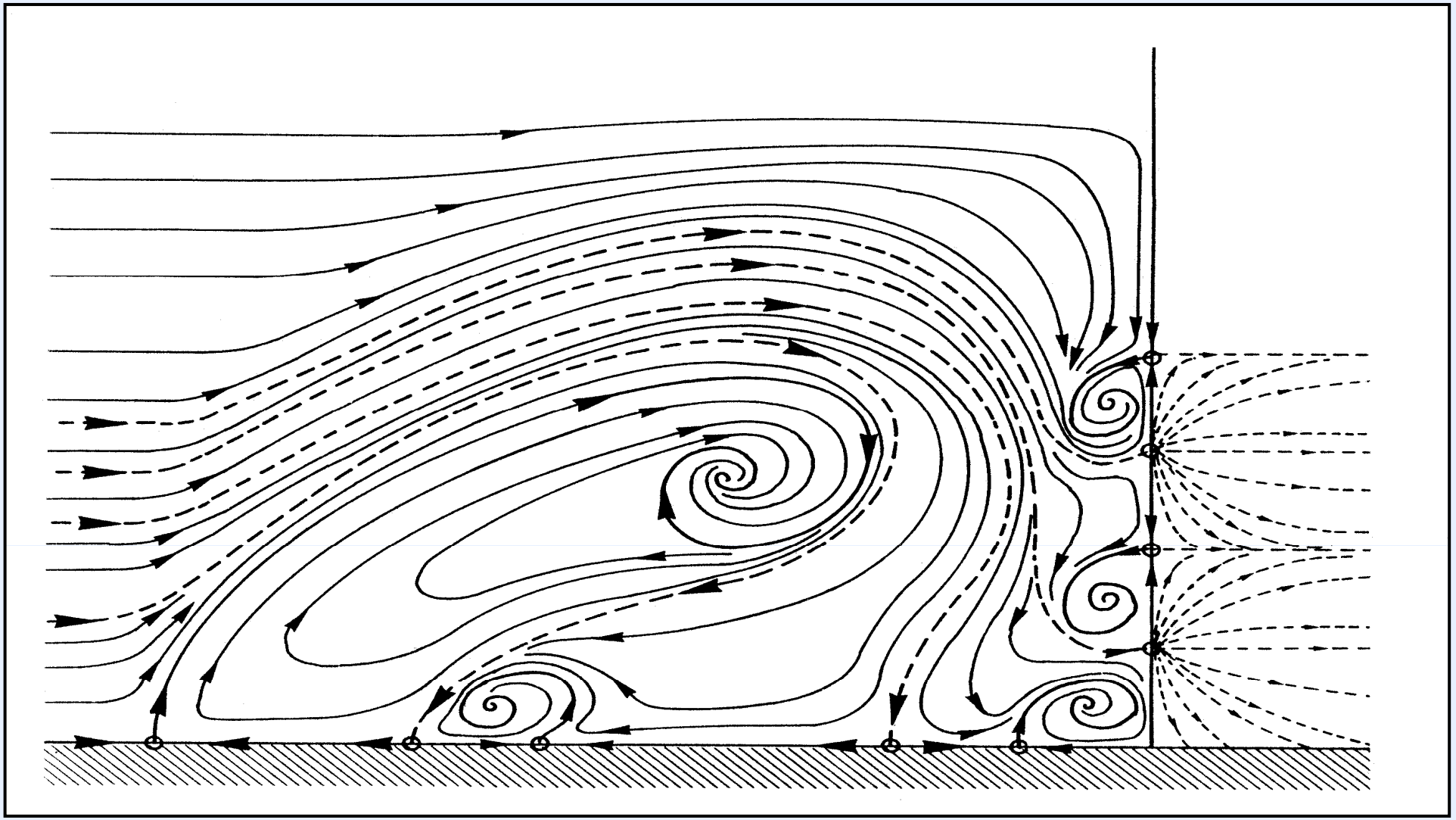


Detachment induced by an obstacle in supersonic flow
Skin friction line pattern on the obstacle

