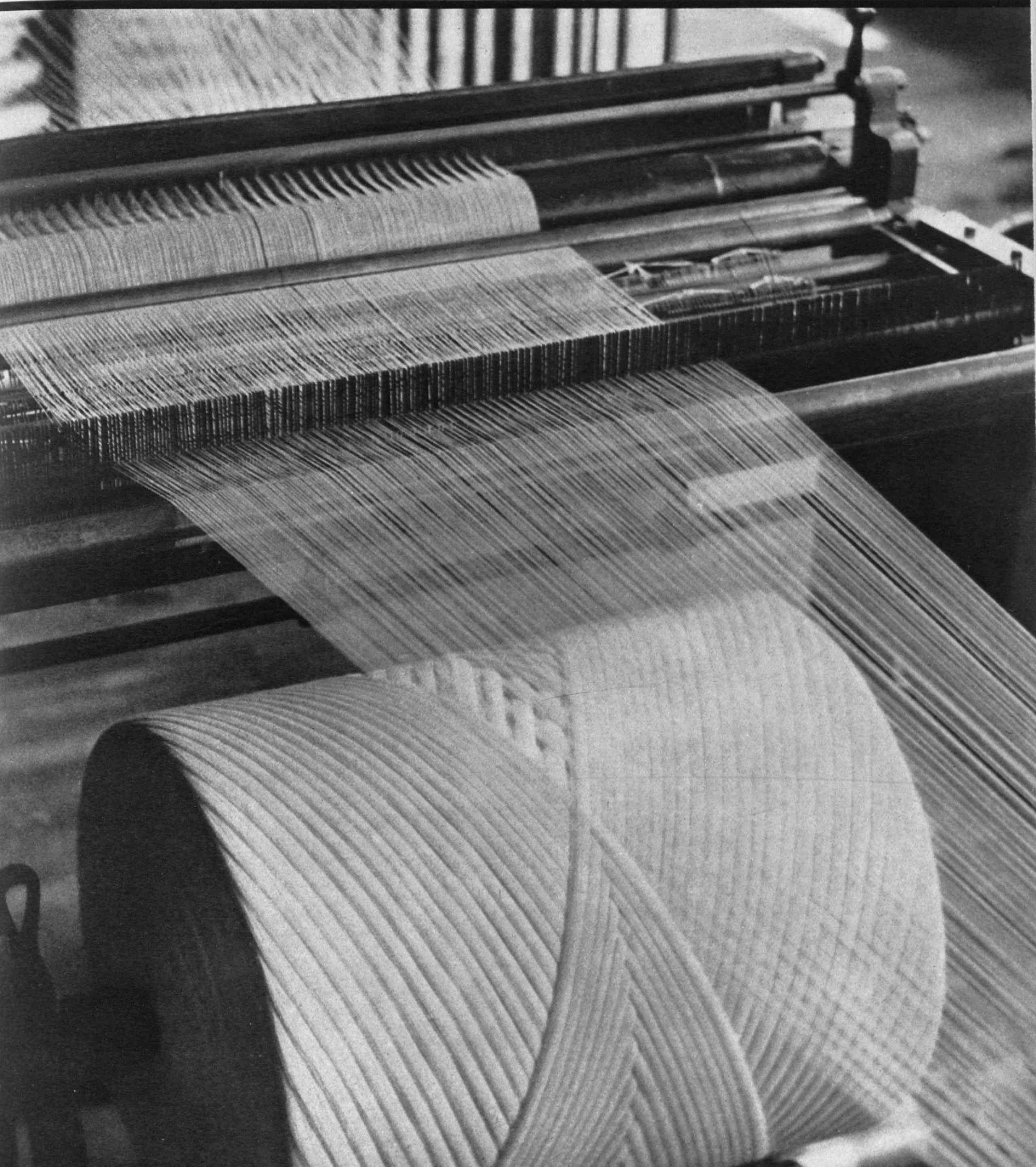
November 1933

TECHNOLOGY REVIEW



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THE TABULAR VIEW

EMINENT as a mathematician, stimulating as a writer, Dr. NORBERT WIENER is welcomed again to the pages of The Review. Articles contributed by him in the past include "Mathematics and Art" (Jan. 1930); "Murder and Mathematics" (Mar. 1929); and "Einsteiniana" (May 1929). It is worthwhile pointing out that Lord Rutherford's recent denial — a denial caged in the argot of *opéra bouffe* — of the availability of atomic energy is not concurred in by all scientists. ¶ Once an instructor in Naval Architecture, F. A. MAGOUN, '18, is now Associate Professor of Humanics at Technology. He is the author of such diverse titles as "The Frigate Constitution and Other Historic Ships"; "Sky High — The Story of Aviation" (with Eric Hodgins, '22, formerly of The Review); "A History of Aircraft" (with same); "Behemoth — The Story of Power" (with same); and "Problems in Human Engineering." The article by Professor Magoun (p. 50) is drawn from an address delivered by him before the Fourteenth Annual Industrial Conference lately held at Pennsylvania State College. ¶ JOHN B. DRISKO, '27, has recently completed for The Technology Press a translation of W. Spannhake's "*Kreiselräder als Pumpen und Turbinen*" ("Pumps, Turbines, and Propellers").

HOLDER of 25 or more patents and author of seven books, JOHN MILLS, '09 (*A Balanced Ration of Work*, p. 56), is now Director of Publication for the Bell Telephone Laboratories. After joining the Bell System in 1911 he contributed to the earliest developments of transcontinental and transatlantic telephony. His interest in personnel problems derives from the personnel work he did in the laboratory unit of the System after the War. Last July, The Review erroneously credited Mr. Mills with the invention of a system for the multichannel transmission of orchestral music and its reproduction in auditory perspective. What Mr. Mills did do was to suggest the word *ceno-orchestra*, meaning "empty orchestra space," as a possible substitute for the large number of words which would otherwise be required to describe the system. Dr. Harvey Fletcher, Director of Acoustical Research for the Bell Telephone