THE AIR WE FLY IN

By E. H. HEINEMANN

THE earth's atmosphere is, at present and probably will be for many years to come, the most important element in the science of flight. Yet this atmosphere, which supports all present day aircraft and is absolutely necessary to the sustenance of human life, is only meagerly understood by most people.

Until only a few years ago, the atmosphere's composition and characteristics were unimportant to all but a few scientists. Today, the rapid strides of air transportation have caused the earth's atmosphere to affect the lives of millions of people either directly or indirectly. The tide of the war was largely influenced by the air battles fought in the earth's atmosphere.

In peace, a knowledge of the earth's atmosphere and its characteristics is essential to air transportation as well as to accurate weather prediction, radio communications, and the understanding of the many phenomena that occur in everyday life on the earth.

To aid in the understanding of the earth's atmosphere, the earth may be visualized as a ball which is surrounded by three gaseous blankets. The weight of these three blankets is not negligible. In fact a one-foot square column of air which extends from sea level to the top of the earth's atmosphere weighs approximately one ton. These blankets of air are pulled to the earth's surface by the forces of the earth's gravity in the same manner the water is held to the ocean's bottom. Since air is easily compressed, it is natural that the weight of the outer blankets compresses the air so that it has the greatest pressure and weight at sea level. At greater distances from the earth's surface there is less and less weight of the air blankets acting and the pressure and weight of air becomes smaller.

Under normal conditions the heat absorbed by the earth and its lower atmosphere from the sun's radiation causes the temperature at sea level to be greater than the temperature at higher altitudes. Under normal conditions, the temperature decreases steadily with increasing height until an altitude is reached, beyond which the temperature remains essentially constant. This altitude determines the upper limit of the first blanket, which is called the troposphere, and the lower limit of the second blanket, which is called the stratosphere.

HEIGHT VARIES

The height of the troposphere varies, due to the earth's rotation, from about five miles at the poles to about ten miles at the equator. Within this first blanket is concentrated about eight-tenths of the weight of the earth's atmosphere. The air in the troposphere is composed almost entirely of a mixture of oxygen and nitrogen with only small quantities of other gases such as argon, carbon dioxide, helium, hydrogen, and water vapor.

Man's direct measurements of temperature and pressure extend upwards through the troposphere and to less than halfway through the stratosphere. The upper limit of the stratosphere blanket is about 50 miles high.

Even less is known about the third blanket, the ionosphere, except that it is within this layer that many electrical phenomena exist. The invisible Kennelly-Heaviside, or "E" layer, which reflects all but ultra-short radio waves back to the earth's surface, and the visible electrical displays such as the Aurora Borealis, are known to exist but are not yet clearly understood. In short, man, who lives at the bottom of the oceanic sea of air, knows very little about what takes place near its surface.

As aviators have ventured farther and farther from the earth's surface they have required a greater knowledge about the air in which they fly. They quickly discovered that the weather disturbances such as thunderstorms, fog, snow, and rain do not exist in the stratosphere. It was also found that, in order for humans to fly at these extreme altitudes, oxygen must be carried along and certain pressures must be maintained in the airplane cabin. Too rapid changes of altitude were found to produce "bends" due to the pressure changes, just the same as it does with deep sea divers. A few of the other interesting factors which restrict flight of extreme altitudes are noted along the right-hand border of the atmosphere chart accompanying this article.

TRADE WINDS

The winds aloft are as important to the pilot as the trade winds were to the old clippership skippers. The wind pattern of the earth is shown in the upper right-hand corner of the atmosphere chart. This wind pattern is caused by the fact that there is an unequal distribution on the earth's surface of the heat which is absorbed from the sun. Since "warm air rises," the air over the warmer areas of the earth rises and is replaced by an inrush of air from the colder regions. This continuous circulation of air is altered by the earth's rotation towards the east about its polar axis. The resulting wind pattern consists of the trade winds, which blow from the east on the earth's surface, the prevailing westerlies which blow from the west, and the polar winds which blow from the east.