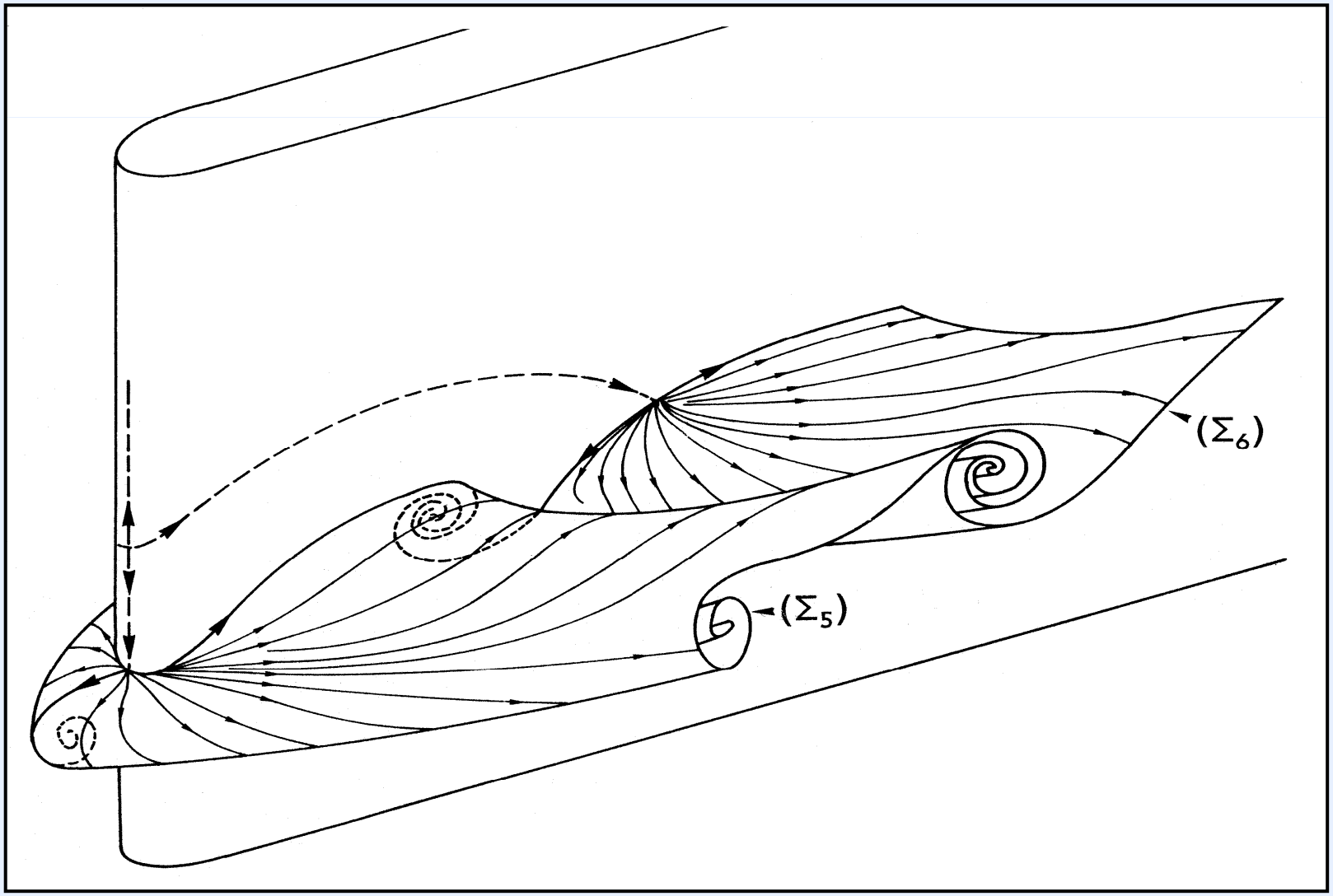
Impact of the shear layer



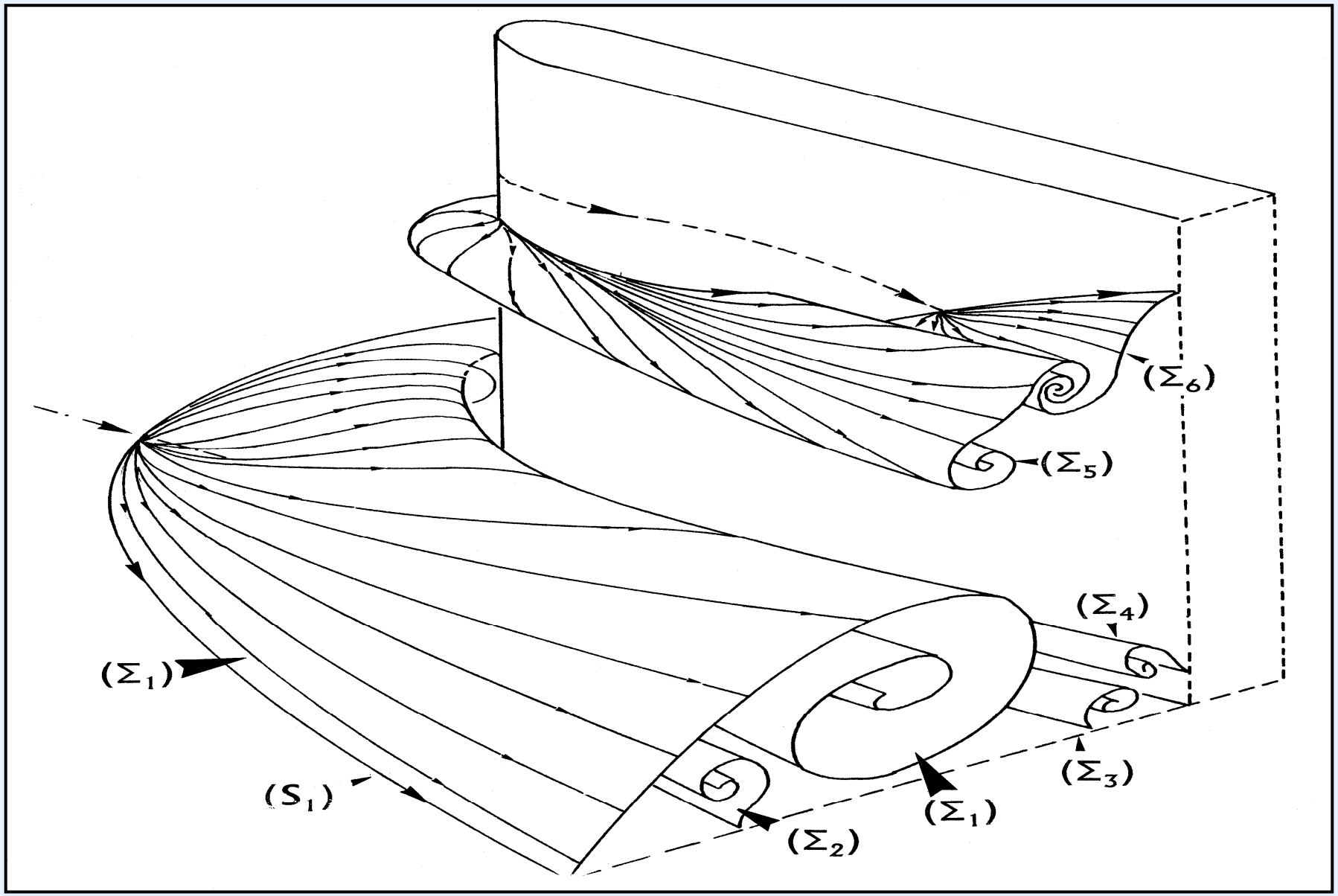
Separation induced by a blunt obstacle
Flow in the vertical symmetry flow



