THE HISTORY OF TRANSPORTATION, WITH A PEAK INTO THE FUTURE

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Smithsonian Institution
Washington, DC

Transportation Beyond 2000:
Engineering Design for the Future

September 26-28, 1995

PREAMBLE

(EDITORIAL)

"Imagine a world airline with those 20 new *Martin Mars Transports!*"

Yes, just imagine an airline equipped with 20 huge Mars flying boats like those now being built for the U. S. Navy! World's largest planes, they weigh 82 tons, ten tons more than the original Mars. World's safest overocean aircraft, they can take off or land at sea. World's most efficient planes, they will operate at the unbelievably low cost of 10 cents per ton mile!

What 20 Martin Mars Could Do

Operating as a fleet of luxury liners, 20 Mars transports could afford complete living facilities for 1600 passengers on non-stop flights of 24 hours duration. As cargo ships, they could rush 400 tons of freight to any spot on earth in 3 days or less. And as mail carriers they could speed 20 million letters to Europe in a few hours. Supreme in the skies, these great aircraft are opening a new era in transportation!

Tested And Proven

No untried, visionary design, the Mars type has been tested and proven in grueling wartime service with the Navy. Victory will find Mars production lines fully manned and tooled to assure prompt delivery and minimum production costs. No wonder Martin Mars transports are known as, "the answer to an airline's prayer!"

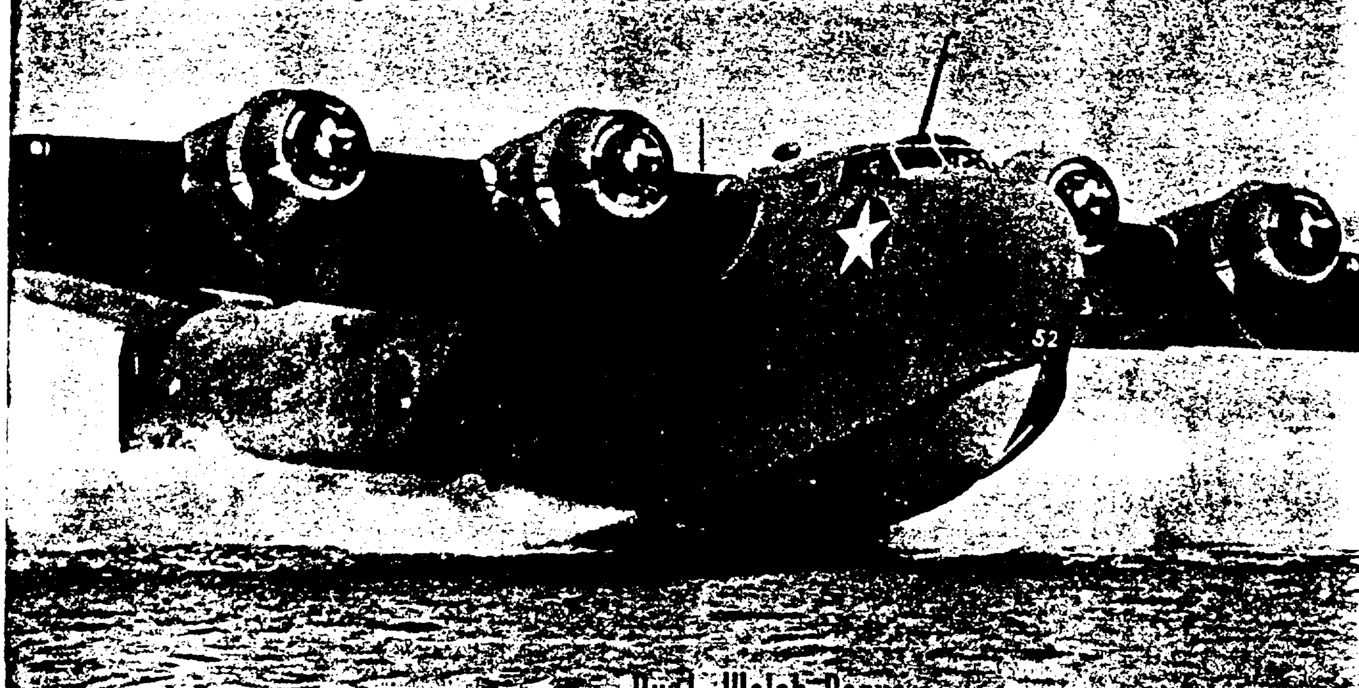
THE GLENN L. MARTIN COMPANY,
BALTIMORE 3, MARYLAND
THE GLENN L. MARTIN-NEBRASKA COMPANY—OMAHA

Martin
AIRCRAFT
Builders of Dependable Aircraft Since 1909

Just How Big Are The New Mars Transports?

- If stood on one wing, the Mars' other wingtip would tower 200 feet into the air . . . as high as a 20-story building.
- Mars' wings are so thick that crew members can enter them to service engines while in flight.
- These Mars transports each have a cubic content equivalent to a 14 to 16 room mansion.
- Each Mars contains 1½ million rivets—4¾ miles of wiring—⅝ of a mile of piping—18 inter-plane phones.
- When fully fueled, these ships carry a tank-car of gasoline for their 4 huge engines.

TOMORROW'S USE OF TODAY'S PLANES



By L. Welch Pogue, CHAIRMAN CIVIL AERONAUTICS BOARD

(L. Welch Pogue's article is the fourth in a series by aviation's top-flight executives. While Air Trails is designed for presenting the more popular aspects of current aviation, thinking readers have expressed interest in matters of moment within the industry. To fill this demand, future lead articles will continue authoritative discussions of topics of paramount importance to your industry.—Editor.)

HOW long will the war continue? How many and what types of surplus aircraft will we have on hand when peace comes? How many war-veteran transports can be used efficiently by our airlines, and how many should we make available to foreign lines? How soon can aircraft manufacturers produce new and more modern types of transport planes? What may be the international arrangements for controlling and regulating international air traffic, and what volume of traffic will be permitted?

Answers to these and many other important questions must be found before we can dispose intelligently of the many-thousand aircraft the United States government will own on the day hostilities cease.

During the war our transport routes have expanded greatly. Under the direction of our armed forces we are operating 150,000 miles of routes. Those planes carry everything from medical supplies to munitions, and provide fast communication all over the world. In addition, our commercial carriers operate some 110,000 miles of regular routes with drastically curtailed fleets.

We have generated a tremendous machinery for air war. With the coming of peace, a great many of these aircraft will lose immediately much of their value. It is very well to say, "Convert them to other uses." But which types of planes and to what uses? The very possession of the vast fleet of bombers and fighters and cargo carriers would prove as great a problem as its lack proved to be when war came.

It is obvious, then, that we must plan for the wisest possible disposition of these planes. Unless our best minds reach sound conclusions with respect to the problem, American progress in air transportation and aircraft development could be arrested for a decade.

No group of individuals, no group of trade associations and councils, no private enterprise whatsoever can cope with the problem successfully. The Federal government alone can hope to take effective action, for the compelling reason that the government will own the tens of thousands of airplanes which will create the problem.

We could, of course, simply make no plans. At the end of the war we could auction the planes to the highest bidders. Were we to take this sort of action, we may be reasonably sure we will have wasted a vast and costly defense reserve, glutted the transport market for years to come and, even more serious, struck a blow at the capacity of the industry to manufacture and develop airplanes from which it could not recover for years.

Such a course not only would hamstring commercial development; it shortly would lay waste to our aerial defenses—a situation of which an alert enemy might readily take sudden advantage.

True, we would possess a military airfleet second to that of no other nation. This would provide insurance against attack, but for only a comparatively short time. Our reserves would become static. We cannot afford to depend upon fixed and unchanging structures, for no instrument of war or peace becomes obsolete so fast as an

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AIR TRAILS *Pictorial*

A STREET AND SMITH PUBLICATION

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COVER PHOTO IN FULL COLOR—COURTESY BELL AIRCRAFT CORP.

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WINGED WORLD

THEODORE ROOSEVELT once said something that could very well be applied today. We forget the exact words, but, in effect, it was "Anyone can make a mistake once. Only a fool makes the same mistake twice." America made her mistakes before this war. Typical was our decision not to fully fortify Guam because it would provoke the Japanese. The next time Guam will be properly fortified. We won't repeat our other errors, either. In aviation, too, there were some slips, due mostly to an intangible something about our outlook; whether it was indifference to what was going on in the world, or lack of imagination, or something else, it is impossible to say. We were looking at the trees instead of the woods.

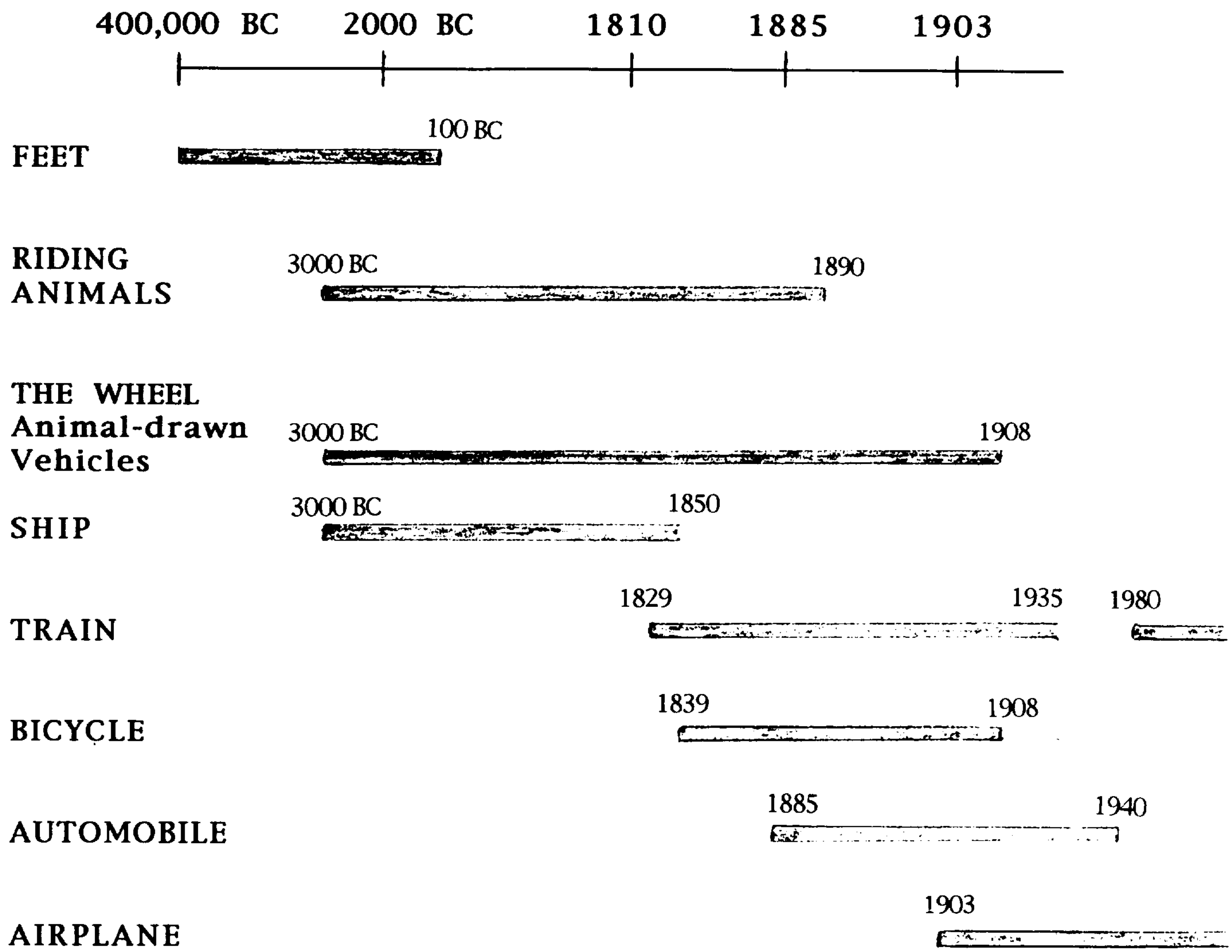
Regardless, we have done marvelously well with the war. We have fine equipment, much of it better than anything comparable in the world, and more of it than all the other air forces of the earth put together. Yes, we can be justly proud of our record in this war. Yet, today, we still make some late starts in experimental aviation. One was the gas turbine and jet propulsion. When, at the time of the Battle of Britain, Italy successfully flew her jet-propelled Caproni-Campini, most of us who should have known better laughed it off as a fraud and the flight photographs as clever trickery. (To keep the record straight Britain's Captain Whittle was then well along with his own experiments.) More recently, Germany has used rocket-propelled fighters, and her Vengeance weapons are admittedly the beginning of a revolutionary trend in warfare the future limits of which no man can pretend to see. The fact that she does these things in desperation should not be an excuse for lack of contemporary pioneering. Now there is a reason why we were not first with jet propulsion. We knew what was cooking. We looked into the matter. But we decided again and again that in the light of the then foreseeable future, such radical proposals were impractical. There we erred, for the future is always soon upon us. It is not that we can't do it. Rather it is that we are too conservative, or too practical in a business-like way, too ready to scorn other people's radical attempts. The truth is that we cannot afford to take chances with our future by not delving into every aspect of every avenue of every possible future aeronautical development.

Research is a guarantee of future existence. For research there must be funds to keep places like the National Advisory Committee for Aeronautics and the Army's Wright Field tooled up with men and equipment to do the job. But just as much, it requires that YOU, you who are in aviation, you who hope to get into aviation, be imaginative in your outlook. Be alert for the faint beginnings of a trend; make a trend your life work, whether it be the perfection of flying wings, turbines, rocket engines, or pushbutton airplanes. But don't let them turn you into a standard AN5 nut and bolt!

AGE

Research is a guarantee of future existence. For research there must be funds to keep places like the National Advisory Committee for Aeronautics and the Army's Wright Field tooled up with men and equipment to do the job. But just as much, it requires that YOU, you who are in aviation, you who hope to get into aviation, be imaginative in your outlook. Be alert for the faint beginnings of a trend; make a trend your life work, whether it be the perfection of flying wings, turbines, rocket engines, or pushbutton airplanes. But don't let them turn you into a standard AN5 nut and bolt!

