

Tommy Flowers

Thomas Harold Flowers, BSc, DSc,^[1] MBE (22 December 1905 – 28 October 1998) was an English engineer with the British Post Office. During World War II, Flowers designed and built Colossus, the world's first programmable electronic computer, to help solve encrypted German messages.

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Early life

Flowers was born at 160 Abbott Road, Poplar in London's East End on 22 December 1905, the son of a bricklayer.^[2] Whilst undertaking an apprenticeship in mechanical engineering at the Royal Arsenal, Woolwich, he took evening classes at the University of London to earn a degree in electrical engineering.^[2] In 1926, he joined the telecommunications branch of the General Post Office (GPO), moving to work at the research station at Dollis Hill in north-west London in 1930. In 1935, he married Eileen Margaret Green and the couple later had two children, John and Kenneth.^[2]

From 1935 onward, he explored the use of electronics for telephone exchanges and by 1939, he was convinced that an all-electronic system was possible. A background in switching electronics would prove crucial for his computer designs.

World War II

Flowers' first contact with wartime codebreaking came in February 1941 when his director, W. Gordon Radley was asked for help by Alan Turing, who was working at Bletchley Park the government codebreaking establishment, 50 mi (80 km) north west of London in Buckinghamshire.^[3] Turing wanted Flowers to build a decoder for the relay-based Bombe machine, which Turing had developed to help decrypt German Enigma codes. The decoder project was abandoned but Turing was impressed with Flowers's work, and in February 1943 introduced him to Max Newman who was leading the effort to automate part of the cryptanalysis of the Lorenz cipher. This was a high-level German code generated by a teletypewriter in-line cipher machine, the Lorenz SZ40/42, one of their *Geheimschreiber* (secret writer) systems, called "Tunny" (tunafish) by the British. It was a much more complex system than Enigma; the decoding procedure involved trying so many possibilities that it was impractical to do by hand. Flowers and Frank Morrell (also at Dollis Hill) designed the Heath Robinson, in an attempt to automate the cryptanalysis of the Lorenz SZ-40/42 cipher machine.^[4]

Thomas Harold Flowers
MBE



Tommy Flowers – possibly taken
around the time he was at Bletchley
Park

Born	22 December 1905 Poplar, London, England
Died	28 October 1998 (aged 92) Mill Hill, London, England
Nationality	English
Occupation	Engineer
Title	Mr
Spouse(s)	Eileen Margaret Green
Children	2

Flowers proposed a more sophisticated alternative, using an electronic system, which his staff called Colossus, using perhaps 1,800 thermionic valves (vacuum tubes) instead of 150 and having only one paper tape instead of two (which required synchronisation) by generating the wheel patterns electronically. Because the most complicated previous electronic device had used about 150 valves, some were sceptical that the system would be reliable. Flowers countered that the British telephone system used thousands of valves and was reliable because the electronics were operated in a stable environment with the circuitry on all the time. The Bletchley management were not convinced and merely encouraged Flowers to proceed on his own.^[5] He did so at the Post Office Research Labs, using some of his own funds to build it.^{[6][7]} Flowers had first met (and got on with) Turing in 1939 but was treated with disdain by Gordon Welchman, because of his advocacy of valves rather than relays. Welchman preferred the views of Wynn-Williams and Keene of the British Tabulating Machine Company (BTM) who had designed and constructed the Bombe and wanted Radley and "Mr Flowers of Dollis Hill" removed from work on Colossus for "squandering good valves".^[8]

Despite the success of Colossus, the Heath Robinson approach was still valuable for solving certain problems.^[9] The final development of the concept was a machine called Super Robinson that was designed by Tommy Flowers. This one could run four tapes and was used for running depths and "cribs" or known-plaintext attack runs.^[9] On 2 June 1943, Flowers was made a member of the Order of the British Empire.^{[10][11]}

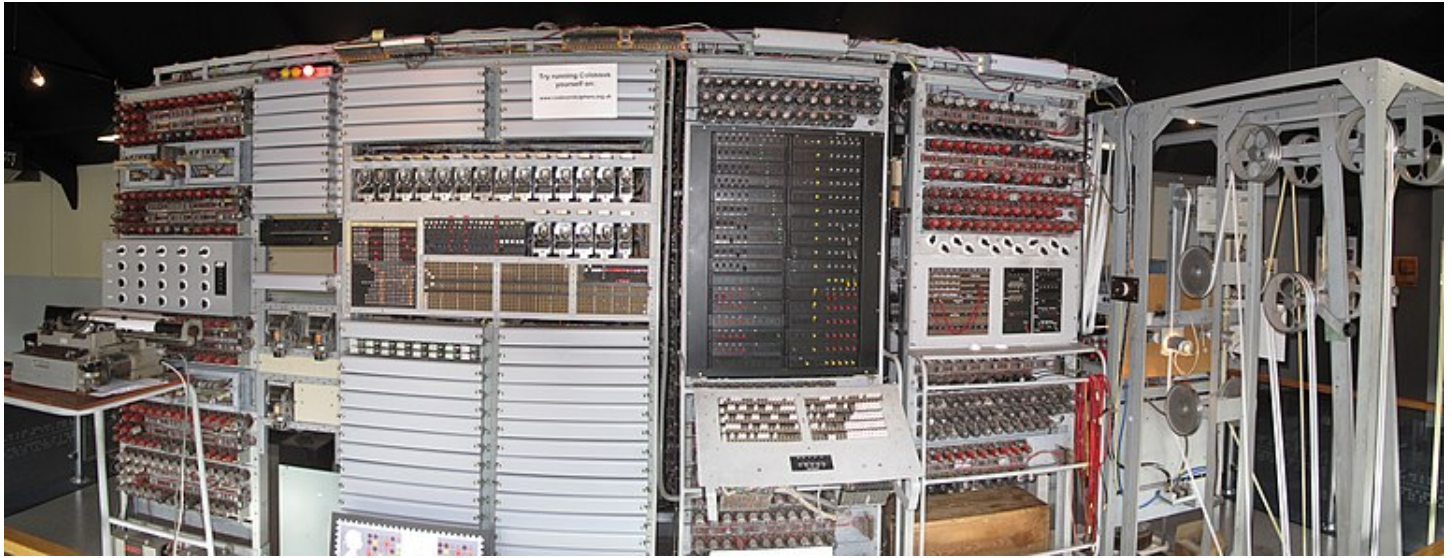
Flowers gained full backing for his project from the director of the Post Office Research Station at Dollis Hill, W. G. Radley. With the highest priority for acquisition of parts, Flowers's team at Dollis Hill built the first machine in eleven months. It was immediately dubbed 'Colossus' by the Bletchley Park staff for its immense proportions. The Mark 1 Colossus operated five times faster and was more flexible than the previous system, named Heath Robinson, which used electro-mechanical switches. The first Mark 1, with 1500 valves, ran at Dollis Hill in November 1943; it was delivered to Bletchley Park in January 1944 where it was assembled and began operation in early February.^[12] The algorithms used by Colossus were developed by W.T. Tutte and his team of mathematicians.^[13] Colossus proved to be efficient and quick against the twelve-rotor Lorenz cipher SZ42 machine.

In anticipation of a need for additional computers, Flowers was already working on Colossus Mark 2 which would employ 2,400 valves.^[4] The first Mark 2 went into service at Bletchley Park on 1 June 1944 and immediately produced vital information for the imminent D-Day landings planned for Monday 5 June (postponed 24 hours by bad weather). Flowers later described a crucial meeting between Dwight D. Eisenhower and his staff on 5 June, during which a courier entered and handed Eisenhower a note summarising a Colossus decrypt. This confirmed that Adolf Hitler wanted no additional troops moved to Normandy, as he was still convinced that the preparations for the Normandy Landings were a feint. Handing back the decrypt, Eisenhower announced to his staff, "We go tomorrow".^[14] Earlier, a report from Field Marshal Erwin Rommel on the western defences was decoded by Colossus and revealed that one of the sites chosen as the drop site for a US parachute division was the base for a German tank division and the site was changed.^[15]

Years later, Flowers described the design and construction of the computers.^[16] Ten Colossi were completed and used during the Second World War in British decoding efforts and an eleventh was ready for commissioning at the end of the war. All but two were dismantled at the end of the war, "The remaining two were moved to a British Intelligence department, GCHQ in Cheltenham, Gloucestershire, where they may have played a significant part in the codebreaking operations of the Cold War".^[17] They were finally decommissioned in 1959 and 1960. A functioning Colossus Mark II was rebuilt by a team of volunteers led by Tony Sale between 1993 and 2008.^[18] It is on display at The National Museum of Computing at Bletchley Park.^{[12][19]}



In 1994, a team led by Tony Sale (right) began a reconstruction of a Colossus at Bletchley Park. Here, in 2006, Sale supervises the breaking of an enciphered message with the completed machine.



Front view of the Colossus rebuild showing, from right to left (1) The "bedstead" containing the message tape in its continuous loop and with a second one loaded. (2) The J-rack containing the Selection Panel and Plug Panel. (3) The K-rack with the large "Q" switch panel and sloping patch panel. (4) The double S-rack containing the control panel and, above the image of a postage stamp, five two-line counter displays. (5) The electric typewriter in front of the five sets of four "set total" decade switches in the C-rack.^[20]

Post-war work and retirement

After the war, Flowers received little recognition for his contribution to cryptanalysis.^[21] The government granted him £1,000 payment which did not cover Flowers' personal investment in the equipment; he shared much of the money amongst the staff who had helped him build and test Colossus. Flowers applied for a loan from the Bank of England to build another machine like Colossus but was denied the loan because the bank did not believe that such a machine could work. He could not argue that he had already designed and built many of these machines because his work on Colossus was covered by the Official Secrets Act. It was not until the 1970s that Flowers' work in computing was fully acknowledged. His family had known only that he had done some 'secret and important' work.^[22] He remained at the Post Office Research Station where he was Head of the Switching Division. He and his group pioneered work on all-electronic telephone exchanges, completing a basic design by about 1950, which led on to the Highgate Wood Telephone Exchange. He was also involved in the development of ERNIE.^[23] In 1964, he became head of the advanced development at Standard Telephones and Cables Ltd.,^[24] where he continued to develop electronic telephone switching including a pulse amplitude modulation exchange, retiring in 1969.^[25]

In 1976, he published *Introduction to Exchange Systems*, a book on the engineering principles of telephone exchanges.^[26]

In 1977 Flowers was made an honorary Doctor of Science by Newcastle University.^[27]

In 1980 he was the first winner of the Martlesham Medal in recognition of his achievements in computing.^[28]

In 1993, he received a certificate from Hendon College, having completed a basic course in information processing on a personal computer.^[29]

Flowers died in 1998 aged 92, leaving a wife and two sons.^[2] He is commemorated at the Post Office Research Station site, which became a housing development, with the main building converted into a block of flats and an access road called Flowers Close. He was honoured by London Borough of Tower Hamlets, where he was born. An Information and Communications Technology (ICT) centre for young people, the Tommy Flowers Centre, opened there in November 2010.^[30] The centre has closed but the building is now the Tommy Flowers Centre, part of the Tower Hamlets Pupil Referral Unit.

In September 2012, his wartime diary was put on display at Bletchley Park.^[31] A road in Kesgrave, near the current BT Research Laboratories, is named Tommy Flowers Drive.^[32]

On 12 December 2013, 70 years after he created Colossus, his legacy was honoured with a memorial commissioned by BT, successor to Post Office Telephones. The life-size bronze bust, designed by James Butler, was unveiled by Trevor Baylis at Adastral Park, BT's research and development centre in Martlesham Heath, near Ipswich, Suffolk. BT also began a computer science scholarship and award in his name.^[33]

On 29 September 2016 BT opened the Tommy Flowers Institute^[34] for ICT training at Adastral Park to support the development of postgraduates transferring into industry. The institute focuses on bringing ICT-sector organisations together with academic researchers to solve some of the challenges facing UK businesses, exploring areas such as cybersecurity, big data, autonomies and converged networks. The launch event was attended by professors from Cambridge, Oxford, East Anglia, Essex, Imperial, UCL, Southampton, Surrey, and Lancaster as well as representatives from the National Physical Laboratory, Huawei, Ericsson, CISCO, ARM and ADVA.^[35]

See also

- List of pioneers in computer science

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External links

- Quotes about Flowers (<http://c2.com/cgi/wiki?TommyFlowers>)
- Tommy Flowers talking about Colossus (<https://www.youtube.com/watch?v=yfz8ZYKIO5g>)
- Imperial War Museum Interview (<http://www.iwm.org.uk/collections/item/object/80017376>)

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Colossus computer

Colossus was a set of computers developed by British codebreakers in the years 1943–1945 to help in the cryptanalysis of the Lorenz cipher. Colossus used thermionic valves (vacuum tubes) to perform Boolean and counting operations. Colossus is thus regarded^[3] as the world's first programmable, electronic, digital computer, although it was programmed by switches and plugs and not by a stored program.^[4]

Colossus was designed by research telephone engineer Tommy Flowers to solve a problem posed by mathematician Max Newman at the Government Code and Cypher School (GC&CS) at Bletchley Park. Alan Turing's use of probability in cryptanalysis (see Banburismus) contributed to its design. It has sometimes been erroneously stated that Turing designed Colossus to aid the cryptanalysis of the Enigma.^[5] Turing's machine that helped decode Enigma was the electromechanical Bombe, not Colossus.^[6]

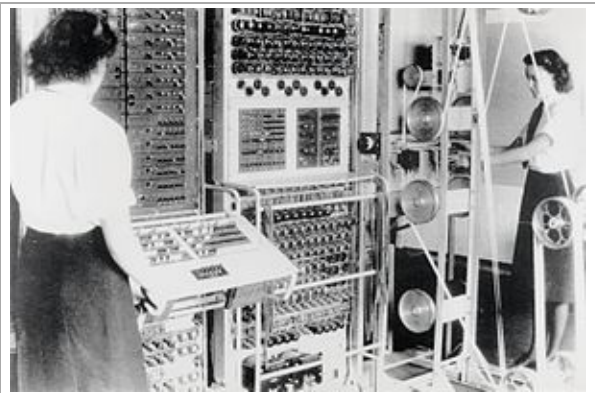
The prototype, **Colossus Mark 1**, was shown to be working in December 1943 and was in use at Bletchley Park by early 1944. An improved **Colossus Mark 2** that used shift registers to quintuple the processing speed, first worked on 1 June 1944, just in time for the Normandy landings on D-Day.^[7] Ten Colossi were in use by the end of the war and an eleventh was being commissioned.^[7] Bletchley Park's use of these machines allowed the Allies to obtain a vast amount of high-level military intelligence from intercepted radiotelegraphy messages between the German High Command (*OKW*) and their army commands throughout occupied Europe.

