is amplified and reshaped, in the loop shown. A mercury tank several feet long will store a pattern of about a thousand pulses about a microsecond apart. So it is equivalent to a thousand flip-flops.

Shorter delay lines are useful for remembering numbers in a computation. Very short delay lines—such as a "one-pulse delay line"—are not of the sonic type but of the electrical type, and consist of a network of capacitors and inductors and are an essential element of the computing circuits of some of the electronic brains. The delays obtainable with a small electrical delay line are from a fraction of a microsecond to a few microseconds.

Mercury delay lines for use in giant automatic electronic computers are being manufactured by the Eckert-Mauchly Computer Corp., Philadelphia, Raytheon Manufacturing Co., Waltham, Mass., and other organizations. The details of their operation in many cases involve trade secrets, although in the literature there is some information about operating details.

It is apparent that if the power goes off, or even flickers, the computer's memory of the pattern of the pulses may be erased in whole or in part. For this reason some of the builders of electronic computers do not like to rely on delay line storage.

Magnetic drum and tape

A compact and efficient device for storing pulses—and storing them even if the power goes off—is the *magnetic drum*. This is a rotating cylinder which may be of different sizes, but one size that has been used is about 12 inches long and 6 or 8 inches in diameter. It usually rotates at 1,800, or 3,600, or 7,200 r.p.m. The drum may be of brass or aluminum, and is coated with a compound containing magnetic particles. The compound is put on like paint, with a brush or spray gun.

Mounted almost touching the drum are small electromagnets or *magnetic heads*, very similar to magnetic tape-recorder heads. The separation between the two sides of the pole piece may be about 3/1000 of an inch, and the distance of the magnetic head from the drum may be perhaps 2/1000 of an an inch. A pulse of current passed through the magnetic head causes the recording of a magnetized spot on the rapidly rotating surface of the drum. A positive pulse will cause, say, a north-south magnetization, and a negative pulse vice versa.

The number of magnetized spots in an inch along the perimeter around the drum may be 20 to 60, and the number of channels side by side along the length of the drum may be 8 or 10 to the inch. So if we can get 400 magnetized spots to the square inch, and put them on 250 square inches of drum surface, the magnetic drum will be the equivalent of 100,000 flip-flops. Magnetic drum storage is being used in automatic electronic computers that have been made by the Harvard Computation Laboratory, Cambridge, Mass., Engineering Research Associates, St. Paul, Minn., Northrup Aircraft Co., Hawthorne, Calif., and other organizations. Here again very little if any information has been published revealing the exact know-how for reading, writing, and erasing pulses on drums, and the normal procedure has apparently been for each laboratory to work out its own technique.

In general, what is needed, of course, is something that will act like the holes in Simon's program tape to connect the pulses that the pickup head senses, into effective use in the computer at the exact instant the head passes over the point which holds the desired pattern of information.

To accomplish this, the information that is on a channel of the drum is always being "read" by the pickup head whose duty is reading; but the pulses are allowed into the computer only when the computer calls for admission, and an electronic switch allows them to come in. The timing is naturally very important, and is based on a series of permanently-recorded equally-spaced pulses on the drum, called the master clock channel.

Magnetic tape wound on a reel, such as is used in magnetic sound recording, has proved to be an important, useful, and reliable means for "slow storage". By this we mean storage of large quantities of information where a relatively long time (seconds) for access to the information is permissible. Six channels across a quarter-inch width of tape, and 100 magnetized spots to an inch of length seems to be a realizable objective.

Magnetic tape is well accepted as about the best device for input, output, and slow storage in an automatic electronic computer. Raytheon Manufacturing Co. is offering for sale multi-channel magnetic heads for reading (sensing), writing (recording), and erasing (eliminating) pulses on magnetic tape, and so undoubtedly would furnish details and know-how for using their heads.

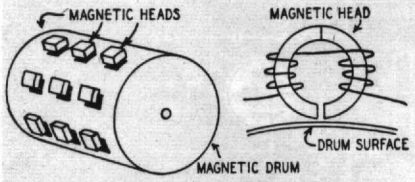

Fig. 5—Magnetic drums make one of the most efficient ways of storing information in smaller electronic computers.

Both the delay line and the magnetic drum have the disadvantages that the computer has to wait for the information to become available. If a delay line or a channel on a drum is storing 20 numbers, and the one you want has just gone by, you have to wait for the other 19 numbers to go by before you can pick up the number you want. In the case of a magnetic drum, you could of course put on additional reading heads and read out from that part of the periphery of the drum which is nearest to the location of the number you are interested in. But that can be troublesome. Why not have all the numbers in storage accessible practically at once?

Electrostatic storage

In one form, the method of electrostatic storage uses a dielectric screen in a cathode-ray tube. The beam that scans the screen divides it into a pattern of, say, 32 by 32, or 1,024 separated spots. Information is stored on these spots as the presence or absence of certain electric charges. The spots are written on or read out or erased by one beam of electrons. The electric charges that have been recorded on the screen are held in their places and prevented from leaking away by another beam of electrons, a so-called "holding beam."

Electrostatic storage has proved to be rather a ticklish technique to master. F. C. Williams at the University of Manchester in England has succeeded in using electrostatic storage in the automatic electronic computer built there. Also, the Servomechanisms Laboratory at Massachusetts Institute of Technology is installing some electrostatic storage memory in Whirlwind I, which will still further raise its speed of 30,000 multiplications a second. Certainly, no miniature automatic electronic computer would be expected to make use of electrostatic storage, whereas a small magnetic drum would be a logical choice for its memory.

(continued next month)