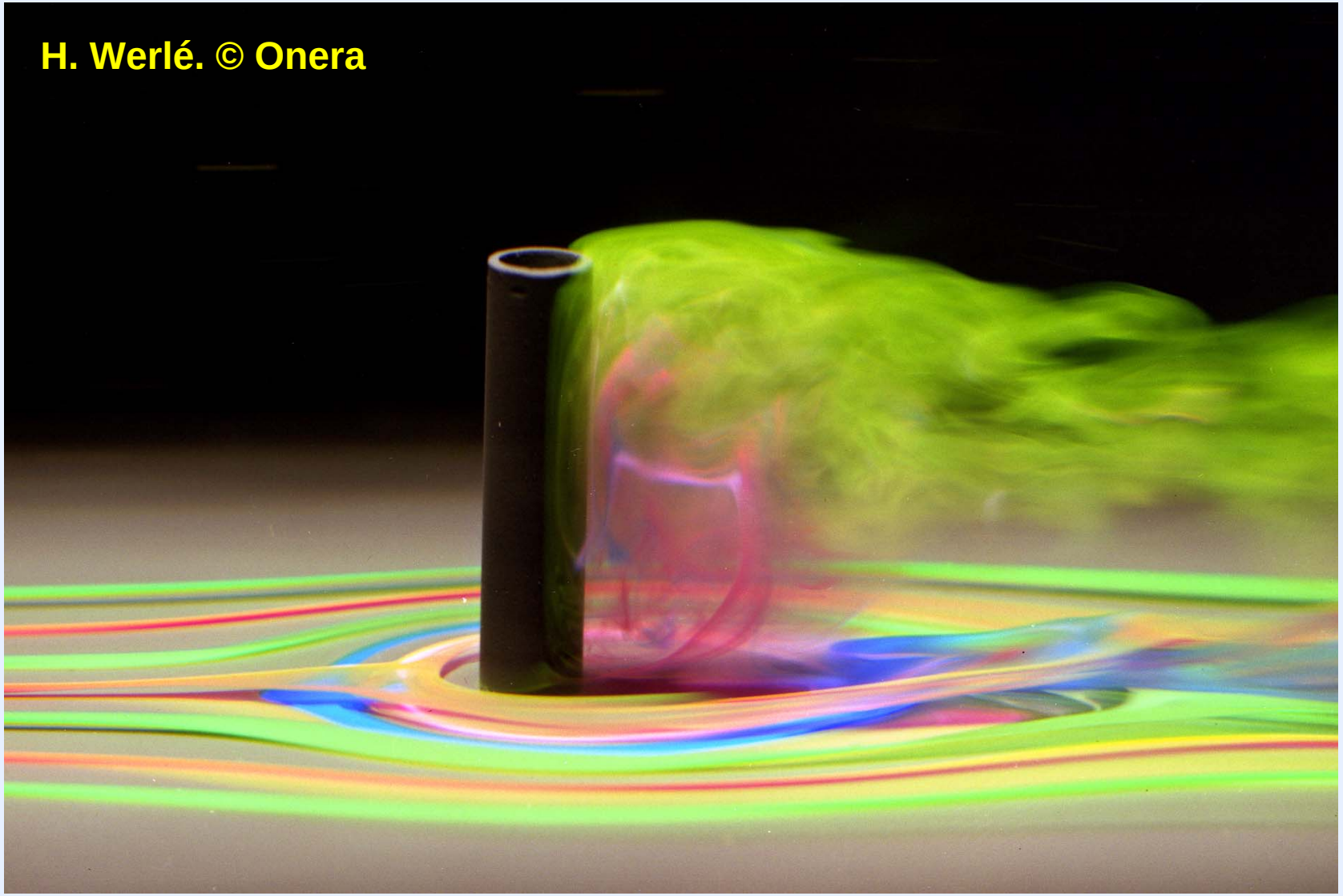
Separation induced by a blunt obstacle
Detachment surfaces forming on the obstacle