The existence of the Colossus machines was kept secret until the mid-1970s; the machines and the plans for building them had previously been destroyed in the 1960s as part of the effort to maintain the secrecy of the project.^{[8][9]} This deprived most of those involved with Colossus of the credit for pioneering electronic digital computing during their lifetimes. A functioning rebuild of a Mark 2 Colossus was completed in 2008 by Tony Sale and some volunteers; it is on display at The National Museum of Computing at Bletchley Park.^{[10][11][12]}

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Colossus computer



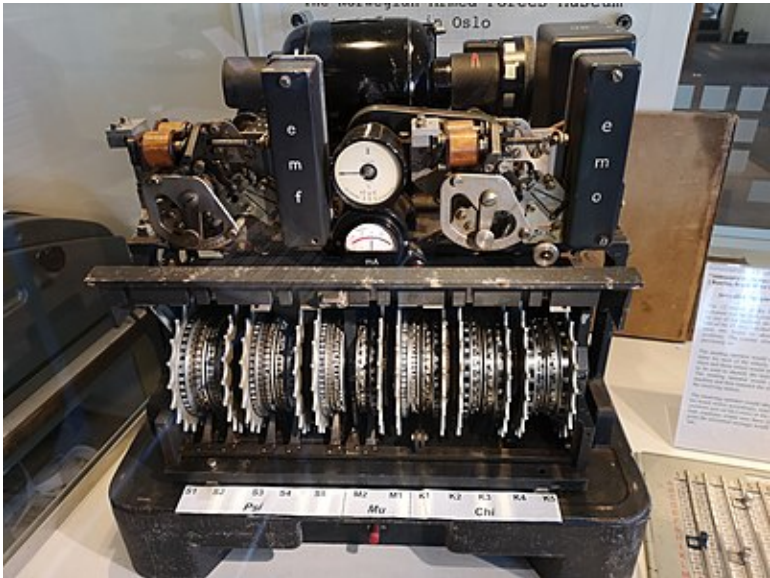
A Colossus Mark 2 computer being operated by Wrens.^[1] The slanted control panel on the left was used to set the "pin" (or "cam") patterns of the Lorenz. The "bedstead" paper tape transport is on the right.

Developer	Tommy Flowers, assisted by Sidney Broadhurst, William Chandler and for the Mark 2 machines, Allen Coombs
Manufacturer	Post Office Research Station
Type	Special-purpose electronic digital programmable computer
Generation	First-generation computer
Release date	Mk 1: December 1943 Mk 2: 1 June 1944
Discontinued	1960
Units shipped	12
Media	Electric typewriter output Programmed using switches and plug panels
CPU	Custom circuits using thermionic valves and thyratrons. A total of 1,600 in Mk 1 and 2,400 in Mk 2. Also relays and stepping switches
Memory	None (no RAM)
Display	Indicator lamp panel
Input	Paper tape of up to 20,000 × 5-

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	bit characters in a continuous loop
Power	8.5 kW ^[2]

Purpose and origins



A Lorenz SZ42 cipher machine with its covers removed at The National Museum of Computing on Bletchley Park

The Colossus computers were used to help decipher intercepted radio teleprinter messages that had been encrypted using an unknown device. Intelligence information revealed that the Germans called the wireless teleprinter transmission systems "*Sägefisch*" (sawfish). This led the British to call encrypted German teleprinter traffic "Fish",^[14] and the unknown machine and its intercepted messages "Tunny" (tunafish).^[15]

Before the Germans increased the security of their operating procedures, British cryptanalysts diagnosed how the unseen machine functioned and built an imitation of it called "British Tunny".

It was deduced that the machine had twelve wheels and used a Vernam ciphering technique on message characters in the standard 5-bit ITA2 telegraph code. It did this by combining the plaintext characters with

a stream of key characters using the XOR Boolean function to produce the ciphertext.

In August 1941, a blunder by German operators led to the transmission of two versions of the same message with identical machine settings. These were intercepted and worked on at Bletchley Park. First, John Tiltman, a very talented GC&CS cryptanalyst, derived a key stream of almost 4000 characters.^[16] Then Bill Tutte, a newly arrived member of the Research Section, used this key stream to work out the logical structure of the Lorenz machine. He deduced that the twelve wheels consisted of two groups of five, which he named the χ (*chi*) and ψ (*psi*) wheels, the remaining two he called μ (*mu*) or "motor" wheels. The *chi* wheels stepped regularly with each letter that was encrypted, while the *psi* wheels stepped irregularly, under the control of the motor wheels.^[17]

With a sufficiently random key stream, a Vernam cipher removes the natural language property of a plaintext message of having an uneven frequency distribution of the different characters, to produce a uniform distribution in the ciphertext. The Tunny machine did this well. However, the cryptanalysts worked out that by examining the frequency distribution of the character-to-character changes in the ciphertext, instead of the plain characters, there was a departure from uniformity which provided a way into the system. This was achieved by "differencing" in which each bit or character was XOR-ed with its successor.^[18] After Germany surrendered, allied forces captured a Tunny machine and discovered that it was the electromechanical Lorenz SZ (*Schlüsselzusatzgerät*, cipher attachment) in-line cipher machine.^[14]

In order to decrypt the transmitted messages, two tasks had to be performed. The first was "wheel breaking", which was the discovery of the cam patterns for all the wheels. These patterns were set up on the Lorenz machine and then used for a fixed period of time for a succession of different messages. Each transmission, which often contained more than one message, was enciphered with a different start position of the wheels. Alan Turing invented a method of wheel-breaking that became known as Turingery.^[19] Turing's technique was further developed into "Rectangling", for which Colossus could produce tables for manual analysis. Colossi 2, 4, 6, 7 and 9 had a "gadget" to aid this process.^[20]

The second task was "wheel setting", which worked out the start positions of the wheels for a particular message, and could only be attempted once the cam patterns were known.^[21] It was this task for which Colossus was initially designed. To discover the start position of the *chi* wheels for a message, Colossus compared two character streams, counting statistics from the evaluation of programmable Boolean functions. The two streams were the ciphertext, which was read at high speed from a paper tape, and the key stream, which was generated internally, in a simulation of the unknown German machine. After a succession of different Colossus runs to discover the likely *chi*-wheel settings, they were checked by examining the frequency distribution of the characters in processed ciphertext.^[22] Colossus produced these frequency counts.



The Lorenz SZ machines had 12 wheels, each with a different number of cams (or "pins").

Wheel number	1	2	3	4	5	6	7	8	9	10
BP wheel name ^[13]	ψ_1	ψ_2	ψ_3	ψ_4	ψ_5	μ_{37}	μ_{61}	χ_1	χ_2	χ_3
Number of cams (pins)	43	47	51	53	59	37	61	41	31	29

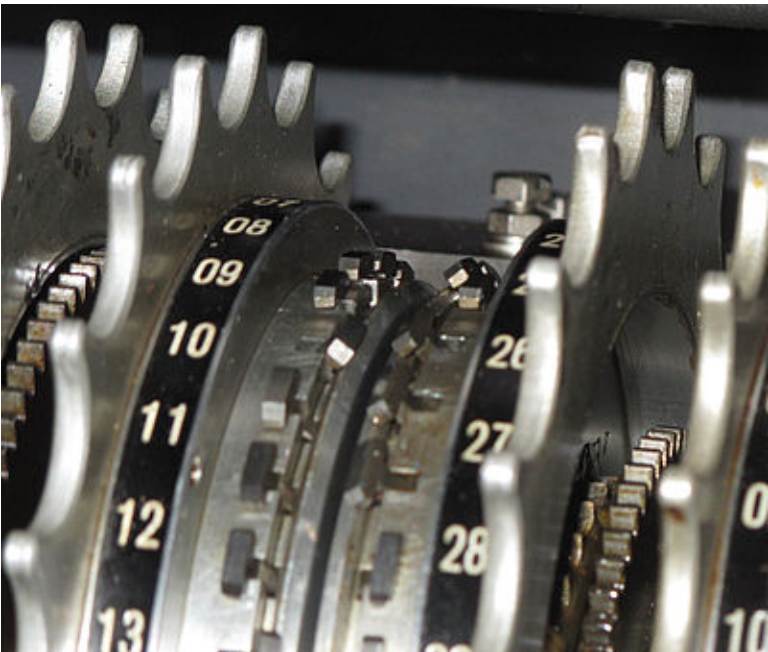
Decryption processes

By using differencing and knowing that the *psi* wheels did not advance with each character, Tutte worked out that trying just two differenced bits (impulses) of the *chi*-stream against the differenced ciphertext would produce a statistic that was non-random. This became known as Tutte's "1+2 break in".^[27] It involved calculating the following Boolean function:

$$\Delta Z_1 \oplus \Delta Z_2 \oplus \Delta \chi_1 \oplus \Delta \chi_2 = \bullet$$

and counting the number of times it yielded "false" (zero). If this number exceeded a pre-defined threshold value known as the "set total", it was printed out. The cryptanalyst would examine the printout to determine which of the putative start positions was most likely to be the correct one for the *chi*-1 and *chi*-2 wheels.^[28]

This technique would then be applied to other pairs of, or single, impulses to determine the likely start position of all five *chi* wheels. From this, the de-*chi* (D) of a ciphertext could be obtained, from which the *psi* component could be removed by manual methods.^[29] If the frequency distribution of characters in the de-*chi* version of the ciphertext was within certain bounds, "wheel setting" of the *chi* wheels was considered to have been achieved,^[22] and the message settings and de-*chi* were passed to the "Testery". This was the section at Bletchley Park led by Major Ralph Tester where the bulk of the decrypting work was done by manual and linguistic methods.^[30]



Cams on wheels 9 and 10 showing their raised (active) and lowered (inactive) positions. An active cam reversed the value of a bit (0→1 and 1→0).

Colossus could also derive the start position of the *psi* and motor wheels, but this was not much done until the last few months of the war, when there were plenty of Colossi available and the number of Tunny messages had declined.

Design and construction

Colossus was developed for the "Newmanry",^[31] the section headed by the mathematician Max Newman that was responsible for machine methods against the twelve-rotor Lorenz SZ40/42 on-line teleprinter cipher machine (code named Tunny, for tunafish). The Colossus design arose out of a prior project that produced a counting machine dubbed "Heath Robinson". Although it proved the concept of machine analysis for this part of the process, it was initially unreliable. The electro-mechanical parts were relatively slow and it was difficult to synchronise two looped paper tapes, one containing the enciphered

message, and the other representing part of the key stream of the Lorenz machine,^[32] also the tapes tended to stretch when being read at up to 2000 characters per second.

Tommy Flowers MBE^[34] was a senior electrical engineer and Head of the Switching Group at the Post Office Research Station at Dollis Hill. Prior to his work on Colossus, he had been involved with GC&CS at Bletchley Park from February 1941 in an attempt to improve the Bombes that were used in the cryptanalysis of the German Enigma cipher machine.^[35] He was recommended to Max Newman by Alan Turing, who had been impressed by his work on the Bombes.^[36] The main components of the Heath Robinson machine were as follows.

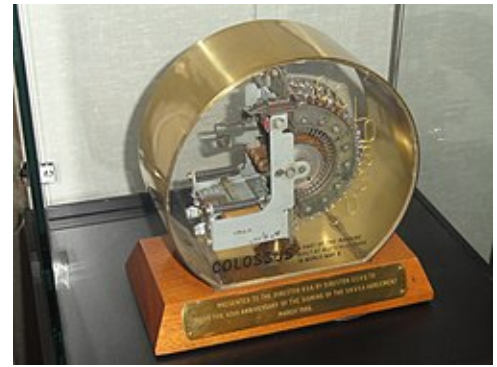
- A tape transport and reading mechanism that ran the looped key and message tapes at between 1000 and 2000 characters per second.
- A combining unit that implemented the logic of Tutte's method.
- A counting unit that had been designed by C. E. Wynn-Williams of the Telecommunications Research Establishment (TRE) at Malvern, which counted the number of times the logical function returned a specified truth value.