INDIRECT MEASUREMENTS

Since direct measurements have been made of the earth's atmospheric characteristics to an altitude of only 25 miles scientists have used indirect means to determine or predict these characteristics above that point. The composition of the gaseous mixture in the stratosphere and ionosphere has been determined by analyzing the spectrum of the light from the aurora displays. Each gas has particular color banks on the spectrum and by observing the spectra from the auroras, the gas can be identified.

By measuring the "reflection" of sound waves from the sky it has been inferred that the temperature must increase rapidly at altitudes greater than 20 miles. The rare appearance of noctilucent clouds at altitudes of about 50 miles plus the deduction, by some scientists, that these clouds must be formed of ice particles, indicates low temperature. There is disagreement on this point, moreover, among the authorities. There seems little doubt, however, that extremely high temperatures, many times as great as the temperatures at sea level, exist at very great altitudes. Since the air is so rare at these altitudes, however, temperature does not have the same meaning as it does on the earth's surface.

CHARACTERISTICS OF THE EARTH'S ATMOSPHERE

SUMMARIZED FROM INFORMATION AVAILABLE IN 1944

PREPARED BY
DOUGLAS AIRCRAFT COMPANY INC.
EL SEGUNDO ENGINEERING DEPT

PERCENTAGE COMPOSITION OF EARTH'S ATMOSPHERE (BY VOLUME)

NITROGEN	78.77
OXYGEN	20.66
WATER VAPOR	.41
ARGON	.93
CARBON DIOXIDE	.03
HYDROGEN	.00005
	100.?

COMPOSITION PRACTICALLY CONSTANT WITH ALTITUDE UP TO 30 MILES. (EXCEPT FOR WATER VAPOR).

CHARACTERISTICS OF UPPER ATMOSPHERE UNDER MOST PROBABLE CONDITIONS

ALTITUDE IN FEET	ALTITUDE IN MILES	WEIGHT OF AIR IN LBS. PER CUBIC FOOT	MEAN FREE PATH IN INCHES	MOLECULES PER CUBIC INCH
500,000	94.6		370.	43×10^{11}
450,000	85.2		65.	25×10^{12}
400,000	75.8		12.	15×10^{13}
350,000	66.3	0.2×10^{-8}	1.9	84×10^{13}
300,000	56.8	2.6×10^{-7}	0.3	48×10^{14}
250,000	47.4	(A) 2.9×10^{-6}	5.8×10^{-2}	27×10^{15}
200,000	37.9	1.6×10^{-5}	1.0×10^{-2}	16×10^{16}
150,000	28.4	9.5×10^{-5}	1.7×10^{-3}	96×10^{16}
100,000	18.9	.00107	2.7×10^{-4}	62×10^{17}
50,000	9.5	.0116	3.6×10^{-5}	47×10^{18}
0	0.0	.0765	(B) 3.5×10^{-6}	(C) 44×10^{19}

