PRESS RELEASE from BELL TELEPHONE LABORATORIES

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An amazingly simple device, capable of performing efficiently nearly all the functions of an ordinary vacuum tube, was demonstrated for the first time yesterday at Bell Telephone Laboratories where it was invented.

Known as the Transistor, the device works on an entirely new physical principle discovered by the Laboratories in the course of fundamental research into the electrical properties of solids. Although the device is still in the laboratory stage, Bell scientists and engineers expect it may have far-reaching significance in electronics and electrical communication.

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The whole apparatus is housed in a tiny cylinder less than an inch long. It will serve as an amplifier or an oscillator -- yet it bears almost no resemblance to the vacuum tube now used to do these basic jobs. It has no vacuum, no glass envelope, no grid, no plate, no cathode and therefore no warm-up delay.

Two hair-thin wires touching a pinhead of a solid semiconductive material soldered to a metal base, are the principal parts of the Transistor. These are enclosed in a simple, metal cylinder not much larger than a shoe-lace tip. More than a hundred of them can easily be held in the palm of the hand.

Since the device is still in the experimental stage, no data on cost are available. Its essential simplicity, however, indicates the possibility of widespread use, with resultant mass-production economies. When fully developed, the Transistor is also expected to find new applications in electronics where vacuum tubes have not proved suitable.

Tests have shown that the Transistor will amplify at least 100 times (20 decibels). Some test models have been operated as amplifiers at frequencies up to ten million cycles per second. Because of the basically simple structure of the new units, stability and long life are expected.

While many scientists and engineers have been associated with the work during the project, key investigations which brought the Transistor to reality were carried out by Dr. John Bardeen and Dr. Walter H. Brattain. The general research program leading to the Transistor was initiated and directed by Dr. William Shockley. All three are members of the Bell Telephone Laboratories technical staff.

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Yesterday's demonstration emphasized some of the many uses the Transistor may have in telephone communication, as well as its ready adaptability to the electronic techniques of radio, television, and public address systems.

In one demonstration, a Transistor was used to amplify the electrical speech waves traveling between two telephones, a function now performed by vacuum tubes.

In another, the audience heard a radio broadcast from a set constructed entirely without vacuum tubes, but using instead several of the tiny Transistors to provide amplification.

A Transistor was also used to generate a standard frequency tone, thus demonstrating its role as an oscillator.

Because of its lack of a heated cathode delay and other differences, the Transistor can also perform some new functions.

The Transistor answers a question scientists have been pondering for many years -- how to make semi-conductors amplify and thus provide a simpler, more rugged, smaller device that could perform the functions of a vacuum tube.

In the Transistor, two point contacts of the "cat's whisker" or detector type, familiar to radio amateurs, are made to the semi-conductor only two thousandths of an inch apart. Input power delivered to one of these contacts is amplified at least 100-fold and transmitted to the other terminal where it is delivered to an output circuit. The Transistor is energized by voltage supplies, such as batteries, which apply bias voltages to the two points. The power actually consumed in the Transistor is less than a tenth that used by an ordinary flashlight bulb.

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The amplification process can be understood in terms of the discovery made by Dr. Bardeen and Dr. Brattain that the input point is surrounded by an "area of interaction." Within this area the electronic structure of the semi-conductor is modified by the input current. Now, if the output point is placed in this area, the output current can be controlled by the input current. This control of output current by input current is the basic mechanism of amplification.

Semi-conductors have for many years been regarded as an ideal field for research at Bell Telephone Laboratories because of their practical possibilities and rich scientific interest. These materials, whose electrical properties are intermediate between those of metals and insulators, offered particular promise of useful electrical applications, since their ability to carry electrical current can be changed over wide ranges in various ways.

These materials, like any having the ability to conduct electrical currents, rely for conductivity on the presence of current-carrying electrons. In metals, which are good conductors, there is a ratio of approximately one current-carrying electron to every atom. In insulators, there are practically no such electrons and therefore little conductivity.

In semi-conductors, such as silicon and germanium, some metallic oxides and other compounds, there may be as few as one current-carrying electron for every million atoms. But -- and this is the significant feature -- this number of carriers may be varied 1,000-fold or more by changing the electronic structure of the materials. Hence the current flowing through the semi-conductor can be controlled.

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Prior to the invention of the Transistor, varying conductivity in semi-conductors was employed in rectifiers, such as the copper oxide and selenium rectifiers, and the silicon detector. Bell Telephone Laboratories have for a long time been active in the development of semi-conductor rectifiers. Before the war they had developed silicon detectors for use in microwave radio apparatus and these were supplied for use in early wartime radars. Largely as a result of radar interest, research and development on semi-conductor point-contact rectifiers and the phenomena involved in their operation have been stimulated at other industrial and several university laboratories.

FURTHER TECHNICAL DETAILS FOLLOW

In critically examining the implications of the prevailing theory of electrical conduction in semi-conductors, Dr. Shockley was able to predict that it should be possible to control the meager supply of electrons inside a semi-conductor by influencing them with an electric field imposed from the outside without actually contacting the material. Realizing the practical implications of such a possibility he devised some experiments to test his hypothesis but was unable to secure positive results. The electrons seemed to get trapped in the surface of the material and did not behave just as anticipated.

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This part of the problem was tackled on a theoretical basis by Dr. Bardeen. He developed a theory of what happened at the surface which was able to explain satisfactorily many of the observed facts and which led to further experiments carried out in collaboration with Dr. Brattain. In the course of these experiments they invented the Transistor.

Transistor action depends upon the fact that electrons in a semi-conductor can carry current in two distinctly different ways. This is because most of the electrons in a semi-conductor do not contribute to carrying the current at all. Instead they are held in fixed positions and act as a rigid cement to bind together the atoms in a solid. Only if one of these electrons gets out of place, or if another electron is introduced in one of a number of ways, can current be carried. If, on the other hand, one of the electrons normally present in the cement is removed, then the "hole" left behind it can move like a bubble in a liquid and thus carry current.

In a Transistor made of semi-conductor which normally conducts only by the extra electron process, current flows easily into the input point, which is at a low positive voltage, and out of the output point, which is at a higher negative voltage. The area of interaction is produced by "holes" introduced by the input current and collected by the output point.

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In announcing the Transistor, the Laboratories pointed out that scientific research is coming more and more to be recognized as a group or teamwork job. This is true not only in industrial research but, to a rapidly increasing degree, in academic research. There continues within the group structure, however, ample opportunity for individual work. The Transistor represents an outstanding example of brilliant individual achievement and emphasizes the value of basic research in an industrial framework.

Scientific publications relating to the Transistor will appear in a forthcoming issue of The Physical Review.

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