Laboratories, was primarily responsible for the *ceno-orchestra* system, and among others who contributed were E. C. Wente, '14, H. A. Affel, '14, E. O. Scriven, '11, and R. A. Miller, '20. ¶ JAMES HOLT, '18, is Assistant Professor of Heat Engineering at Technology. As teacher, researcher, and consultant, he is an authority on the mechanical equipment of buildings. ¶ Quotation from a letter written by a retrieved subscriber and obviously inspired by Professor Millard's article, "Falling Apples": "The posthumous October number of The Technology Review proved to be a falling apple which hit me on the head with such effect that I am enclosing a check . . . for the renewal of my subscription, cancellation of which probably crossed said apple . . . in Missouri. Drastic reductions in my magazine list will not include The Review. I particularly appreciated the pictures, 'Day's End' and 'A Dream of the Babylonians'."

A SAVING OF 25% PER TON

..... AND THE G.T.M.

THE best records of three good quality belts on the hot coke conveyor of a big New York State plant showed an average tonnage of 225,634 tons at a cost of $0.0455.

Interspersed with these were the performances of other belts which were used up so rapidly no cost records on them were considered.

The G.T.M. — Goodyear Technical Man — studied the job with the idea of providing a belt specially designed for this duty and therefore capable of setting a new standard of longer life and lower cost per ton carried.

This was a job of conveying coke that is dry quenched, and dry quenching does not permit moisture on the belt. Ordinary belts don't live long here. The G.T.M. specified a Goodyear Special Hot Coke Conveyor Belt, 5 x 7, 32-oz. duck, top 3/8th-inch cover in center, 1/16th-inch bottom, 28 inches wide.

The Goodyear Belt carried 417,781 tons, at an average cost of $0.0341 per ton — a saving of 25% per ton!

This is the kind of service — more efficient, more economical — you may expect from Goodyear Belts expertly specified and scientifically built for the job, and never so high in quality as now.

The G. T. M. may be able to help you reduce your belting costs. Why not get him in? Write to Goodyear, Akron, Ohio, or Los Angeles, California, or call your nearest Goodyear Mechanical Rubber Goods Distributor.