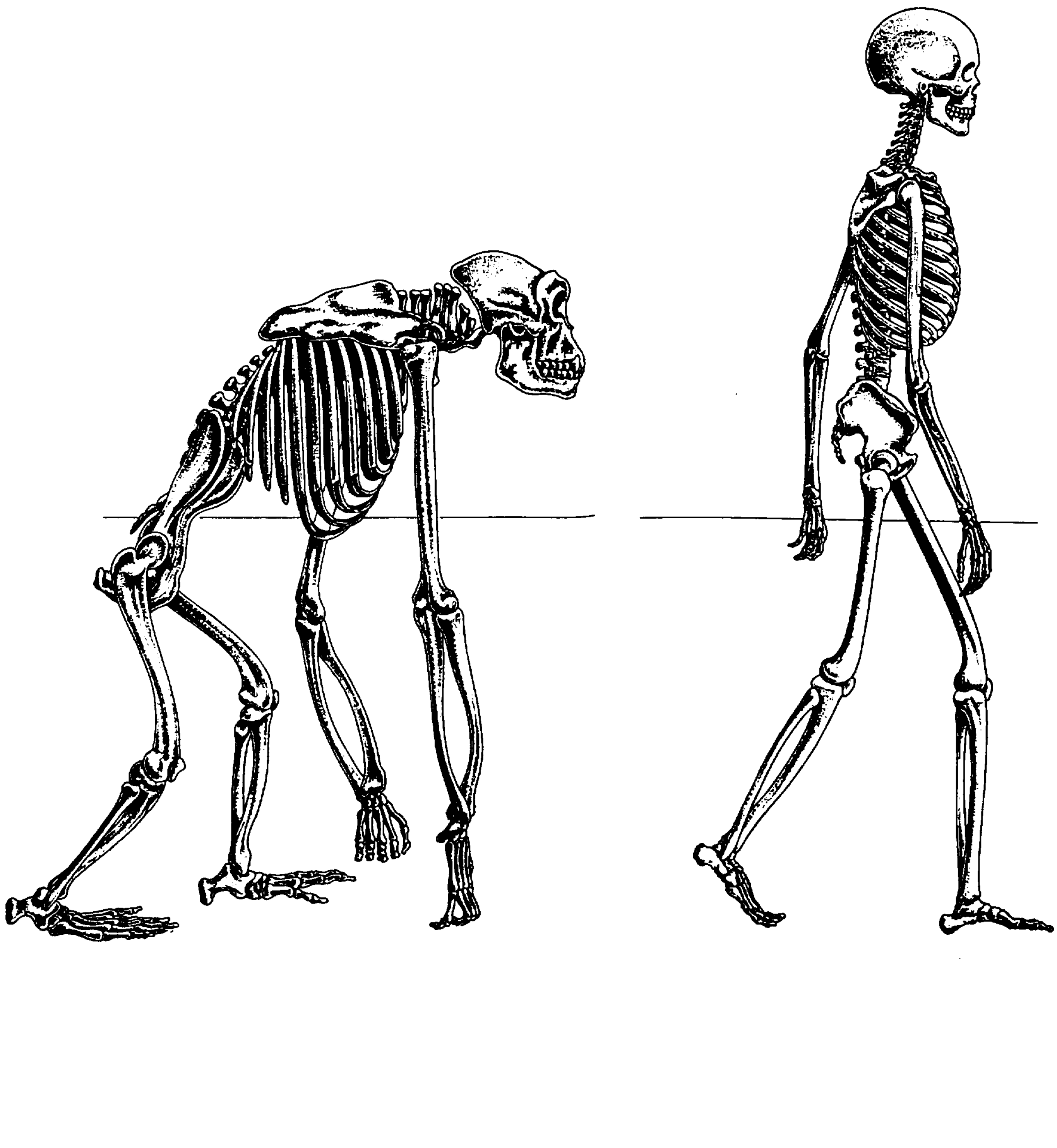
HEYDAYS OF MODES OF TRANSPORTATION

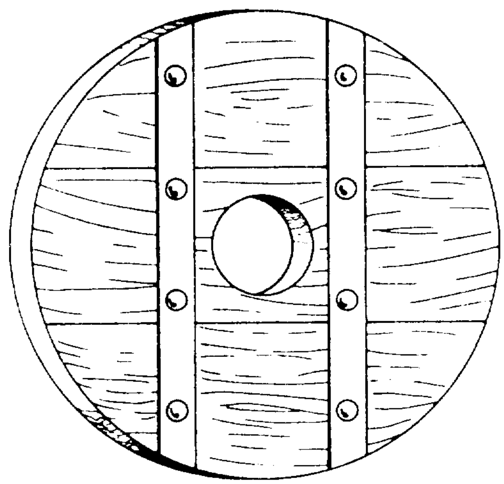


Strut-and-wire biplane

Mature Propeller-driven monoplane

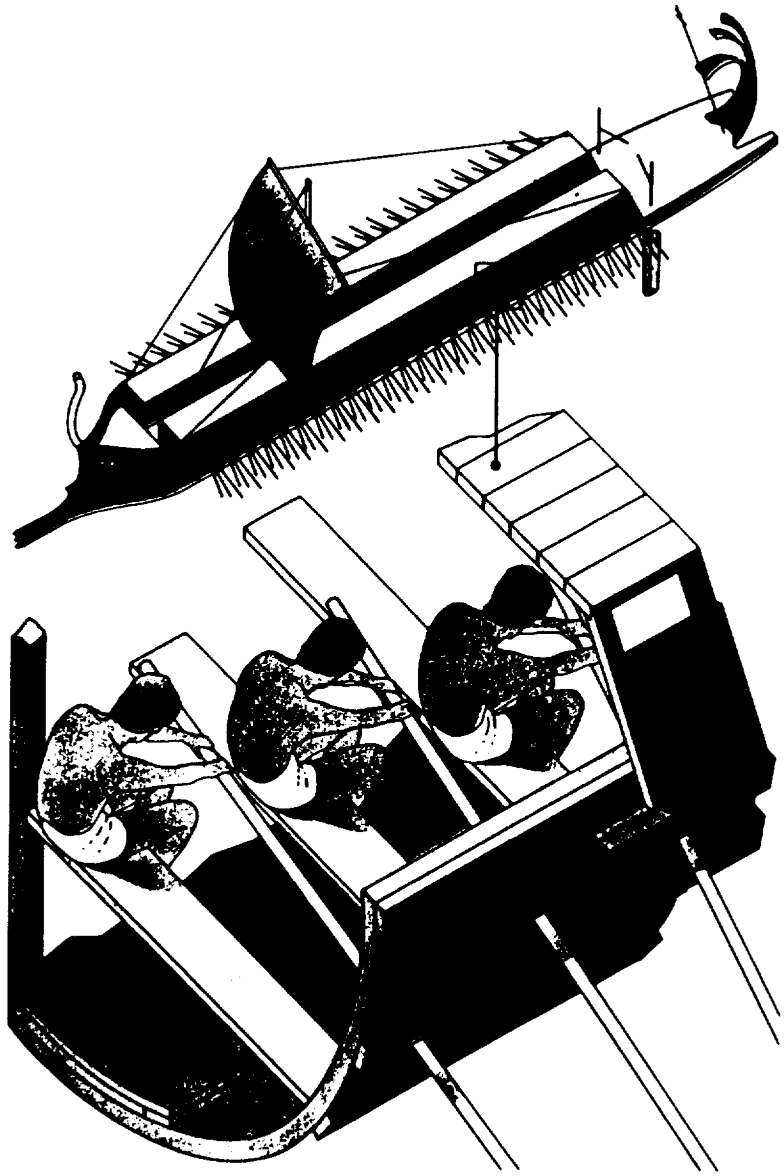
Jet-propelled airplane



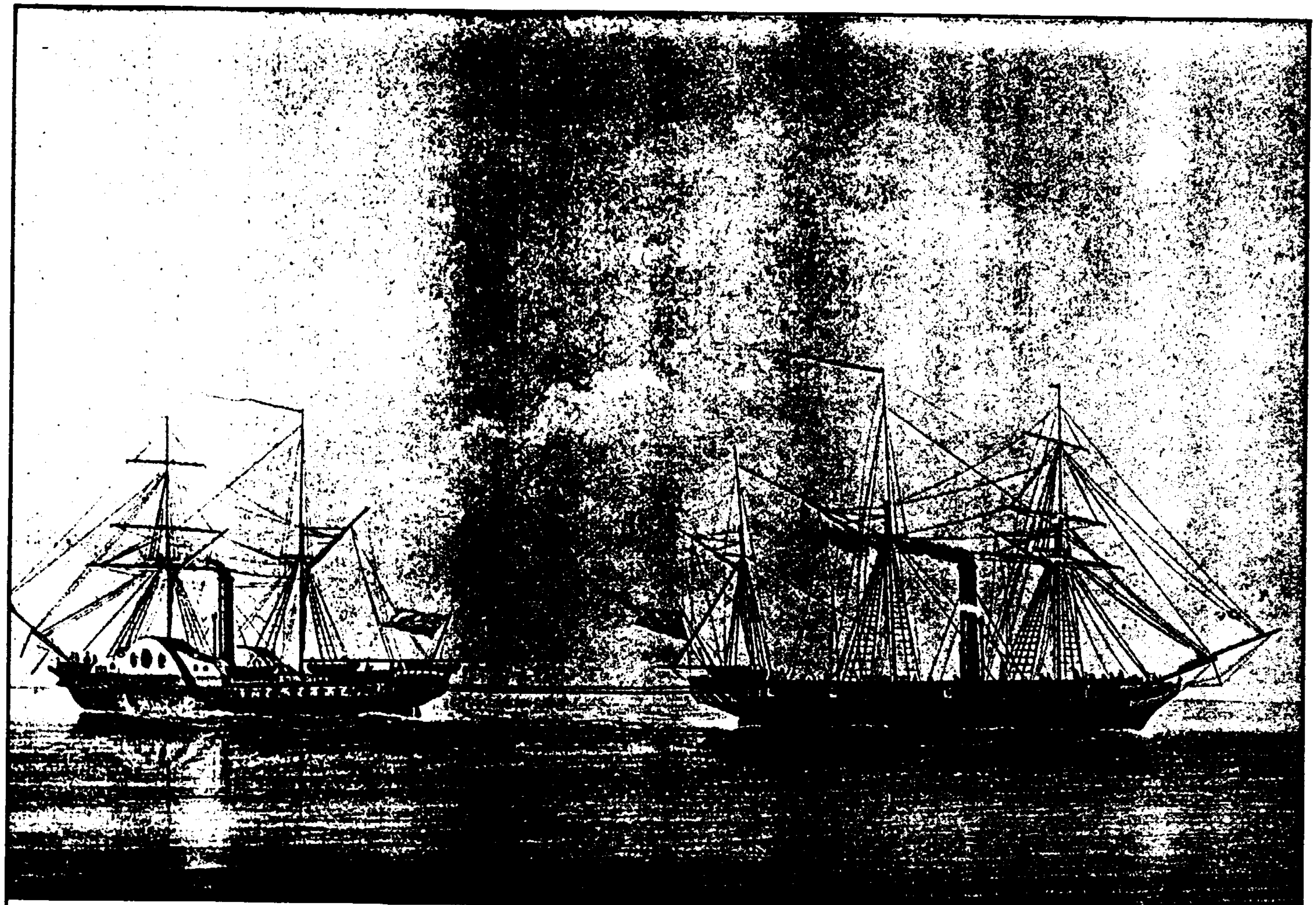


Wheel fashioned from wooden planks held together with metal clamps

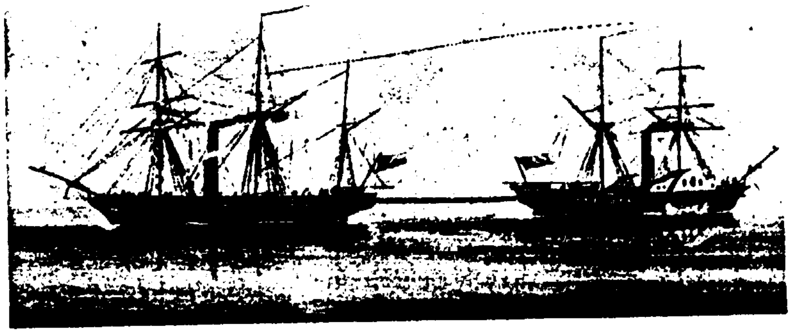
Dugout Canoe (Bronze Age)



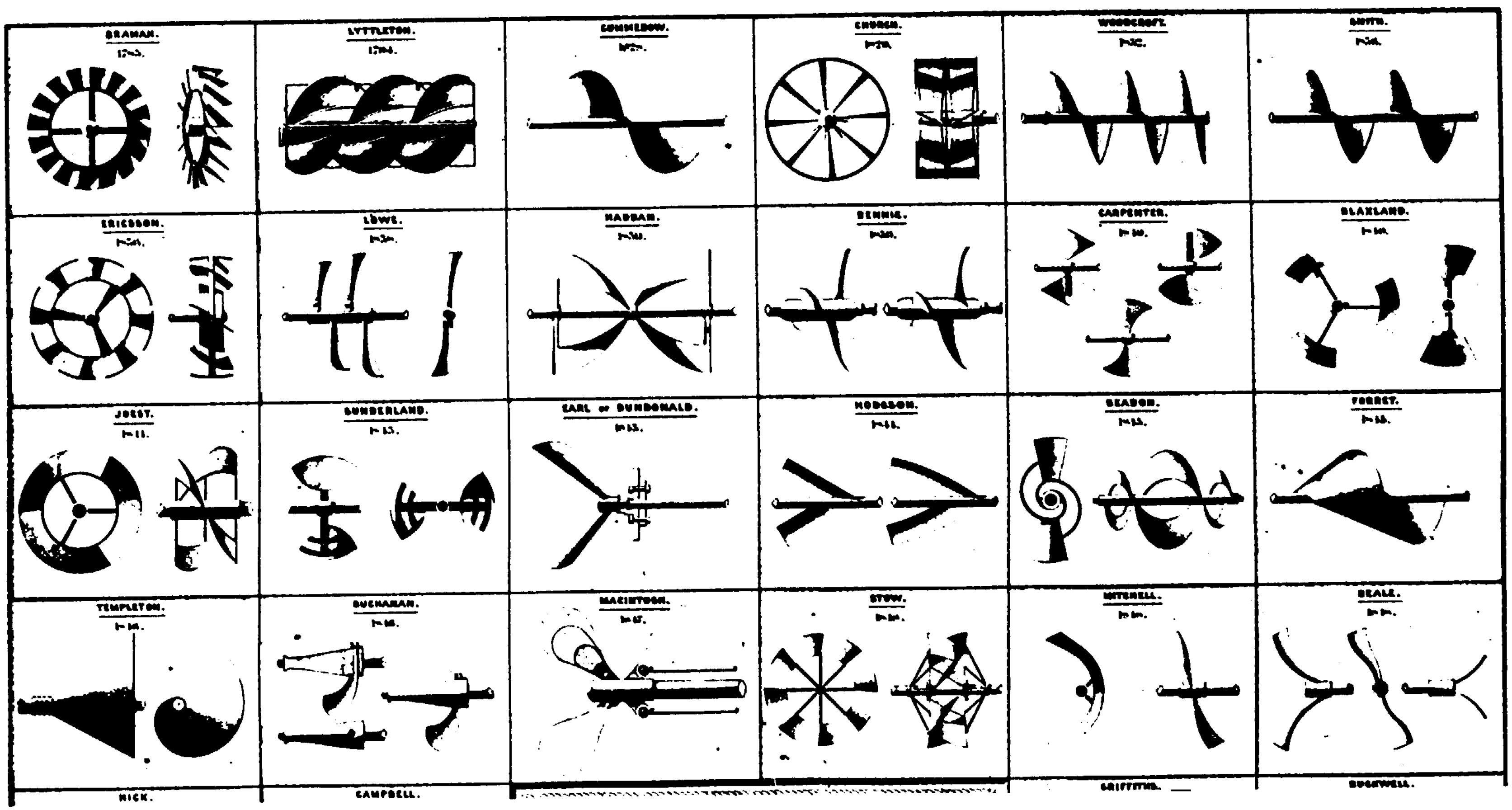
A Greek trireme of about 500 BC. There were three banks of oars pulled by 180 rowers, probably one to an oar. Sails supplemented the oars, except during battle. Note the powerful ram.



The *Rattler* and the *Alecto* struggling
against each other in 1845 – screw against paddle-power.



The superiority of the screw for marine propulsion was convincingly demonstrated in 1845 in a contest (left) between the warships *Rattler* (propeller) and *Alecto* (paddle-wheels). By that time screw propulsion had been tested for more than half a century, using a great variety of designs (below).



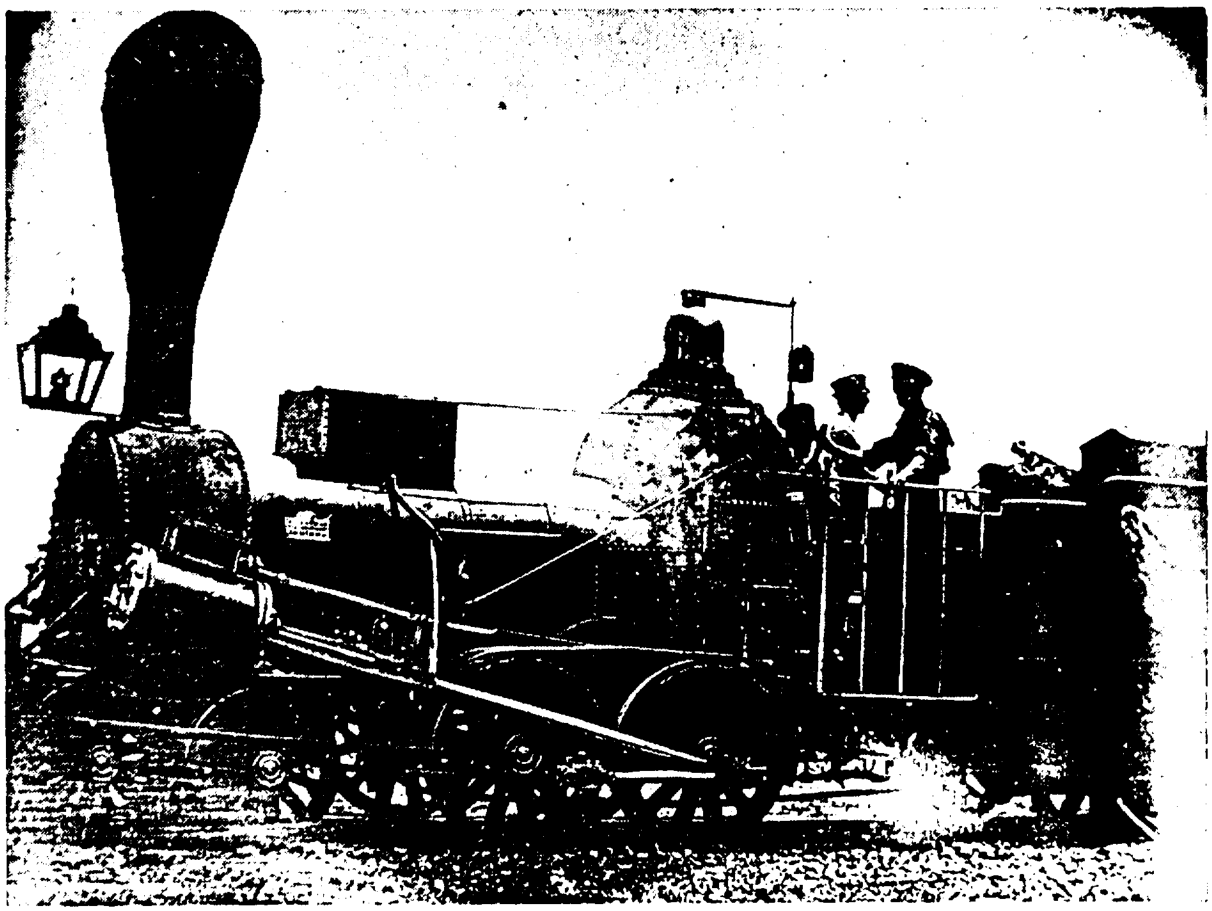


Figure 12.1 Early locomotive of American type, New London and Northern Railroad, 1843 (Courtesy New London Historical Society)