Flowers had been brought in to design the Heath Robinson's combining unit.^[37] He was not impressed by the system of a key tape that had to be kept synchronised with the message tape and, on his own initiative, he designed an electronic machine which eliminated the need for the key tape by having an electronic analogue of the Lorenz (Tunny) machine.^[38] He presented this design to Max Newman in February 1943, but the idea that the one to two thousand thermionic valves (vacuum tubes and

Notation ^[23]

P	plaintext
K	key – the sequence of characters used in binary <u>XOR</u> with the plaintext to give the ciphertext
χ	<i>chi</i> component of key
ψ	<i>psi</i> component of key
ψ'	extended <i>psi</i> – the actual sequence of characters added by the <i>psi</i> wheels, including those when they do not advance ^[24]
Z	ciphertext
D	de- <i>chi</i> —the ciphertext with the <i>chi</i> component of the key removed ^[23]
Δ	any of the above XOR'ed with its successor character or bit ^[18]
\oplus	the XOR operation ^{[25][26]}
•	Bletchley Park shorthand for telegraphy code <i>space</i> (zero)
x	Bletchley Park shorthand for telegraphy code <i>mark</i> (one)

thyratrons) proposed, could work together reliably, was greeted with great scepticism,^[39] so more Robinsons were ordered from Dollis Hill. Flowers, however, knew from his pre-war work that most thermionic valve failures occurred as a result of the thermal stresses at power up, so not powering a machine down reduced failure rates to very low levels.^[40] Additionally, the heaters were started at a low voltage then slowly brought up to full voltage to reduce the thermal stress. The valves themselves were soldered in to avoid problems with plug-in bases, which could be unreliable. Flowers persisted with the idea and obtained support from the Director of the Research Station, W Gordon Radley.^[41] Flowers and his team of some fifty people in the switching group^{[42][43]} spent eleven months from early February 1943 designing and building a machine that dispensed with the second tape of the Heath Robinson, by generating the wheel patterns electronically. Flowers used some of his own money for the project.^{[44][45]}



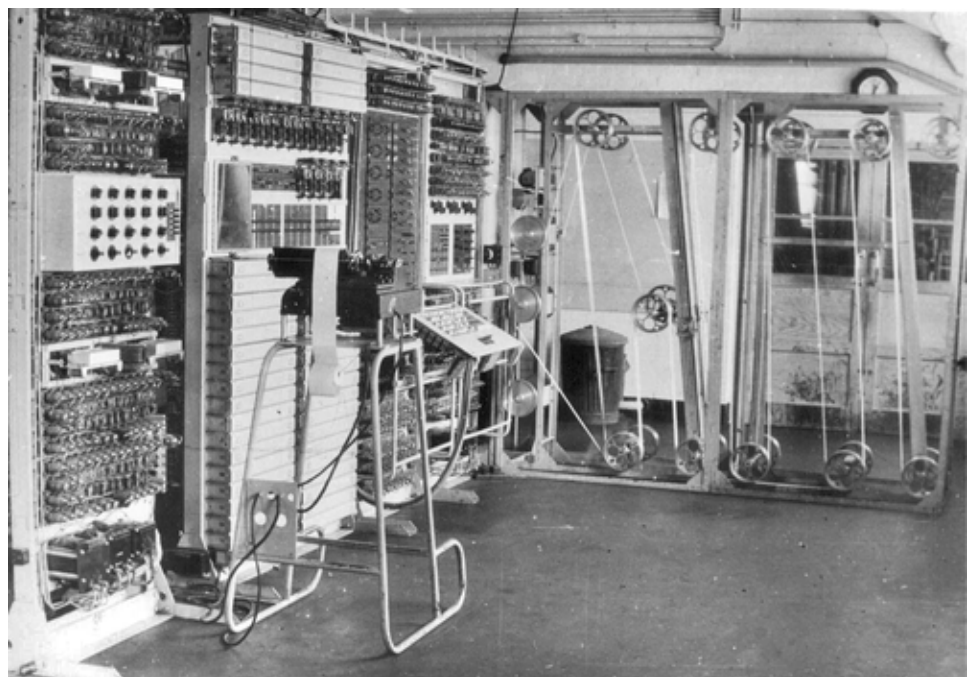
Stepping switch allegedly from an original Colossus presented by the Director of GCHQ to the Director of the NSA to mark the 40th anniversary of the UKUSA Agreement in 1986^[33]

This prototype, Mark 1 Colossus, contained 1600 thermionic valves (tubes).^[42] It performed satisfactorily at Dollis Hill on 8 December 1943^[46] and was dismantled and shipped to Bletchley Park, where it was delivered on 18 January and re-assembled by Harry Fensom and Don Horwood.^{[47][48]} It was operational in January^{[49][50]} and it successfully attacked its first message on 5 February 1944.^[51] It was a large structure and was dubbed 'Colossus', supposedly by the WRNS operators. However, a memo held in the National Archives written by Max Newman on 18 January 1944 records that 'Colossus arrives today'.^[52]

During the development of the prototype, an improved design had been developed – the Mark 2 Colossus. Four of these were ordered in March 1944 and by the end of April the number on order had been increased to twelve. Dollis Hill was put under pressure to have the first of these working by 1 June.^[53] Allen Coombs took over leadership of the production Mark 2 Colossi, the first of which – containing 2400 valves – became operational at 08:00 on 1 June 1944, just in time for the Allied Invasion of Normandy on D-Day.^[54] Subsequently, Colossi were delivered at the rate of about one a month. By the time of V-E Day there were ten Colossi working at Bletchley Park and a start had been made on assembling an eleventh.^[53]

The main units of the Mark 2 design were as follows.^{[38][55]}

- A tape transport with an 8-photocell reading mechanism.
- A six character FIFO shift register.
- Twelve thyatron ring stores that simulated the Lorenz machine generating a bit-stream for each wheel.
- Panels of switches for specifying the program and the "set total".
- A set of function units that performed Boolean operations.
- A "span counter" that could suspend counting for part of the tape.
- A master control that handled clocking, start and stop signals, counter readout and printing.
- Five electronic counters.
- An electric typewriter.



Colossus 10 with its extended bedstead in Block H at Bletchley Park in the space now containing the Tunny gallery of The National Museum of Computing

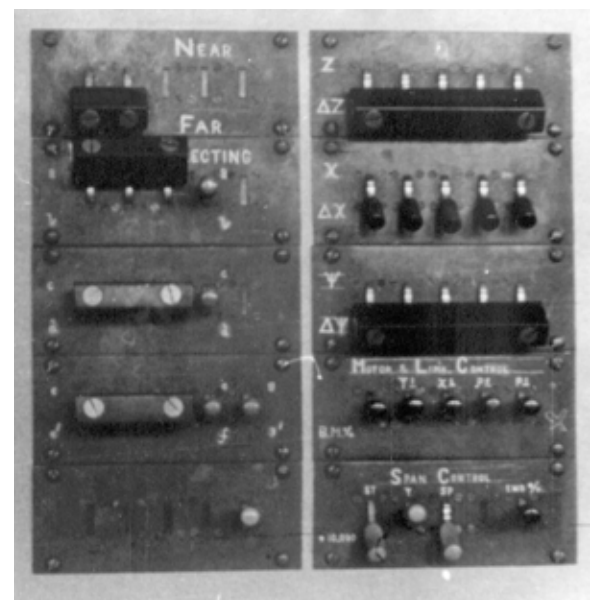
Most of the design of the electronics was the work of Tommy Flowers, assisted by William Chandler, Sidney Broadhurst and Allen Coombs; with Erie Speight and Arnold Lynch developing the photoelectric reading mechanism.^[56] Coombs remembered Flowers, having produced a rough draft of his design, tearing it into pieces that he handed out to his colleagues for them to do the detailed design and get their team to manufacture it.^[57] The Mark 2 Colossi were both five times faster and were simpler to operate than the prototype.^[58]

Data input to Colossus was by photoelectric reading of a paper tape transcription of the enciphered intercepted message. This was arranged in a continuous loop so that it could be read and re-read multiple times – there being no internal store for the data. The design overcame the problem of synchronizing the electronics with the speed of the message tape, by generating a clock signal from reading its sprocket holes. The speed of operation was thus limited by the mechanics of reading the tape. During development the tape reader was tested up to 9700 characters per second (53 mph) before the tape disintegrated. So 5000 characters/second (40 ft/s (12.2 m/s; 27.3 mph)) was settled on as the speed for regular use. Flowers designed a 6-character shift register, which was used both for computing the delta function (ΔZ) and for testing five different possible starting points of Tunny's wheels in the five processors.^{[59][60]} This five-way parallelism^[61] enabled five simultaneous tests and counts to be performed giving an effective processing speed of 25,000 characters per second.^[60] The computation used algorithms devised by W. T. Tutte and colleagues to decrypt a Tunny message.^{[62][63]}

Operation

The Newmanry was staffed by cryptanalysts, operators from the Women's Royal Naval Service (WRNS) – known as "Wrens" – and engineers who were permanently on hand for maintenance and repair. By the end of the war the staffing was 272 Wrens and 27 men.^[53]

The first job in operating Colossus for a new message, was to prepare the paper tape loop. This was performed by the Wrens who stuck the two ends together using Bostik glue, ensuring that there was a 150-character length of blank tape between the end and the start of the message.^[64] Using a special hand punch they inserted a start hole between the third and fourth channels 2½ sprocket holes from the end of the blank section, and a stop hole between the fourth and fifth channels 1½ sprocket holes from the end of the characters of the message.^{[65][66]} These were read by specially positioned photocells and indicated when the message was about to start and when it ended. The operator would then thread the paper tape through the gate and around the pulleys of the bedstead and adjust the tension. The two-tape bedstead design had been carried on from Heath Robinson so that one tape could be loaded whilst the previous one was being run. A switch on the Selection Panel specified the "near" or the "far" tape.^[67]



Colossus selection panel showing selections amongst others, of the far tape on the bedstead, and for input to the algorithm: ΔZ , ΔX and $\Delta \psi$.

After performing various resetting and zeroizing tasks, the Wren operators would, under instruction from the cryptanalyst, operate the "set total" decade switches and the K2 panel switches to set the desired algorithm. They would then start the bedstead tape motor and lamp and, when the tape was up to speed, operate the master start switch.^[67]

Programming

Howard Campaigne, a mathematician and cryptanalyst from the US Navy's OP-20-G, wrote the following in a foreword to Flowers' 1983 paper "The Design of Colossus".

My view of Colossus was that of cryptanalyst-programmer. I told the machine to make certain calculations and counts, and after studying the results, told it to do another job. It did not remember the previous result, nor could it have acted upon it if it did. Colossus and I alternated in an interaction that sometimes achieved an analysis of an unusual German cipher system, called "Geheimschreiber" by the Germans, and "Fish" by the cryptanalysts.^[68]

Colossus was not a stored-program computer. The input data for the five parallel processors was read from the looped message paper tape and the electronic pattern generators for the *chi*, *psi* and motor wheels.^[69] The programs for the processors were set and held on the switches and jack panel connections. Each processor could evaluate a Boolean function and count and display the number of times it yielded the specified value of "false" (0) or "true" (1) for each pass of the message tape.

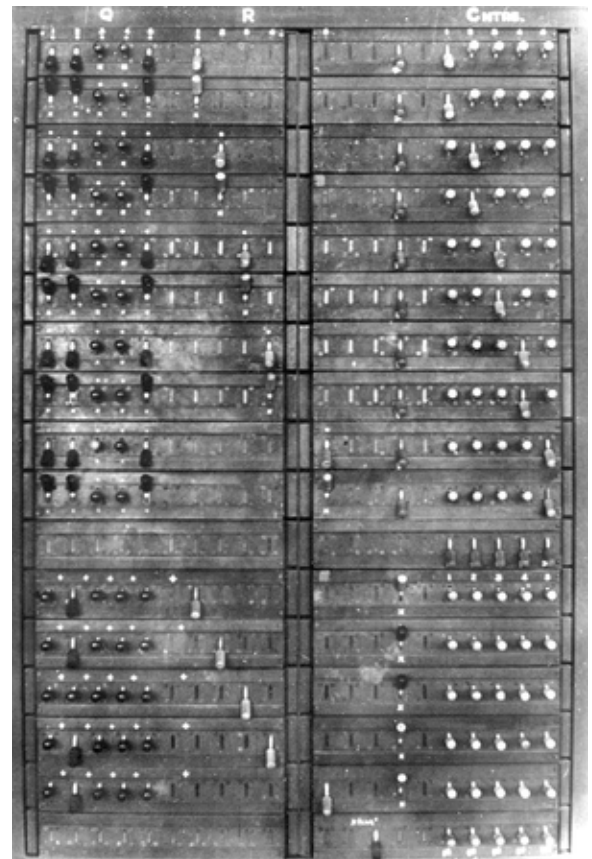
Input to the processors came from two sources, the shift registers from tape reading and the thyatron rings that emulated the wheels of the Tunny machine.^[70] The characters on the paper tape were called **Z** and the characters from the Tunny emulator were referred to by the Greek letters that Bill Tutte had given them when working out the logical structure of the machine. On the selection panel, switches specified either **Z** or ΔZ , either χ or $\Delta\chi$ and either ψ or $\Delta\psi$ for the data to be passed to the jack field and 'K2 switch panel'. These signals from the wheel simulators could be specified as stepping on with each new pass of the message tape or not.

The K2 switch panel had a group of switches on the left hand side to specify the algorithm. The switches on the right hand side selected the counter to which the result was fed. The plugboard allowed less specialized conditions to be imposed. Overall the K2 switch panel switches and the plugboard allowed about five billion different combinations of the selected variables.^[64]

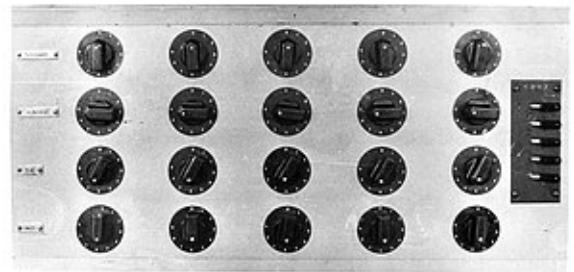
As an example: a set of runs for a message tape might initially involve two *chi* wheels, as in Tutte's 1+2 algorithm. Such a two-wheel run was called a long run, taking on average eight minutes unless the parallelism was utilised to cut the time by a factor of five. The subsequent runs might only involve setting one *chi* wheel, giving a short run taking about two minutes. Initially, after the initial long run, the choice of next algorithm to be tried was specified by the cryptanalyst. Experience showed, however, that decision trees for this iterative process could be produced for use by the Wren operators in a proportion of cases.^[71]

Influence and fate

Although the Colossus was the first of the electronic digital machines with programmability, albeit limited by modern standards,^[72] it was not a general-purpose machine, being designed for a range of cryptanalytic tasks, most involving counting the results of evaluating Boolean algorithms.