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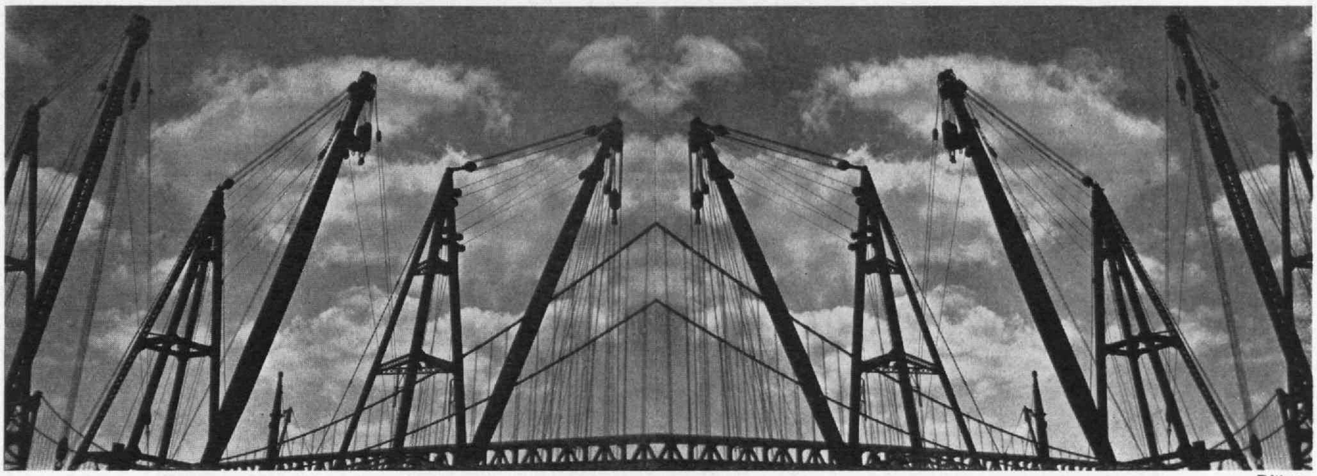

Rittase

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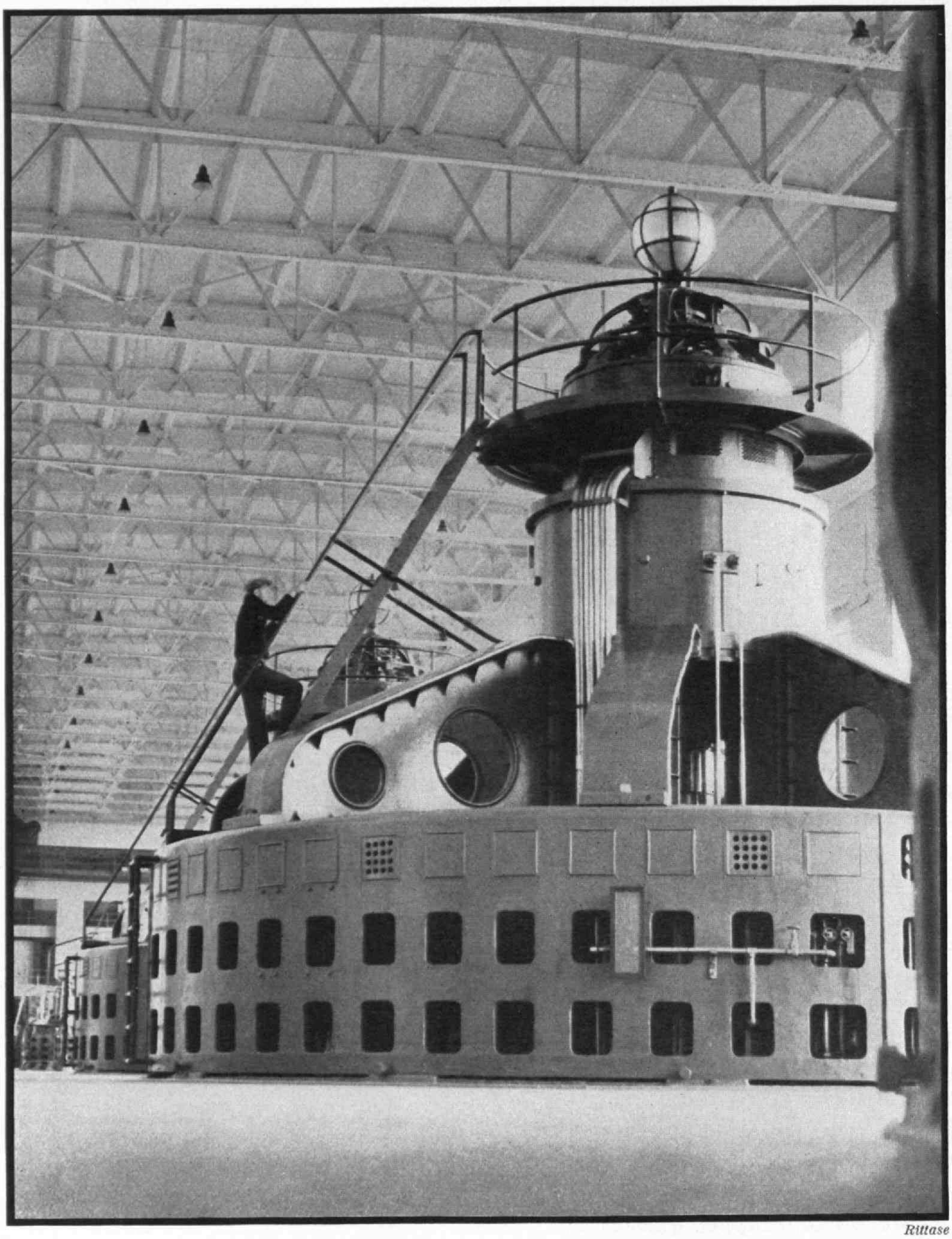