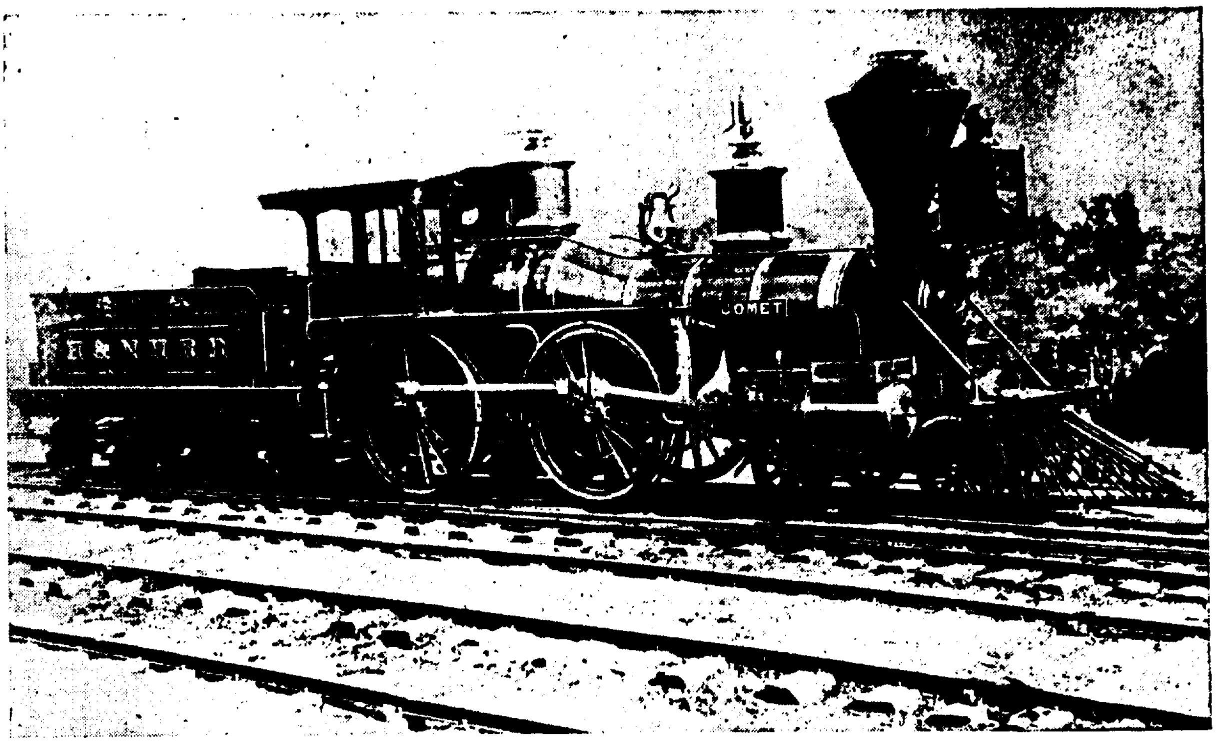


Figure 12.2 Coal-burning passenger locomotive, 1864

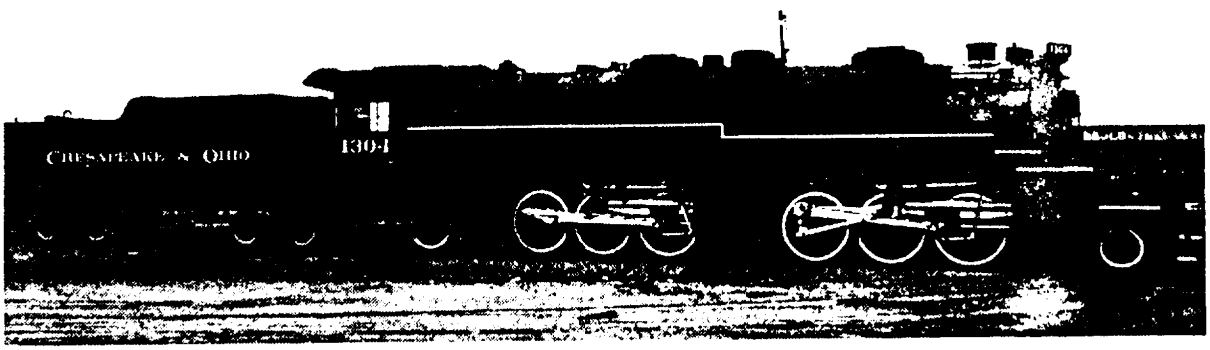


Figure 12.7 Last main-line steam locomotive built by the Baldwin Locomotive Works for use in the United States (Courtesy Chesapeake and Ohio Railway)

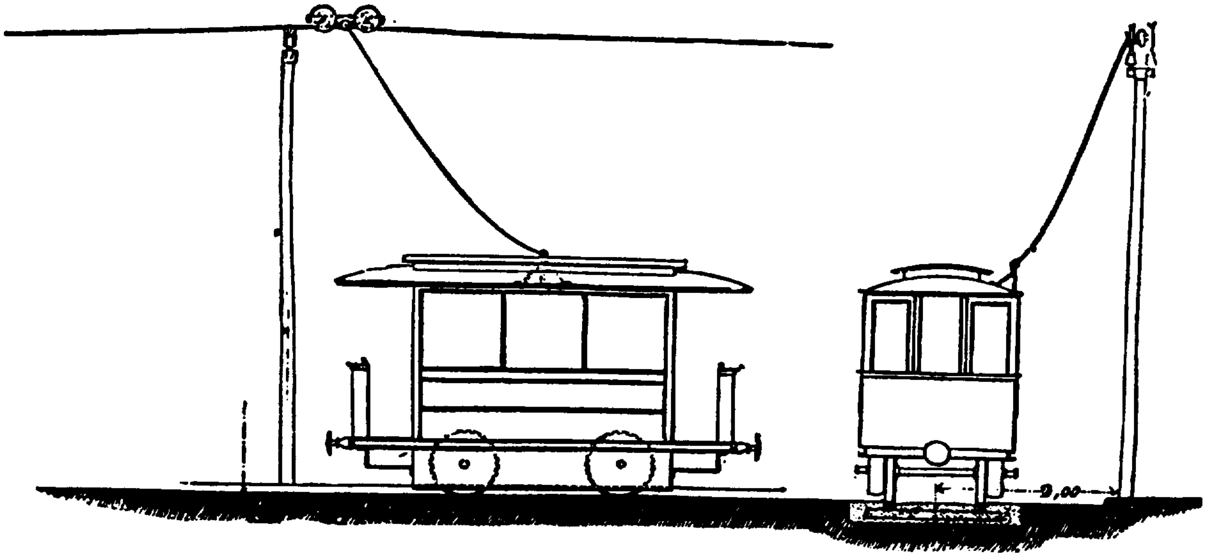
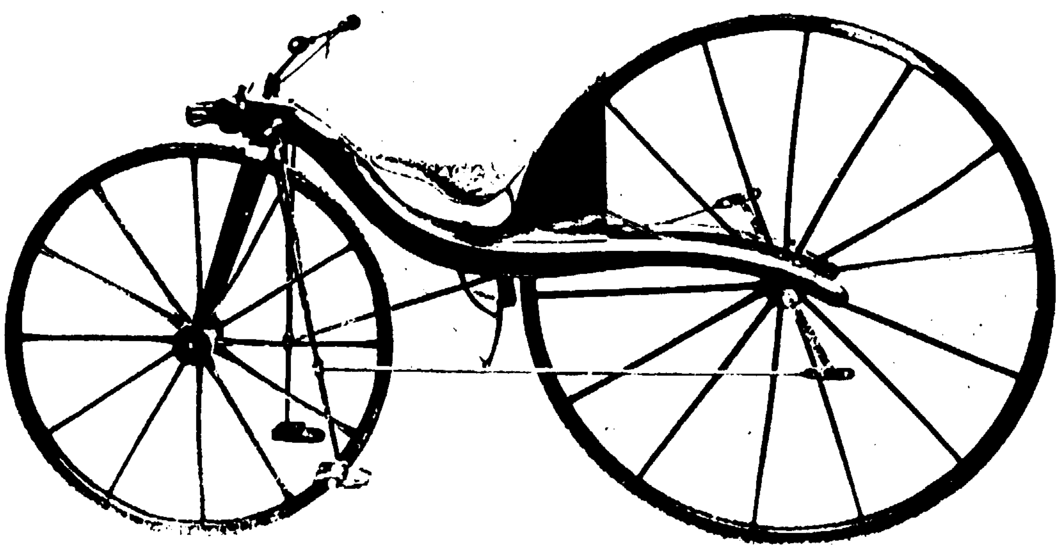


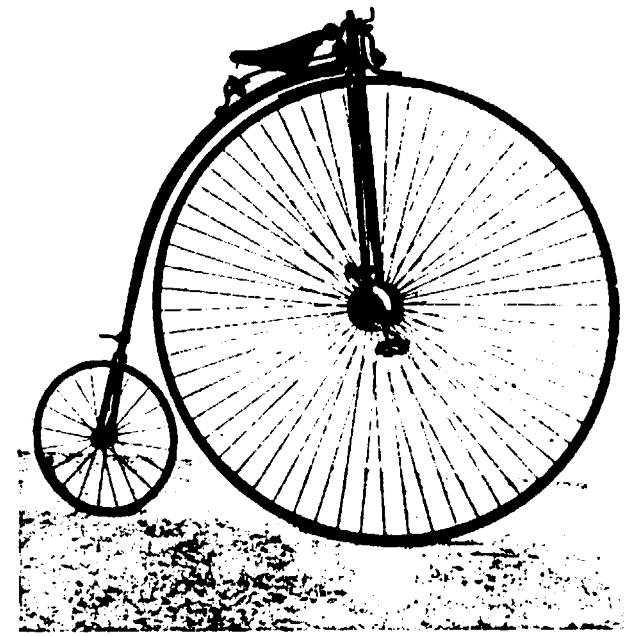
Figure 12.11 Electric street railway in Lichterfelde near Berlin (From *Die Eisenbahn*, 1881)

Figure 12.3 First American electric freight locomotive, Ansonia, Connecticut (Courtesy Charles Rufus Harte)

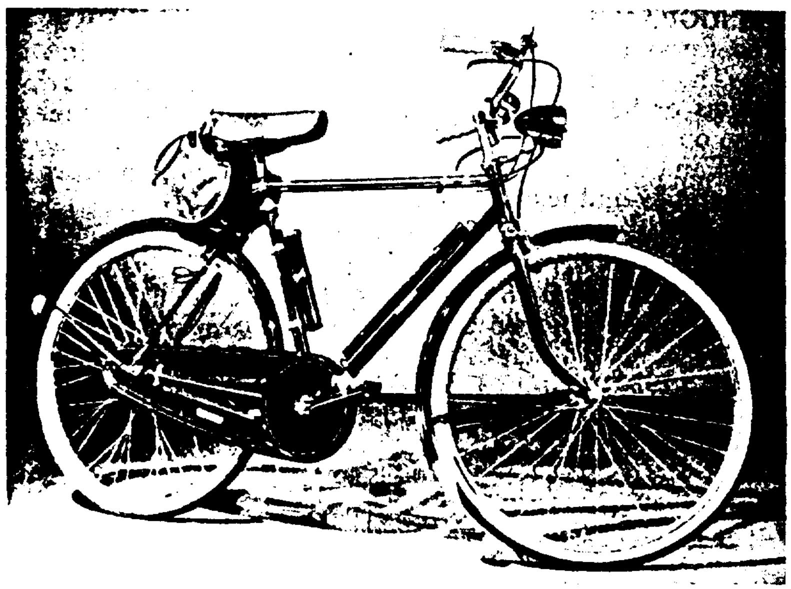
Figure 12.5 Electric locomotive pulling Baltimore and Ohio train, 1895 (Courtesy General Electric Co.)

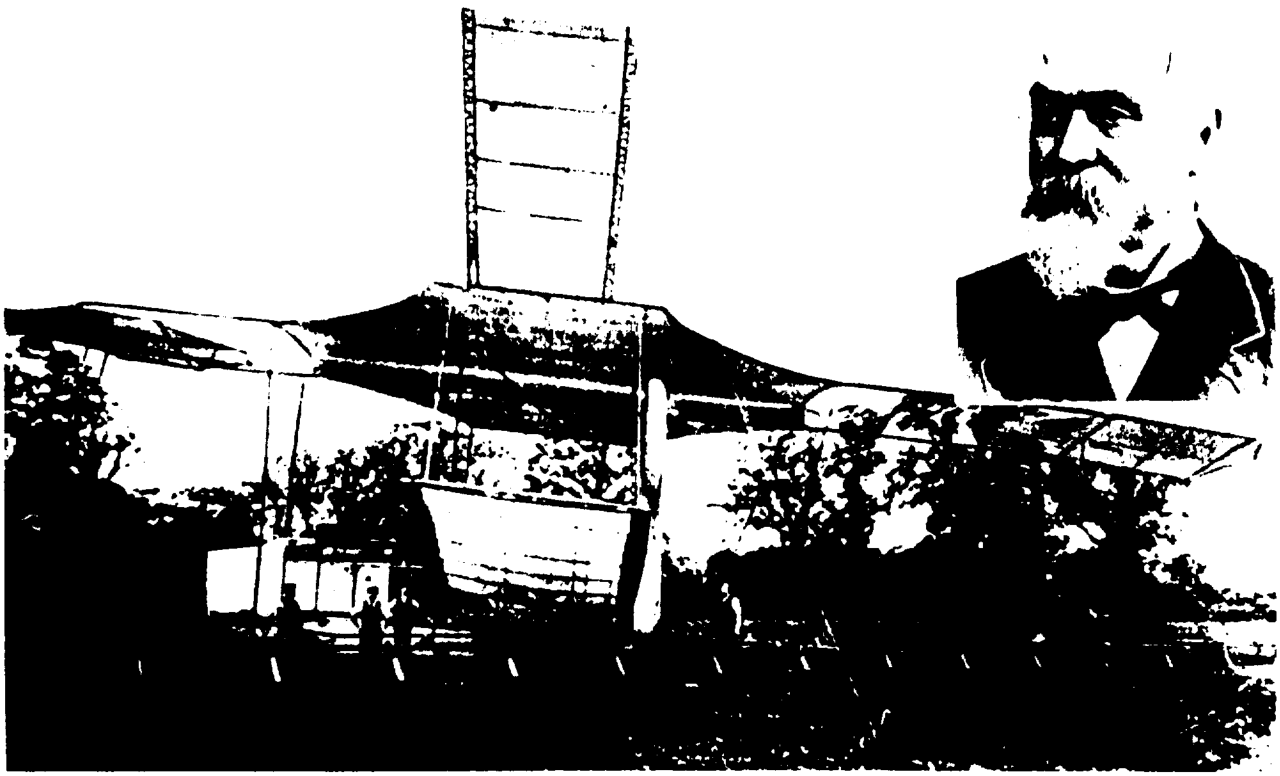
Figure 12.8
Diesel-electric locomotive (Courtesy New York, New Haven and Hartford Railroad)





(Left) Macmillan's Hobbyhorse, *c.* 1839. (Right) Ordinary bicycle, 1883.





Hiram Maxim

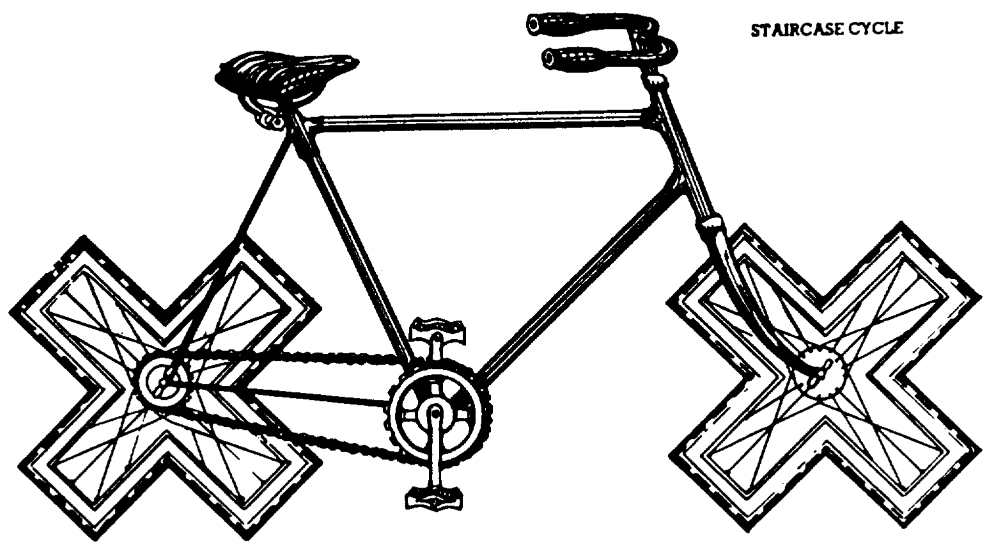


Figure III.5. A bicycle adapted for stairs. One of the many ordinary objects that have been "improved" for the modern consumer by Jacques Carelman and illustrated in his *Catalogue of unfindable objects*. The catalog contains "improvements" to various items, including plumbing fixtures, furniture, household goods, and sports equipment. Source: Jacques Carelman, *A catalogue of unfindable objects* (London, 1984), p. 56.