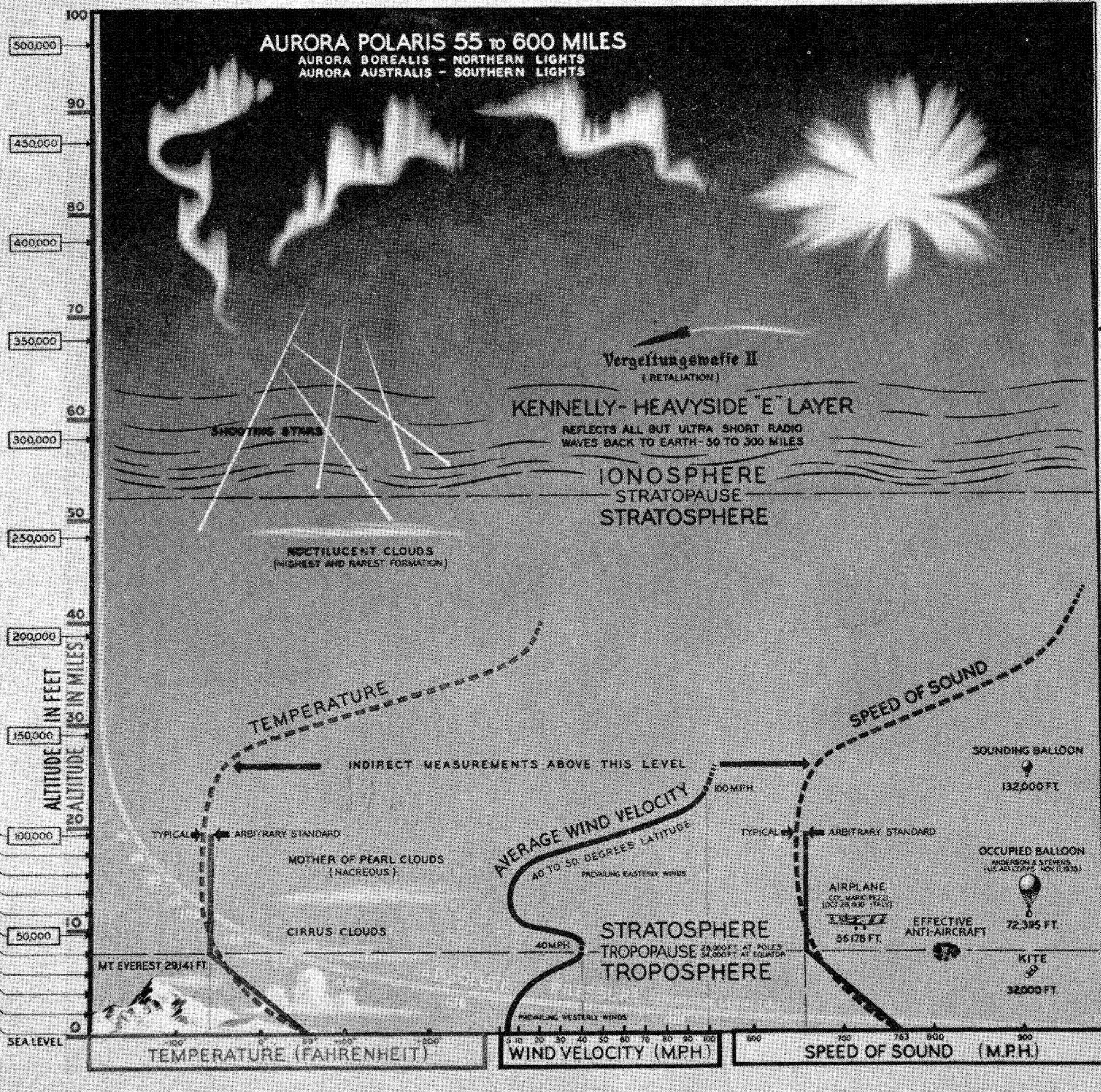
(A) 2.9×10^{-6} = 2.9 POUNDS PER MILLION CUBIC FEET

(B) 3.54×10^{-6} = 3 1/2 MILLIONTHS OF AN INCH BETWEEN MOLECULAR COLLISIONS

(C) 44×10^{19} = 440,000,000,000,000,000,000 MOLECULES PER CUBIC INCH

ARBITRARY STANDARD ATMOSPHERE FOR 45° LATITUDE

ALTITUDE IN FEET	SPEED OF SOUND (MPH)	RATIO OF ALTITUDE TO SEA LEVEL DENSITIES	PRESSURE (LBS. PER SQUARE INCH)	F° TEMPERATURE	C° TEMPERATURE	WEIGHT OF AIR (LBS. PER CUBIC FOOT)
100,000	664	.014	.16	-67°	-55°	.0011
90,000	664	.023	.28	-67°	-55°	.0017
80,000	664	.036	.40	-67°	-55°	.0028
70,000	664	.058	.65	-67°	-55°	.0044
60,000	664	.094	1.05	-67°	-55°	.0072
50,000	664	.152	1.69	-67°	-55°	.0116
40,000	664	.245	2.72	-67°	-55°	.0187
30,000	680	.374	4.36	-48°	-44°	.0286
20,000	708	.533	6.76	-12°	-25°	.0408
10,000	736	.738	10.11	+23°	-5°	.0565
0	763	1.000	14.70	+59°	+15°	.0765



