Thomas Harold (“Tommy”) Flowers: Designer of the Colossus Codebreaking Machines

Born: 22 December 1905
Died: 28 October 1998

Tommy Flowers (see Figure 1) grew up in the East End of London in a working class neighborhood. His father, John Thomas Flowers, was a bricklayer. Compulsory education then stopped at the age of 14. His family’s limited resources narrowed the options available to Flowers, but his mathematical ability won him a fellowship to attend the East Ham Technical School until the age of 16. Schools of this kind were intended to prepare boys for trade apprenticeships, a good fit for Flowers who had for years been building mechanical and electrical devices with his fathers’ tools. (Like many of the details that follow, this information is taken from the 1998 interview Flowers conducted with Peter M. Hart, published by the Imperial War Museum.1 This is by far the most extensive published oral history interview conducted with Flowers, though he was very close to the end of a long life and the dates and details given in the interview are not always accurate.)

After leaving school, Flowers started his technical apprenticeship at the nearby Royal Arsenal in Woolwich. The arsenal was a sprawling complex, combining the scientific analysis and development of new munitions (analogous to some of the work carried out at the Aberdeen Proving Ground in the US) with a network of weapons factories. During the interwar period it even manufactured steam locomotives. He also embarked on the evening study that would eventually lead to a degree, beginning in 1922 at Woolwich Polytechnic, a school for working class men situated close to the arsenal. In 1925, he passed the University of London’s intermediate examination in engineering, as an external student. That examination marked the midpoint of a degree and covered the basics of engineering practice, skills such as technical drawing, and relevant areas of science such as mathematics and physics. Passing it allowed a student to proceed with the more specialized parts of the degree.
In combination, his apprenticeship and evening classes gave Flowers a thorough grounding in different areas of engineering, but he was drawn most powerfully to the newer field of electrical engineering. Engineering offered Flowers a path toward middle class stability and a professional career. He began to work for the Post Office, which ran Britain’s telephone and telegraph networks as well as its mail service, in 1926 in its Engineering Department. His first job was looking after its stores. In 1928, he was promoted to the rank of Inspector. Flowers continued to study, taking classes at West Ham Municipal College (now part of the University of East London) from 1926 to 1928, when he shifted to the Northampton Polytechnic Institute (later City University). Both were locally oriented institutions established for the technical education of people from non-elite backgrounds, but their curriculum was rigorous and they granted degrees though the University of London.

In 1930, he did well enough in the Post Office’s competitive engineering examinations to win a job in its newly created Post Office Research Station at Dollis Hill on the outskirts of London. The Post Office began developing this research center, analogous to the Bell Labs research group in New York City, in the mid-1920s. From the 1930s to the 1970s it was Britain’s main research and development center for telecommunications. After its eventual demolition and redevelopment as housing, an access road for the new apartment building was named Flowers Close in his honor.

Telephony had begun in the 1870s as a patchwork of local services. Wires ran from telephones into local exchanges, where human operators plugged cables to form a circuit between the originator and recipient of the call. Trunk lines were soon built between nearby cities, but this technology did not work over longer distances as voice transmissions eventually faded. The transmission of messages across and between continents remained the province of telegraphy, which needed only to transmit a pulse. Scientists at Bell Labs experimented with the use of vacuum tubes to amplify signals, and by the 1910s were deploying the first trans-continental telephone lines. As such connections were enormously expensive to build and maintain, researchers also used electronics to shift the frequencies of speech so that several conversations could occur simultaneously over the same wire. The technique was called “multiplexing.”
These developments had put electronics at the heart of telecommunications research by the time Flowers arrived at Dollis Hill. As Flowers recalled the “Circuit Laboratory” “chucked me in at the deep end” with little formal instruction.1 Flowers, despite his unimpressive job title of “Probationary Assistant Engineer,” established himself as an expert in the use of electronics.3 By 1931, he had already applied for a patent on “A Method of Electrical Signaling Employing Damped Alternating Currents” (UK Patent no. 390,161). More patents applications followed in 1932 and 1934.