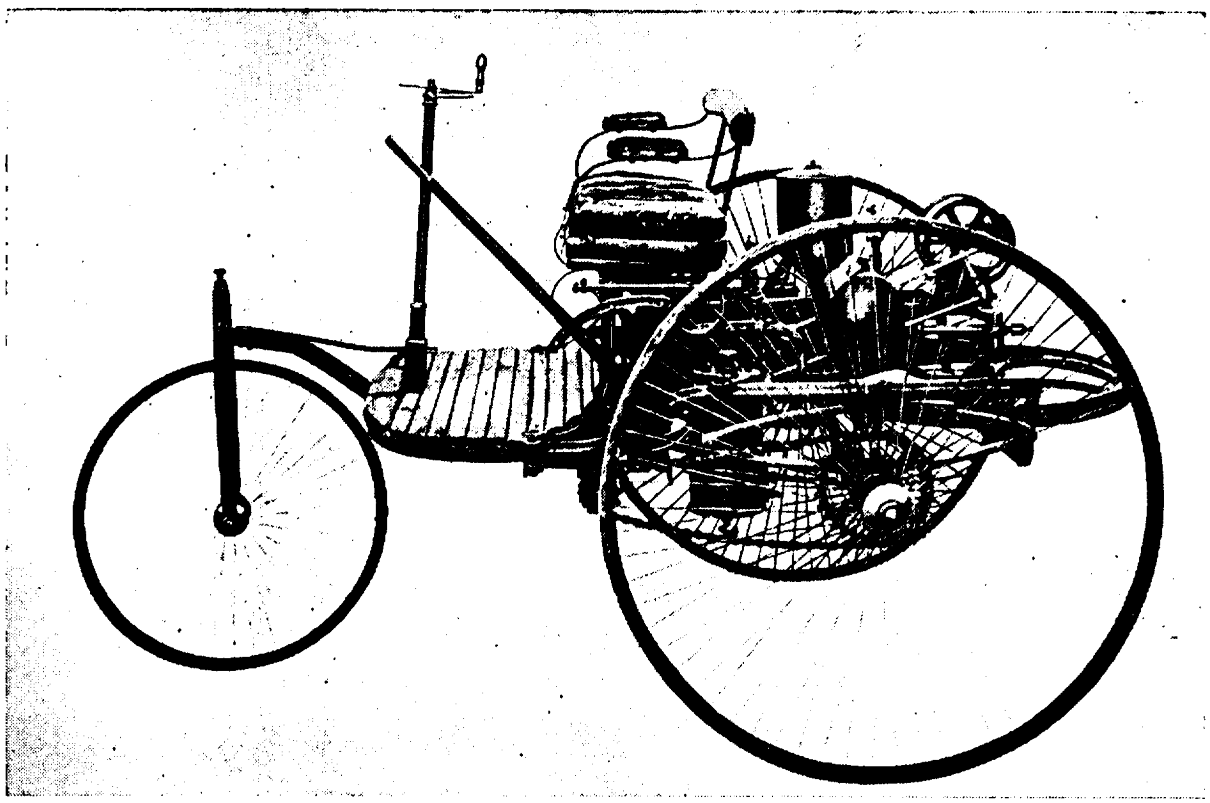


Figure 12.13 First automobile–Benz, 1885 (Courtesy Daimler-Benz Aktiengesellschaft)

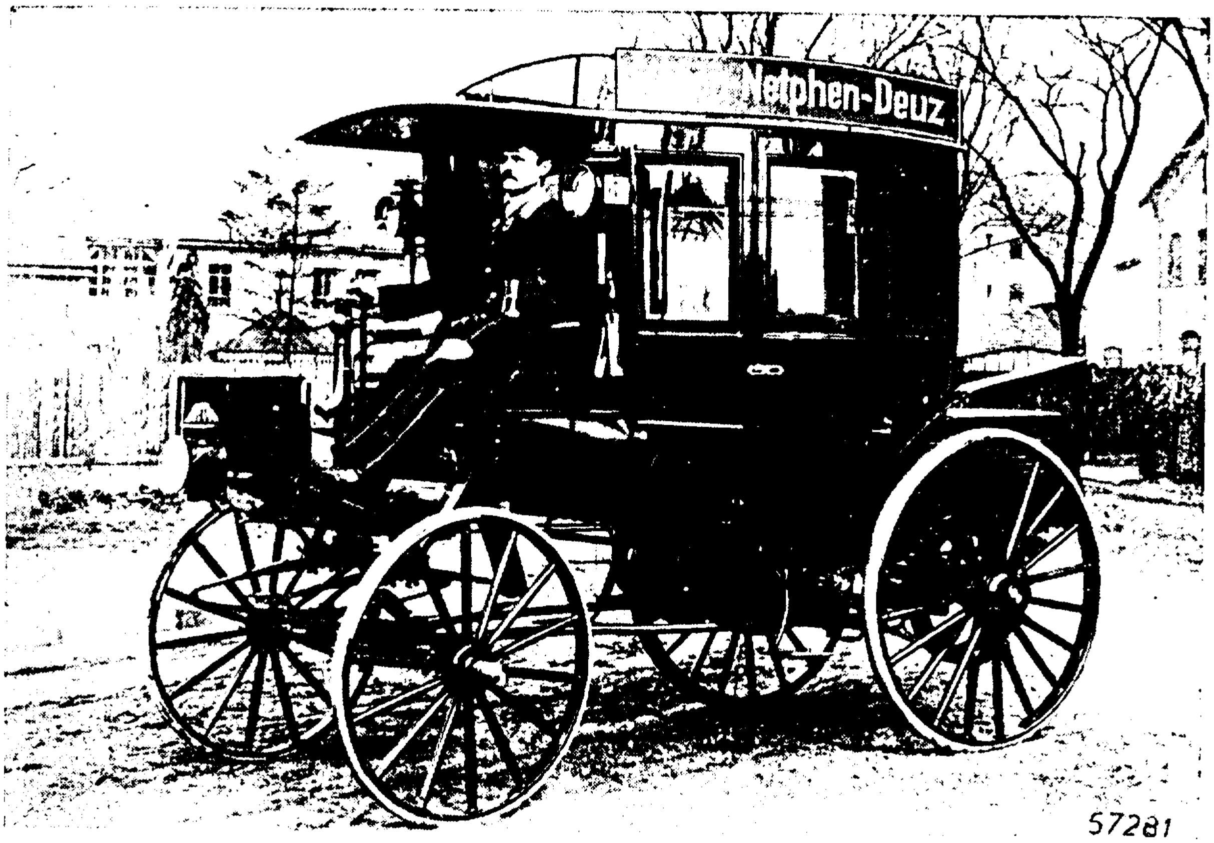
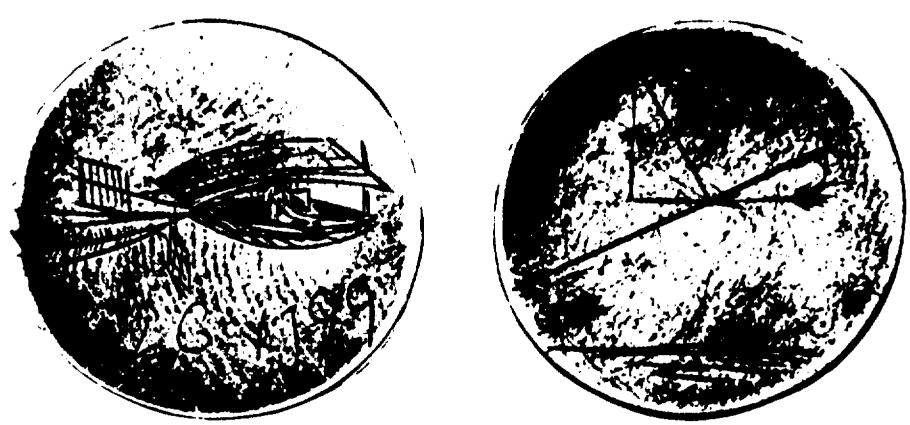
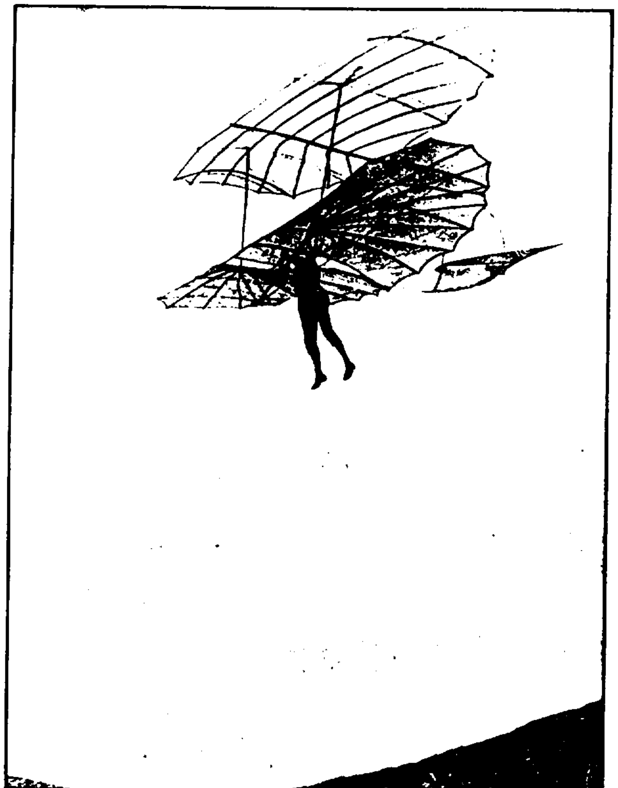


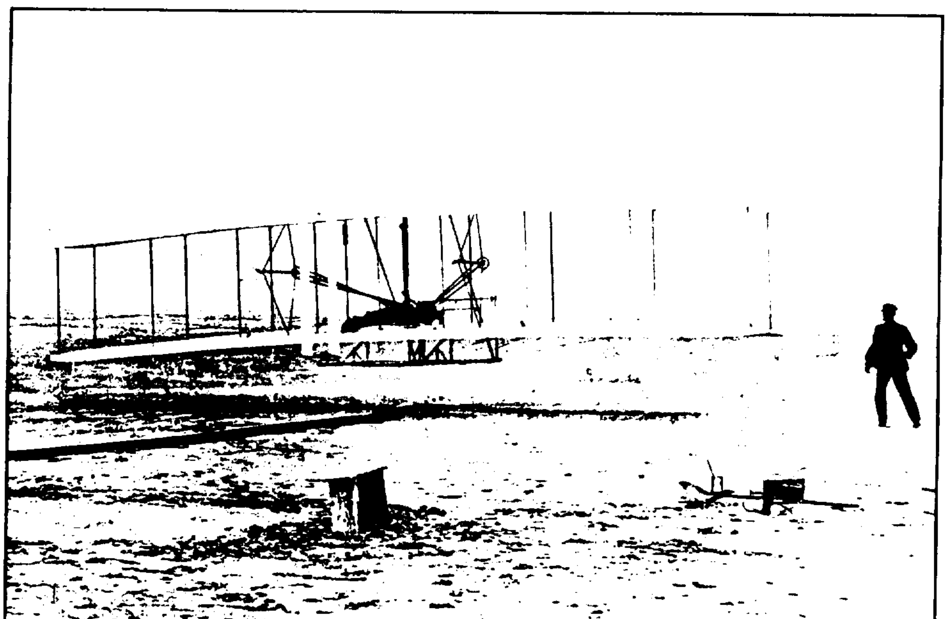
Figure 12.14 First motorbus–Benz, 1895 (Courtesy Daimler-Benz Aktien gesellschaft)



George Cayley



Otto Lilienthal in
one of his gliders, 1896.



The first powered free flight at Kitty Hawk, North Carolina,
17 December, 1903; Orville Wright in the plane, Wilbur Wright on foot.

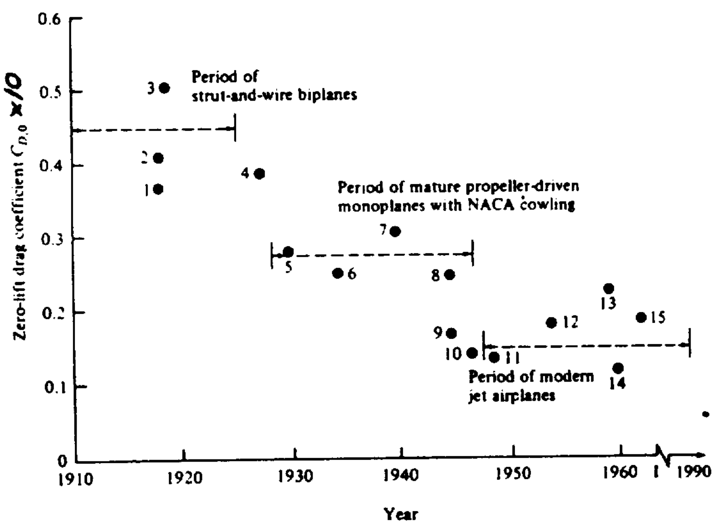


Figure 6.60 Use of zero-lift drag coefficient to illustrate three general periods of twentieth-century airplane design. The numbered data points correspond to the following aircraft: (1) SPAD XIII, (2) Fokker D-VII, (3) Curtiss JN-4H Jenny, (4) Ryan NYP (*Spirit of St. Louis*), (5) Lockheed Vega, (6) Douglas DC-3, (7) Boeing B-17, (8) Boeing B-29, (9) North American P-51, (10) Lockheed P-80, (11) North American F-86, (12) Lockheed F-104, (13) McDonnell F-4E, (14) Boeing B-52, (15) General Dynamics F-111D.

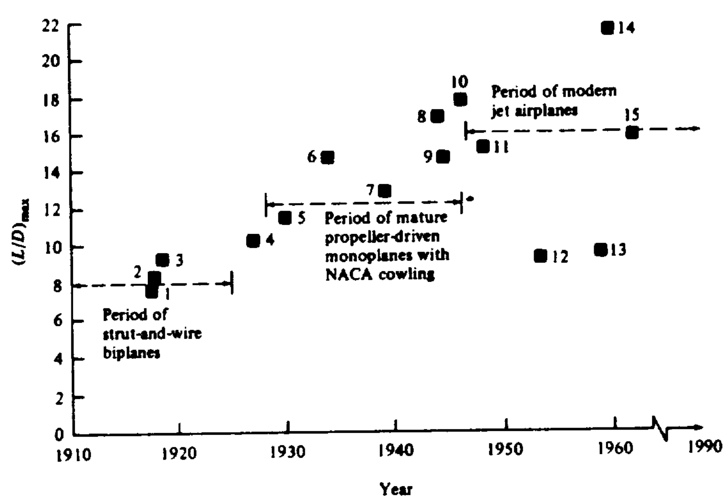
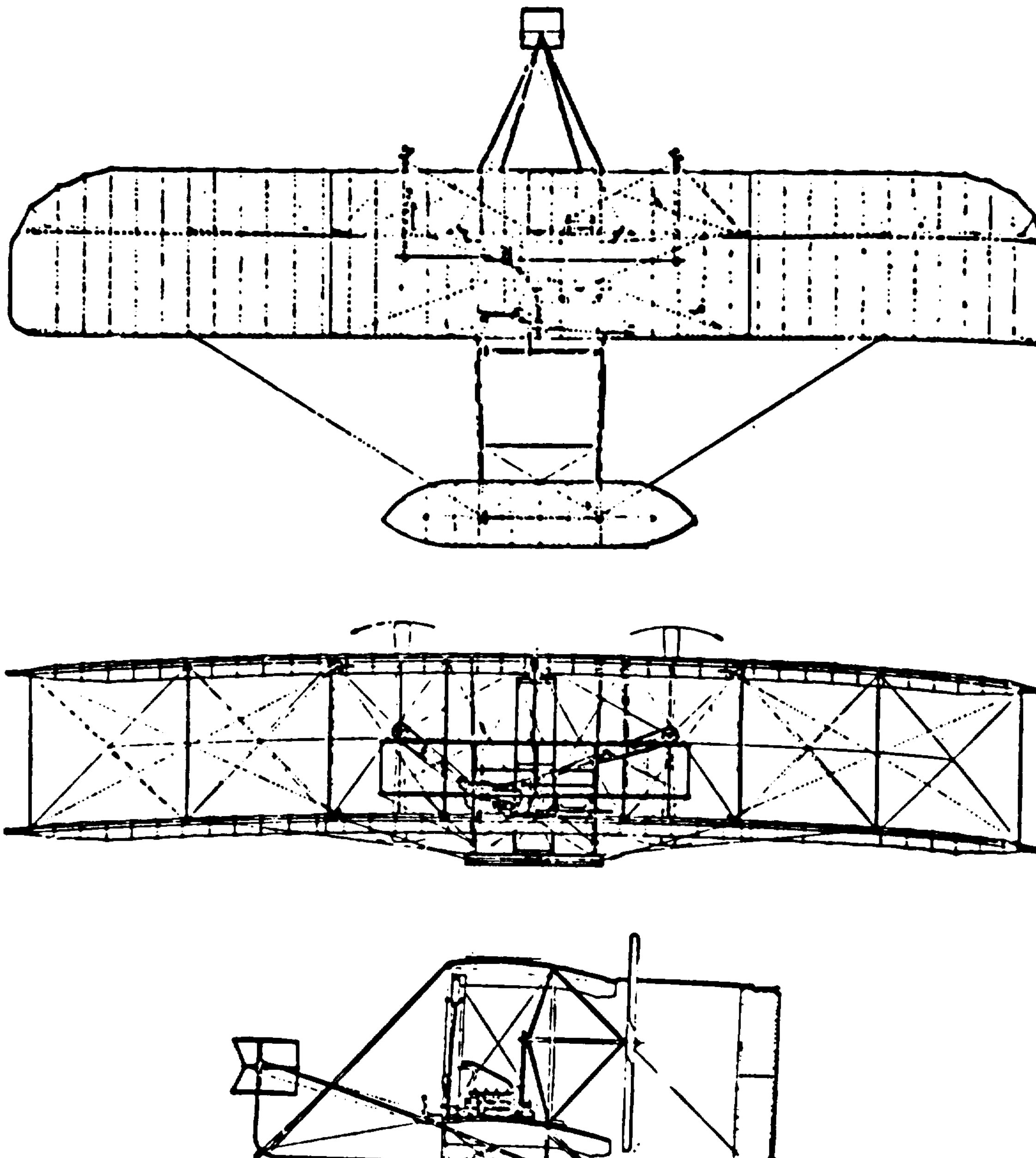
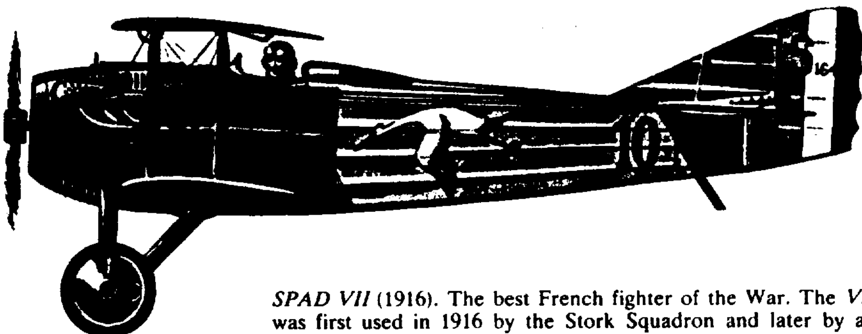


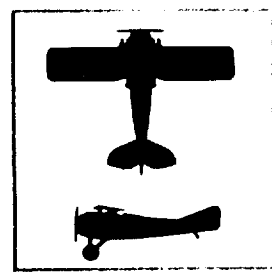
Figure 6.61 Use of lift-to-drag ratio to illustrate three general periods of twentieth-century airplane design.