Colossus K2 switch panel showing switches for specifying the algorithm (on the left) and the counters to be selected (on the right).



Colossus 'set total' switch panel

A Colossus computer was thus not a fully Turing complete machine. However, University of San Francisco professor Benjamin Wells has shown that if all ten Colossus machines made were rearranged in a specific cluster, then the entire set of computers could have simulated a universal Turing machine, and thus be Turing complete.^[73] The notion of a computer as a general purpose machine — that is, as more than a calculator devoted to solving difficult but specific problems — did not become prominent until after World War II.

Colossus and the reasons for its construction were highly secret, and remained so for 30 years after the War. Consequently, it was not included in the history of computing hardware for many years, and Flowers and his associates were deprived of the recognition they were due. Colossi 1 to 10 were dismantled after the war and parts returned to the Post Office. Some parts, sanitised as to their original purpose, were taken to Max Newman's Royal Society Computing Machine Laboratory at Manchester University.^[74] Tommy Flowers was ordered to destroy all documentation and burnt them in a furnace at Dollis Hill. He later said of that order:

That was a terrible mistake. I was instructed to destroy all the records, which I did. I took all the drawings and the plans and all the information about Colossus on paper and put it in the boiler fire. And saw it burn.^[75]

Colossi 11 and 12, along with two replica Tunny machines, were retained, being moved to GCHQ's new headquarters at Eastcote in April 1946, and again with GCHQ to Cheltenham between 1952 and 1954.^[76] One of the Colossi, known as *Colossus Blue*, was dismantled in 1959; the other in 1960.^[76] There had been attempts to adapt them to other purposes, with varying success; in their later years they had been used for training.^[77] Jack Good related how he was the first to use Colossus after the war, persuading the US National Security Agency that it could be used to perform a function for which they were planning to build a special-purpose machine.^[76] Colossus was also used to perform character counts on one-time pad tape to test for non-randomness.^[76]

A small number of people who were associated with Colossus—and knew that large-scale, reliable, high-speed electronic digital computing devices were feasible—played significant roles in early computer work in the UK and probably in the US. However, being so secret, it had little direct influence on the development of later computers; it was EDVAC that was the seminal computer architecture of the time. In 1972 Herman Goldstine, who was unaware of Colossus and its legacy to the projects of people such as Alan Turing (ACE), Max Newman (Manchester computers) and Harry Huskey (Bendix G-15), wrote that,

Britain had such vitality that it could immediately after the war embark on so many well-conceived and well-executed projects in the computer field.^[78]

Professor Brian Randell, who unearthed information about Colossus in the 1970s, commented on this, saying that:

It is my opinion that the COLOSSUS project was an important source of this vitality, one that has been largely unappreciated, as has the significance of its places in the chronology of the invention of the digital computer.^[79]

Randell's efforts started to bear fruit in the mid-1970s, after the secrecy about Bletchley Park was broken when Group Captain Winterbotham published his book *The Ultra Secret* in 1974.^[80] In October 2000, a 500-page technical report on the Tunny cipher and its cryptanalysis—entitled *General Report on Tunny*^[81]—was released by GCHQ to the national Public Record Office, and it contains a fascinating paean to Colossus by the cryptographers who worked with it:

It is regretted that it is not possible to give an adequate idea of the fascination of a Colossus at work; its sheer bulk and apparent complexity; the fantastic speed of thin paper tape round the glittering pulleys; the childish pleasure of not-not, span, print main header and other gadgets; the wizardry of purely mechanical decoding letter by letter (one novice thought she was being hoaxed); the uncanny action of the typewriter in printing the correct scores without and beyond human aid; the stepping of the display; periods of eager expectation culminating in the

sudden appearance of the longed-for score; and the strange rhythms characterizing every type of run: the stately break-in, the erratic short run, the regularity of wheel-breaking, the stolid rectangle interrupted by the wild leaps of the carriage-return, the frantic chatter of a motor run, even the ludicrous frenzy of hosts of bogus scores.^[82]

Reconstruction

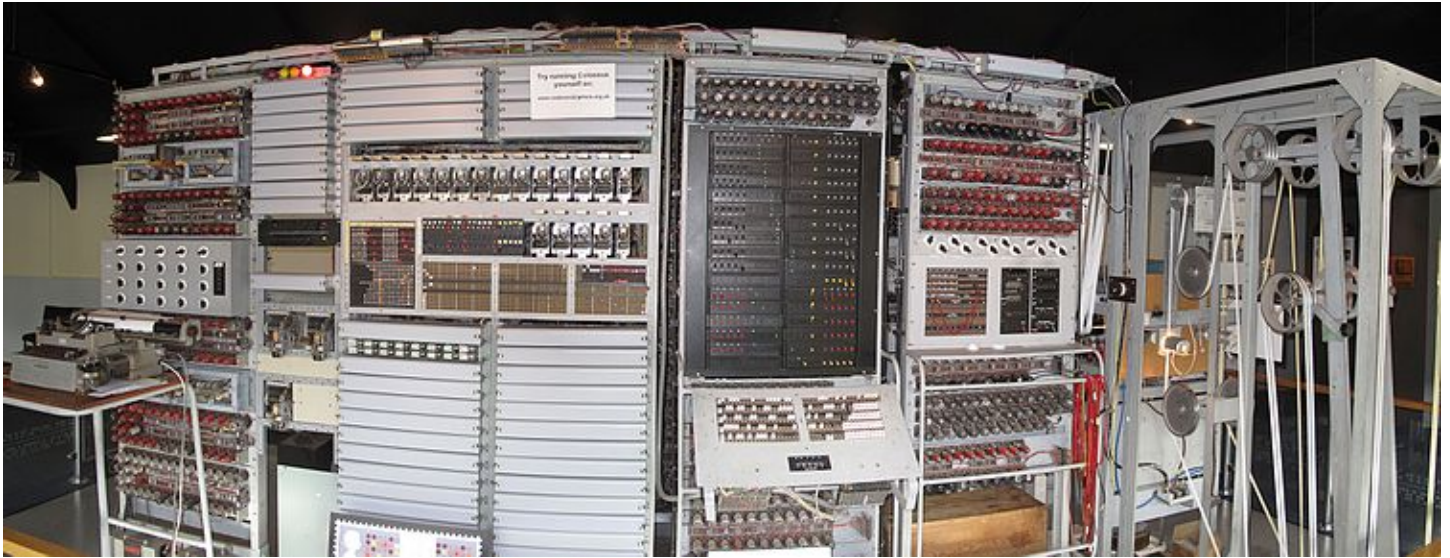
Construction of a fully functional rebuild^{[83][84]} of a Colossus Mark 2 was undertaken between 1993 and 2008 by a team led by Tony Sale.^{[12][11]} In spite of the blueprints and hardware being destroyed, a surprising amount of material survived, mainly in engineers' notebooks, but a considerable amount of it in the U.S. The optical tape reader might have posed the biggest problem, but Dr. Arnold Lynch, its original designer, was able to redesign it to his own original specification. The reconstruction is on display, in the historically correct place for Colossus No. 9, at The National Museum of Computing, in H Block Bletchley Park in Milton Keynes, Buckinghamshire.

In November 2007, to celebrate the project completion and to mark the start of a fundraising initiative for The National Museum of Computing, a Cipher Challenge^[85] pitted the rebuilt Colossus against radio amateurs worldwide in being first to receive and decode three messages enciphered using the Lorenz SZ42 and transmitted from radio station DLOHNF in the *Heinz Nixdorf MuseumsForum* computer museum. The challenge was easily won by radio amateur Joachim Schüth, who had carefully prepared^[86] for the event and developed his own signal processing and code-breaking code using Ada.^[87] The Colossus team were hampered by their wish to use World War II radio equipment,^[88] delaying them by a day because of poor reception conditions. Nevertheless, the victor's 1.4 GHz laptop, running his own code, took less than a minute to find the settings for all 12 wheels. The German codebreaker said: "My laptop digested ciphertext at a speed of 1.2 million characters per second—240 times faster than Colossus. If you scale the CPU frequency by that factor, you get an equivalent clock of 5.8 MHz for Colossus. That is a remarkable speed for a computer built in 1944."^[89]

The Cipher Challenge verified the successful completion of the rebuild project. "On the strength of today's performance Colossus is as good as it was six decades ago", commented Tony Sale. "We are delighted to have produced a fitting tribute to the people who worked at Bletchley Park and whose brainpower devised these fantastic machines which broke these ciphers and shortened the war by many months."^[90]



A team led by Tony Sale (right) reconstructed a Colossus Mark II at Bletchley Park. Here, in 2006, Sale supervises the breaking of an enciphered message with the completed machine.



Front view of the Colossus rebuild showing, from right to left (1) The "bedstead" containing the message tape in its continuous loop and with a second one loaded. (2) The J-rack containing the Selection Panel and Plug Panel. (3) The K-rack with the large "Q" switch panel and sloping patch panel. (4) The double S-rack containing the control panel and, above the image of a postage stamp, five two-line counter displays. (5) The electric typewriter in front of the five sets of four "set total" decade switches in the C-rack.^[91]

Other meanings

There was a fictional computer named *Colossus* in the 1970 movie *Colossus: The Forbin Project* which was based on the 1966 novel *Colossus* by D. F. Jones. This was sheer coincidence as it pre-dates the public release of information about Colossus, or even its name.

Neal Stephenson's novel *Cryptonomicon* (1999) also contains a fictional treatment of the historical role played by Turing and Bletchley Park.

See also

- History of computing hardware
- List of vacuum tube computers
- Manchester Baby
- Z3
- Z4

Footnotes

- The two operators have been variously identified as Dorothy Du Boisson (left) and Elsie Booker, Vivian Vorster (left) and Catherine Kennedy, and (unknown) and Patricia (Pat) Davis (right).
- Based on what the National Museum of Computing state is the power consumption of the Colossus rebuild. In the absence of information to the contrary, the original is presumed to be similar.
- Copeland 2006, Copeland, Jack, *Introduction* p. 2.
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7. Flowers 1983, p. 246.
8. Barber, Nicola (21 December 2015). *Who Broke the Wartime Codes?* (<https://books.google.com/?id=mRprCwAAQBAJ&pg=PT59&dq=Bletchley+destroyed+Colossus+machines+and+plans#v=onepage&q=Bletchley+destroyed+Colossus+machines+and+plans&f=false>). Capstone. ISBN 9781484635599. Retrieved 26 October 2017 – via Google Books.
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14. Good, Michie & Timms 1945, 1 Introduction: 11 German Tunny, 11A Fish Machines, (c) The German Ciphered Teleprinter, p. 4.
15. Hinsley, F. H.; Stripp, Alan (26 October 2017). *Codebreakers: The Inside Story of Bletchley Park* (<https://books.google.com/?id=j1MC2d2LPAC&printsec=frontcover&dq=Codebreakers+the+inside+story+of+Bletchley+Park,#v=onepage&q=Introduction+to+fish&f=false>). Oxford University Press. ISBN 9780192801326. Retrieved 26 October 2017 – via Google Books.
16. Copeland 2006, Budianski, Stephen *Colossus, Codebreaking and the Digital Age* pp. 55–56.
17. Copeland 2006, Tutte, William T. *My Work at Bletchley Park* p. 357.
18. Good, Michie & Timms 1945, 1 Introduction: 11 German Tunny, 11C Wheel Patterns, (b) Differenced and Undifferenced Wheels, p. 11.
19. Copeland 2006, Copeland, Jack, *Turingery* pp. 378–385.
20. Good, Michie & Timms 1945, 24 – Rectangling: 24B Making and Entering Rectangles pp. 114–115, 119–120.
21. Good, Michie & Timms 1945, 1 Introduction: 11 German Tunny, 11E The Tunny Network, (b) Wheel-breaking and Setting, p. 15.
22. Small 1944, p. 15.
23. Good, Michie & Timms 1945, 1 Introduction: 12 Cryptographic Aspects, 12A The Problem, (a) Formulae and Notation, p. 16.
24. Good, Michie & Timms 1945, 1 Introduction: 11 German Tunny, 11B The Tunny Cipher Machine, (e) Psi-key, p. 7.
25. The Boolean or "truth" function XOR, also known as Exclusive disjunction and Exclusive or, is the same as binary modulo 2 addition and subtraction
26. Good, Michie & Timms 1945, 1 Introduction: 11 German Tunny, 11B The Tunny Cipher Machine, (a) Addition, p. 5.
27. Copeland 2006, Budiansky, Stephen, *Colossus, Codebreaking, and the Digital Age* pp. 58–59.
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29. Small 1944, p. 65.
30. Roberts 2009, 34 minutes in.
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35. Randell 1980, p. 9.
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39. Flowers 1983, p. 244.
40. Copeland 2006, Copeland, Jack, *Machine against Machine* p. 72.
41. Copeland 2006, Copeland, Jack, *Machine against Machine* p. 74.
42. Copeland 2006, Flowers, Thomas H. *Colossus* p. 80.
43. Copeland 2006, Randell, Brian *Of Men and Machines* p. 143.
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55. Flowers 1983, pp. 249–252.
56. Flowers 1983, pp. 243, 245.
57. Coombs 1983.
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59. Flowers 1983.
60. Copeland 2006, Flowers, Thomas H. *Colossus* p. 100.
61. This would now be called a systolic array
62. Copeland 2011.
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64. Good, Michie & Timms 1945, 5 Machines: 53 Colossus 53A Introduction, p.333.
65. Flowers 1983, pp. 241,242.
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- Enever, Ted (1999), *Britain's Best Kept Secret: Ultra's Base at Bletchley Park* (3rd ed.), Sutton Publishing, Gloucestershire, ISBN 978-0-7509-2355-2 – A guided tour of the history and geography of the Park, written by one of the founder members of the Bletchley Park Trust
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- Rojas, R.; Hashagen, U. (2000), *The First Computers: History and Architectures*, MIT Press, ISBN 0-262-18197-5 – Comparison of the first computers, with a chapter about Colossus and its reconstruction by Tony Sale.
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- Smith, Michael (2007) [1998], *Station X: The Codebreakers of Bletchley Park*, Pan Grand Strategy Series (Pan Books ed.), London: Pan MacMillan Ltd, ISBN 978-0-330-41929-1