By 1932, Flowers was an Assistant Engineer, no longer probationary, and part of a small, four-person group for Automatic and Manual Signaling Problems Using D.C. and A.C. The next year, he completed his university education, earning first class honors in the University of London examinations.4 This distinction was given to less than ten percent of the graduating class, quite a distinction at a time when less than two percent of the population held university degrees. (University of London records confirm that the graduation date of 1926 found in many profiles of Flowers is incorrect.)

Flowers later characterized himself as a “workaholic” during this period. His promotions to Executive Engineer in 1937 and to Assistant Staff Engineer in 1943, capped an exceptionally rapid rise through the ranks of the department. Along the way, he had found time to get married to Eileen Margaret in 1935. They had two sons.

During the 1910s, number dials began to appear on British telephones. These let users connect directly to others on the same local telephone exchange, using a four-digit number, but calls outside the local area still had to be connected by a human operator. From 1927 onward, the Post Office started rolling out its “Director telephone system” which automated calls to other exchanges in the same city. Users received seven-digit numbers, the first three identifying the exchange. These systems were electromechanical—dialing a digit on the handset produced a series of pulses. As each pulse reached the exchange, it incremented an electric switch called a “uniselecter.” This enabled the extension of direct dialing across large cities such as London and Manchester—though budget concerns during the Depression led to a very slow rollout.

Flowers worked out a scheme for the electronic encoding and transmission of dialing pulses, in a form that could be amplified and routed between exchanges on long distance voice circuits to extend direct dialing nationally. He recalled testing this on a London to Bristol link, at night when the lines were quiet, in 1939 just before the war.1 That meant distinguishing between speech and control information, just as later tone dialing systems did. Given the timing, this was probably the system that Flowers had in mind in 1977, when he wrote that before the outbreak of war “under construction at Dollis Hill … was a processor using thermionic valves for high speed processing with maximum reliability, the processor being time shared among numerous smaller processors using relays for simple and slow operations.”5 As telephone switching was all about counting pulses, work on electronic switching would have involved thinking about, and perhaps building, ring-counting circuits that mimicked the action of the uniselectors.

Flowers believed that electronic technology was potentially more reliable than electromagnetic switches. This went against the daily experience of radio owners during the 1930s, who found that tubes frequently failed and so were by far the least reliable part of the machine. But Flowers knew that vacuum tubes had no moving parts, so if run for switching purposes at low voltages and left with their heater circuits turned on continually could continue working for a very long time. In contrast, relay switches, which used an electromagnet to move a piece of metal back and forth to complete a circuit, would inevitable wear out or fill up with dust.

Flowers also served as a British delegate to international telecommunications groups, which played a vital role in ensuring the interoperability of telephone and telegraph networks. Most dramatically, he visited Berlin in preparation for an upcoming office just prior to the outbreak of war in 1939. He recalled leaving abruptly after a warning from Embassy staff, arriving back in Britain hours before the border was closed.1
This expertise in telecommunications made Dollis Hill a natural partner for the Government’s wartime work intercepting and decoding enemy signals. The work was centered on Bletchley Park, a large country estate around 50 miles from central London. The Post Office as a whole had a crucial role to play in the war effort, being charged with keeping the telephone and telegraph networks running for vital wartime use while assisting with special projects and dealing with the conscription of much of its workforce. In the early years of the war, Flowers helped to establish communication links to switch communications with radar installations and command centers.

Flowers’ first involvement with Bletchley Park came in spring 1942. He was asked to work on an “automatic stop tester” by Alan Turing who was leading the group tackling German (Army) Enigma. Flowers built the device to the required specifications, but it turned out not to be useful.