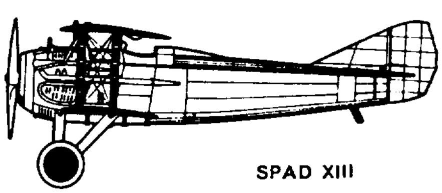


Three views of the Wright Flyer I, 1903.

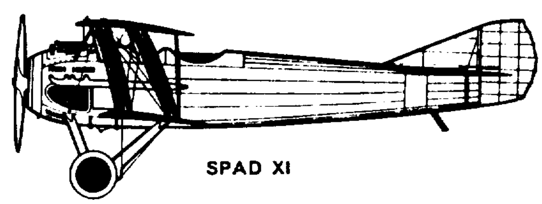


SPAD VII (1916). The best French fighter of the War. The *VII* was first used in 1916 by the Stork Squadron and later by all French and American fighter squadrons, 11 Italian squadrons and one Belgian. In 1917 it was replaced by the faster and better armed *XIII* model. It was the favorite plane of the aces Fonck, Guynemer, Barracca and Rickenbacker. Of the nearly 15,000 *Spads* built, only a few were the *XI* two-seat reconnaissance type.

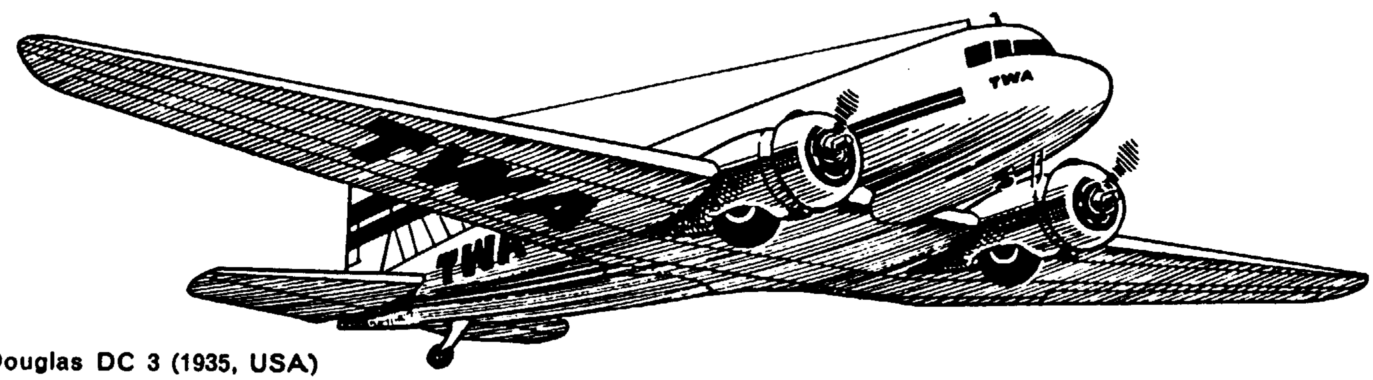




SPAD XIII

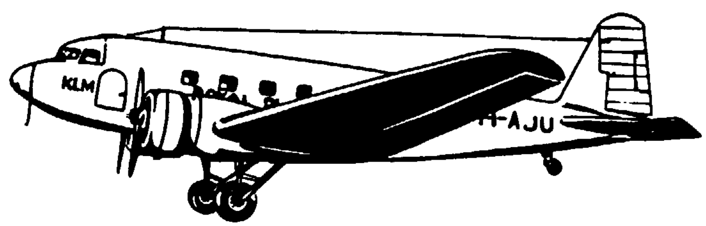


SPAD XI



Douglas DC 3 (1935, USA)

Douglas DC 2 (1934, USA)



The modern and original *DC-2* began service in 1934. Two hundred and twenty were built. But its successor, the *DC-3,* which flew for the first time on December 17, 1935, was to become the most prestigious aircraft in the world. It was used by nearly all civilian airlines and was an essential model for military aviation during the War. About 13,000 were built, of which at least 1000 are still in service today!

Figure 11. Detailed design of the He 178 in 1938.

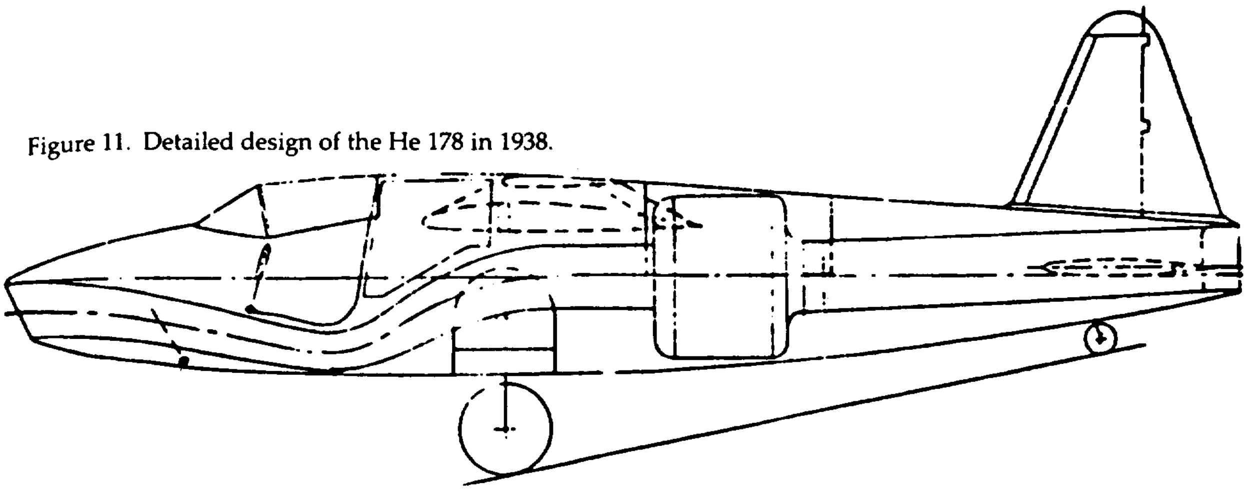
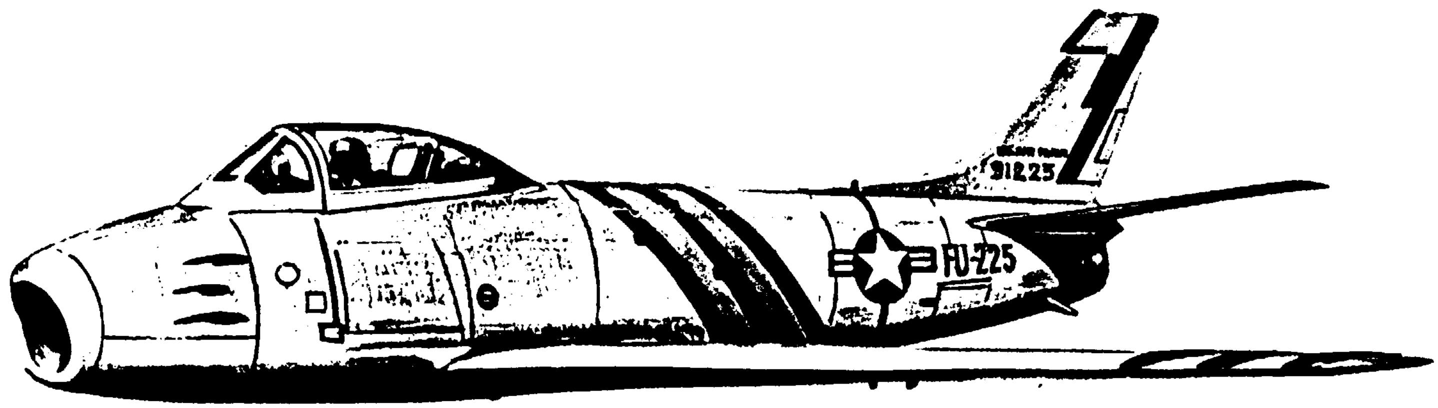
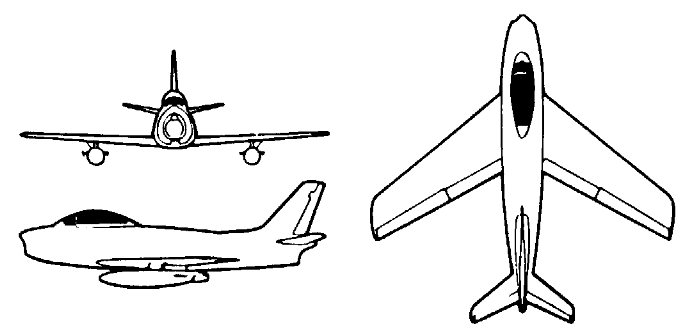
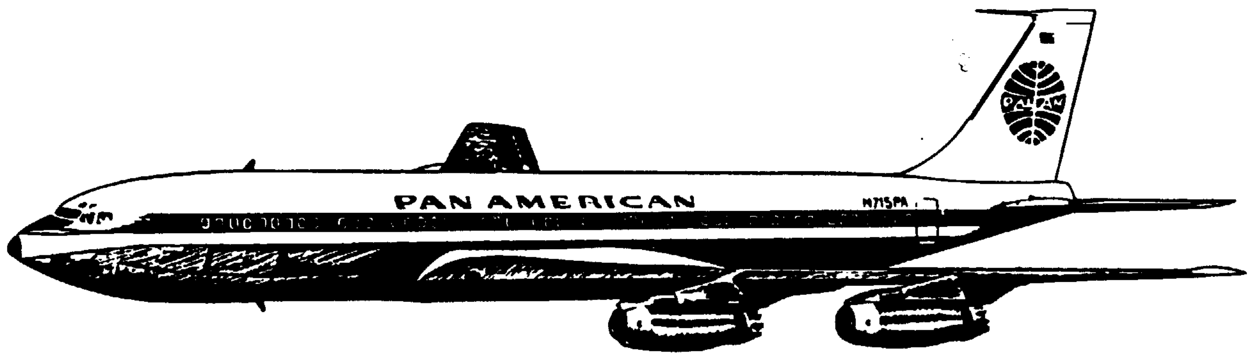


Figure 12. The world's first aircraft to fly purely on turbojet power, the Heinkel He 178. Its first true flight was on August 27, 1939.

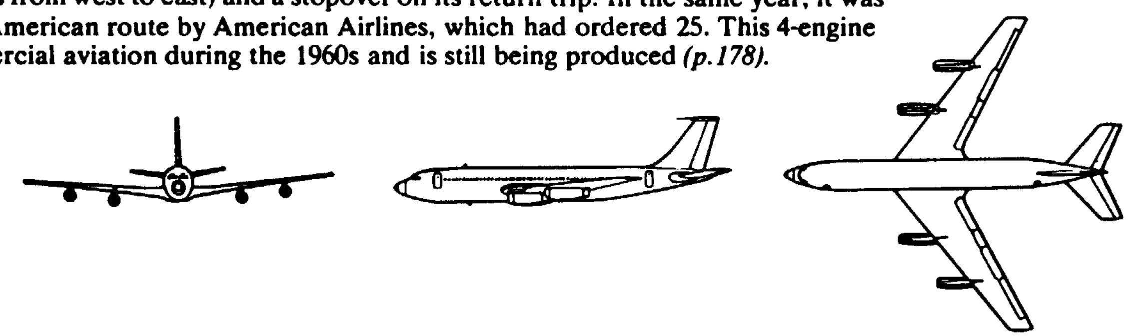


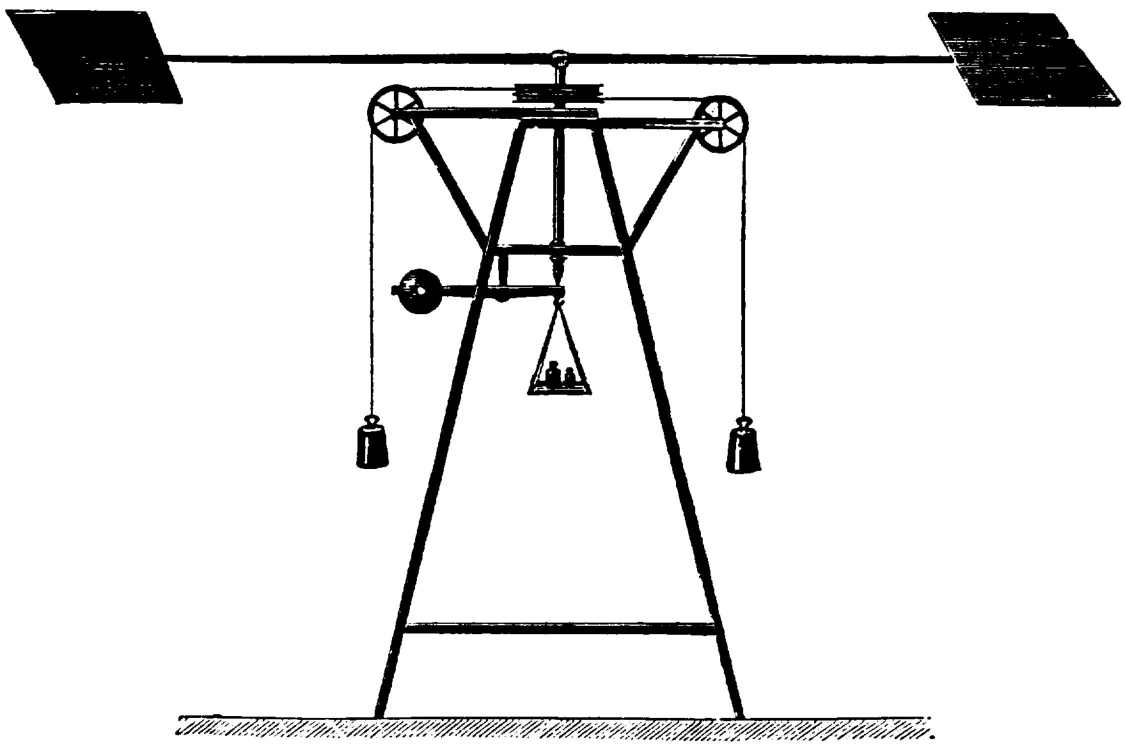
NORTH AMERICAN F-86 SABRE (1949, USA). The first American fighter with swept wings, it flew for the first time on October 1, 1947, and had its baptism by fire in Korea in December 1950, where it fared better than the *P-80* against the Russian *MIG-15*'s. This outstanding aircraft became the standard fighter in the air forces of about 30 countries, European, South American and Asian. It was also built in Canada, Australia, Japan and Italy by Fiat. It was produced in many versions. Production was stopped at the end of the 1950s after about 5800 units had been delivered to Fighter Squadrons of half the world's air forces.