External links

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- Tony Sale's Codes and Ciphers (<http://www.codesandciphers.org.uk/index.htm>) Contains a great deal of information, including:
 - Colossus, the revolution in code breaking (<http://www.codesandciphers.org.uk/virtualbp/fish/colossus.htm>)
 - Lorenz Cipher and the Colossus (<http://www.codesandciphers.org.uk/lorenz/index.htm>)
 - The machine age comes to Fish codebreaking (<http://www.codesandciphers.org.uk/lorenz/colossus.htm>)
 - The Colossus Rebuild Project (<http://www.codesandciphers.org.uk/lorenz/rebuild.htm>)
 - The Colossus Rebuild Project: Evolving to the Colossus Mk 2 (<http://www.codesandciphers.org.uk/lorenz/mk2.htm>)
 - Walk around Colossus (<http://www.codesandciphers.org.uk/lorenz/colwalk/colossus.htm>) A detailed tour of the replica Colossus – make sure to click on the "More Text" links on each image to see the informative detailed text about that part of Colossus
 - IEEE lecture (<http://www.codesandciphers.org.uk/lectures/ieee.txt>) – Transcript of a lecture Tony Sale gave describing the reconstruction project
- BBC news article reporting on the replica Colossus (<http://news.bbc.co.uk/1/hi/technology/3754887.stm>)
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- Was the Manchester Baby conceived at Bletchley Park? (http://www.bcs.org/upload/pdf/ewic_tur04_paper3.pdf)
- Walk through video of the Colossus rebuild at Bletchley Park (<https://www.youtube.com/watch?v=NWYzwIjSk6s>) on YouTube
- online virtual simulation of Colossus (<http://www.virtualcolossus.co.uk>)

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Brian Randell

Brian Randell (born 1936) is a British computer scientist, and Emeritus Professor at the School of Computing, Newcastle University, UK He specialises in research into software fault tolerance and dependability, and is a noted authority on the early pre-1950 history of computers.

Brian Randell	
Born	1936 

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Biography

Randell was employed at English Electric from 1957 to 1964 where he was working on compilers. His work on Algol 60 is particularly well known, including the development of the compiler for the English Electric KDF9, an early stack machine.^[1] **In 1964 he joined IBM,** where **he worked at the Thomas J. Watson Research Center** on high performance computer architectures and also on operating system design methodology. In May 1969 he became a Professor of Computing Science at the University of Newcastle upon Tyne, where he has been working ever since in the area of software fault tolerance and dependability.

He is a member of the Special Interest Group on Computers, Information and Society (SIGCIS) of the Society for the History of Technology CIS, and a founding member of the **Editorial Board of the IEEE Annals of the History of Computing** journal. He was also a founding member of IFIP WG2.3 Programming Methodology, and is a founding member of IFIP WG10.4 about Dependability and Fault Tolerance. He is a Fellow of the Association for Computing Machinery (2008).

He is married (to Liz, a teacher of French) and has four children^[2]

Work

Brian Randell's main research interests are in the field of computer science, specifically on system dependability and fault tolerance. His interest in the history of computing was started by coming across the then almost unknown work of Percy Ludgate. This was over thirty years ago, when he was preparing an inaugural lecture, and led to his producing the book:

"The Origins of Computers". This triggered his further investigation of the Colossus wartime code-breaking machines.^[1]

Bletchley Park

In 1972, Randell wrote to Prime Minister Ted Heath regarding the wartime status of Bletchley Park, and obtained the first-ever admission of the existence of the war-time organisation, let alone its impact.^{[3][4][5]} Subsequently, the role of Bletchley Park and its main outstation at Eastcote, in reducing the length of the Second World War, has been widely acknowledged as well as the pioneering role of Colossus in the history of the development of computing.

Software engineering

In the 1960s Randell was "involved in the original NATO Software Engineering Conferences" in 1968 on Software engineering, at the time he was working at IBM in the very secret Project Y and then ACS super-computer projects.

Software fault tolerance

Beginning in the 1970s, Randell "set up the project that initiated research into the possibility of software fault tolerance, and introduced the "recovery block" concept. Subsequent major developments included the Newcastle Connection,^{[6][7]} and the prototype distributed Secure System".^[8]

Northern Informatics Applications Agency

In the 1990s Randell "became involved in a project to improve data networking provisions in the North of England, and to promote their effective use by all sectors of the community. This project resulted in the setting up of NiAA, the Northern Informatics Applications Agency". He wrote: "I served for several years as a member of NiAA's Management Group, until my attempts to delegate this to others bore fruit! NiAA existed, and worked to good effect, for seven years."^[9]

Work in Genealogy

Brian Randell has for many years been one of the leading members of the team of volunteers responsible for GENUKI, the web portal for Genealogy in the United Kingdom and Ireland. He maintains the pages relating to the county of Devon, and has transcribed and made available online many documents of genealogical interest.

See also

- Analytical engine
- ALGOL
- ALGOL 68
- Colossus computer
- Dependability
- Fault-tolerant system
- Friedrich L. Bauer
- National Programme for IT

Publications

Randell published several articles and books. A selection:^[10]

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Articles

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- 1979. "Software Engineering in 1968", in *Proc. of the 4th Int. Conf. on Software Engineering*, (Munich), pp. 1–10.
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3. Professor Brian Randell. "Uncovering Colussus" (<https://www.youtube.com/watch?v=Yl6pK1Z7B5Q>).
4. Professor Brian Randell. "The Computer Pioneers" (<https://www.youtube.com/watch?v=9HFyrJq3e1E>).
5. Professor Brian Randell. "The Computer Pioneers" (https://www.youtube.com/watch?v=TxC_ziacMKs).
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10. Brian Randell (http://www.ncl.ac.uk/computing/people/profile/brian.randell#tab_publications) Publications.

External links

- School of Computing Science — Brian Randell (<http://www.cs.ncl.ac.uk/people/brian.randell>)
 - Personal home page (<http://homepages.cs.ncl.ac.uk/brian.randell/>)
 - History of Computing Bibliography (<http://homepages.cs.ncl.ac.uk/brian.randell/History/>)
-

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Of FRIDAY, the 28th of MAY, 1943

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FRIDAY, 4 JUNE, 1943

CENTRAL CHANCERY OF THE ORDERS OF KNIGHTHOOD.

*St. James's Palace, S.W.1.
2nd June, 1943.*

The KING has been graciously pleased, on the occasion of the Celebration of His Majesty's Birthday, to give orders for the following promotions in, and appointments to, the **Most Excellent Order of the British Empire**:—

*To be Additional Officers of the Civil Division
of the said Most Excellent Order:—*

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Lionel Raymond Allen, Esq., D.S.O., Chairman, Hosiery and Knitwear Export Group.

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Leslie Herbert Bedford, Esq., Chief Research Engineer, A. C. Cossor, Limited.

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Captain Gordon William Bennett, Captain of Aircraft, British Overseas Airways Corporation.

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Thomas William Birnie, Esq., Chief Engineer Officer, Merchant Navy.

Arnold du Toit Bottomley, Esq., Group Engineer, Group 3, London Civil Defence Region.

John Brockis, Esq., Manager of the County Supplies Department, West Riding of Yorkshire County Council. For services to Civil Defence.

Captain Samuel Browne, Master, Merchant Navy.

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Major Bernard Peace Hall, Local Welfare Officer, Northern Command.

Robert Hannah, Esq., Chief Engineer Officer, Merchant Navy.

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Alick Robin Walsham Harrison, Esq., lately Private Secretary to the Minister of Food; now Deputy Director of Public Relations, Ministry of Food.

William Arthur Harrison, Esq., Borough Engineer and Surveyor, Bootle. For services to Civil Defence.

Captain William Horatio Hartman, Master, Merchant Navy.

Surgeon Captain Gerald Silvester Harvey, M.B., B.Ch., R.N. (Retired), Senior Instructor (Medical) and Deputy Commandant, Ministry of Home Security School, Falfield.

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James William Innes, Esq., Chief Engineer Officer, Merchant Navy.

Humphrey Jamison, Esq., General Secretary, Ulster Farmers' Union.

Captain David Jacob Jones, Master, Merchant Navy.

Captain Frederick Arthur Kennett, Master, Merchant Navy.

Captain Thomas Arthur Kent, Master, Merchant Navy.

Harold Charles Kenworthy, Esq., employed in a Department of the Foreign Office.

Lawrence William Kershaw, Esq., A.M.Inst.C.E., Principal, Leicester College of Technology and Commerce.

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Captain Charles Rolls Knight, Master, Merchant Navy.

George Harry Knighton, Esq., Principal Cost Officer, War Office.

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- Captain George Legg, Master, Merchant Navy.
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- James Miller Linton, Esq., Chief Engineer Officer, Merchant Navy.
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- Lieutenant-Colonel Claude Darcy George Lyon, D.S.O., D.L., Secretary, Territorial Army Association of the County of Somerset.
- Gerald Bernard McCormick, Esq., M.B.E., Principal Deputy Director of Armament Supply, Admiralty.
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- The Honourable Walter Symington Maclay, M.D., M.R.C.P., Medical Superintendent of Mill Hill Emergency Hospital.
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- Archibald McTaggart, Esq., J.P., Regional Secretary, Scottish Regional Council, National Federation of Building Trades' Operatives.
- John George Mann, Esq., Chief Engineer Officer, Merchant Navy.
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- Councillor Harry Percival Evelyn Mears, Air Raid Precautions Controller and Group Officer, Bournemouth.
- Oliver Mee, Esq., M.B.E., Director of Labour, North-Western Region, Ministry of Fuel and Power.
- Professor Stephen Pascal Mercer, Senior Technical Research Officer, Ministry of Agriculture, Northern Ireland.
- Major David Kinloch Michie, D.S.O., F.S.I., J.P., D.L., Air Raid Precautions Controller, Renfrewshire and Port Glasgow.
- Adam McMorran Millar, Esq. For public services in Edinburgh.
- Captain David Miller, Master, Merchant Navy.
- Harold Mills, Esq., Chief Controller of Supplies, Navy, Army and Air Force Institutes.
- Captain Frederick Monckton Milnes, Master, Merchant Navy.
- Alexander Alfred Moffat, Esq., Town Clerk and Clerk of the Peace, Ipswich. For services to Civil Defence.
- George Mould, Esq., Regional Information Officer, North Western Region, Ministry of Information.
- John Wallis Muirhead, Esq., Honorary Fire Prevention Adviser, North Western Civil Defence Regional Headquarters.
- Thomas Frederick Mulvenny, Esq. For services to seamen's welfare.
- Captain Horace Frederick Moncrieff Munro, Chief Constable of Ayrshire.
- Thomas Murray, Esq., Chief Engineer Officer, Merchant Navy.
- Percy Bantock Nevill, Esq., F.C.A. For services to the Boy Scout Movement.
- Joseph William Newsom, Esq., Chief Engineer Officer, Merchant Navy.
- Noël Francis Newsome, Esq., Director of European Broadcasts, British Broadcasting Corporation.
- Reginald Alfred Nursey, Esq., Head of Branch, Ministry of Health.
- Patrick O'Neill, Esq., Chief Constable, Kendal, and Air Raid Precautions Controller for Westmorland.
- Captain Ellis Arthur Organ, Master, Merchant Navy.
- Captain Lewis Tecwyn Owen, Master, Merchant Navy.
- Frederick Harold Dunn Page, Esq., Signal and Telegraph Engineer, Reading, Great Western Railway Company.
- Captain John Hutt Patterson, Master, Merchant Navy.
- Lieutenant-Colonel John Norman Peck, M.C., District Civil Engineer, London, Midland and Scottish Railway Company.
- Bernard William Phillips, Esq., Principal, Ministry of Agriculture and Fisheries.
- Alfred Pilling, Esq., F.C.A., J.P., Chairman of Bolton Employment Committee.
- William Thomas Pirie, Esq., Town Clerk and Air Raid Precautions Controller, Borough of Willesden.
- Charles Montague Power, Esq., M.C., Inspector of Hospitals, Joint War Organisation of the British Red Cross Society and Order of St. John.
- Alderman Noel Edward Purcell. For public services in Cornwall. Vice-Chairman of the Cornwall County Council.
- Samuel Herbert Quayle, Esq., Controller, Statistical Office, Board of Customs and Excise.
- Herbert Vere Redman, Esq., Director, Far East Division, Ministry of Information.
- Captain David MacQueen Reid, D.S.C., Master, Merchant Navy.
- Geraldine Elizabeth de Teissier, Lady Rendel, Vice-Chairman, Catholic Women's League Huts and Canteens Committee.
- Lieutenant-Colonel Henry Sacheverell Carleton Richardson, D.L., County Commandant, Ulster Special Constabulary.
- Mrs. Janie Lemey Craig Robertson, President, Glasgow Division, Soldiers', Sailors' and Airmen's Families' Association.
- Captain George Edward Roberts, Master, Merchant Navy.
- Major Gilbert Odell Searle, Superintendent, His Majesty's Norfolk Flax Establishment.
- Captain William Shaw, Master, Merchant Navy.
- Alfred Younger Smellie, Esq., M.B.E., Assistant Director of Accounts, Air Ministry.
- Herbert Smith, Esq., Secretary of the Agricultural Seed Trade Association, the Seeds Import Board and the Agricultural Machinery Dealers' Association.
- Harry Adam Smith, Esq., Honorary Secretary and Treasurer, Soldiers', Sailors' and Airmen's Help Society for Sussex.
- Miss Olga May Snowden, Chief Matron, City of Birmingham Municipal Hospitals. For services to Civil Defence.