Rittase

Generator Room, Wilson Dam (Muscle Shoals)

WILSON DAM vs. ONE POUND (*of matter*)

Physicists estimate, as Dr. Wiener points out in his annexed article, that one pound of matter contains (in yet unavailable form) about 11,300,000,000 kilowatt hours (over 15,000,000,000 horse-power hours) of energy. Wilson Dam, running at full ultimate capacity for a year, would generate only about one-third as much as that contained in a pound of butter!

THE TECHNOLOGY REVIEW

Vol. 36, No. 2 November, 1933

Putting Matter to Work

The Search for Cheaper Power

By Norbert Wiener

The Methods of Energy Storage — How the Strength of Materials Limits Power Storage — The Energy Stored in a Pound of Matter — Social and Economic Consequences of Cheaper Energy

ENGINEERING development has taken place in what seems at first sight to be two essentially different directions — the improvement of design and the improvement of materials. These two directions of improvement cannot be separated. We often think of Watt's steam engine as one of the greatest developments in engineering design and as, in a large measure, responsible for the century and a half of engineering progress which has followed it, yet Watt's engine could scarcely have been invented at any preceding period owing to the lack of engineering materials previously available and within the manipulative powers of contemporary craftsmen. Parenthetically, it is curious to reflect that the predecessors of our present mechanical engineers were the instrument makers and clock makers of the Eighteenth Century. The desire for accurate timepieces and instruments of navigation perfected the art of machining metals, and in particular cast metals, to the point where the accurate cylinders, pistons, shafts, and gears required by Watt's steam engine could for the first time be produced commercially.

There are two fields of engineering of great interest at the present time in which improvement in design is directly circumscribed by improvement in materials. I refer to the storage and the production of energy. These problems are inextricably united. We can never effectively tap such low-grade and fluctuating sources as wind and waves until we can concentrate and store the energy generated. Moreover, there is another direction in which the question of getting the largest amount of energy stored in an apparatus of a given bulk of a given weight has recently acquired an importance perhaps greater than it has ever had. The need for great economy of weight began to make its appearance really felt in the automobile and has become the dominating consideration in the airplane engine.

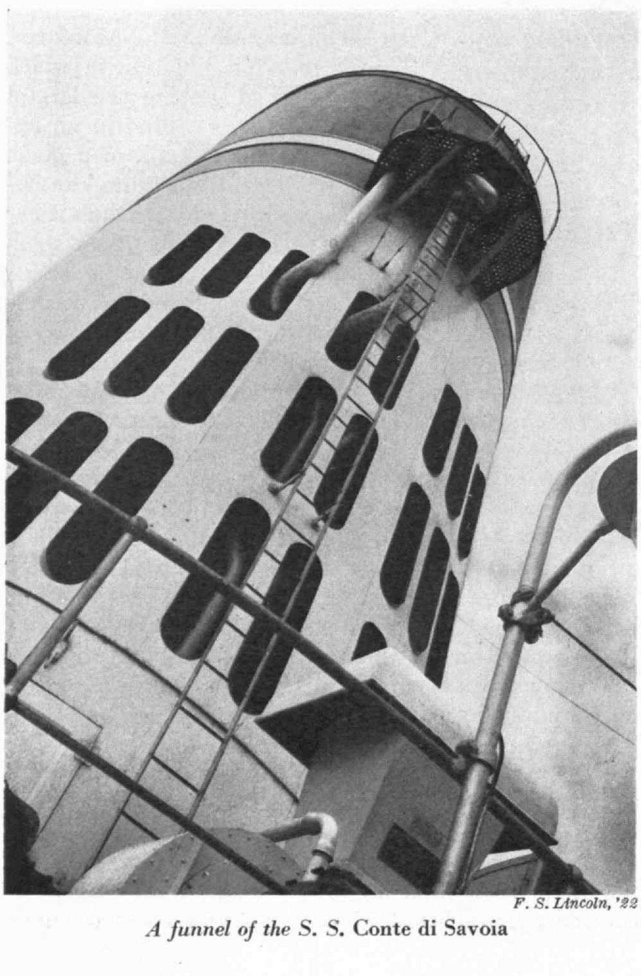
Indeed, the airplane was only made practicable by the invention of the internal combustion engine, a power plant of previously unimagined lightness and efficiency. I am not yet 40, but I can well remember the time when the flying machine was spoken of as a twin sister to the *perpetuum mobile*. Nevertheless, the idea of the flying machine is older than Leonardo da Vinci, and for a century before the successful experiments of the Wrights, more than one tentative flying machine had borne a form closely reminiscent of the modern airplane. It is unquestionable that some of these early airplanes could have been flown effectively, if insecurely, had they been equipped with an internal combustion engine of the type available to Wright.

