The Installation and Maintenance of Colossus

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The article describes the procedures adopted for the installation and maintenance of the Colossus machines installed at Bletchley Park during the latter years of World War II.

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The Colossus machines used by cryptanalysts at Bletchley Park were produced and installed from mid-1943 to the end of World War II in 1945. This article describes the procedures adopted for installation and maintenance of Colossus during that period. My main contribution to the program was to act as chief installation engineer and to devise ways of testing the machines and ensuring their satisfactory operation.

Installation of Mark I Machine

Mark I Colossus was the first of the series of Colossus machines and was the only one initially completed at the Post Office Research Station at Dollis Hill and subsequently moved to Bletchley. Construction of the machine had proceeded during the summer of 1943, the circuit design and the manufacture of the equipment being carried out more or less in parallel. As each new group of circuits was designed, the various panels and their interconnections were constructed. In order to test the equipment, loops of input teleprinter tape having repetitive patterns were fed into the photoelectric tape reader, providing an easy means of synchronizing the oscilloscope time base, so that satisfactory operation of the individual circuits could be established.

By the autumn of 1943, sufficient progress had been made to initiate the removal of the machine to Bletchley. This involved undoing the interrack cabling, but fortunately it was found that only one end of most of the interrack cables needed to be disconnected, because the positioning of the racks at Bletchley was similar to that adopted at Dollis Hill. Some cabling, notably that between the two suites of racks, could not be so accommodated, however, and totally new cabling and cable supports had to be made to complete the assembly.

When the equipment had been reassembled, the process of retesting the machine could begin. All the valves (vacuum tubes) had been removed for transportation, and it was thought unwise just to plug them in and switch on the machine because, quite apart from the risk of damage if there had been wiring mistakes or short circuits, the presence of a possibly large number of simultaneous faults would have rendered their location and cure an almost impossible task. Accordingly, we replaced the valves gradually. Starting with the tape-reading photocells and their amplifiers, input signals and clock pulses could be derived; from this starting point, the correct functioning of each panel could be confirmed before proceeding to the next one. This technique proved to be of immense value because, in general, only one problem was being investigated at a time. Moreover, if a fault

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developed on a previously tested section, we could be confident that it had previously functioned correctly. Finally, when all had been completely checked, the first "live" run was made. The results were impressive, particularly with regard to the consistency with which results could be repeated.

Mark II Machines

By February 1944, sufficient operational experience had been obtained with the Mark I machine to cause the cryptanalysts to request a further supply of 12 machines. The first was required by June 1, 1944. It was decided that a considerable redesign should be attempted to provide more facilities and much greater effective speed of operation than the Mark I machine. In view of the urgency of the program, we realized that assembly and testing would have to be done on site. The organization of work at Dollis Hill and subsequently at the Birmingham factory has already been described. Racks were erected on site at Bletchley, and panels were put on them when they were completed at Dollis Hill. Measurement of rack layouts enabled cable forms to be constructed at Dollis Hill, both for the interpanel wiring on each rack and for the cabling between racks. The actual work of erection was carried out by Post Office staff attached to Bletchley, as will be described later. Individual panels were tested continuously as they arrived. As more of the equipment was positioned, more exhaustive testing could be undertaken. The enthusiasm with which everyone worked effectively contributed to the final completion by the due date.

The remainder of the machines were installed in much the same way, but by this time the cryptanalysts were beginning to have fresh ideas for variations in the basic operation of the machine. They requested alternative facilities on certain machines, and although all the 10 Mark II machines that were completed before the end of the war were of the same basic design, almost every one finally differed in some respect from all the others. Some of the modifications were extensive, involving additional panels, while others were trivial and needed only a few extra components and wiring changes. It says much for the flexibility of the original design that these modifications could be incorporated.

Maintenance Staff

It was realized at the outset that special arrangements would have to be made for the maintenance of the equipment. Most regular Post Office technicians were accustomed to maintaining either relay-switching or transmission equipment; very few were experienced in both technologies, and none had any experience at all with the valve-switching circuitry that formed the backbone of the Colossus machines. Thus it was arranged that suitable (i.e., very bright!) technicians should be temporarily transferred ("seconded") in groups of three or four, first to Dollis Hill for training and then to Bletchley to form the basis of the maintenance staff. These technicians were recruited from many Post Office regional headquarters.

The training at Dollis Hill consisted of taking part in the wiring and assembly of the equipment panels and performing experiments in the actual design of the circuits. As a result, the technicians became thoroughly familiar with the circuit techniques; in fact, several made valuable contributions to the detailed design.

The first groups of these technicians were associated with the individual machines and moved to Bletchley with them to assist in the initial testing and proving. After the organization of continuous manufacture was arranged, the new groups spent only a few weeks at Dollis Hill before moving to Bletchley. The entire team grew to about 15 in number and was organized in shifts to provide round-the-clock cover. A Post Office inspector was employed permanently at Bletchley to supervise the team.

Maintenance Procedures

There is little doubt that the reliability and ease of maintenance of the Colossus equipment were far higher than had been anticipated and in fact exceeded what was achieved in early computing machines built after the war. During the initial operation period, many of the valves failed—usually catastrophically, so they were easy to locate. After three to four weeks, the number of such failures had fallen to such an extent that they were negligible. The machines settled

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down, and valve faults became almost insignificant—certainly no more than the failure rate of other components.

More trouble was experienced with the electromechanical components such as the electric typewriters and uniselectors, which often required readjustment. A maintenance routine was organized for the typewriters, each one being replaced by a spare at regular intervals for cleaning and readjusting. The only routine electronic maintenance involved the photocells used in the tape readers. We found that their photoelectric emission fell after a few days of use, but when they were stored in a dark cupboard for a day or two, the emission recovered, and they were again usable. Accordingly, a regular routine for "resting" the photocells was inaugurated and proved extremely effective.

The most important tool used for maintenance—and indeed for initial testing and proving—was a cathode-ray oscilloscope. The most used model was a double-beam instrument, of which we had many. The twin-beam facility enabled us to assess the effect of relative timings of different parts of a circuit. These commercially produced oscilloscopes had deflection amplifiers, but they did not respond to direct current. Hence the instruments were usually used with signals applied directly to the deflection plates, because the accuracy of direct-current couplings in the circuitry was of paramount importance. Later an oscilloscope design that had been developed at Dollis Hill and included a calibrated direct-current amplifier was used and was very valuable although it did not possess the double-beam facility.

General Remarks on Maintenance

The reliability of the Colossus equipment was very high and was, in my opinion, the result of three main features that were quite fortuitous.

First, the necessity of providing 24-hour service resulted in the valve heaters never being switched off. Most of the machines, having been installed and handed over, had their valve heaters on literally until the end of the war. There is little doubt that expansion and contraction of valve heaters being switched on and off caused many valve failures in computing equipment built soon after the war.

Second, the relatively low digit rate of the electronic equipment necessitated by the tape-handling equipment enabled the valves to be operated well below their maximum dissipation. Most valves only operated at some 25 percent of the maximum dissipation, thus reducing the amount of heat generated.

Third, the physical size of the valves was such that they could not be placed so close together that high-temperature "hot spots" could develop. Thus, although the machines did get quite warm, we did not have to adopt the forced cooling systems that were necessary on some of the large computers made in the decade after the war.