His next project was closer to the heart of the attack on Enigma. By early 1942, the massive effort to decrypt Naval Enigma messages was in crisis. The Enigma machines were widely used throughout the German military services to transmit messages from commanders to units in the field. They encrypted text one letter at a time, displaying substitute letters that were then tapped out by Morse code operators. Hundreds of machines called “bombes,” manufactured by British Tabulating Machines according to a basic design by Turing and Gordon Welchman, had given the Allies a vital edge in the struggle against submarine packs preying on trans-Atlantic supply convoys. Unfortunately, the Germans had begun to use four encryption wheels in their Enigma machines, making the code much harder to break. Bletchley Park’s leaders believed that beating the upgraded cipher would require upgraded bombes, able to simulate a fourth rotor and to function more rapidly to offset the much larger number of possible combinations of code settings.

Flowers quickly found himself in conflict with one of Bletchley Park’s other partners, the physicist C.E. Wynn-Williams who spent the war at the Telecommunications Research Establishment, the center of British work on radar. Wynn-Williams had pioneered the use of electronics for counting in his experiments to measure the frequency of cosmic rays. The Post Office was supposed to manufacture a large batch of sensing units based on a prototype designed by Wynn-Williams. This was to be used with an add-on for the existing bombes nicknamed “Cobra,” which incorporated a high-speed drum. The original bombes used physical brush connectors hooked up to electromagnetic relays to read the information encoded on their spinning drums. Wynn-Williams believed that electronic switches, rather than relays, would be needed at the higher speeds required with the new drum. Flowers shared this enthusiasm for electronics, but disliked the Wynn-Williams’ design, and wanted to substitute one of his own. The dispute dragged on for months, fueled by delays in Wynn-Williams producing his prototype, which eventually arrived in September 1942. Unfortunately, the first “Cobra” didn’t work, which meant that neither design for the sensing unit could be evaluated.

Meanwhile, “Doc” Keen, the chief engineer of the British Tabulating Machine company, who had been responsible for engineering the original bombes, had come up with a rival design for an entirely new bombe. Codenamed “Mammoth,” it used the same sensing and counting technology as the existing bombes. During summer 1943, Flowers and his boss, Gordon Radley, repeatedly warned Gordon Welchman, leader of the Naval Enigma effort, that relays could never work reliably for long periods in the Mammoths. Welchman heard them out, but decided by August that “the arguments in favor of valves turned out to be very week indeed.” Flowers had lost his long battle. In the end, most of the high-speed bombes deployed at Bletchley Park were Mammoths, and the small number of unreliable Cobra devices produced did not use the Dollis Hill design for their sensors.

On 2 June 1943, the King’s birthday honors list included an honor for Flowers—a Member of the Order of the British Empire (MBE)—the lowest of the three main grades of honor presented twice yearly by the monarch to recognize national service. While this honor is often said to have been for his work on Colossus, the timeline suggests that if it was for his work with Bletchley Park, it was more likely for his efforts to improve the bombes.
Historians of computing have tended to stress the bravery of engineers behind early electronic computing designs, such as J. Presper Eckert or Julian Bigelow, in proposing devices with thousands of tubes at a time when existing machines held no more than a few dozen. While the techniques needed to make such machines work reliably do seem to have been independently discovered by several groups during the mid- to late-1940s, it is also clear that the first devices to use digital electronics on a large scale were not computers. In addition to the experimental switching system mentioned by Flowers, and his wartime Colossus machines, they included the 121 “Dayton Bombes” produced by NCR for codebreaking work carried out by the US Navy, each built from around 300 vacuum tubes. These provided the bulk of the allied decryption capability against four-wheel Enigma traffic.

COLOSSUS AND TUNNY

As his work on the bombes progressed, Flowers was also enlisted for what quickly became a central role in the design of equipment to tackle the other main code cracked at Bletchley Park, the Lorenz teleprinter cipher codenamed “Tunny” by the British. By spring 1942, codebreakers had already deduced the internal structure of the German machine and had some success in devising manual methods to crack it. By July, a new codebreaking section was attempting to break the code routinely, with mixed results. Then in November, mathematician Bill Tutte came up with a new, statistical way of determining the code wheel settings needed to decrypt a message. This would work reliably but require far too much comparing and counting of message text against code wheel output to be practical without mechanical assistance. In February 1943, Max Newman, later to launch the Manchester University computing project, was appointed to lead a new group charged with mechanizing the cracking of Tunny.