Cynthia Elinor Beatrix, Countess Spencer, Chairman, Women's Land Army County Committee for Northamptonshire.
 Augustus Neville Spriggs, Esq., General Works Manager, Hawker Aircraft Limited.
 Miss Alice Gwendolen Stokoe, Canteen Organiser under the Kent Education Committee.
 Edgar Rouse Sutcliffe, Esq., Chairman and Managing Director, Sutcliffe Speakman and Company Limited.
 Richard Courtney Smith Taylor, Esq., Deputy Assistant Paymaster-General.
 Councillor William Johnson Taylor, D.L., Chairman, Yorkshire Air Training Corps Association.
 Robert Attey Thomas, Esq., Chief Engineer Officer, Merchant Navy.
 Captain Percy Dudley Townsend, Master, Merchant Navy.
 George Walter Tripp, Esq., Deputy Director, Gun Ammunition Production, Ministry of Supply.
 Captain William Trowsdale, Master, Merchant Navy.
 Henry Edward Upton, Esq., M.I.Mech.E., M.I.Mar.E., Technical Director of Serck Radiators Limited.
 Cyril Frank Uwins, Esq., Chief Test Pilot, Bristol Aeroplane Company.
 Frederick George Webster, Esq., Town Clerk, Carlisle.
 Captain Alfred Paget Whitehead, Master, Merchant Navy.
 Captain William Henry Wilcox, Liverpool Pilot, Mersey Docks and Harbour Board.
 Charles Douglas Young, Esq., Collector, Dover, Board of Customs and Excise.
 James Thomas Young, Esq., Regional Manager, Reading, War Damage Commission.

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 Robert Adam, Esq., General Secretary of the Young Men's Christian Association, Edinburgh.
 Miss Alice Agar, J.P., County Officer (Hampshire and Isle of Wight), St. John Ambulance Association. For services to Civil Defence.
 Miss Doris Ethel Agnew, Inspector, Insurance Department, Ministry of Health.
 Thomas Allen, Esq., Youth Organiser, Northern Ireland Council of Social Service.
 Edward Simpson Anderson, Esq., Production Manager, Northern Aluminium Company Limited.
 Albert Frank Archer, Esq. (Major, Home Guard), Civil Assistant and Accountant, Ministry of Aircraft Production.
 Cecil Edward Asher, Esq., Senior Staff Officer, Ministry of Fuel and Power.
 Frederick William Bagnall, Esq., Director and Works Manager, Walter Somers, Ltd.
 Frederick William Baldock, Esq., Senior Contract Officer, Admiralty.
 Albert Frederick Baldwin, Esq., Higher Clerical Officer, H.M. Stationery Office.
 Martin George Ball, Esq., Assistant Works Manager, Torpedo Tube Section, Peter Brotherhood Ltd.
 Charles Ballin, Esq., General Manager, Liverpool Branch, United Molasses Company Ltd.

William Theodore Barker, Esq., Senior Technical Officer, Ministry of Labour and National Service.
 James Isaac Barrance, Esq., Staff Officer, Office of the Minister of State, Cairo.
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 Stanley John Batchelder, Esq., Secretary of the Leeds Chamber of Commerce.
 Edwyn Ernest Hope Bate, Esq., Superintending Progress Engineer, Ministry of Works.
 Robert Edgar Bates, Esq., Works Director, Luxfer Ltd.
 Robert Glover Baxter, Esq., Borough Engineer, County Borough of Southend-on-Sea. For services to Civil Defence.
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 Elsie Dorothea, Mrs. Baynham, Local Welfare Officer, Western Command.
 William George Bedford, Esq., Superintendent, Austin Motor Company Ltd.
 John Edward Benham, Esq., Director, Benham and Sons Ltd.
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 Squadron Leader Neill Gibson Bennett, R.A.F.V.R., Senior Inspector of Accidents, Air Ministry.
 William Henry Bennett, Esq., Chief Steward, Merchant Navy.
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 Frank Blair, Esq., Chief Assistant to the National Registration Officer, Leeds.
 Harry Frederick Blenkarn, Esq., Chief Steward, Merchant Navy.
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 John Boneham, Esq., Managing Director, Boneham and Turner, Ltd.
 Miss Lily Mary Booker, Superintendent Health Visitor and Inspector of Midwives, Devon County Council.
 Miss Bessie Philip Boyes, Regional Welfare Officer, Ministry of Labour and National Service.
 Robert Braid, Esq., Chairman and Managing Director, Braid Bros.
 Sidney Bramhall, Esq., Works Director, Smith's Stamping Works Ltd.
 Captain Frank Thomas Bright, D.F.C., Observer Commander, Royal Observer Corps.
 Arthur Brooks, Esq., District House Coal Officer, Hull.
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- Richard Chandler, Esq., Chief Officer, Merchant Navy.
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- Frederick Augustus Clubley, Esq., Chief Engineer Officer, Merchant Navy.
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- Thomas Leslie Lane, Esq., Alarm Controller, South Eastern Region, Ministry of Home Security.
- George Laws, Esq., Chief Sanitary Inspector and Housing Officer, Richmond, Surrey.
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- Harold Lingard, Esq., M.I.E.E., Principal Lighting and Power Officer, Passive Air Defence Department, Ministry of Supply.
- Miss Elizabeth Duff Linn, Controller of Typing, Ministry of Supply.
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- Robert Lowry, Esq., Establishment Officer, Central Ordnance Depot, War Office.
- Miss Susan Lushington. For services to music in Hampshire.
- Tom Lyon, Esq., Railway Superintendent, Liverpool Dock Estate, Mersey Docks and Harbour Board.
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- Miss Janet McGilp, Headmistress of Lochburn Home, Glasgow.

- James Charles Fairlie McIntyre, Esq., Executive Officer, Agricultural Executive Committee for East Fife.
- Captain Donald Macbeath Mackay, Master, Merchant Navy.
- Captain Alexander McLachlan, Master, Merchant Navy.
- Captain William McLeod, Master, Merchant Navy.
- Albert Percival Mallaby, Esq., Senior Second Engineer Officer, Merchant Navy.
- Miss Edith Louise Manley, Women's Land Army County Secretary, Cheshire.
- Edward Grey Marchant, Esq., Senior Staff Officer, Air Ministry.
- Percy Walter John Martin, Esq., Personal Assistant to the General Manager, Port of London Authority.
- Leonard Mellor, Esq., Divisional Commander, Special Constabulary, Durham County Police Force.
- Miss Florence Milnes, Librarian, British Broadcasting Corporation.
- Arthur Robert Mitchell, Esq., M.C. (Captain, Home Guard), Chief of the Ship Drawing Office, Yarrow and Company Ltd.
- Leonard Thomas Moorby, Esq., Senior Staff Officer, Board of Trade.
- Maurice Desmond Morrissey, Esq., Station Manager, British Overseas Airways Corporation.
- Captain Samuel Bond Mosley, Master, Merchant Navy.
- Alexander James Muir, Esq., Technical Assistant II, Ministry of Aircraft Production.
- Councillor Miss Eunice Guthrie Murray, J.P. For public services in Dunbartonshire.
- Captain John Murray, Master, Merchant Navy.
- Captain Harold Bishop Mylchreest, Partner in Pedder and Mylchreest Ltd., Delivery Contractors.
- Francis Neal, Esq., Assistant to the Coal Supplies Officer for the Midland (Amalgamated) District.
- John Nicol, Esq., deceased, Chief Engineer Officer, Merchant Navy (dated 18th March, 1943). (Subsequently lost at sea as a result of enemy action.)
- Harry Nodder, Esq., Assistant to the Divisional Engineer, Great Western Railway Company, Plymouth. For services to Civil Defence.
- Hubert Oliver, Esq., First Radio Officer, Merchant Navy.
- John Bernard Olley, Esq., Works Manager, ASEA Electric Company.
- Alexander Park, Esq., Chief Engineer Officer, Merchant Navy.
- John Cecil Parker, Esq., Manager, Net Department, Rylands Bros. Ltd.
- Victor Parry, Esq., Air Raid Precautions Officer, Chief Warden and Fire Guard Officer, Walsall.
- David Paterson, Esq., Sub-District Manager, Edinburgh, Emergency Road Transport Organisation, Ministry of War Transport.
- Henry John Pearson, Esq., First Refrigerating Engineer Officer, Merchant Navy.
- Reginald Philip Perry, Esq., Manager of Brass Plant, John Lysaght Ltd.
- Payne Harry Pettiford, Esq., Deputy Superintendent of the Operative Department, Royal Mint.
- Maurice Frank Pinnock, Esq., Staff Officer, Offices of the War Cabinet.
- Henry Alfred Plastow, Esq., M.M., Senior Staff Officer, British Air Commission, Washington.
- John James Plimmer, Esq., Manager, Ministry of Supply Agency Factory.
- Miss Helen Frances Plumbly, Supervising Clerk, Grade I, Ministry of Economic Warfare.
- William Pook, Esq., Chief Engineer Officer, Merchant Navy.
- Herbert Lloyd Poulson, Esq., Chief Officer, Merchant Navy.
- Daniel Powell, Esq., Senior Sanitary Inspector, Bedwellty Urban District Council.
- Harry Powell, Esq., Headmaster, Meir Senior Mixed Council School, Stoke-on-Trent.
- Albert Henry Poynton, Esq., Superintendent of Stores, G. W. Lewis Tileries, Ltd.
- Lady Olein Eva Constance Wyndham-Quin, Head of the Army Records Department, Wounded and Missing Department, Joint War Organisation of the British Red Cross Society and Order of St. John.
- Charles Percival Raffill, Esq., Assistant Curator, Royal Botanic Gardens, Kew.
- William Raitt, Esq., Honorary Secretary, Morpeth Savings Committee.
- Miss Jessie Millar Ralston, lately Superintendent of Typists, Colonial Office.
- William Leonard Rawson, Esq., Superintendent, B.S.A. Guns Ltd.
- Miss Amelia Jane Rees, Higher Clerical Officer, Office of the Public Trustee.
- James Henry Reeves, Esq., Clerical Officer, Department of the Director of Public Prosecutions.
- Alexander Duncan Reid, Esq., Chief Production Engineer, Scottish Motor Traction Company Ltd.
- George Gapon Rich, Esq., Chief Officer, Merchant Navy.
- Thomas Edward Richardson, Esq., Flying Instructor, No. 4 Elementary Flying Training School, R.A.F. Flying Training Command.
- Alfred Riggall, Esq., Honorary Treasurer and Accountant of the North Midland Divisional Union of the Young Men's Christian Association.
- Douglas Craig Robinson, Esq., Assistant Works Superintendent, Handley Page, Ltd.
- Adam Robson, Esq., Probation Officer, Newcastle-on-Tyne.
- Miss Wilhelmine Wallace Robson, Headmistress, Sunderland Road Girls School, Gateshead.
- Captain John Lamb Rogerson, Master, Merchant Navy.
- Donalda Macleod, Mrs. Ross, Chairman, Women's Land Army Sub-Committee of the Agricultural Executive Committee for Ross and Cromarty (Main-land).
- Frederick Alexander Ross, Esq., A.M.I.E.E., Chief Electrical Engineer, Swan, Hunter, and Wigham Richardson, Ltd.
- William Martin Rowland, Esq., Joint Managing Director, Universal Grinding Wheel Company Ltd.
- Alan Ruddle, Esq., Secretary-Superintendent, Royal Gwent Hospital, Newport, Monmouthshire. For services to Civil Defence.
- Geoffrey Terence Ryan, Esq., Superintendent of Docks, Avonmouth and Portishead.
- Cyril Hugh Sanders, Esq., Superintendent (Telegraphs), Head Post Office, Swansea.
- Captain Harold Ernest Sanderson, Regional Officer, Grade II, Scotland Region, Ministry of Home Security.

