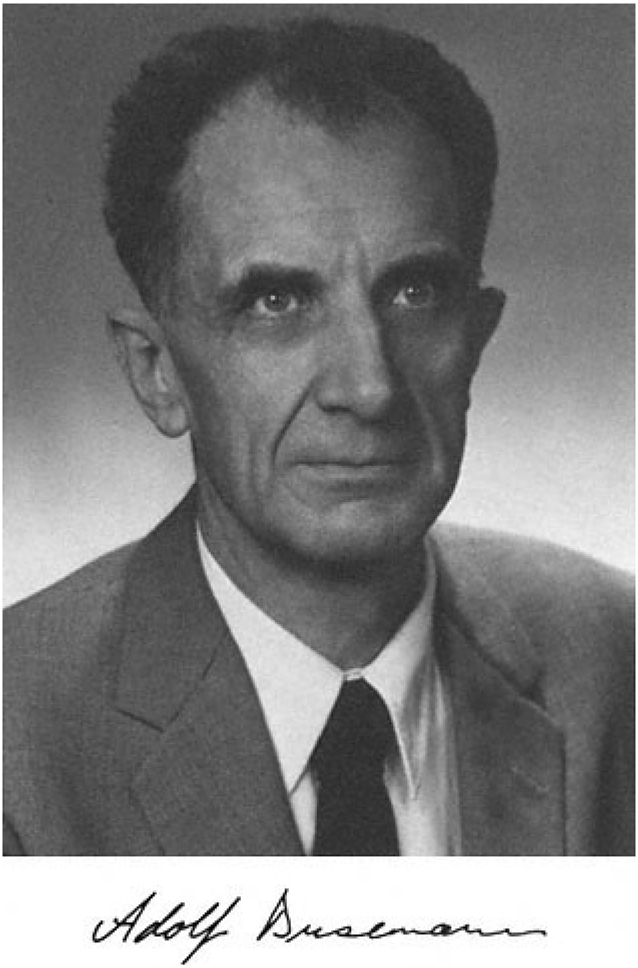
Adolf Busemann

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1901–1986

By Robert T. Jones

Adolf Busemann, an eminent scientist and world leader in supersonic aerodynamics who was elected to the National Academy of Engineering in 1970, died in Boulder, Colorado, on November 3, 1986, at the age of eighty-five. At the time of his death, Dr. Busemann was a retired professor of aeronautics and space science at the University of Colorado in Boulder.

Busemann belonged to the famous German school of aerodynamicists led by Ludwig Prandtl, a group that included Theodore von Karman, Max M. Munk, and Jakob Ackeret. Busemann was the first, however, to propose the use of swept wings to overcome the problems of transonic and supersonic flight and the first to propose a drag-free system of wings subsequently known as the Busemann Biplane. His "Schock Polar," a construction he described as a "baby hedgehog," has simplified the calculations of aerodynamicists for decades.

Adolf Busemann was born in Luebeck, Germany, on April 20, 1901. He attended the Carolo Wilhelmina Technical University in Braunschweig and received his Ph.D. in engineering there in 1924. In 1930 he was accorded the status of professor (Venia Legendi) at Georgia Augusta University in Goettingen. In 1925 the Max-Planck Institute appointed him to the position of aeronautical research scientist. He subsequently held several positions in the German scientific community, and during the war years, directed research at the Braunschweig Laboratory.

In the late 1920s Italy was producing the fastest airplanes in the world and had won the famous Schneider Trophy in competition with American racers. To further development in this arena, the Italian government, under Mussolini, decided to hold an international meeting on the problems of high-speed aeronautics—the 1935 Volta Congress. The American delegation, which included Eastman N. Jacobs of the National Advisory Council on Aeronautics's Langley Laboratory and Theodore von Karman, traveled to the meeting on the luxurious *Conte de Savoia,* courtesy of the Italian government.

At this early period, the maximum speed that had been achieved, even by the Schneider Cup racers, was less than 300 miles per hour, and the idea of flying at supersonic speeds was far from the consciousness of the aeronautical community. Yet it was at this meeting that Busemann presented his first theory of the effect of sweep in reducing the drag of a wing at supersonic speed.

In his Volta Congress paper, Busemann used the so-called independence principle, which states that the air forces and pressures on a sufficiently long and narrow wing panel are independent of that component of the flight velocity in the direction of the long axis. The air forces, then, depend only on the reduced component perpendicular to the long axis. The independence principle had been used previously by Munk in a discussion of the effect of sweep on lateral stability, but no one had thought of using it to reduce the effective Mach number of the wing.