GERMAN V2 ROCKET BOMBS ATTAIN THIS ALTITUDE DURING FLIGHT APPROX. 340,000 FT. (REPORTED TO HAVE ATTAINED AN ALTITUDE OF 160 MILES IN EXPERIMENTAL VERTICAL FLIGHT.)

SOUND WAVES NOT PROPAGATED ABOVE THIS ALTITUDE DUE TO INCREASED DISTANCE BETWEEN MOLECULES.

TWILIGHT LIMIT. FIRST MAGNITUDE STARS ARE VISIBLE DIRECTLY OVERHEAD WHEN SUN SETS. 210,000 FT.

MAXIMUM OZONE CONCENTRATION (ONE PART OZONE TO 100,000 PARTS ATMOSPHERE.) 106,000 FT.

BLOOD BOILS AT BODY TEMPERATURE. 98.6° FAHRENHEIT 63,000 FT.

100% OXYGEN NEEDED FOR SUSTENANCE OF LIFE. EXACT ALTITUDE DEPENDS ON INDIVIDUAL AND EXPOSURE. 40,000 TO 45,000 FT.

BREATHING PURE OXYGEN EQUIVALENT TO BREATHING SEA LEVEL AIR. 33,000 FT.

GASOLINE BOILS AT NORMAL TEMPERATURE, -65° FAHRENHEIT 32,000 FT.

SKY APPEARS PURPLE ABOVE THIS POINT. 30,000 FT.

CANDLE NO LONGER BURNS. 21,000 FT.

HIGHEST COMMUNITY OF HUMAN BEINGS ANDES MTS., SOUTH AMERICA. 18,000 FT.

OXYGEN REQUIRED FOR SUSTENANCE OF LIFE BY SEA LEVEL DWELLERS. ALTITUDE DEPENDS ON PHYSICAL CONDITION AND DURATION OF STAY. 15,000 FT. TO 20,000 FT.

WIND PATTERN OF THE EARTH

The data which are presented on the atmospheric chart represent the best information available at the present time and have been gathered from many authorities on the subject. As more and more information is obtained these data may have to be modified and extended.

One potential source of direct measurement of atmospheric characteristics at extremely high altitudes is the sounding rocket. Notice that the German V-2 rocket is reported to have achieved altitudes of more than six times as high as any other man-made device yet flown. Balloons are definitely restricted as to their maximum altitude, since they rely on the weight of the surrounding air to support them.

NEW RESEARCH FIELDS

For our present knowledge of the air we fly in, we are greatly indebted to the painstaking and sometimes unrecognized research of many scientific institutions. As man's inquisitive nature forces him to venture outside of the air realm in which we fly at present, he must rely entirely on the knowledge of these scientists if he hopes to return to the earth in safety. It is clearly seen, therefore, that air transportation's desire to learn more about the composition and characteristics of the earth's upper atmosphere opens a vast new field of scientific research. The development of the rocket has supplied the scientist with a new tool with which he can investigate the upper atmosphere. It is hoped that now the scientist will be able to supply the aeronautical engineers with a reliable and complete knowledge of the atmosphere beyond which man-carrying vehicles have flown so that he, in turn, may design aircraft to extend the realm of "The Air We Fly In" to "The Atmosphere We Fly In" and, one day, "The Universe We Fly In."

