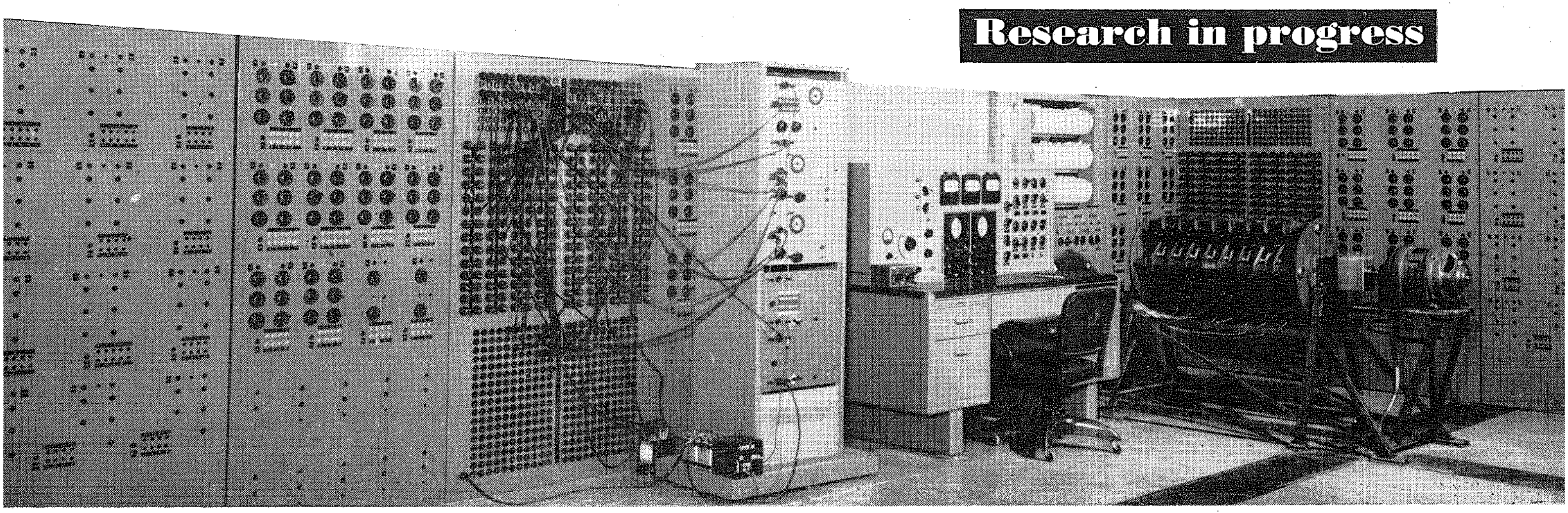


This is one of two control panels for the Electric Analog Computer located in Caltech's Analysis Laboratory.

The Electric Analog Computer

SMOOTHER riding trains, stronger buildings and machinery, better jet engines—these are just a few of the things that may come as a result of work now in progress on Caltech's electric analog computer.

This 33,000-pound machine is the first of its kind to be put into service. Under the supervision of the men who feed it mathematical problems, the computer takes just a few days to solve problems that once would have kept three or four mathematicians busy for years.

The product of several years of research itself, the computer has been in limited operation for over a year, and in full operation for the last few months in the Institute's Analysis Laboratory. This laboratory, with Dr. G. D. McCann, developer of the computer, as director, has been set up to study and develop a number of different types of "thinking machines." And the facilities of the laboratory are available not only to research groups at the Institute, but to industrial and engineering organizations everywhere.

The Analysis Laboratory was established late in 1946. Its first objective was the development and construction of the analog computer—chosen as the first unit in the laboratory because of its usefulness in such a wide variety of industrial problems. Under the supervision of Dr. C. H. Wilts, the computer has been enlarged recently so that it can handle linear partial differential equations with up to three independent variables, and non-linear partial differential equations with two independent variables.