Newman turned to the same institutional partners then working on electronics for the bombes: Wynn-Williams as an expert on high-speed electronic counting and the Post Office to engineer and manufacture what would later be dubbed the “Robinson” machines. The new machine would spin two tape loops, one holding code wheel bits and the other the encrypted message. It had three main units:

- First the “reader” to electronically sense the data stored on the two loops of five-channel paper tape.
- Second the “combining unit” to perform logic tests on inputs chosen from the two readers yielding an output pulse for each character position in the message where the tests evaluated to “true.”
- Third, the counters, to tally the number of output pulses produced each time the message tape was read.

The tape lengths were selected so that each revolution of the message tape would align with a different start position on the code wheel tape, representing a different possible wheel start setting.

Dollis Hill had expertise in storing telegraphic messages on paper tape, and was chosen to design the tape mechanisms and readers. Flowers recalled that he got involved only after the teleprinter group there realized it needed help from an electronic expert. As the tape would spin at unprecedented speed, the readers used optical electronic sensing—holes let light from a lightbulb reach a photodiode cell, generating an input pulse to the combining unit. Testing showed that the tape could be spun and read reliably at an unprecedented 2,000 characters per second—though it took some time to resolve the engineering issues involved in coordinating two tape readers at this speed. The combining unit for the prototype machine, named “Heath Robinson” after a British cartoonist known for drawing implausibly complex mechanisms, was built at Dollis Hill to a design from Wynn-Williams. Its counting unit was constructed at TRE, but Dollis Hill was charged
with reproducing it for production machines once the prototype had been tested—a process that began on 14 June 1943 when “the chi wheels of a known message were set, the results agreeing with those obtained by hand.”

Flowers again thought that using more electronics and fewer electromagnetic components would improve performance. His initial suggestion to Newman in February, not long after design work on Heath Robinson began, was for a machine that replaced both of the paper tapes with data held in vacuum tubes. By March 1943, he had decided that reading the message from tape and generating the code wheel impulses electronically from simulated code wheels would provide the optimum balance of practicality, performance, and convenience in changing wheel settings. Newman authorized work to go forward on the electronic machine as long as “the simpler tape machine … should be gone on with also, at full speed.” After meeting with Flowers, he noted that “they are putting the simple machine with tapes, first, as we want.”

Flowers treated Heath Robinson as a prototype for what became Colossus. The machines used the same tape and reader mechanisms, but could spin the tape at 5,000 characters per second as synchronization with a second tape was no longer required. As Dollis Hill got ready to build the counting and combining units for the production run of 24 Robinson machines ordered by Bletchley Park, this gave him an opportunity to work up a new design that used many more tubes and employed what we would think of as digital electronics rather than the ingenious but temperamental circuits designed by Wynn-Williams. The Robinsons arrived later and in much smaller quantities than expected, perhaps because Flowers was switching his focus to the remaining components needed for Colossus—primarily the electronic ring counters used to simulate the code wheels. These must have had a lot in common with the circuits needed to switch calls in an electronic telephone exchange. In November 1944, Flowers applied for a patent on “Improvements in or relating to Electronic Valve Apparatus Suitable for Use in Counting Electrical Impulses,” covering ring counters—presumably those developed for Colossus (UK Patent no. 584,704). Colossus also drew on standard post office equipment such as the uniselectors, which were used to store the starting positions for the code wheels and step them each time the message tape completed a revolution.