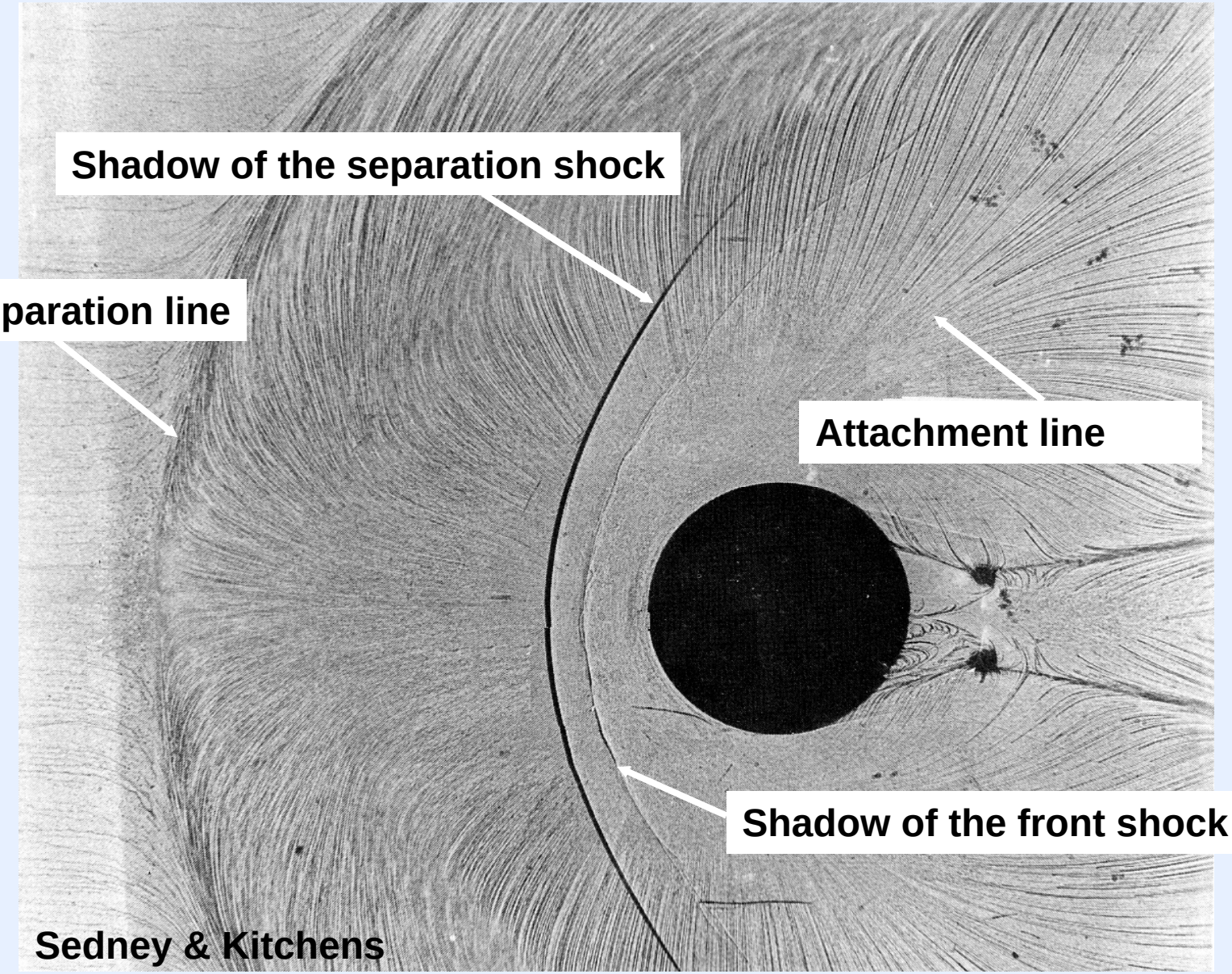
Separation on a blunt obstacle
The various detachment surfaces