In most engineering fields the mathematical problems of greatest complexity—and greatest importance—have to do with equations of this type. In the past engineers have not had adequate facilities for solving these problems fast enough. Manufacturers have had to put equipment into use through the expensive process of building and testing models, or through the even more expensive process of building equipment, trying it out, and eliminating defects in a later model. Now, however, manufacturers can send problems to the Analysis Laboratory where they can be speedily solved.

A case in which the computer's speed was of great importance occurred during the war. At that time the computer's pilot model, developed by Dr. McCann and Dr. H. E. Criner at the Westinghouse Research Laboratories, was given the job of finding out just how electron tubes for vital radar sets should be packaged for overseas shipment so that they could not be harmed by vibration.

Ordinarily a vibration analysis of this sort would have taken two mathematicians about three years to complete. The machine did it in a little over a week and turned the results over to the Bell Telephone Laboratories, where they were needed.

The scope of the computer has been greatly expanded since the days of the pilot model. The machine has already solved a number of problems for leading aircraft companies, and done a vibration analysis for the Pullman Standard Car Company. In addition it is serving as a teaching aid to course work in applied mathematics, electrical engineering and mechanics, and as a research tool for the Institute and its Jet Propulsion Laboratory.

A recent publication by Dr. McCann lists 92 fields in which the computer can be useful to industry. These range all the way from the analysis of electrical circuits for utilities companies to problems of applied mechanics, such as the study of gas and Diesel engines, or the shock problems created by the firing of big guns. The list includes problems in temperature distribution in jet engines and gas turbines, aircraft vibration analysis, wing flutter and landing shock, general aerodynamic stability and the stability of autopilots for guided missiles. Along more fundamental lines, the computer can be of great help to the researchers who must analyze electromagnetic radiation in the course of their investigation of the ultimate particles of matter.

Many of these problems have no simple answer. Some of them require as many as 10,000 answers for a full solution. Often in the past these answers had to be found many times over by mathematicians working in different parts of the country. But the analog computer tabulates its answers once and for all, so that they can be distributed wherever and whenever they are needed. The machine's efficiency is further increased by its being able to handle two separate problems at one time.

Digital vs. analog

There are, in general, two types of computers. "Digital" computers operate in a step-by-step fashion, while "analog" computers operate continuously. Your hand is a digital computer; it can count, finer-by-finger, up to five, and if the thumb "remembers" five, it can count up to nine. The abacus is a more efficient digital computer, and most modern office machinery is based on the digital principle.

Recently digital computers have been developed to work on more complex mathematical problems. They can do arithmetical calculation, store numbers, look up functions, control the sequence of computation, feed data into the computer and record the solutions of advanced problems in algebra and calculus. There are successful machines of this type in operation at many centers: the Automatic Sequence Analyzer built by the International Business Machines Company for Harvard University, for instance, and the ENIAC developed at the University of Pennsylvania. Recently the facilities of the Analysis Laboratory at Caltech have been extended by the addition of a digital computing group which has been set up under the direction of Dr. Stanley P. Frankel (see page 16).

Analog computers operate by means of a system that is an analog or replica of the physical system to be studied. A slide rule is a simple analog computer; it finds its answers in terms of logarithms. The first successful large-scale analog computer for the solution of complex problems was the differential analyzer developed at the Massachusetts Institute of Technology. This machine, and newer ones based on the same principle, operate by means of a mechanical system set up to represent the conditions of a problem.