But the airplane, made possible by a great improvement in power plant, is awaiting a still greater improvement of the same kind to become a really first-rate factor in modern civilization. The one limitation that militates more than all others against the success of transoceanic flights, that renders them a sort of superathletic stunt rather than a routine commercial undertaking, is the excessive amount of fuel which they require, to the almost complete exclusion of pay load. The transatlantic flight is so near the limit of present possibility that it involves the double risk of an initial load too heavy for a take-off and of a terminal landing without fuel for power. It is hard to see how this difficulty can ever be met with present types of engines. The suggested use of vessels of various specialized types for intermediate landing platforms may indeed solve the commercial problem, but the engineering problems await some new development.

The nature of this development will obviously be some device whereby an abnormally large store of energy is carried in a relatively light apparatus. This engineering development also depends in equal measure on an improvement in technique and an improvement in materials. Let me discuss the problem of the storage of energy from a very general standpoint.

Among the various methods which may be adapted to this purpose are:

1. GRAVITATIONAL STORAGE: *clock weights, dams*
2. KINETIC STORAGE: *flywheels*
3. ELASTIC STORAGE: *springs, rubber cords, compressed air*
4. MAGNETIC STORAGE: *choke coils*
5. DIELECTRIC STORAGE: *condensers, Leyden jars*
6. THERMAL STORAGE: *storage boilers*
7. CHEMICAL STORAGE with electrical utilization: *accumulators*
8. CHEMICAL STORAGE with thermal utilization: *fuels and explosives*
9. ATOMIC STORAGE (not yet employed in practice).



F. S. Lincoln, '22

A funnel of the S. S. Conte di Savoia

The limitations of gravitational storage are shown by the fact that an airplane when gliding from its ceiling uses up in a very few miles its entire available gravitational energy. Storage as kinetic energy is worth a more serious consideration. It is manifestly impossible to store any large amount of energy as energy of translation, and so energy of rotation in the form of the energy of flywheels is the only kind worth discussing. Now the flywheel has a very definite limit of speed which is determined by its shape and size and by the strength of the materials used. Thus, any improvement over the relatively small amount of energy which may at present be stored in flywheels is directly dependent on an improvement in the mechanical strength of metals available. We leave the consideration of friction out of account entirely, although in practice this is by no means negligible, for windage can be practically entirely eliminated by a vacuum mounting and pivot friction can be greatly reduced by the use of very hard bearings, such as jewels. Here again, however, questions of strength of material are the dominating ones, for the friction of a pivot can be cut down still further by the discovery of still harder and tougher substances. At any rate, until we have some improvement in materials, we have already realized the maximum storage of energy per pound obtainable in kinetic form.

Elastic storage depends even more obviously on the properties of materials. The amount of elastic storage possible in a pound of material under a given type of stress is obtained by integrating the deforming force with respect to the deformation up to the point of permanent set, which we call the elastic limit. This maximum density of energy will be independent of the shape of the piece of material stressed. If we halve the cross-section and double the length, we halve the force and double the deformation for a given force. This is a constant for the material and the type of strain—tension, compression, or shear. It is greater for a pure strain of one of these types than for any bending or torsion which does not strain the parts of the material equally.

The amount of energy which may be stored per unit mass is quite low in most materials and the maximum is already attained in practice. Steel has great strength but the strain at the elastic limit is small. We all know the relatively small amount of energy per pound which can be stored in the springs of an automobile, which break at a point at which the stored energy is only enough to propel the car a few feet. Of all materials, rubber has the greatest power for the elastic storage of energy. While the elastic limit in the sense of a limit of linearity of the stress-strain relation is reached fairly soon, rubber can be extended several times its own length before requiring any great degree of permanent set, and this is what counts. The changes undergone by rubber in stretching seem to be of a complicated character and are perhaps not to be called purely elastic. The molecule of rubber appears to have an entirely different mode of absorbing energy when stretched than does that of the ordinary material. Indeed, rubber as an elastic material offers a rather interesting analogy to