Fluoroscope Examination

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To investigate the possibilities of higher voltage fluoroscopy, a fluroscope was constructed incorporating features which were found to be desirable in the use of the earlier model. The fluoroscopic viewing unit consists of a wooden frame structure mounted on heavy rubber-tired casters. The viewing window, a lucite cell filled with lead perchlorate solution, is 4½ inches thick and gives a viewing area of 16 inches by 14 inches. The fluorescent screen is mounted in an aluminum frame which can be moved toward or away from the viewing window by means of a motor. The object under examination is hung from a support mounted on a shuttle. This shuttle, mounted on small ball-bearing wheels, runs on tracks within the cabinet. The shuttle can then be driven into or out of the cabinet, bringing the object to be examined in front of the viewing window. When one end of the shuttle is outside the cabinet the other end is in the viewing position. The cabinet is lined with lead sheet ¼ inch thick, providing ample protection for personnel. During observation the operator may move the part being examined back and forth across the field of view. Provision is also made so that the casting can be rotated as it hangs in front of the viewing window.

The X-ray tube is mounted on its tube stand and is provided with a counter-balance so that it can be moved up or down with ease. The tube port extends through a hole in the cabinet, and protection is provided by means of suitable lead flanges. The tube can be moved up or down a distance of 4 inches from the center position by means of a motor mounted on the cabinet itself.

For the higher voltage work a 220 kv constant potential unit was secured as a loan through the courtesy of the Westinghouse Electric Corporation. This tube had a focal spot of approximately 5 mm. It is common practice to employ X-ray equipment producing half-wave rectified voltage. However, one might expect for fluoroscopic examination that the higher output of constant potential type equipment would prove to be superior, in view of the higher screen brightness attainable. The aluminum artificial specimens referred to before were again utilized in the evaluation of this equipment. Complete tests were made with aluminum varying in thickness from ½ inch to 2½ inches, at voltages varying from 140 to 220 kv. In all of these tests the tube current was maintained at approximately 15 ma.

The results of these tests indicated that no particular advantage was to be gained in the detection of defects 0.050 inch or less in maximum dimension in aluminum in the range of thickness from ½ inch to 2½ inches by using X-ray tube voltages greater than approximately 150 kv. Furthermore, it was evident that there is no particular advantage in constant potential X-ray equipment over the commonly used half-wave rectified type.

In view of the greater X-ray density of steel, it was believed desirable to study the performance of this equipment with samples of steel containing artificial defects. A series of samples was made in the same manner as described for aluminum; thicknesses of from ¼ inch to ½ inch, and voltages of from 140 to 200 kv were employed. The results of these tests indicated definitely that the results secured by operating at a voltage of 200 kv were better than those obtained at 140 kv. It is therefore apparent that with higher voltages fluoroscopy of steel is possible within a certain range of thickness.

FURTHER STUDY REQUIRED

While these studies have been exploratory, they have shown that fluoroscopy can be employed for the detection of certain classes of defects which may appear to be structurally significant. There is no reason why fluoroscopy should not be used as an inspection tool, provided its limitations are recognized. The influence of defects which either can or cannot be observed fluoroscopically, or for that matter radiographically, must be determined in any event, and this leads to a very fundamental research program which it is hoped may be considered sometime in the future.

RED CROSS FUND

THE American Red Cross enters its 1946 campaign for funds in February. The generous contributions made during the war must continue even though the budget has been reduced 45 per cent. More than any other agency, the Red Cross administers to the comfort and welfare of:

a) Our occupational forces, which still number 1,500,000.
b) The 170,000 servicemen still in the hospitals.
c) The several hundred thousand disaster victims (floods, tornadoes, etc.) in our own country each year.
d) Those unfortunates in the war-devastated areas overseas.

While this is but a partial list of major Red Cross activities, everyone should be able to pick out a particular reason for the urgency of his gift.

At C.I.T., the campaign is being started February 25 by Bob Lehman '31. The support of your local solicitation is strongly encouraged.

R. A. Millikan.