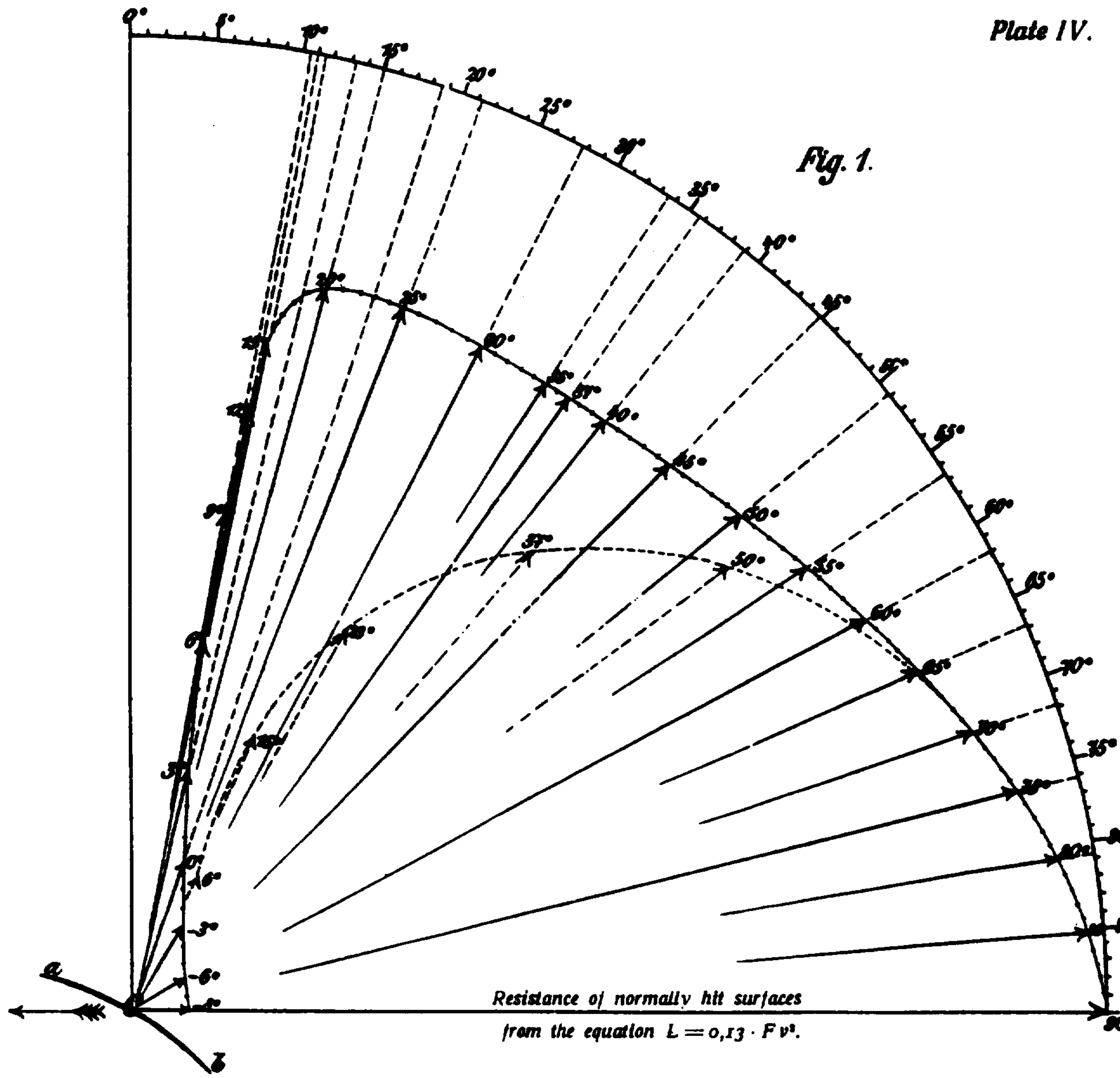
BOEING 707-121 (1958, USA). The prototype of one of the most successful passenger aircraft of all times, the *707* made its first flight on July 15, 1954. On October 26, 1958, Pan American was the first to use it nonstop across the Atlantic to Europe (aided by the favorable winds on flights from west to east) and a stopover on its return trip. In the same year, it was put into service on a transcontinental North American route by American Airlines, which had ordered 25. This 4-engine jet was to become one of the pillars of commercial aviation during the 1960s and is still being produced *(p.178)*.





Lilienthal's Whirling Arm

Plate IV.



Camber 1/12 width.

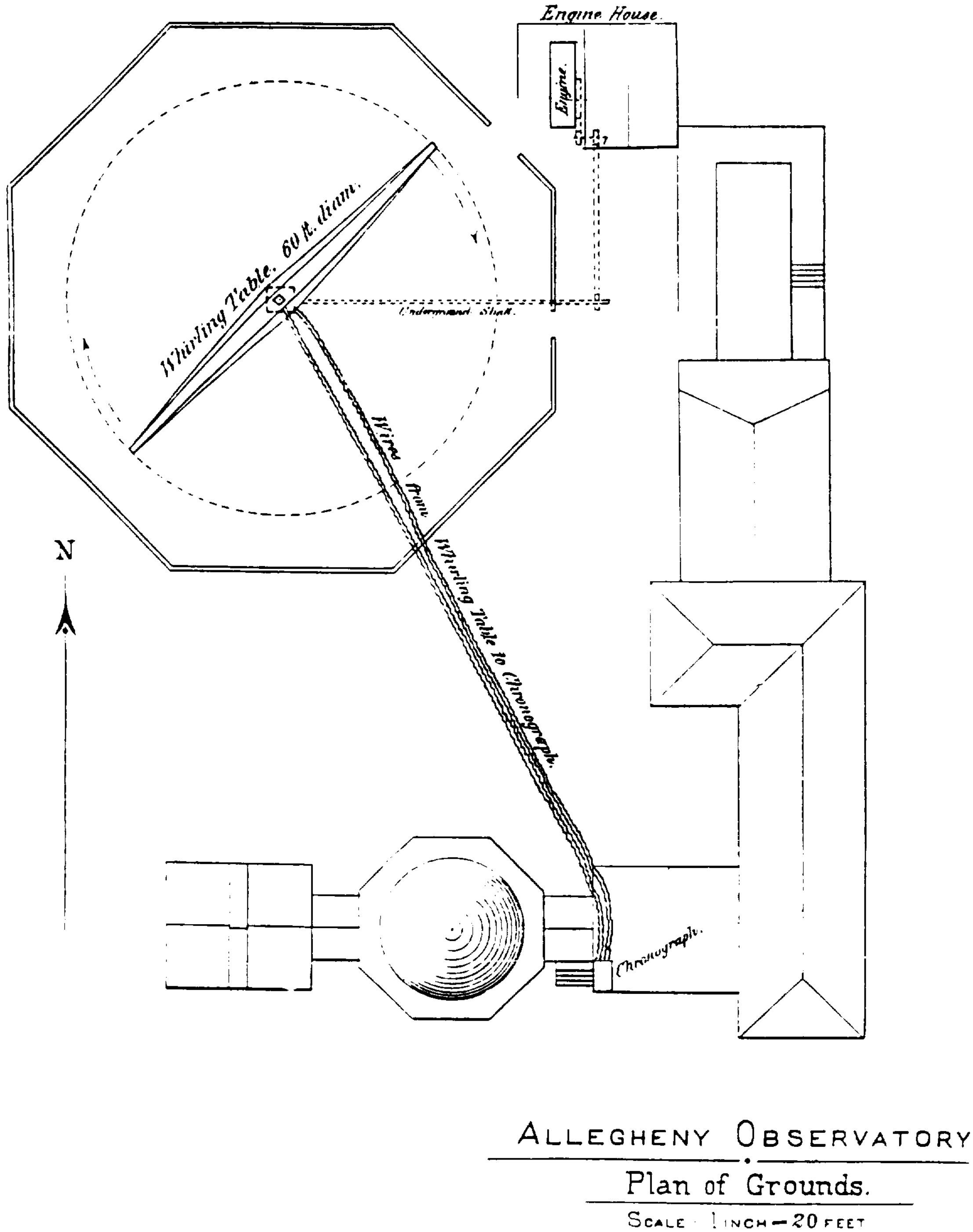
Air pressure on curved surfaces determined during rotation in still air.

The First Drag Polar, Lilienthal--1889

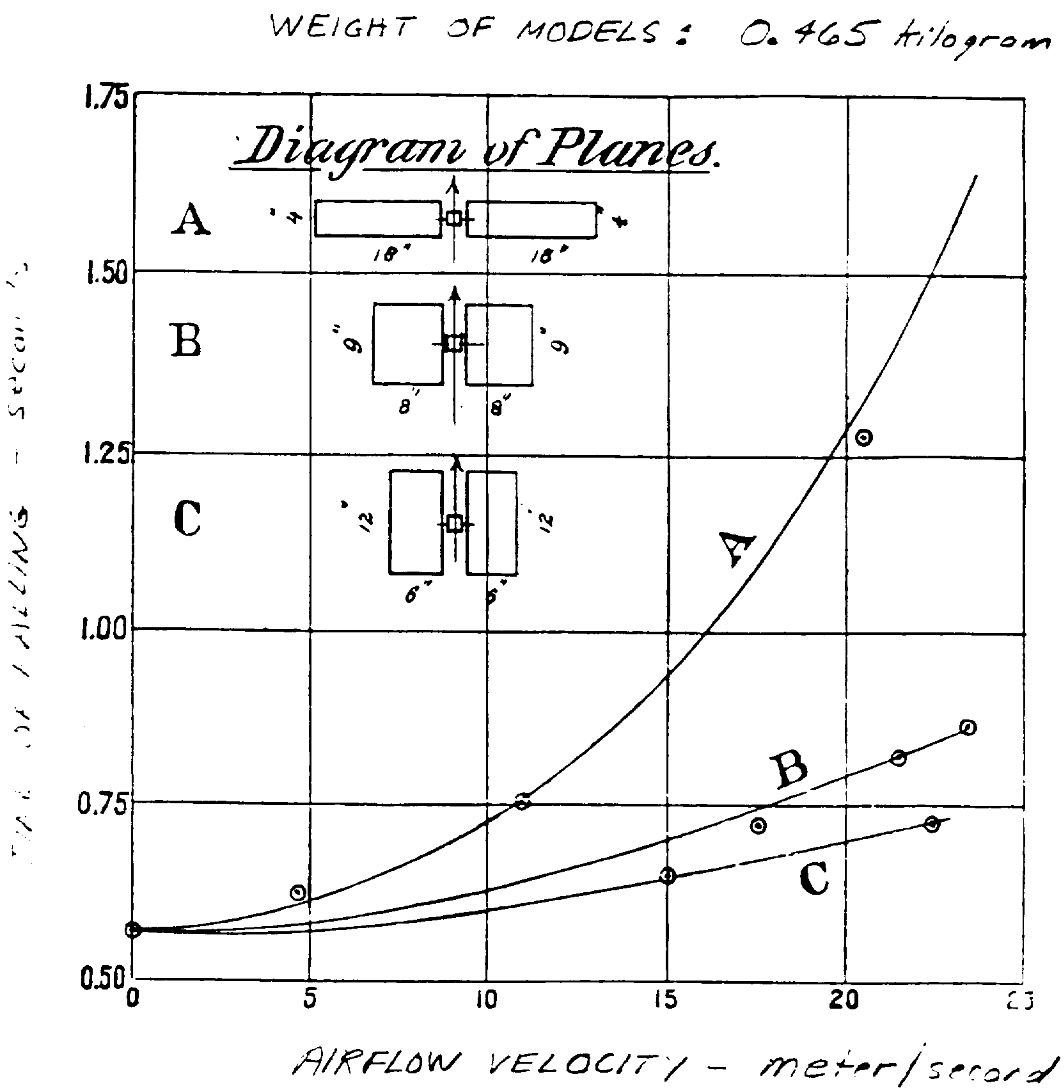
TABLE OF NORMAL AND TANGENTIAL PRESSURES

Deduced by Lilienthal from the diagrams on Plate VI., in his book "Bird-flight as the Basis of the Flying Art."

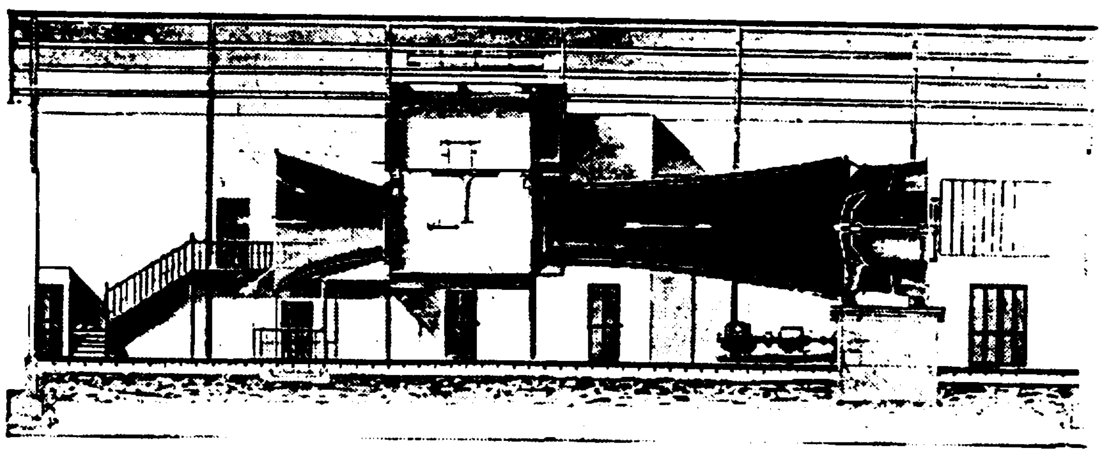
α Angle.	η Normal.	ϑ Tangential.	α Angle.	η Normal.	ϑ Tangential.
— 9°	0.000	+ 0.070	16°	0.909	— 0.075
— 8°	0.040	+ 0.067	17°	0.915	— 0.073
— 7°	0.080	+ 0.064	18°	0.919	— 0.070
— 6°	0.120	+ 0.060	19°	0.921	— 0.065
— 5°	0.160	+ 0.055	20°	0.922	— 0.059
— 4°	0.200	+ 0.049	21°	0.923	— 0.053
— 3°	0.242	+ 0.043	22°	0.924	— 0.047
— 2°	0.286	+ 0.037	23°	0.924	— 0.041
— 1°	0.332	+ 0.031	24°	0.923	— 0.036
0°	0.381	+ 0.024	25°	0.922	— 0.031
+ 1°	0.434	+ 0.016	26°	0.920	— 0.026
+ 2°	0.489	+ 0.008	27°	0.918	— 0.021
+ 3°	0.546	0.000	28°	0.915	— 0.016
+ 4°	0.600	— 0.007	29°	0.912	— 0.012
+ 5°	0.650	— 0.014	30°	0.910	— 0.008
+ 6°	0.696	— 0.021	32°	0.906	0.000
+ 7°	0.737	— 0.028	35°	0.896	+ 0.010
+ 8°	0.771	— 0.035	40°	0.890	+ 0.016
+ 9°	0.800	— 0.042	45°	0.888	+ 0.020
10°	0.825	— 0.050	50°	0.888	+ 0.023
11°	0.846	— 0.058	55°	0.890	+ 0.026
12°	0.864	— 0.064	60°	0.900	+ 0.028
13°	0.879	— 0.070	70°	0.930	+ 0.030
14°	0.891	— 0.074	80°	0.960	+ 0.015
15°	0.901	— 0.076	90°	1.000	0.000