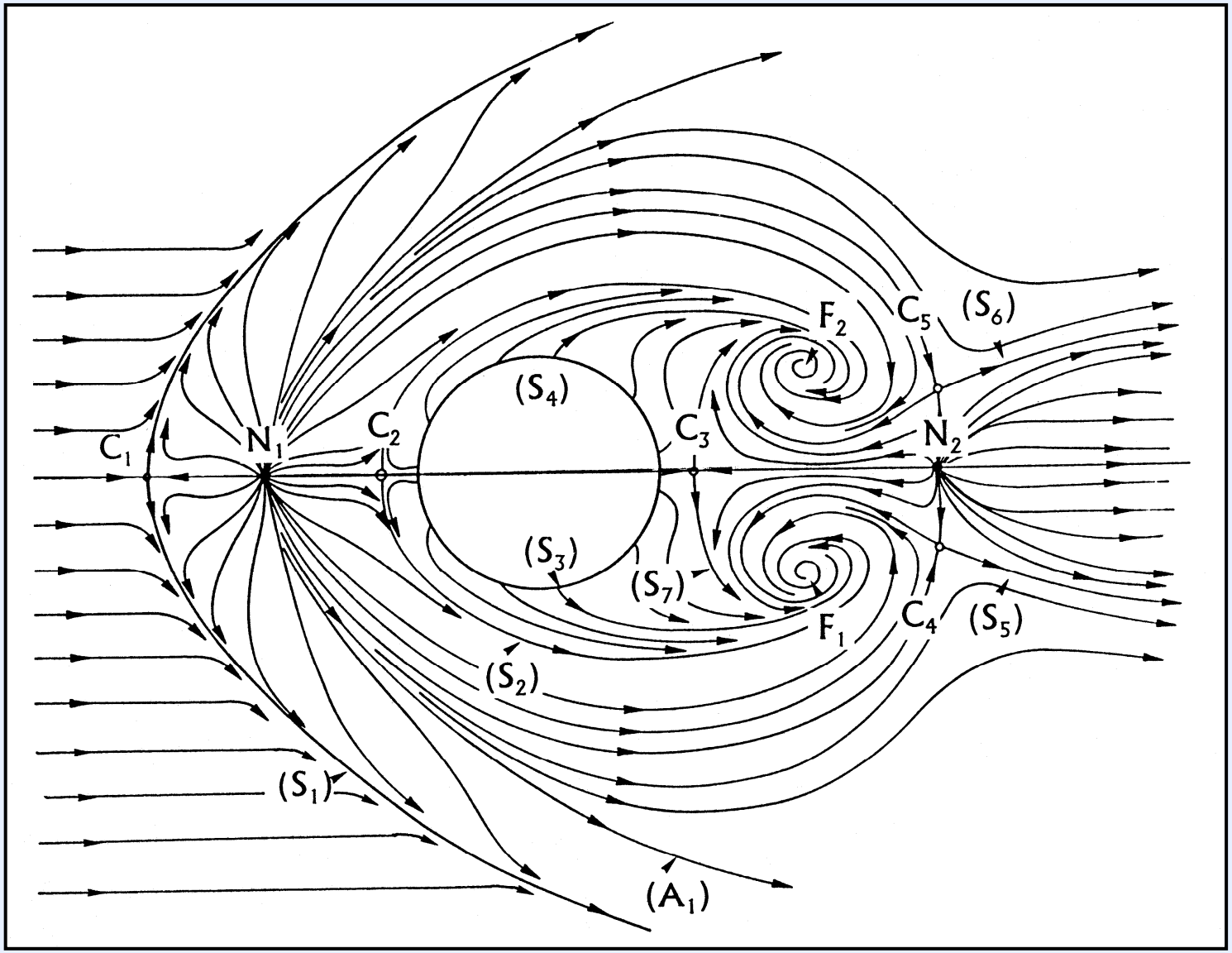
Separation induced by a protuberance



Separation induced by a protuberance in supersonic flow
Surface flow visualisation