- Miss Eleanor Saunders, Chief Clerk, Telephone Manager's Office, South East Area, General Post Office.
- Major John Walter Saunders, Employed in a Department of the Foreign Office.
- William James Sayer, Esq., Superintendent acting as Head Postmaster, Head Post Office, Eastbourne.
- Shirley Martin Searle, Esq., Staff Officer, War Office.
- Captain Edward Shaw, Master, Merchant Navy.
- Alfred John Shrieves, Esq., Higher Clerical Officer, Postal and Telegraph Censorship Department.
- Captain George Simison, Master, Merchant Navy.
- Captain David Sinclair, Master, Merchant Navy.
- Harry Singleton, Esq., Works Director, The Tempered Spring Company, Ltd.
- John Campbell Sloan, Esq., Electrical Manager, Barclay Curle & Company Ltd.
- Ernest Small, Esq., Joint Managing Director, M. B. Wild and Company Ltd.
- Ralph Wyman Smart, Esq., Staff Officer, General Post Office.
- Major Alexander Smith, M.C., Superintendent, City of Glasgow Special Constabulary. For services to Civil Defence.
- Miss Hilda Edwards Smith, Controller of Typists, Ministry of Aircraft Production.
- Miss Mabel Smith, Matron, Royal South Hants and Southampton Hospital. For services to Civil Defence.
- Captain Thomas William Smith, Master, Merchant Navy.
- William Henry Smith, Esq., Member of the National Savings Committee, and of the Birmingham Local Savings Committee.
- Joseph Smyth, Esq., lately General Secretary and Treasurer of the Ulster Teachers' Union.
- Brian Furnstone Rice Stack, Esq., Superintendent, Stores Branch, Board of Customs and Excise.
- Gerald Stanning, Esq., Works Manager, Allen West & Company Ltd.
- George Staveley, Esq., Boiler Works Manager, Cammell Laird & Company Ltd.
- Robert Stein, Esq., Chief Trial Trip Engineer, G. & J. Weir, Ltd.
- Annie Ramsay, Mrs Stevenson, Organising Secretary, Glasgow Centre, Women's Voluntary Services for Civil Defence.
- Miss Penuel Grant (Daisy) Stewart, Secretary, East Scottish Branch and Divisional Secretary, Edinburgh, Soldiers', Sailors' and Airmen's Families Association.
- Wing Commander Douglas Stewart, M.C., A.F.C. (R.A.F., Retd.), Observer Commander, Royal Observer Corps.
- Miss Katharine Bedingfeld Shaw Stewart, Honorary Secretary of the Inverness County Nursing Association.
- Nest Jessie, Mrs. Stoneham, Supervisor of Women's Studies, National Fire Service College.
- Frank Cyril Alexander Street, Esq., Engineer Works Manager, Vosper, Ltd.
- Robert Stuart, Esq., Chief Inspector, Bristol Aeroplane Company.
- Major Martin Stutfield (Retired), Assistant to the Controller of Factory Transportation, Ministry of Supply.
- Frank Swift, Esq., Manager of Foundry, Darlington Forge, Ltd.
- Captain Hugh Tait, Master, Merchant Navy.
- Miss Irene Compton Tappenden, Domiciliary Midwife, London County Council. For services to Civil Defence.
- Sidney Taylor, Esq., Chairman and Managing Director, General Engineering Company Ltd.
- Captain Thomas Thirlaway Telford, Master, Merchant Navy.
- Noel Goddard Terry, Esq., Controller, Royal Observer Corps.
- Percy William Earl Thatcher, Esq., Secretary, Port Emergency Committee, Southampton Docks.
- Captain David John Thomas, Master, Merchant Navy.
- John Thorburn, Esq., Chief Electrician, Merchant Navy.
- Claude John Thorne, Esq., Chief Assistant, Paper Control, Ministry of Supply.
- Basil Duncan Tims, Esq., Staff Officer, India Office.
- Miss Dorothy Lee Todd, Superintendent of Typists, London County Council.
- Caroline Marie, Mrs. Tucker, Private Secretary to the Lord Chancellor.
- William Turner, Esq., Honorary Secretary, Rawtenstall Savings Committee.
- Leslie Donald Tyrrell, Esq., Chief Planning Engineer, Rootes Securities Ltd. (Airframe Factory).
- Captain James Alfred Uglow, Master, Merchant Navy.
- Miss Sylvia Vachell, Regional Administrator for Wales, Women's Voluntary Services for Civil Defence.
- Walter Edwin Vickers, Esq., Public Assistance Officer, County of Lincolnshire, Parts of Kesteven. For services to Civil Defence.
- Miss Margaret Callander Wade, Commandant, Larbert District, Stirlingshire, British Red Cross Society. For services to Civil Defence.
- Henry Johnston Wallace, Esq., Superintendent and Deputy Chief Constable, Selkirkshire.
- Albert Walmsley, Esq., Chairman of the Stretford and District Employment Committee.
- Henry Neville Walton, Esq., Secretary of the Newcastle Coasting and Short Sea Shipping Committee, Ministry of War Transport.
- Miss Eirene Mervynia Wanstall, Secretary of the Juvenile Employment Bureau, Newcastle-on-Tyne.
- Percy Wharton Waters, Esq., Chief Chemist and Metallurgist, Ford Motor Company Ltd.
- Donald Harlock Watkins, Esq., Constructor, Dockyard Department, Admiralty.
- Victor Grant Watson, Esq., Purser, Merchant Navy.
- William Anthony Graham Watson, Esq., Divisional Officer, No. 5 Fire Area, National Fire Service.
- William Norman Wheat, Esq., Manager, Optical Department, Chance Bros. & Company Ltd.
- Marjorie Joyce, Mrs. Whimster, County Borough Organiser, Bath, Women's Voluntary Services for Civil Defence.
- John Whitehead, Esq., Civil Defence District Controller, County Durham. Clerk to Billingham Urban District Council.
- Thomas George Willett, Esq., Secretary, Soldiers', Sailors', and Airmen's Help Society for Brighton and Hove.
- Captain Hugh James Williams, Master, Merchant Navy.

Robert Willis, Esq., Manager, C. H. Bailey, Ltd.

Miss Stella Mary Willis, Secretary to the Foreign Relations Department, Joint War Organisation of the British Red Cross Society and Order of St. John.

Ernest Wilson, Esq., Assistant to the Chief Accountant, Navy, Army and Air Force Institutes.

John Frederick Wilson, Esq., Manager in charge of Admiralty repairs at Palmers Hebburn Company Ltd.

Victor Franklin Wood, Esq., Head of Branch, Ministry of Food.

William Arthur Victor Wood, Esq., Technical Assistant (Airframe Component Repair), Civilian Repair Organisation.

Cyril Wright, Esq., Shop Superintendent, Standard Motor Company Ltd. (Aero-Engines).

William Edgar Wright, Esq., H.M. Assistant Inspector of Schools.

Arthur Frank Young, Esq., Staff Officer, Board of Inland Revenue.

Noah Mackintosh Youngson, Esq., Chief Engineer Officer, Merchant Navy.

CENTRAL CHANCERY OF THE ORDERS OF KNIGHTHOOD,

*St. James's Palace, S.W.1,
2nd June, 1943.*

The KING has been graciously pleased, on the occasion of the Celebration of His Majesty's Birthday, to make the following appointments to the Imperial Service Order:—

To be Companions of the Order:—

HOME CIVIL SERVICE.

Edward Halsey Bourne, Esq., Director, Investigation Branch, General Post Office.

Frank Everard Cook, Esq., M.B.E., Deputy Establishment Officer, Ministry of Fuel and Power.

Francis William Filbee, Esq., Assistant Director of Contracts, Ministry of Aircraft Production.

John William Glennie, Esq., Head of Branch, Ministry of Food.

James Hook, Esq., Accountant, Board of Education.

Lewis Montgomery Jones, Esq., Senior Executive Officer, Air Ministry.

John Oliver McFadden, Esq., Deputy Director of Audit, Exchequer and Audit Department.

Alexander Cruikshank Milne, Esq., lately Chief Accountant, War Office.

John Clarence Monahan, Esq., Assistant Chief Instructions Officer, Ministry of Labour and National Service.

Harry John Pearman, Esq., Senior Staff Officer, Ministry of Health.

William Perry, Esq., O.B.E., Chief Clerk, Royal Mint.

Arthur Silvester, Esq., F.S.I., Superintending Quantity Surveyor, Ministry of Works.

Adam Smail, Esq., lately General Inspector, Department of Health for Scotland.

Leonard Smith, Esq., 1st Class Inspector, Board of Customs and Excise.

Arthur Roger Straw, Esq., M.B.E., Assistant Director of Stores, Admiralty.

Thomas Daniel Williams, Esq., M.V.O., D.C.M., lately Superintendent, Master of the Household's Department, Buckingham Palace (dated 1st April, 1943).

CENTRAL CHANCERY OF THE ORDERS OF KNIGHTHOOD,

*St. James's Palace, S.W.1,
2nd June, 1943.*

The KING has been graciously pleased, on the occasion of the Celebration of His Majesty's Birthday, to approve the award of the British Empire Medal (Civil Division) to the under-mentioned:—

UNITED KINGDOM.

Harry Albert Victor Abbott, Works Manager, Chambon Ltd.

Arthur Adams, Setter, Fuze Department, George Kent Ltd.

Charges Agg, Dock Labourer, London.

Robert Aitman, Boatswain, Merchant Navy.

Charles Aldridge, Foreman Plater, Harland & Wolff Ltd.

Robert Calaghan Allan, Head Foreman Plater, Greenock Dockyard Company Ltd.

Bachameah Jeenat Allee, Engine-room Serang, Merchant Navy.

Bertie Robert Allen, Chief Steward, Merchant Navy.

Frank Allen, Foreman, Firestone Tyre & Rubber Company Ltd.

Robert James Allen, Station Officer, Coast-guard Service, Ministry of War Transport.

Themistocle Anastasiu, Chief Steward, Merchant Navy.

Joseph Anderson, Electrician, Swan, Hunter & Wigham Richardson, Ltd.

Albert Arthur Andrews, Section Foreman, Lehmann Archer & Lane Ltd.

Miss Fanny Louise Arnold, Sorting Clerk and Telegraphist, Head Post Office, Abingdon.

Miss Irene Arnold, Assistant, Cypher Office, R.A.F. Headquarters, Malta.

Walter John Arnold, Jig Tool and Gauge Hardener, Mollart Engineering Company, Ltd.

Miss Margaret Atherton, Inspector, Pollard Bearings Ltd.

Thomas Bagley, Transport Foreman, Imperial Chemical Industries, Ltd.

Percy Mozart Bailey, Ganger, Kettering, London, Midland & Scottish Railway Company.

William Bainbridge, Foreman Fitter, Vickers-Armstrongs Ltd.

Miss Sarah Jane Bartlett, Forewoman, William Edwards & Sons (Bridport), Ltd.

James Barton, Foreman, Greenwood & Batley.

Lilian, Mrs. Baskeyfield, Assistant Forewoman, Royal Ordnance Factory, Ministry of Supply.

Thomas Bates, Able Seaman and Lamp Trimmer, Merchant Navy.

Albert Batey, Head Foreman of Machine Shop, Clarke, Chapman & Company, Ltd.

John Embury Battin, Goods Foreman, Birkenhead, Great Western Railway Company.

Alexander Baxter, Second Fisherman of a Steam Trawler.

George Baxter, Dock Labourer, Leith.

Cecil John Bayliss, Grinder, Austin Motor Company, Ltd.

Thomas Beardsmore, D.C.M., Office Keeper, Ministry of Aircraft Production.

Thomas Beck, Foreman Boilermaker, Harland & Wolff Ltd.

Albert Victor Bennett, Signal and Telegraph Supervisor, Eastleigh, Southern Railway Company. For services to Civil Defence.

Miss Hilda Bennett, Chargehand, British Aluminium Company, Ltd.

- Charles Bernard, Chief Steward, Merchant Navy.
- Jack Berry, Foreman Fitter, Short Bros., Ltd.
- Prudence, Mrs. Berry, Forewoman, Gauge Department, Hoffmann Manufacturing Company, Ltd.
- Cecil George Birch, Civilian D.F. Operator, Bomber Command, Air Ministry.
- Harry Birch, Dock Labourer, Scruttons Ltd.
- Henry Stoddard Bishop, Chargehand Tool-maker, Monotype Corporation Ltd.
- Hilda Mary, Mrs. Blackburn, General Leader, Y.M.C.A. Services Canteen, Bletchley Station.
- James Edis-Blewitt, Planer-machinist, Arthur Pattison Ltd.
- George Ernest Bohey, Shift Engineer, Middle East Command, Air Ministry.
- Thomas Bolton, Foreman Turner, Brown Bros. & Company, Ltd.
- Harold Bond, Supervisor, Civil Defence Rescue Service, Exmouth.
- Frank Bones, Carpenter, Merchant Navy.
- Albert Edward Bonner, Able Seaman, Merchant Navy.
- William Ewart Bosher, Foreman of Trades, Maintenance Command, Air Ministry.
- James Boyle, Greaser, Merchant Navy.
- James Arthur Bradley, Centre Lathe Turner, Sheepbridge Coal & Iron Company.
- Charles Bradshaw, Chief Engineer of a Steam Trawler.
- Arthur Bright, Instrument Maker, Cambridge Instrument Company, Ltd.
- James Stephens Brodie, Donkeyman, Merchant Navy.
- Henry Edward Brooker, Acting First Class Draughtsman, Naval Ordnance Department, Admiralty, Canada.
- Frank Brown, Divisional Head Warden, Civil Defence Wardens Service, Derby.
- Kenneth Charles Brown, Works Superintendent, De Havilland Aircraft Company, Ltd.
- Leslie Richmond Brown, Company Officer, No. 12 (Cambridge) Area, National Fire Service.
- Robert Brown, Lieutenant, Dundee Police Force. For services to Civil Defence.
- Miss Sara Miriam Browne, Supervisor, Telephones, Post Office, Belfast.
- Archibald Brownlee, Boatswain, Merchant Navy.
- Lyon Buchanan, Fieldsman, Home Grown Flax Production Department, Ministry of Supply.
- Thomas Budge, Skipper of a Motor Fishing Boat.
- Leonard Ronald Bullinaria, Acting Inspector of Storehousemen, Royal Victoria Yard, Deptford.
- Cyril Inglis Burns, Training Officer, Civil Defence Casualty Services, Norwich.
- Reginald John Butcher, Inspector, Folkestone Police. For services to Civil Defence.
- Edward Byrne, Acting Foreman of Engineer Branch, H.M. Dockyard, Simonstown.
- Charles Caffrey, Fireman, Merchant Navy.
- Michael William Caine, Machine Shop Foreman, Enfield Cycle Company, Ltd.
- Miss Irene May Frances Cameron, Plotter, Operations Room, R.A.F. Headquarters, Malta.
- Alexander Graham Campbell, Chief Steward, Merchant Navy.
- Charles Archibald Carter, Superintendent of Messengers and Office Keeper, 10, Downing Street.
- Arthur Gerald Casey, Evangelist, Church Army. For services to the Forces in the Middle East.
- Candido Castanos, Fireman and Trimmer Greaser, Merchant Navy.
- Edward Owen Chapman, Foreman, Gent & Company, Ltd.
- Porteous Chapman, Chief Carpenter, Merchant Navy.
- Richard Hall Charlton, Technical Assistant to Works Manager, Peter Brotherhood Ltd.
- Henry Appleby Churnside, Chief and Ship's Cook, Merchant Navy.
- Luke Clarke, Foreman Founder, Optical Department, Chance Bros.
- Francis Charles Cobbledick, Senior Company Officer, No. 19 (Plymouth) Area, National Fire Service.
- George Edward Cobden, Sergeant, Salisbury City Police. For services to Civil Defence.
- Kenneth Archibald Cockle, Turner, Dowty Equipment Ltd.
- Morris Edward Colbeck, Deputy Head Warden, Civil Defence Wardens Service and Deputy Head Fire Guard, Abbey Division, Lincoln.
- Harold William Coles, Acting Foreman, H.M. Dockyard, Sheerness.
- Miss Ethel Collins, Supervisor, Crompton Parkinson Ltd.
- Harold Godfrey Constable, Foreman, Campbell & Isherwood Ltd.
- Miss Gertrude Eileen Cooper, Telephone Supervisor, Southampton Docks, Southern Railway Company. For services to Civil Defence.
- Alfred Davies Corrigan, Employed in a Department of the Foreign Office.
- Harold Stanley Cox, Toolroom Foreman, Newman Hender & Company.
- Charles Cranfield, Night Foreman, Camberwell Garage, London Passenger Transport Board. For services to Civil Defence.
- Reginald Spenser Crighton, Inspector, Eastbourne Borough Police. For services to Civil Defence.
- John Croft, Chief Warden's Staff Officer, Civil Defence Wardens Service, Co. Durham.
- Joseph Crosbie, Engine-room Storekeeper, Merchant Navy.
- William Richard Crossbie, Chargeman, Vickers-Armstrongs Ltd.
- Percival Edward Crosson, Shops Superintendent, Royal Aircraft Establishment, Ministry of Aircraft Production.
- George Edward Curd, Fireman, Merchant Navy.
- Harold Dalton, Docker, Manchester.
- Bertram William Davies, Foreman of M/T., Maintenance Command, Air Ministry.
- Joseph William Davies, Chief Steward, Merchant Navy.
- Ernest Davis, Foreman, Erecting Shop, Airspeed (1934) Ltd.
- John Dawson, Foreman, Gun Department, Vickers-Armstrongs Ltd.
- Arthur James Denzey, Senior Laboratory Assistant, Admiralty Outstation.
- George De Silva, Chief Steward, Merchant Navy.
- William Thomas Douglas, Boatswain, Merchant Navy.
- James Dow, Chief and Ship's Cook, Merchant Navy.
- Reginald Arthur Drake, Staff Officer for Civil Defence First Aid Parties, Southend-on-Sea.
- Gerald Walton Drewitt, Staff Officer, Civil Defence Casualty Services, Canterbury.