Langley's Whirling Arm--1887

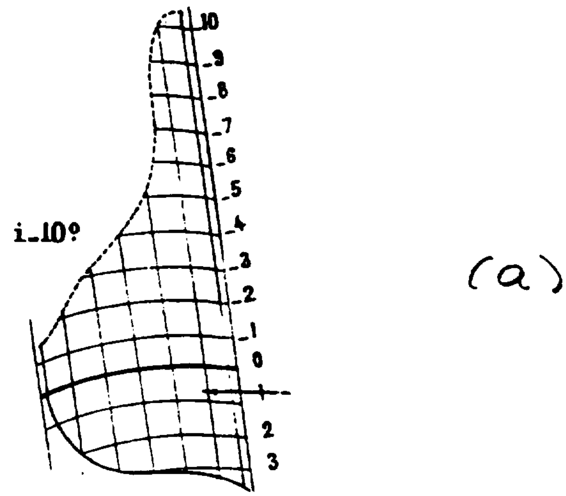


From Langley, Experiments in Aerodynamics, 1891



Eiffel's Wind Tunnel (His Second Tunnel)--1912

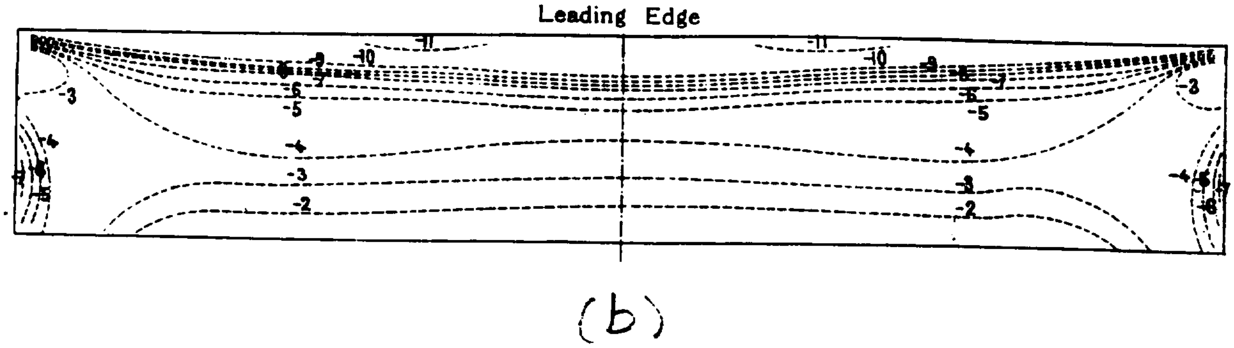
Pressure along centre line



Curves of equal pressure on back

i_10°

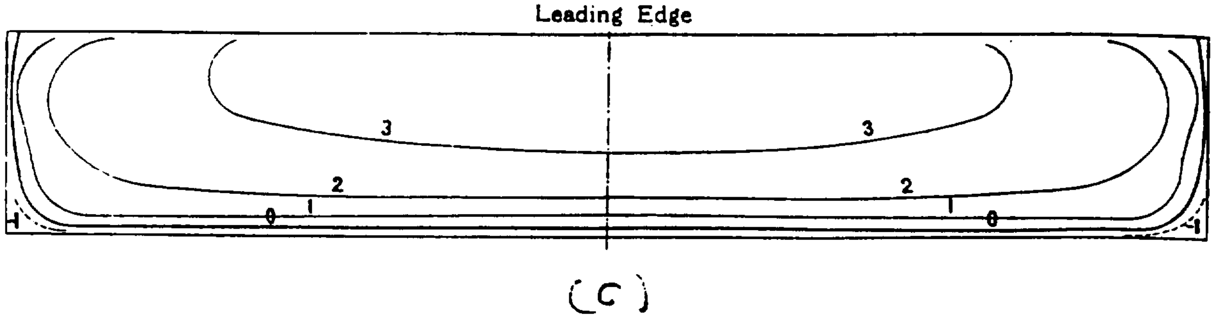
Leading Edge



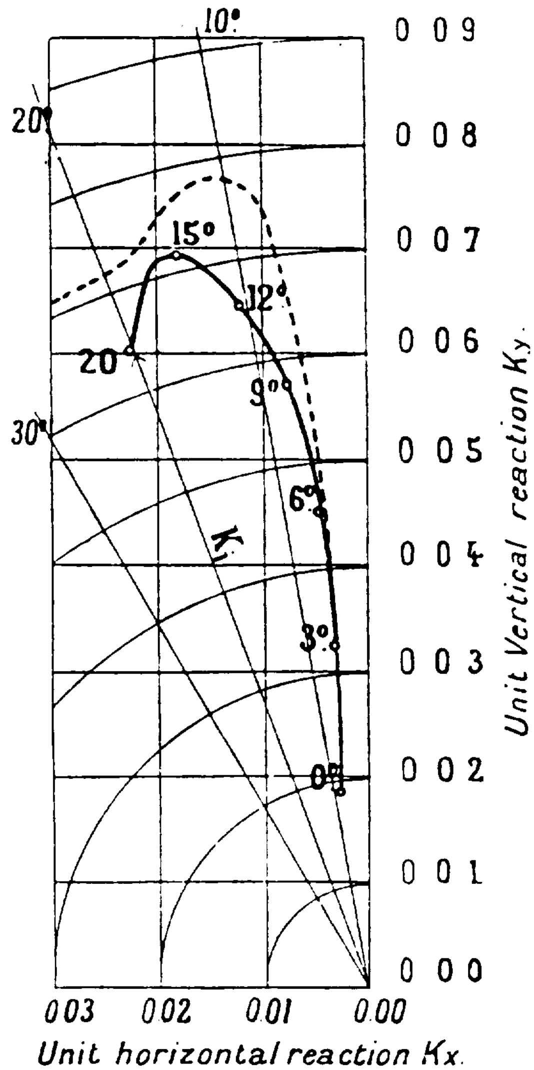
Curves of equal pressure on face

i_10°

Leading Edge



Pressure Contours, Eiffel--1910



Drag Polar for the Wright Type A Wind, Data from Eiffel--1910

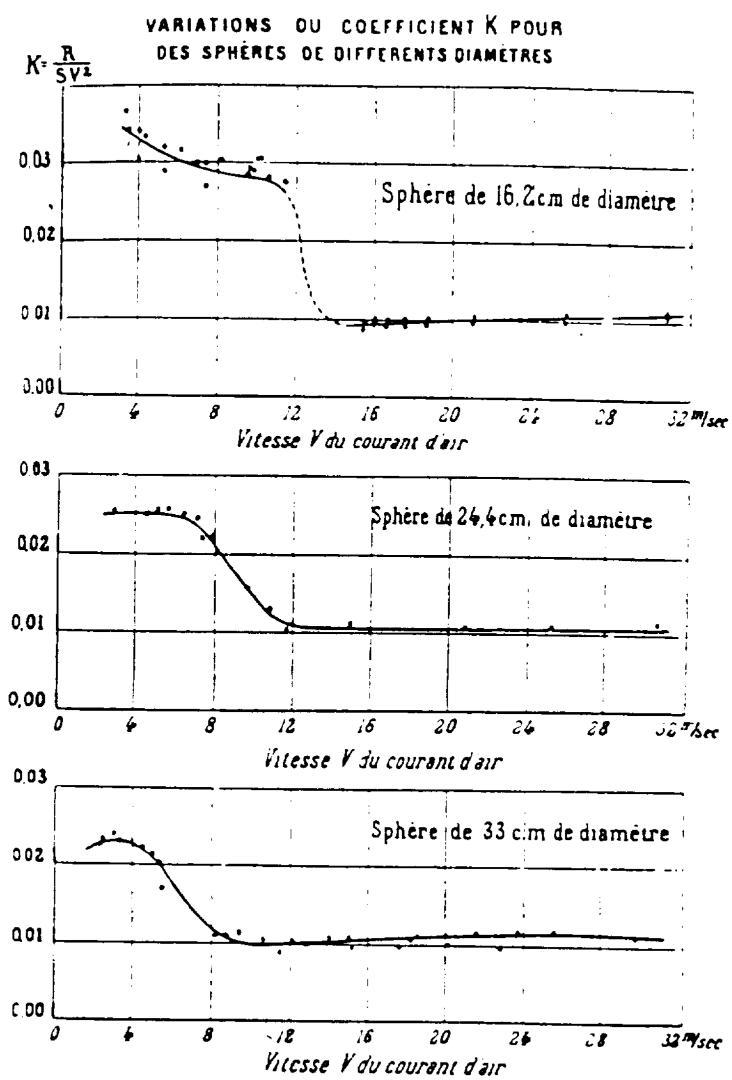
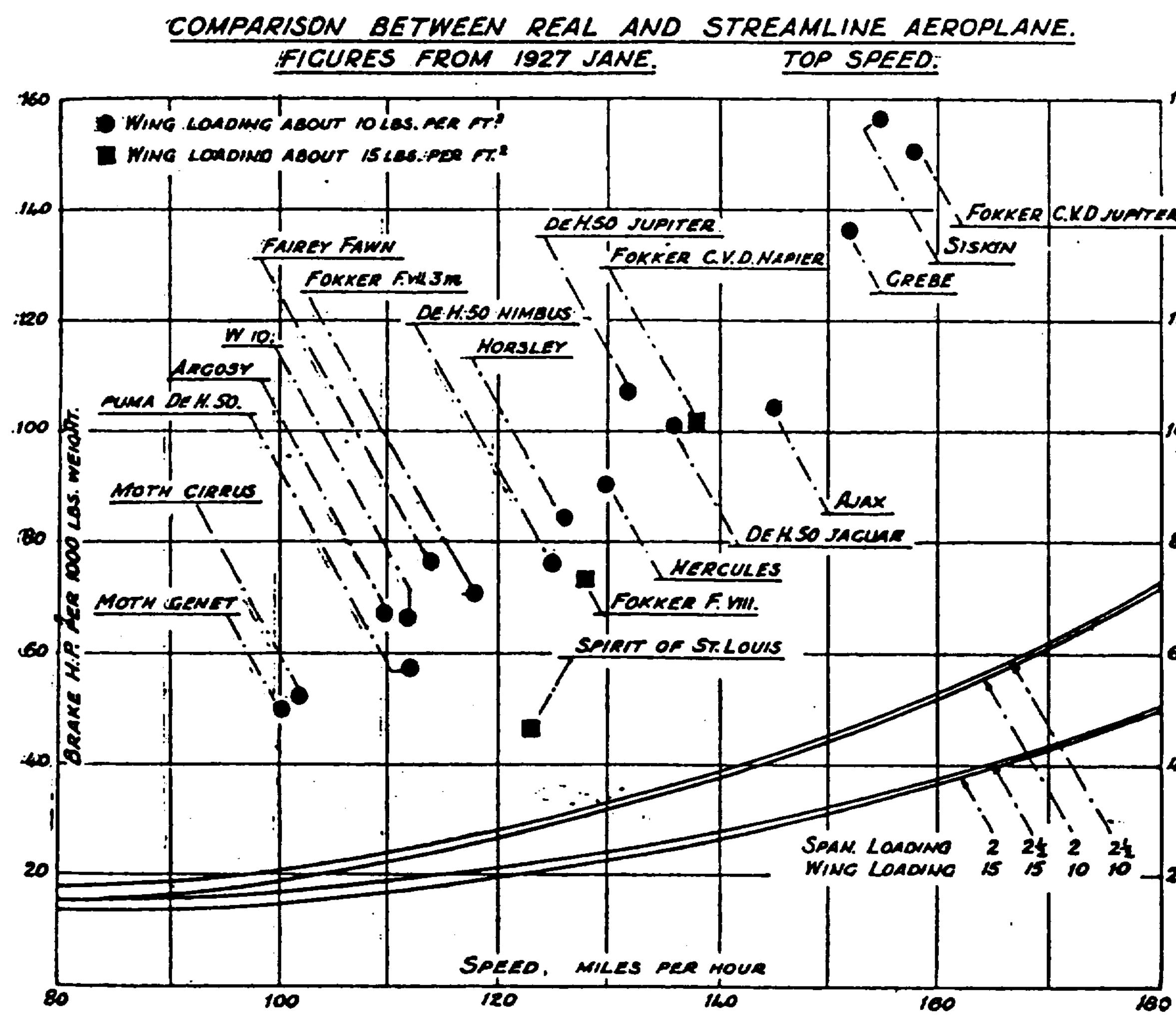


FIG. 56. — *Résistances unitaires K des sphères, en fonction de la vitesse.*

Sphere Drag Coefficient, Measurements from Eiffel--c. 1915



Melvill Jones's Ideal Airplane--1929

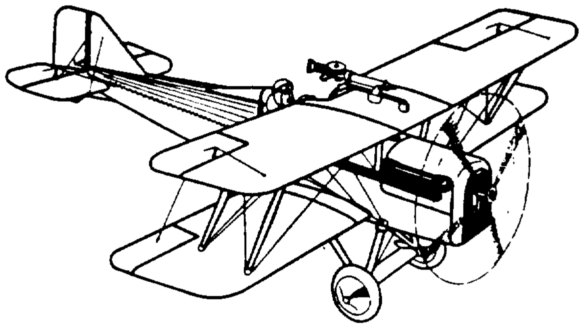


FIG. 1.

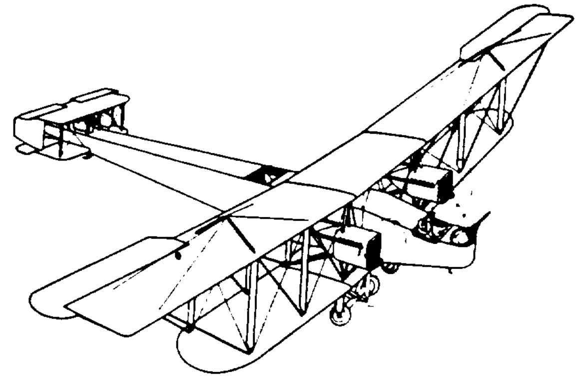


FIG. 4.

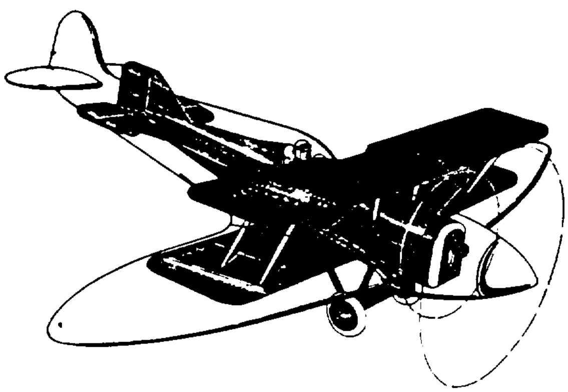


FIG. 2.

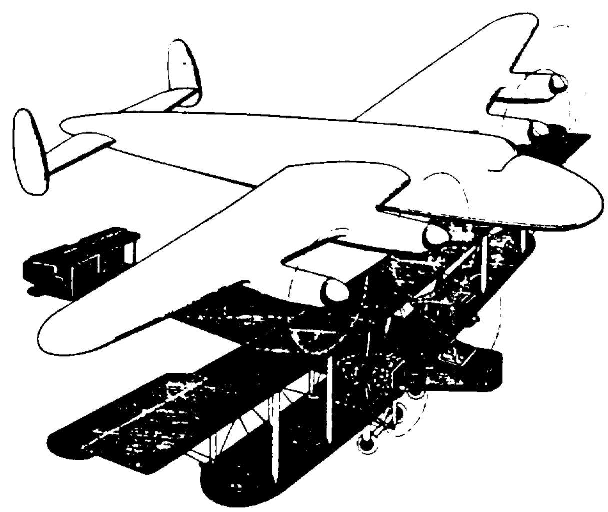


FIG. 5.

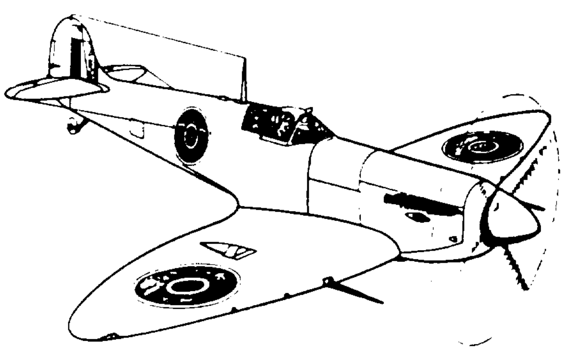


FIG. 3.

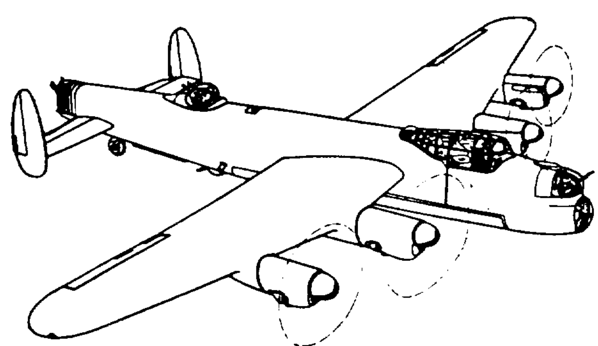
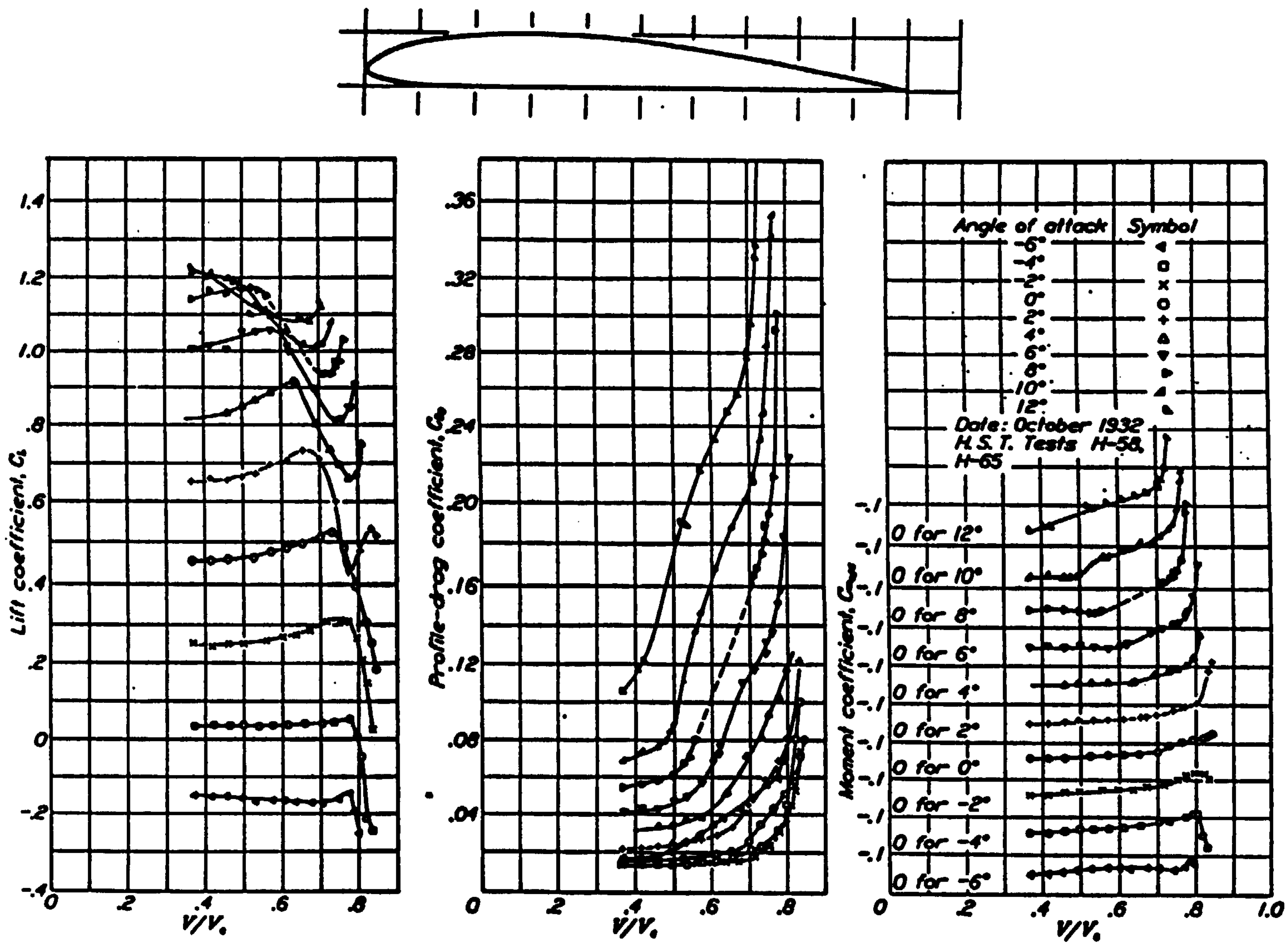
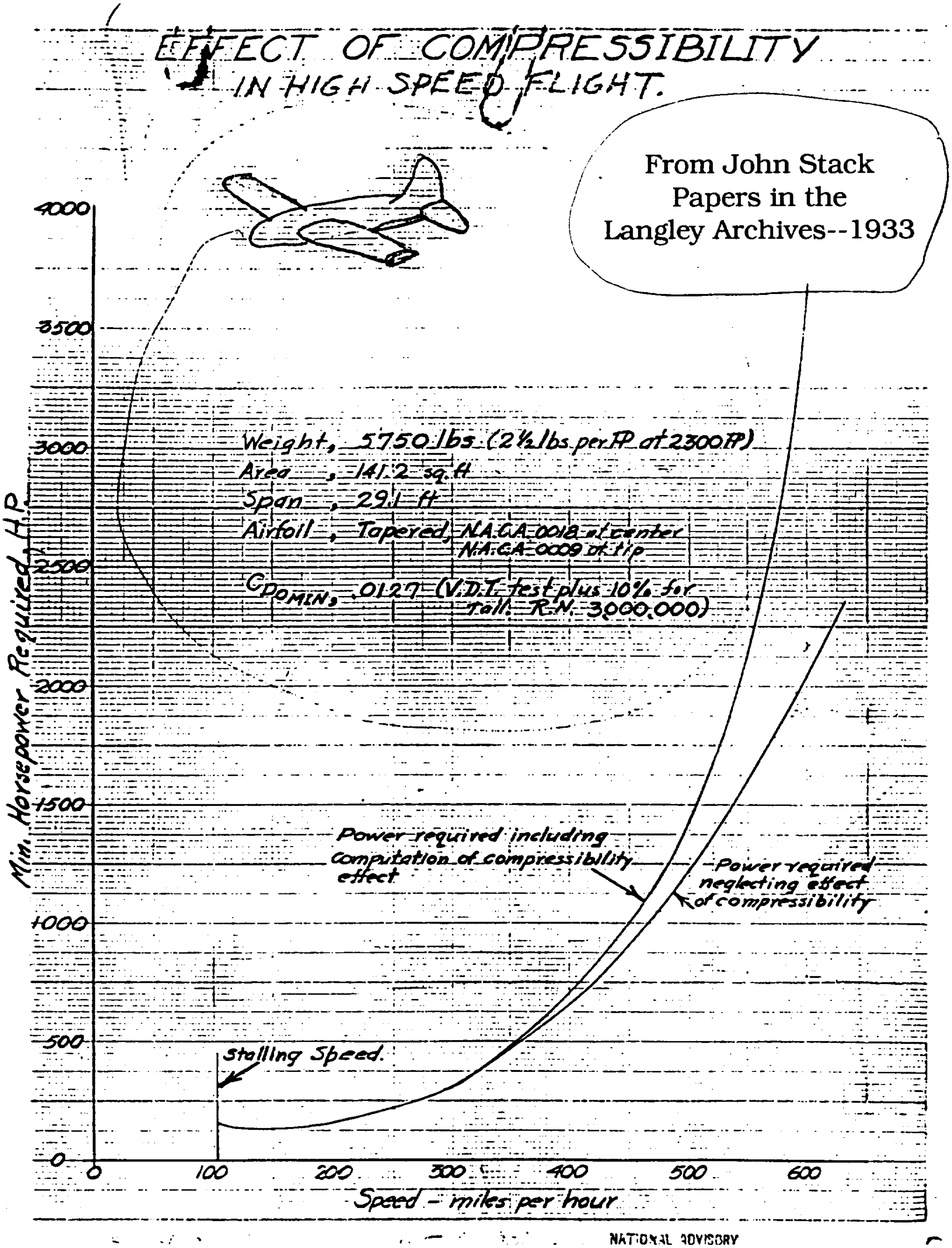