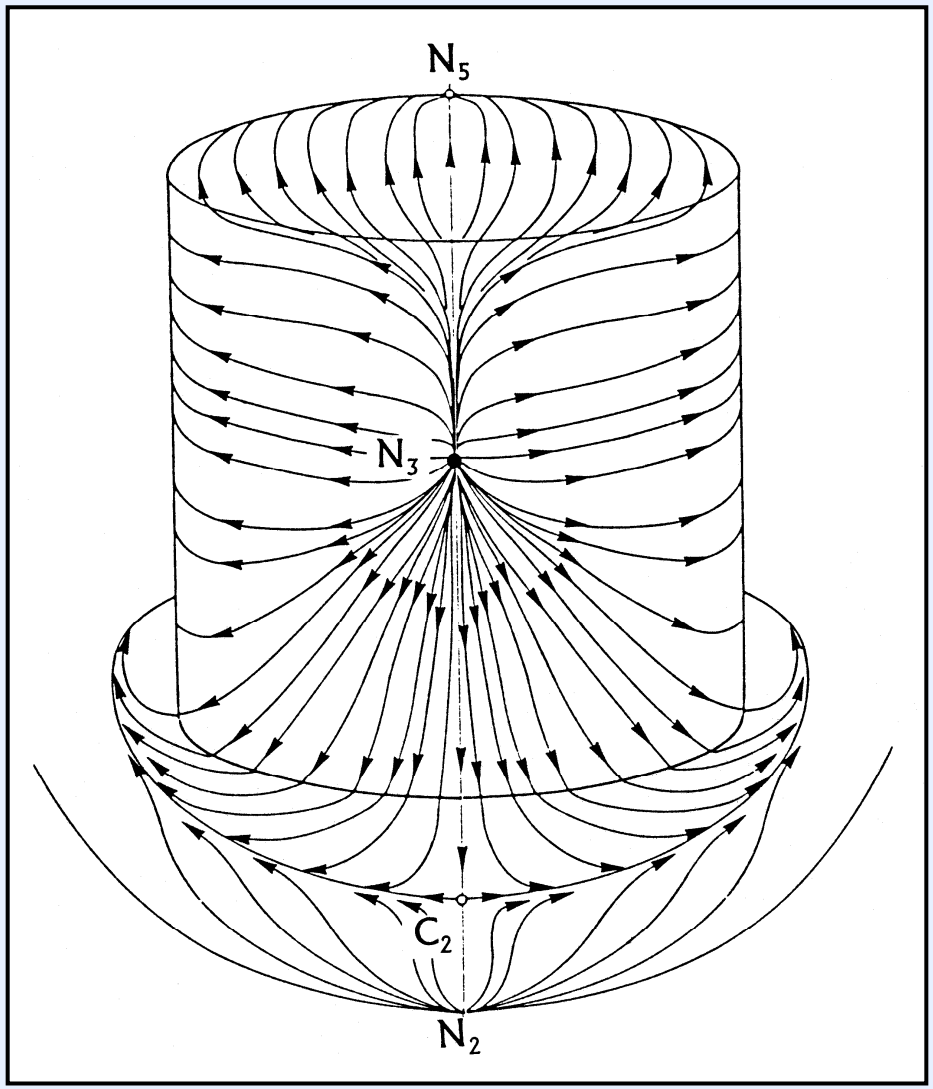


Separation induced by a protuberance

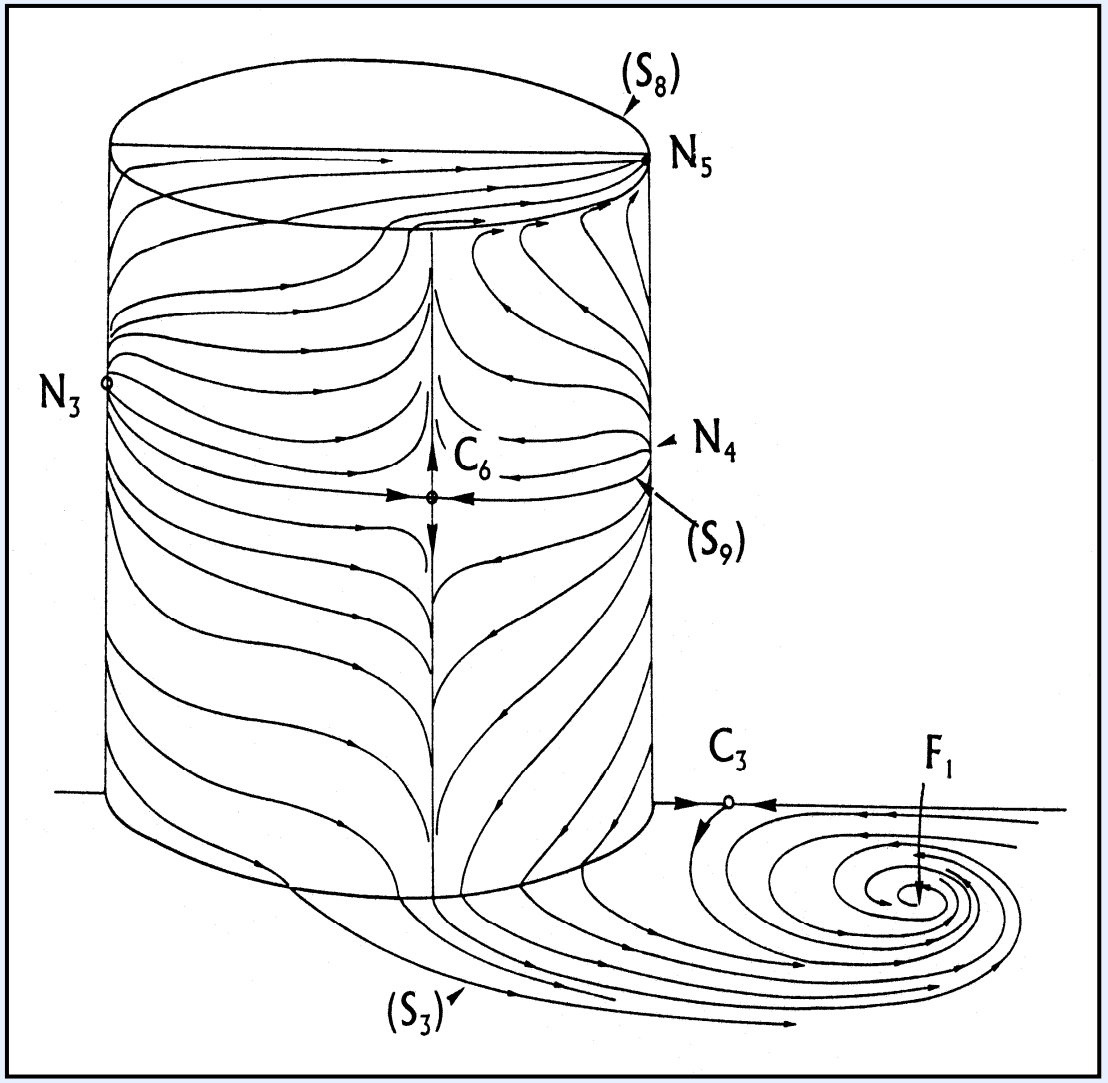


Skin friction line pattern on the flat plane

Separation induced by a protuberance
Skin friction line pattern on the protuberance