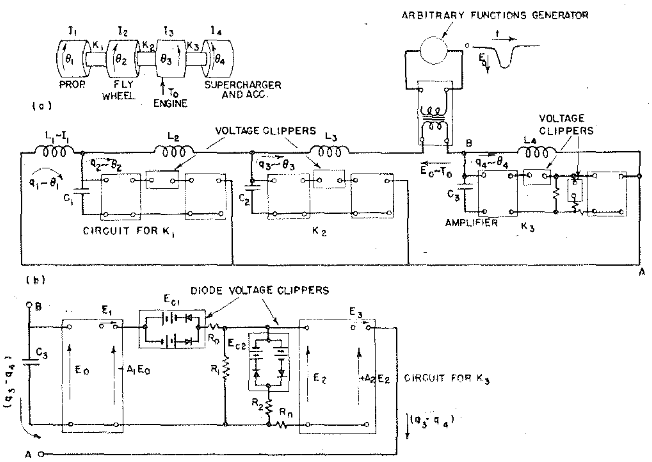
In the Caltech computer, however, the analogous system is an electric curcuit. The computer is the result of a program, begun jointly in 1946 by Westinghouse and the Institute, for the development of two identical large-scale, general-purpose computers. The Westinghouse unit, known as the Anacom, is located at the Research Laboratories in East Pittsburgh; the Caltech computer is in the Norman Bridge Laboratories on the Caltech campus.

It was decided to limit the accuracy of these two machines to one percent—a figure which makes the computers adaptable to the vast majority of problems in the general field of engineering analysis. Development of the computer has reached the point where analogous electrical circuits can be devised for almost any physical system for which differential equations can be written. Electric circuits can readily simulate addition, subtraction, multiplication by constants, integrating or differentiating and the formation of equations. Special electronic multipliers have been developed to make the computer adaptable to non-linear equations, also.

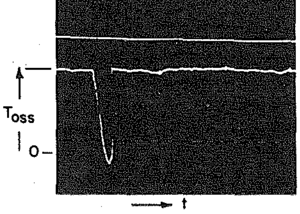
The computer has three main elements: the "forcing function"—to generate electrical voltages equivalent to the forces applied to the actual physical system; the electric counterpart of the system being studied—110 sets of special precision capacitors, inductors and resistors and 25 sets of special transformers; and the measuring equipment, where the machine delivers its answers. While the type of measurement varies with each analysis, in general answers are read in terms of currents and voltages on meters and oscilloscopes.

Actually the Institute's machine offers far more than a mere computation service. It offers a complete engineering service as well. This is partly because of the close association between the Laboratory's staff and the rest of the Institute's faculty and partly because of the nature of the electric analog principle of operation. Because answers are read from a continuous record which can be photographed and then analyzed, the effect of changing one design requirement in a system can be studied for the entire system.

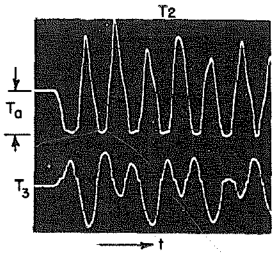
The development of large-scale computers has greatly speeded up technological progress in recent years, and has brought forth predictions about "thinking" machines that will rival the human brain in their ability to remember and handle data. While Institute researchers make no predictions about machines that can think, they do predict that the Institute computers will continue to be invaluable in research and in the service they offer to industry.



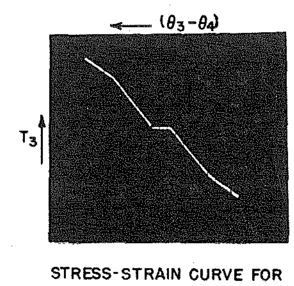
Circuit above is part of analogy for rotating mechanical system of radial aircraft engine studied extensively on computer. Typical solutions, right, include transient torque pulse from single cylinder misfiring and stress-strain curve for nonlinear shaft.



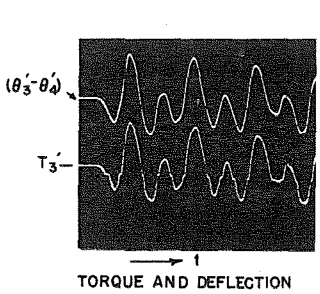
ENGINE MISSFIRE TORQUE PULSE



SHAFT TORQUES



STRESS-STRAIN CURVE FOR SHAFT NO. 3



TORQUE AND DEFLECTION FOR SHAFT NO. 3