The first Colossus is said to have included about 1,600 vacuum tubes. It was built and assembled at Dollis Hill under the close supervision of Flowers. Several other engineers contributed to the design, and much of the production and wiring was done by women. According to Newman’s later recollection, he worked to identify the controls and capabilities it needed for Colossus from September onwards. It seems unlikely that any construction, or even much detailed design, took place on Colossus prior to this, as Flowers and his team had been immersed in work on Heath Robinson, on the design and production of a batch of machines based on it, and on electronic sensing for the bombes. But these projects served as prototypes for most of the capabilities needed in Colossus. Some accounts, based in part on Flowers’ own remarks, have suggested that Flowers developed Colossus without the knowledge or official approval of Bletchley Park and took the codebreakers by surprise when he delivered the machine. That suggestion is hard to square with the archival record. By November, Newman was eagerly awaiting the arrival of Colossus and was discussing his plans for the machine with Edward Travis, the operational head of Bletchley Park. Welchman too was supportive—going so far as to ask a contact whether he had “any luck” with the “valves you were trying to get” for Flowers.

In January, Flowers oversaw the installation of the first Colossus machine at Bletchley Park. By March, it was fully operational. Colossus teams could process about 15 messages a day, compared to a single message for their colleagues using Robinson machines. Contrary to popular belief, Colossus did not itself decrypt messages. Rather it was useful (along with other methods) in several of the steps involved in identifying the settings used to encrypt messages.

By early February 1944, before the first Colossus was fully operational, Bletchley Park staff were already writing hopefully of the expected arrival of a second, even faster, machine. The second Colossus began work in June 1944, just in time for the D-Day landings. It incorporated many improvements and held around 2,400 tubes. Most significant was a facility known as “multiple testing” in which its five counters tallied the scores applicable to five different combination code wheel start positions during a single rotation of the message tape. For many of the longest runs carried out on Colossus, including Chi wheel setting, this delivered up to 4.55 times
the performance of a Colossus 1. According to Flowers, “that was the last I saw of” Colossus; he spent the last year of the war working on an electronic radar-driven anti-aircraft gun director that “didn’t get very far.”

Leadership of the Colossus effort passed to Allen W.M. Coombs, a member of Flowers’ team at Dollis Hill. By the time of the German surrender 10 Colossus machines were in use, equipped with a variety of little tweaks and unique capabilities to help with different tasks involved in the attack on Tunny. They were so tightly coupled to the specifics of this cipher as to be almost useless for any other purpose. At the end of the war, all but the two most recent Colossus machines were disassembled and their parts recycled.

AFTER THE WAR

After the war, Flowers returned to the development of electronic systems for Post Office use. Others who worked on classified electronic projects during the war played key roles in late-1940s British computer projects, including Alan Turing, Max Newman, Freddie Williams, and Tom Kilburn. Flowers, however, was more interested in telephone exchanges. He had a chance to shift to computers in 1946 when Charles Darwin, head of the National Physical Laboratory, wrote to the Post Office’s Engineer in Chief promising tens of thousands of pounds to construct a computer, ACE, that Turing had designed for the laboratory. Darwin was well aware that Flowers had accomplished something great in this area: “it works using principles developed by your staff during the war for a certain Foreign Office project, and we want to be able to take advantage of this, enlisting the help of your Research Department, and in particular of Mr. Flowers who has much experience in working out the electronic side of it.”

As Flowers himself wrote, “I was not myself interested so much in computers as in telephone exchanges.” The Post Office signed a contract to build ACE, but did not complete the promised work. It withdrew after carrying out only six hundred pounds of billable work, a small fraction of what had been planned, though this had reportedly produced a working mercury delay line memory by January 1947. Flowers later recalled spending “years” after the war working on delay line memory. If so, perhaps his personal involvement with this technology continued with the MOSAIC computer built at Dollis Hill between 1947 and 1953 under the direction of Coombs and fellow Colossus veteran William Chandler. This was designed to process radar tracking data for the Telecommunications Research Establishment, and made extensive use of mercury delay lines and of paper tape storage.

In 1950, an announcement of Flowers’ promotion to the rank of Staff Engineer called it “a step not only in his own career but also in the art and science of telephone exchange systems.” The announcement noted that Flowers had spent his career “engaged on problems connected with telephone signaling and switching, or on work of an allied nature. The alternative refers in particular to special work done during the war, the quality of which has been properly recognized by the authorities concerned.” This was his final promotion, and his first since 1943, which suggests that his earlier career momentum dissipated after the war.