Busemann's 1935 theory was incomplete in the sense that only wings having supersonic sweep were considered; the component velocity perpendicular to the edge, although reduced, remained supersonic. In this configuration a wave drag would still exist, although the force would be directed partly inward by the inclination of the wing panels. Later, during the war, Busemann extended his theory to include subsonic sweep, placing the wing panels inside the Mach cone and thereby reducing the effective component velocity to a subsonic value. In this configuration the wave drag would disappear completely in the limiting case.

During the war years, communication with German scientists was lost, and my own somewhat belated discovery of the sweep effect, which emphasized subsonic sweep, was not immediately accepted by American aerodynamicists, including those who had attended the Volta Congress. Consequently, the first American supersonic airplane, the X-1, had no sweep. However, the National Advisory Council on Aeronautics decided to test the idea, and Robert Gilruth was able to show experimentally that the drag of a wing having forty-five degrees of sweep can be as little as one tenth that of a straight wing at Mach one.

At the end of the war, a group of American scientists traveled to Germany to learn what progress had been made in aerodynamics during the preceding years. The group included von Karman, H. S. Tsien, H. L. Dryden, and George Schairer of the Boeing Company. Schairer relates that the validity of my proposal was a principal topic of discussion during the twenty-six-hour flight to Europe.

On arrival, the group found that much research had been done on the sweep effect. When the group finally met with Busemann, von Karman asked, "What is this about wing sweep?" According to Schairer, Busemann's face lit up and he said, "Oh, you remember, I read a paper on it at the Volta Congress in 1935." Busemann went on to remind them that at a dinner following the meeting, Luigi Crocco, the prominent Italian aerodynamicist, had sketched an airplane having swept wings "and a swept propeller," labeling it "the airplane of the future."

Schairer recalls that five of the 1935 dinner guests were present at the 1945 interview, and all remembered the incident, although they had completely forgotten about the wing sweep concept during the ten-year interval. How could this have happened? Clearly, Busemann's thinking was ahead of its time. Perhaps also, as a true scientist, he had emphasized too much the limitations of his theory.

In his biplane concept, Busemann disclosed an arrangement of airfoils in which the wave system would be completely trapped between the two wings of a biplane, resulting in zero wave drag but also, unfortunately, zero lift. In principle, one could form a lifting system with no wave drag by flying the upper wing of the biplane in close proximity to a flat reflecting surface. In one experiment at the National Aeronautics and Space Administration's Ames Research Center, we enclosed the streamlines of a Busemann biplane within a tube bounded by a circular cylinder and demonstrated the absence of wave drag.

Among the most interesting and important of Busemann's ideas revealed at the end of the war was his theory of supersonic conical flow. By means of a transformation, which he attributed to Chaplygin, Busemann reduced the flow around triangular wings and around wing edges to a problem of conformal mapping in the complex plane. The conical flow theory has played an important role in subsequent studies of wing theory.

After coming to the United States in 1947, Busemann devoted considerable effort to analyze the sonic boom made by a supersonic transport. The sonic boom phenomenon was for a time not well understood, being attributed to a focusing along a caustic curve produced by the accelerated motion of the airplane. Of course, everyone knew that a supersonic plane would make waves, but who would think of the waves reaching all the way to the ground from 60,000 feet? Busemann analyzed this problem carefully and for several years sought a means to eliminate the boom. The fact that he could not find a satisfactory solution probably means that none exists.

Outwardly Adolf Busemann seemed an intense, almost ascetic figure. His scientific discussions, however, frequently relied on slightly humorous, sometimes outrageous, but very concrete analogies. Thus, writing on the occasion of Busemann's seventieth birthday, Professor Milton Van Dyke of Stanford University said:

> Others of his friends will certainly praise his great contributions to fluid mechanics. I would like to recall a peripheral aspect of his genius that gives us a glimpse of how that inventive mind works. He thinks always in concrete images. Thus in extending our knowledge of fluid motion he has created a fantastical Alice in Wonderland world filled with imaginary animals, shapes, and people. Has any bestiary a more lovable animal than the "baby hedgehog"—or any utopia a shape more pleasantly named than the "apple curve"? My favorite character in all this magical kingdom is the "ingenious pipefitter," endlessly fitting his stream tubes around a body in the hope of constructing a transonic flow and then, like Sisyphus, starting over again when he fails to match the condition at infinity. I hope that these charming creatures will thrive in the literature as long as Busemann's ideas and equations themselves.