FIG 6.

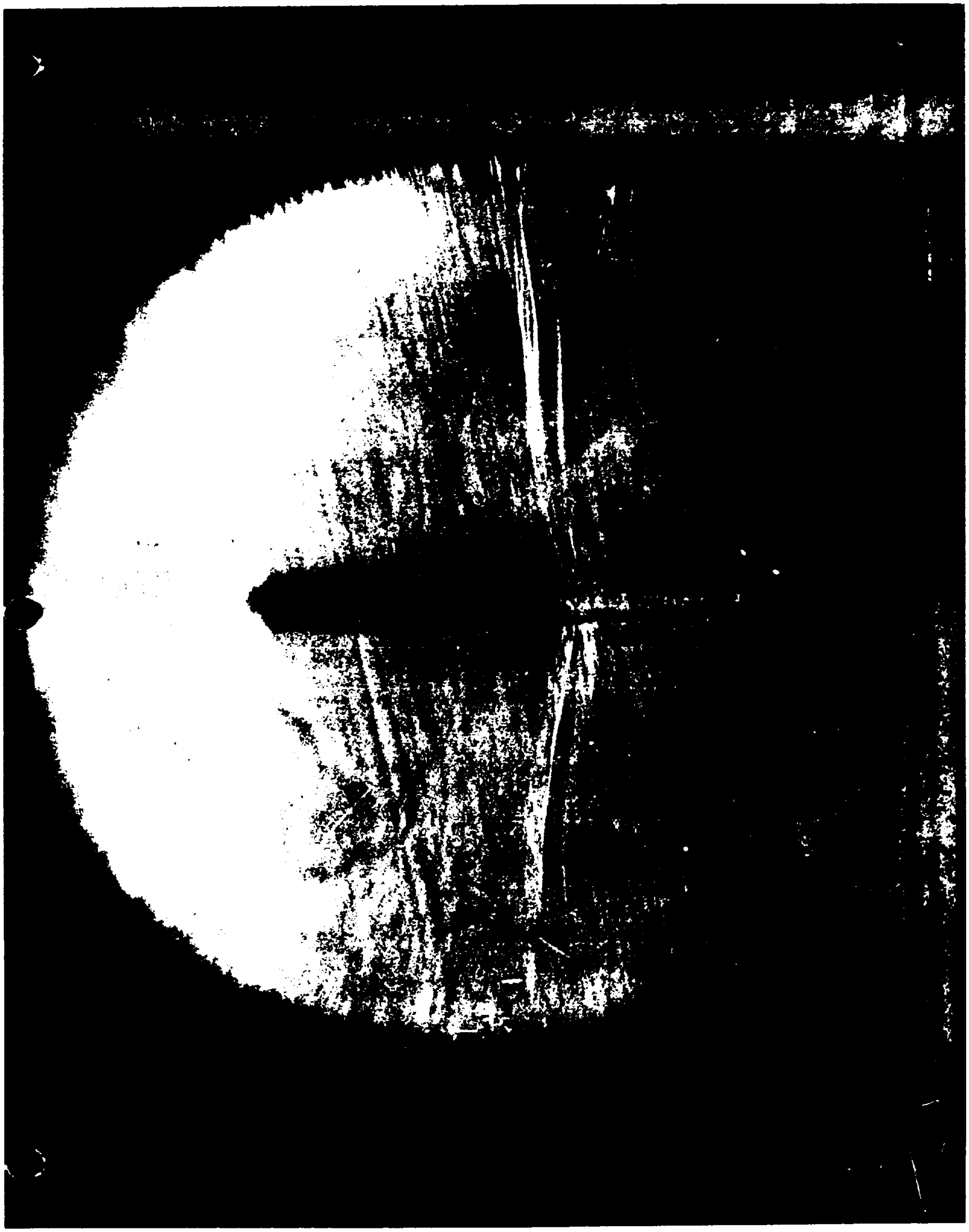
From Farren, Evolution of Streamlining, 7th Wright Brothers' Lecture, 1943, (IAS) Journal of the Aeronautical Sciences, April 1994



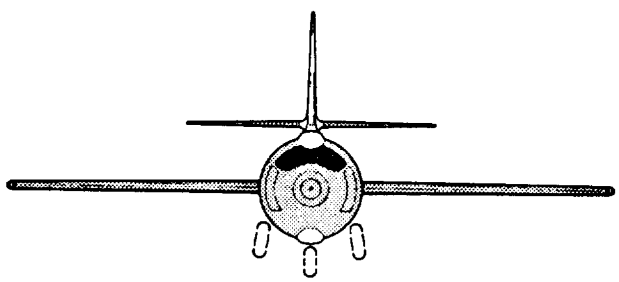
Wind Tunnel Data--John Stack, NACA, 1932

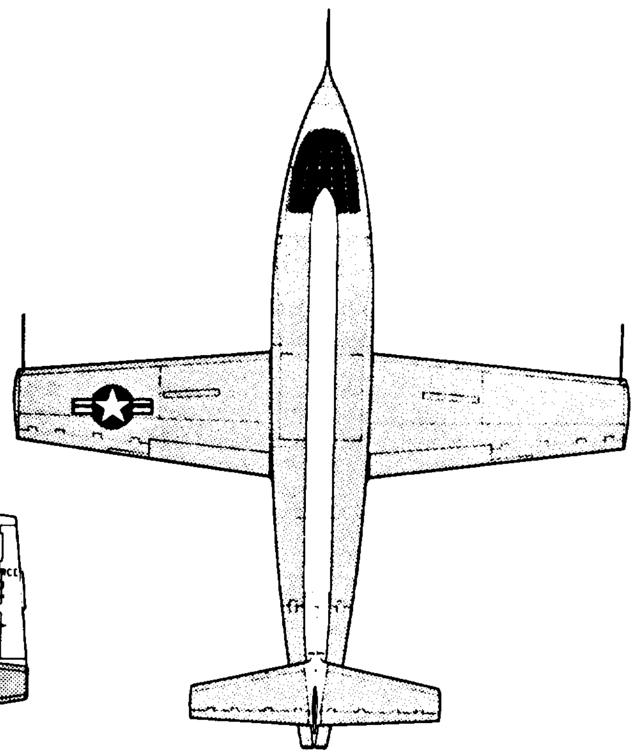

EFFECT OF COMPRESSIBILITY
IN HIGH SPEED FLIGHT.
From John Stack Papers in the Langley Archives--1933
Weight, 5750 lbs. (2½ lbs. per HP at 2300 HP)
Area, 141.2 sq. ft.
Span, 29.1 ft.
Airfoil, Tapered, N.A.C.A. 0018 at center
N.A.C.A. 0009 at tip
$C_{D_0 MIN}$, .0127 (V.D.T. test plus 10% for tail. R.N. 3,000,000)
Power required including computation of compressibility effect
Power required neglecting effect of compressibility
Stalling Speed.
Min. Horsepower Required, H.P.
4000
3500
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
600
Speed - miles per hour
NATIONAL ADVISORY

Schlieren Photo, Shock Waves on an NACA 0012 Airfoil--1934

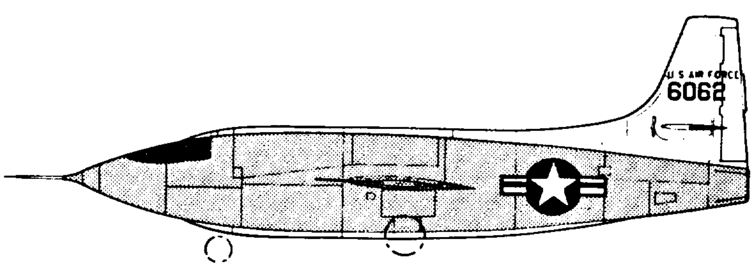


Bell X-1 (First Generation)





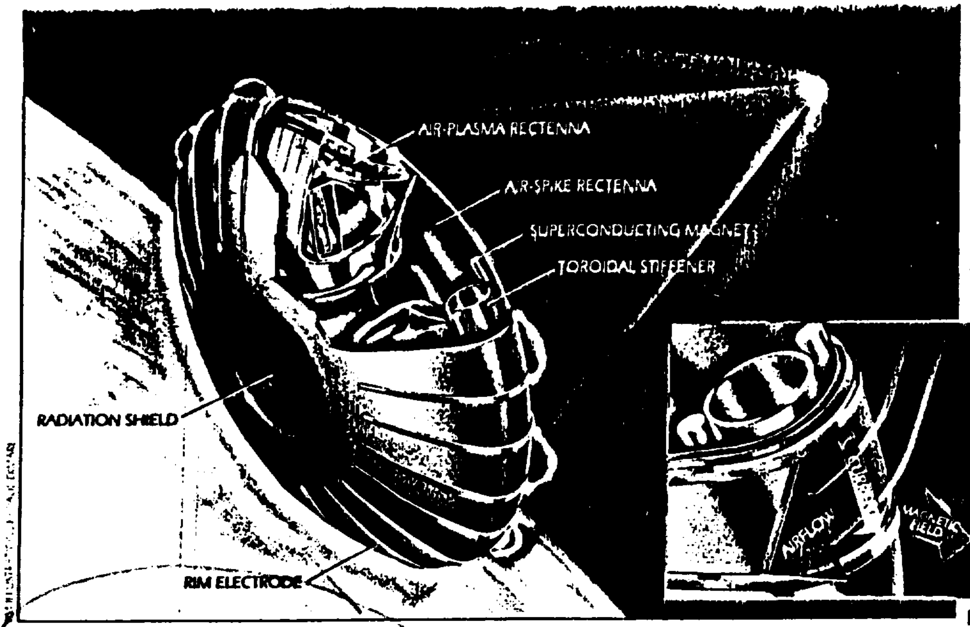
Colors:
F.S. 12243 gloss orange over-all w/F.S. 17925
gloss white trim



SCIENCE

Fly By Microwaves

BY GREGORY T. POPE, Science/Technology Editor



● Engineers come in two varieties. Some push the envelope from within, squeezing every last advantage out of existing technology. Their insights can turn a desktop computer into a notebook, or a Ford Fairlane into a Taurus. Without them, for sure, we'd be leading poorer lives.

But then there are engineers who perch outside the envelope and stir up trouble. Impatient with the pace of progress, they stretch for undeveloped technologies, mix and match nascent concepts and challenge the world to prove them wrong. They endure condescension while they're working out their ideas. But if their ideas do work out, they're lauded as visionaries.

Put Leik Myrabo into this second category. An associate professor of mechanical engineering at Rensselaer Polytechnic Institute, in Troy, New York, Myrabo is rewriting the laws of flight. But he's not tinkering with jet or rocket engines. Nor is he reformulating fuels or propellants. Instead, he's blueprinting a vehicle that does nothing less than streak into the sky on a beam of microwaves.

For more than a decade, Myrabo has pursued a vision he calls "Highways of Light." The concept began as a means of boosting a spacecraft without burdening it with fuel (see Tech Update, page 21, April '90). Shining up from the ground, a heavy-duty laser would illuminate the spacecraft's lower surface. The barrage of energy would break air molecules into plasma—a blazing vapor of ions, or charged particles. The explosive expansion that accompanied this ionization would shove the vehicle skyward.

In experiments with scale models, the technique proved capable of imparting thrust. But the Strategic Defense Initiative Organization, which helped bankroll Myrabo's research, soon pulled the plug on 100-megawatt-laser development.

Unfazed, Myrabo joined forces with Yuri Raizer of the Russian Academy of Sciences. The Space Studies Institute, in Princeton, New Jersey, picked up the funding. Myrabo recalls the Institute's reasoning: "They said, 'We love your lasercraft, but we're still waiting for the high-powered lasers. High-powered microwave sources are here now—is it possible to design something around them?' "

The switch from laser to less energetic microwave power sent Myrabo and Raizer scurrying for ideas. As is often the case, the wealth of unexploited aerospace theory from the 1950s and 1960s proved a fertile hunting ground. Within weeks, the engineers concocted a fresh design, a disc-shaped vehicle called a microwave lightcraft. Myrabo has since refined the design into one that brims with exciting, albeit untried, technologies.

Take the propulsion system, for example. Instead of simply riding a wave of expanding plasma, the lightcraft would wield electromagnetic forces to whisk the plasma past itself.

The driving force begins as a shaft of pulsed microwave energy. This beam showers the lightcraft from an overhead satellite that converts sunlight into microwaves. The energy hits two rectifying antennas, or rectennas, that lie beneath the vehicle's microwave-transparent surface. These antennas, in turn, convert much of the microwave energy into electrical power. At the same time, they work like lenses to focus the rest to points outside the spacecraft.

Shaped like a shallow, curved lampshade, one of the rectennas rings the craft. This air-plasma rectenna drives the craft at subsonic speeds. It focuses the incoming microwaves into an ignition circle around the vehicle's periphery. There, the microwaves blast air into plasma.

As the plasma expands, it gets caught up in electromagnetic fields from two superconducting magnets that encircle the craft. Their relative strengths being adjustable, these fields can form a magnetic nozzle that propels the plasma downward, imparting lift to the spacecraft.

Futuristic enough? Yet at supersonic speeds, an even more radical propulsion method takes over. In this mode, the other rectenna—located on the lightcraft's upper face—joins in. It focuses part of the microwave beam back ahead of the vehicle, forming a conical reflection known as an air spike. Like the pointed nose of a fighter jet, this cone reduces aerodynamic drag, keeping a shock wave from hammering the vehicle's flat upper surface. Instead, the shock wave arches around the air spike. In

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"The power of knowledge, put it to the task,
No barrier will be able to hold you back,
It will supprt you even in flight!
It cannot be your Creator's desire
To chain his finest in the muck and mire,
To eternally deny you flight!"

Poem by Otto Lilienthal, in his book
Birdflight as the Basis of Aviation. 1889

These lines are engraved into a commemorative stone which marks the site of Lilienthal's crash at Gollenberg, Germany