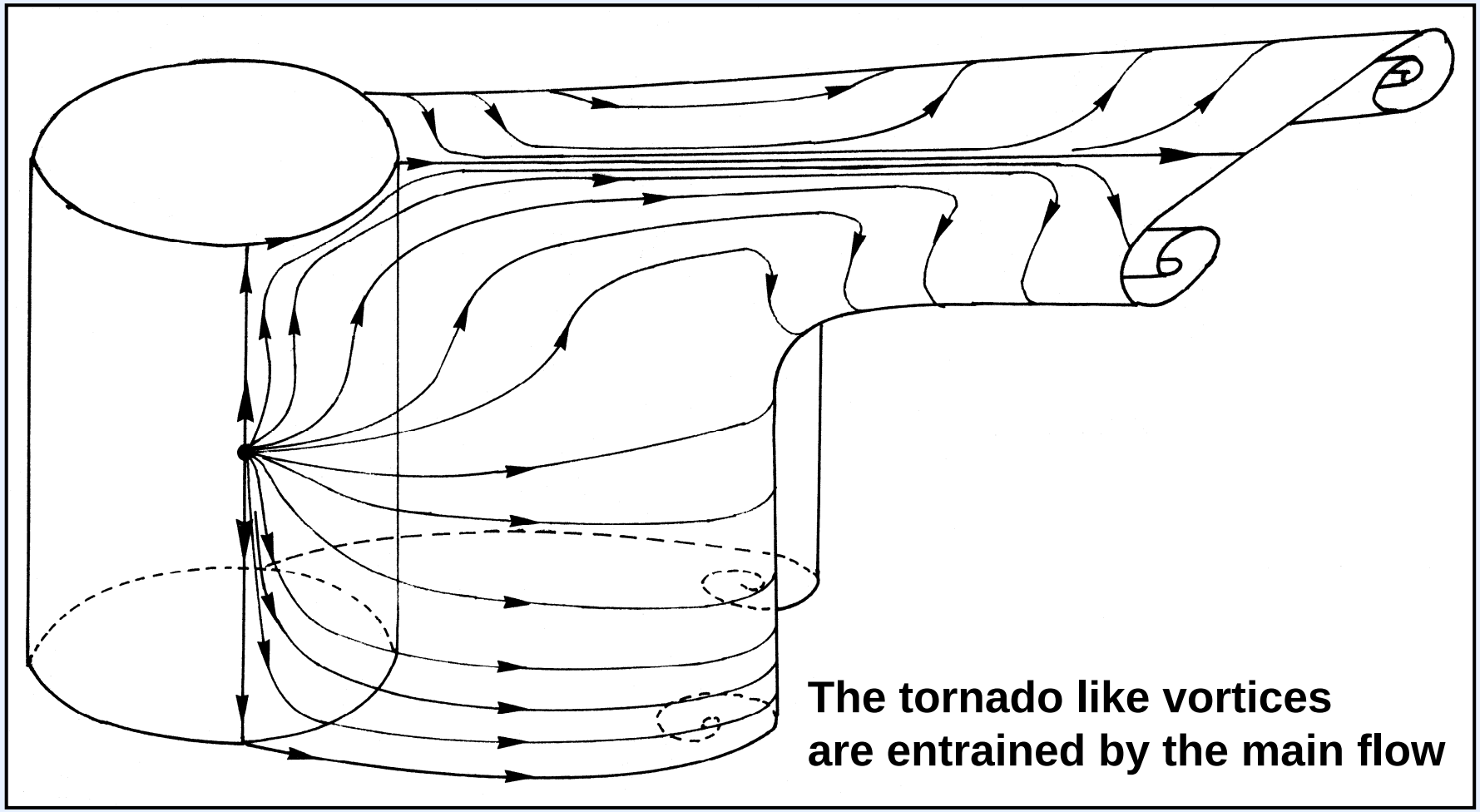


Front view



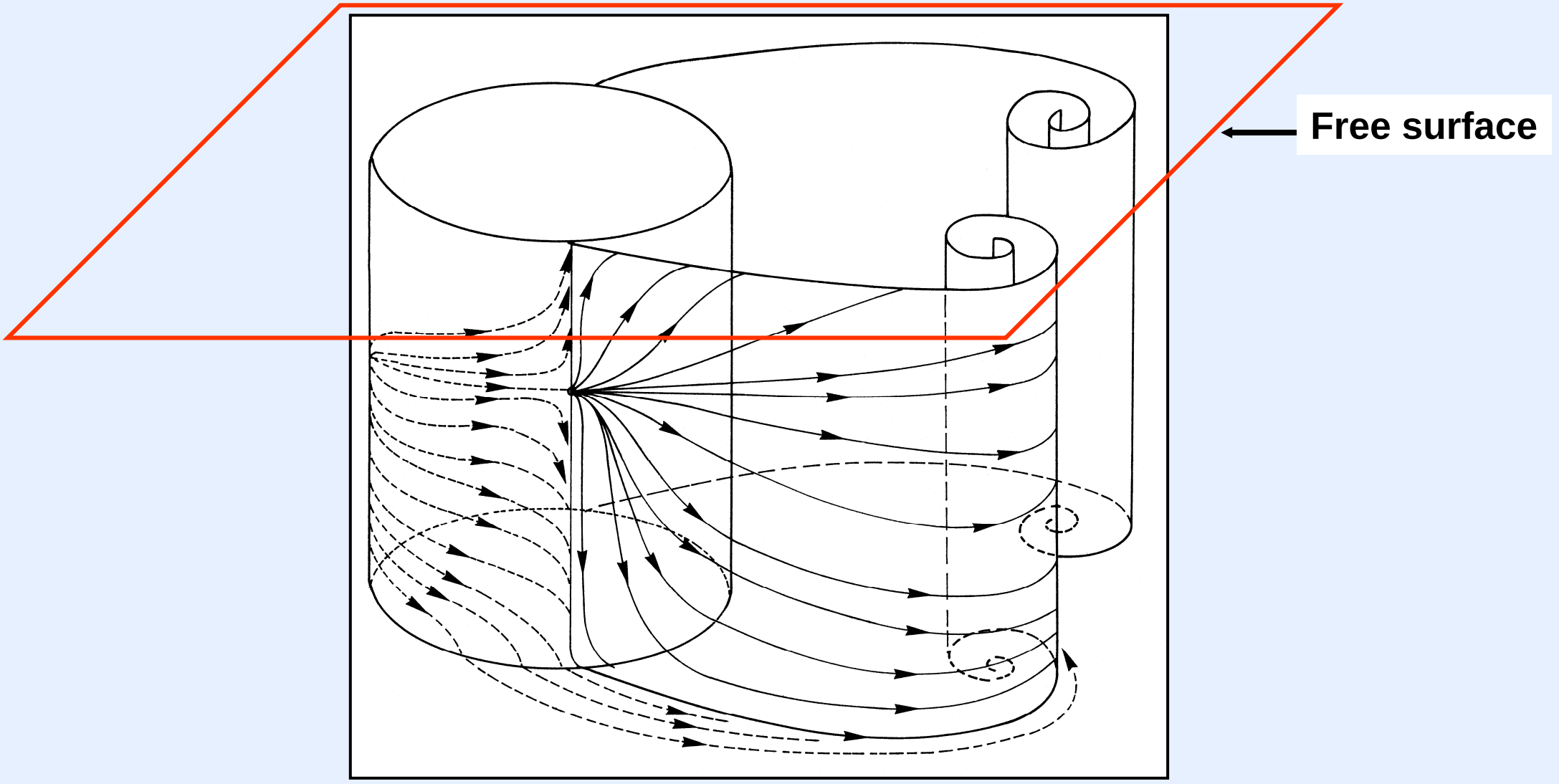
Side view

Separation induced by a protuberance
Rear tornado like vortices



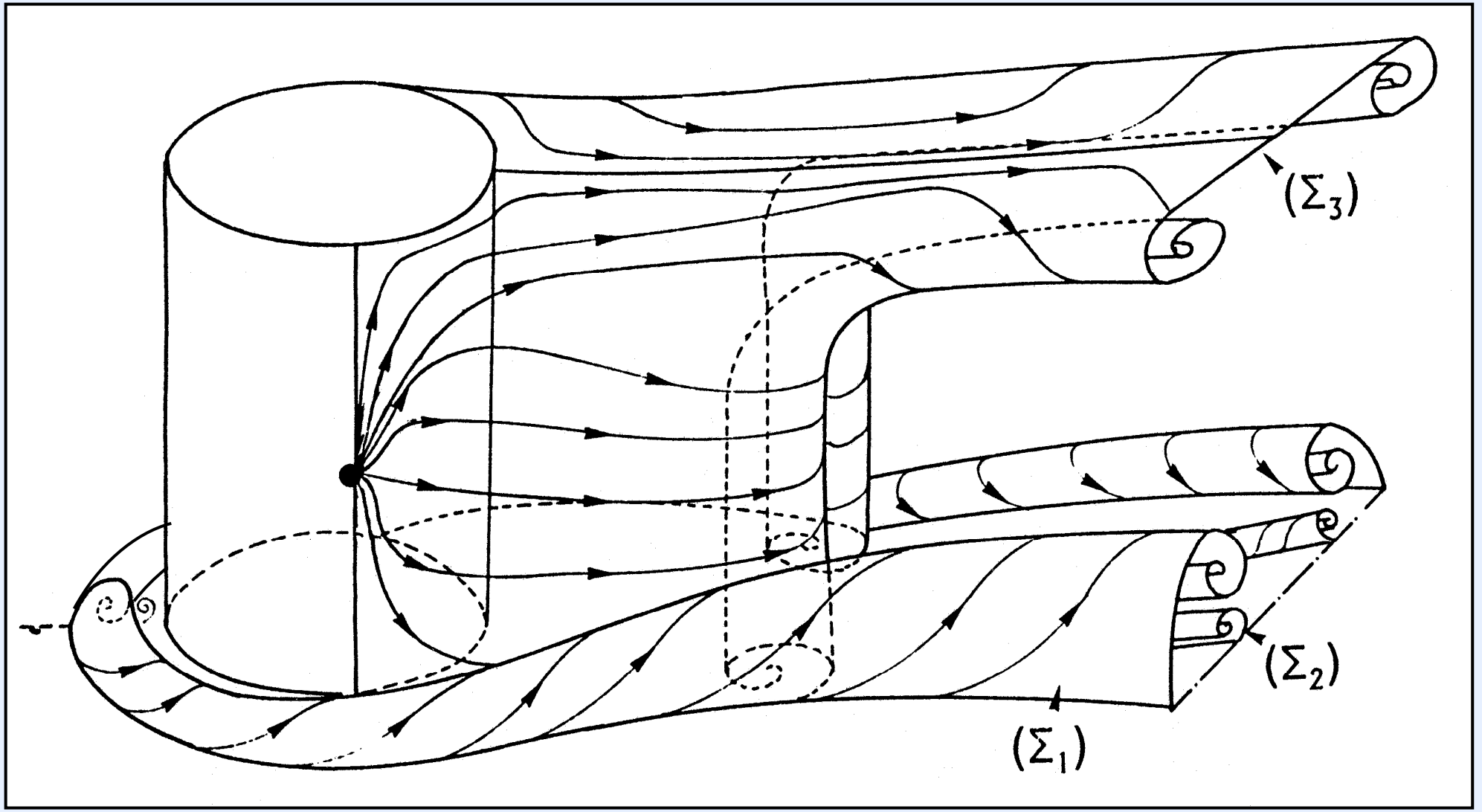
Completely immerged protuberance

Separation induced by a protuberance
Rear tornado like vortices



Configuration with a free surface

Separation induced by a protuberance
The detachment surfaces



Separation induced by a protuberance
Field projected in a downstream vertical plane