ELECTRONIC EXCHANGES

Flowers laid out his vision for electronic exchanges in a series of articles published in 1950 and 1951. As Flowers observed, electronics had “become basic to telephone speech transmission over all but the shortest distances.” In contrast, the switching of calls was still carried out by electromagnetic devices. To date, effort had focused on using electronics to control conventional switches. That approach was taken further in the 1960s when Bell Labs first used a general purpose computer to control telephone switching—an approach Flowers was critical of. Instead Flowers consistently promoted what he called in his 1950 article “a fully electronic exchange” in which speech circuits were switched by the automatic flipping of electronic circuits rather than of physical switches. His articles explored a variety of possible switching mechanisms, including “valves, gas discharge tubes, cathode-ray tubes, and rectifiers.” Flowers also discussed arrangements for the transmission of the control information needed to complete circuits, and in the second part of the series the possibility of introducing a national system of telephone numbers for
direct dialing through the use of “electronic registers” to decode exchange codes and route calls appropriately. The third article discussed the application of electronics to “trunking” the hierarchies of switches used to route calls within an exchange. These arrangements imposed limits on the patterns of connections that could be made simultaneously. Flowers believed that “with electronic switching selection, trunking systems hitherto impractical” could be considered, using new network topologies to interconnect switches more flexibly and efficiently.

In addition to working on switching, Flowers also worked with Colossus veteran Harry Fensom to design a high-profile electronic machine, ERNIE (Electronic Random Number Indicator Equipment), unveiled in 1956. This machine was the public face of a new government-backed savings scheme, administered through the Post Office (which had long offered savings accounts and payment facilities to the public). Premium bonds, issued in denominations as small as one pound, were a hybrid of government bond and lottery ticket. Instead of paying interest, like a normal bond, they offered a chance of winning a tax-free prize of up to one thousand (eventually one million) pounds in a weekly drawing. ERNIE made the weekly drawing of winning bond numbers, adding an aura of technological modernity to the new scheme. “Honest Ernie” was therefore promoted to the public as a robot immune to corruption. It used noise produced by a gas diode to produce true random numbers.

Jork Andrews, who worked under Flowers in the post-war years, recalled him as a natural leader “who one would follow anywhere.” According to Andrews, the challenges of making electronic switching cost effective with traditional methods were essentially impossible to solve during the 1950s, but this did not stop engineering groups around the world from pushing forward with plans. “Like everyone else, we shut our eyes to the impossible problem and kept on doing the pieces that were possible.” As a result, “After two decades of striving, the whole world was not much closer to a system.”

Flowers worked for years on an analog voice transmission system with electronic switching. This would carry 30 channels of voice communication between exchanges using a single wire and switch, relying on the earth to complete the circuit. Avoiding the cost of a second wire, and more importantly a second switch, helped to make electronics cost effective. What Andrews called the “impossible problem” was doing this on a practical scale without introducing unacceptable amounts of noise onto the call. In 1962, after years of work by a consortium, the Post Office had formed with equipment manufacturers, the world’s first all-electronic exchange went into use at Highgate Wood. It failed in use, falling victim to noise issues on the longer cable runs needed in a real exchange.

In 1964, the Research Department’s director decided that only a balanced pair approach would work with analog signals, which in turn meant that only electronically controlled switches that relied on fast and compact reed relays, rather than valves or transistors, to do the actual switching would be cost effective. This technology had been proven in 1960 during field trials at the Leighton Buzzard exchange. “All other developments that had promised so much and delivered so little,” recalled Andrews, “were to be stopped.” Reed relay technology was rolled out commercially during the late-1960s.

Flowers, who refused to accept this verdict, was moved sideways to a post overseeing work on radio telegraphy. In response, he abruptly left the Post Office to continue work on his preferred single wire analog system with STC, which had been a partner of the project. Unfortunately for Flowers, STC also recognized that the fully electronic switching of analog voice signals was not going to be the wave of the future and soon canceled its own commitment. Flowers did not retire from STC until at least 1970 (the date given by Andrews, though an article published in 1971 listed him as still working there) but in the opinion of Andrews found “no work at all worthy of him” during his years there.
After the departure of Flowers in 1964, Harry Law, the new leader of the Switching Division, devised a different approach around the emerging technology of pulse code modulation, already entering use to sample and digitize voice calls for long distance transmission. These digital signals were easier to switch and less vulnerable to noise. That became the “Empress” prototype electronic exchange, inaugurated in 1968, which provided a model for the electronic switching of digital traffic. Andrews noted that “it was Dr. Flowers who produced the team that was capable of producing such a ground-breaking design, even if the switch was not his chosen architecture.”

BELATED HONORS

When Flowers received public recognition for Colossus, from 1977 onward, he consistently depicted it as part of his lifelong quest to build an electronic switching system. He recalled the aim of the Colossus group as being “to break through to a new switching technique which we called and is now universally known as electronic,” cautioning that “no thought of computers was in our minds.” Flowers usually referred to Colossus as an “electronic processor” rather than a computer, and saw it as the forerunner to electronic telecommunications equipment rather than digital computers. Instead Flowers noted the “irony of recent events which credit me with some pioneering work on computers, when it was my refusal to use a computer when everyone else said it was the right thing to do that which led to my downfall in the telephone industry.”

Flowers was of course aware, and proud, of the similarities between the techniques he used to engineer Colossus and those used to build computers. He later wrote that “the basic technology used in a modern computer—data storage and retrieval, ultrafast processing, variable programming, the printing out of the results of the processing, and so forth—were [sic] all anticipated by Colossus.”

Flowers seemed tantalized by the possibility that his new recognition, if it had come decades earlier, might have helped him build an electronic exchange. He complained that lacking “administrative or executive powers,” he was unable to build properly on his wartime achievements, unlike others such as Max Newman who could “use their knowledge effectively without disclosing the source,” “I was in a similar position in the telephone industry,” he continued, “except for having no power or opportunity to use the knowledge effectively.”

First public disclosure of Colossus was made by Brian Randell in a technical report in 1976 based in part on interviews with Flowers. After discovering the scope of Flowers’ secret achievements, Randell arranged for him to receive an honorary doctoral degree from Newcastle University. Colossus caused similar excitement at the celebrated 1976 Los Alamos conference that gathered together the small group of people then interested in the history of computing (many of them the builders of early machines). According to Coombs, who joined Randell at the meeting, “so great was the interest shown that a special evening meeting was convened,” which “lasted for 2 hours, and showed no sign of ending even then.”

After Colossus was made public, Flowers began to win broader attention and was invited to address various computing groups and to document his work. He received some long-delayed credit from his former employer when Sir William Barlow, chairman of the Post Office, presented him with the inaugural Martelsham Medal in 1980. Flowers was in attendance in 1996 when a replica Colossus machine was inaugurated by the Duke of Kent at the National Museum of Computing in Bletchley Park.

His fame, and recognition, has grown further since his death in 1998, though despite a burgeoning literature on Colossus and Tunny, journalists still sometimes give credit for Colossus to Alan Turing or suggest that it targeted the Enigma code. In 2013, on the 70th anniversary of the first Colossus, British Telecom unveiled a bronze bust of Flowers at the Adastral Park center, the successor to Dollis Hill. In 2016, it followed up with the Tommy Flowers Institute, a training center to support collaboration of British businesses with graduate degree holders trained in computing research.
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REFERENCES

3. List of the Principal Officers in the Post Office, 1 August 1931.
12. Newman to Travis, HW 14/19, UK National Archives, 18 June 1943.
17. Newman to Travis, HW 14/92, UK National Archives, 8 November 1943.
18. Welchman to (Benjamin De Forest) Bayly, HW 62/5, UK National Archives, 26 November 1943.

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