- Timothy Topping Duff, Trawl Fisherman of a Steam Trawler.
- James Anthony Duncan, Foreman, Northern Aluminium Company.
- Frederick James Dunk, Head Observer, Royal Observer Corps.
- Robert Alfred Durent, Foreman Ship's Electrician, A. Anderson & Son, Ltd.
- Charles Maynard Dutton, Foreman, Sheet Metal Shop, Aeronautical & General Instruments Ltd.
- Eugene Duvoisin, Chef, Merchant Navy.
- James Dyson, Draughtsman, Vulcan Foundry Ltd.
- George William Eason, Chargeman Fitter, Richardsons Westgarth & Company, Ltd.
- James Edwards, Storehouse Assistant, H.M. Dockyard, Portsmouth.
- William Stanley Eggbeer, Chief Steward, Merchant Navy.
- Frederick George Ellingham, Ganger, St. Pancras, London, Midland & Scottish Railway Company. For services to Civil Defence.
- Charles William England, Goods Agent, Portsmouth, Southern Railway Company. For services to Civil Defence.
- Alfred William Evans, Chargehand Driller, Gloucester Railway Carriage & Wagon Company, Ltd.
- John William Evans, Foreman, Brass Strip Mill, Imperial Chemical Industries Ltd.
- Henry Owen Eves, Quartermaster, Merchant Navy.
- Harry Exley, lately Shop Foreman, John Holroyd & Company, Ltd.
- James Anderson Falconer, Docker, Liverpool.
- John Mary Farrugia, Clerk of Works, Air Ministry Works Department, Kalafrana, Malta.
- John William Stanley Fielding, Area Chief Warden and Incident Officer, Civil Defence Services, Borough of Glossop.
- Arthur Ernest Fildes, Clerk of Works, Air Ministry Works Department, Luqa, Malta.
- Samuel Firth, Foreman, Jig and Tool Department, Prince Smith & Stells Ltd.
- Donald Fletcher, Quartermaster, Merchant Navy.
- Marigold, Mrs. Fletcher, Plotter, Operations Room, R.A.F. Headquarters, Malta.
- Sidney Flowers, Foreman Shipwright, W. Overy & Son.
- Herbert John Folland, Electric Furnace Feeder and Unloader, W. Martin Winn Ltd.
- Albert Victor Francis, Plant Inspector, Post Office (London) Railway.
- John Fraser, Boatswain, Merchant Navy.
- Robert Fraser, Boatswain, Merchant Navy.
- Phyllis, Mrs. Frederick, lately Assistant, Cypher Office, R.A.F. Headquarters, Malta.
- Frederick Charles Freeman, Mortuary Keeper, Chelsea. For services to Civil Defence.
- James Frid, Established Skilled Labourer, R.N. Armament Depot, Upnor.
- Edwin George Frost, Principal Storeholder, R.N. Armament Depot, Woolwich.
- James Fyles, Foreman, Imperial Chemical Industries (Explosives) Ltd.
- Archibald Duncan Galbraith, Cook Steward, Merchant Navy.
- Miss Carmela Eileen Galea, Assistant, R.A.F. Headquarters, Malta.
- Charles Henry Galvin, Designer's Assistant, Halex Ltd.
- George Sydenham Gant, Civilian Armament Instructor Grade I, Flying Training Command, Air Ministry.
- James Gardiner, M.M., Principal Foreman of Stores, Maintenance Command, Air Ministry.
- Amos Arnold Garner, Foreman, Machine Shop, Vickers-Armstrongs Ltd.
- Miss Marjorie Elizabeth Garner, Chief Woman Welfare Supervisor, Turbine Blading Department, Vickers-Armstrongs Ltd.
- James Gaughran, Chargeman of Joiners and Storewrights, Naval Store Department, Admiralty.
- Susan, Mrs. Gibson, Matron, Millvale Hostel, Wooler, Northumberland. For services to Civil Defence.
- John Gill, Boatswain, Merchant Navy.
- William Edward Gillard, Joiner in charge, Frederick Sage & Company, Ltd.
- Alfred William Godfrey, Filer, Royal Small Arms Factory, Ministry of Supply.
- Christopher Gordon, Foreman Stevedore, Bromborough Dock.
- John Graves, Head Warden, Civil Defence Wardens Service, Sheffield.
- Harold Ivan Thomas Greatrex, Foreman Toolmaker, James Booth & Company (1915), Ltd.
- Hubert John Green, Progressman (Technical), R.N. Torpedo Factory, Greenock.
- William Griffin, Chargeman of Joiners and Storewrights, Admiralty Outstation.
- George Griffiths, Body Shop Foreman, Austin Motor Company, Ltd.
- Leonard Charles Phillip Grimbly, Technical Officer, Cable and Wireless Ltd.
- Henry Walter Grose, Sorter, London Postal Region.
- Andrew Guild, Boatswain, Merchant Navy.
- Joseph Victor Harold Gurney, Station and Yard Master, Banbury, Great Western Railway Company.
- Joseph Alfred Gwinnett, Toolroom Foreman, L. H. Newton & Company, Ltd.
- Annie, Mrs. Halifax, Capstan Operator, British Vacuum Cleaner and Engineering Company, Ltd.
- James Henry Hamilton, Foreman Fitter, Crossley Bros., Ltd.
- Miss Rose Hammond, Winder, C.A.V. Ltd.
- William Hammond, Skilled Setter, Royal Ordnance Factory, Ministry of Supply.
- Charles Handley, Chief Inspector, War Department Constabulary.
- James Robert Hanvey, Acting Assistant III, Admiralty Outstation.
- Charles Leo Harnett, Turner, R.N. Torpedo Factory, Greenock.
- William Henry House Harper, Able Seaman, Merchant Navy.
- Harry Burnett Harris, Machine Shop Superintendent, F. Perkins Ltd.
- Thomas Albert Carden Harris, Boatswain, Merchant Navy.
- Henry Hartley, Foreman Boilermaker, Cardiff Channel Dry Docks and Pontoon Company, Ltd.
- Frederick Hawkins, Blacksmith, Wolverhampton, London, Midland & Scottish Railway Company.
- Robert J. Heathwood, Company Officer, National Fire Service, Northern Ireland.
- William Helps, Sector Leader, Civil Defence Wardens Service and Head Fire Guard, Leicester.

- Mabel Ellen, Mrs. Henderson, Adviser, Housewives' Service, Group 9 (Surrey), Women's Voluntary Services for Civil Defence.
- John Henry, Able Seaman, Merchant Navy.
- John Hibberd, Chief Boatswain, Merchant Navy.
- Henry Hooper Hicks, Chief Steward, Merchant Navy.
- Dorothy Annie Frances, Mrs. Hide, Message Supervisor, Civil Defence Report and Control Service, Hammersmith.
- William Franklin Higgin, Skilled Turner, Yorkshire Engineering Supplies Company.
- Miss Elizabeth Mary Higgins, Canteen Officer, Civil Defence Services, Birkenhead.
- Robert Hill, Head Foreman Shipwright, Cammell Laird & Company, Ltd.
- Sidney Arthur Hobbs, Skilled Workman, Class I, Bristol Telephone Area.
- Robert Black Hoggan, Established Chergeman of Fitters, R.N. Torpedo Depot, Rosyth.
- Thomas Frederick Hole, Engine Test Superintendent, British Overseas Airways Corporation.
- Albert Walter Holland, Operations Foreman, Home Grown Timber Department, Ministry of Supply.
- Herbert Joseph Holliday, Chief Steward, Merchant Navy.
- Thomas Holly, Cranedriver, Cardiff.
- Frank Holmes, Chargehand Setter, Automatic Department, British Manufacturing & Research Company Ltd.
- George Holmes, Foreman Shipwright, Tees Side Bridge & Engineering Works Ltd.
- Miss Marie Homer, Overseer, Bournville Utilities Ltd.
- Thomas William Hopkins, Foreman, Jowett Cars Ltd.
- Joseph Horton, Toolmaker, Joseph Lucas Ltd.
- James Houghton, Furnace Foreman, Umbroc Ltd.
- William Hounscome, Greaser, Merchant Navy.
- William John Hover, Supervisor of Steel Structures, London Bridge, Southern Railway Company. For services to Civil Defence.
- Albert Edwin Hufton, Works Superintendent, S. & R. J. Everett & Company, Ltd.
- Thomas Sims Hyde, Foreman, Williams & Williams Ltd.
- Peter Ritchie Inglis, Carpenter, Merchant Navy.
- Ralph Jarvis, Foreman Fitter, James Robertson & Sons, Ltd.
- Robert Jeffrey, Foreman Smith, Laird & Son, Ltd.
- Charles Walter Johnstone, Principal Foreman, Royal Aircraft Establishment, Ministry of Aircraft Production.
- Frederick James Jolliffe, Principal Lighthouse Keeper, Corporation of Trinity House.
- Miss Elizabeth Venning Jones, Manageress, Navy, Army and Air Force Institute, Northwood.
- Sidney Robert Jones, Supervisor of Outside Erection, Vickers-Armstrongs Ltd.
- Edward Keightley, Air Raid Precautions Instructor, London, Midland & Scottish Railway Company.
- Archibald Kerr, Foreman, De Havilland Aircraft Company, Ltd.
- John Edward Laurie King, Cook Steward, Merchant Navy.
- Cecil Kingdom, 2nd Class Master, Naval Armament Vessels, Admiralty.
- Hero Kuhlmann, Boatswain, Merchant Navy.
- Lueng Kwai, Quartermaster, Merchant Navy.
- Clifford Cecil Lambert, Foreman, County Industries Ltd.
- Thomas Morgan Langley, Port Transport Worker, Swansea Dock.
- Martin Larsen, Greaser, Merchant Navy.
- John Thomas Lathey, Foreman, Pymore Mill Company, Ltd.
- Joseph Law, Works Inspector, Watford, London, Midland & Scottish Railway Company. For services to Civil Defence.
- John Edward Laws, Chief Steward, Merchant Navy.
- Ernest Frank Baker Lea, Duty Controller, Royal Observer Corps.
- Councillor Arthur Sidney Leather, Chief Warden, Civil Defence Wardens Service, Borough of Stourbridge.
- Frederick Leeder, Foreman, Hawker Aircraft Company, Ltd.
- Phyllis, Mrs. Liddle, Assistant Forewoman, Armaments Inspection Department, Ministry of Supply.
- Orlando Lifton, Acting First Class Draughtsman, Admiralty.
- Robert Lloyd, Greaser, Merchant Navy.
- Robert Lloyd, Boatswain, Merchant Navy.
- Cecil Walter Longman, Production Designer, Pressed Steel Company, Ltd.
- William Thomas Berry Lorimer, Superintendent of Works, Ministry of Finance, Northern Ireland.
- Frederick Albert Luff, Acting Inspector of Storehousemen, H.M. Naval Victualling Depot, Milford Haven.
- Walter Lynch, Able Seaman and Cook, Merchant Navy.
- William John Mabbett, Rollerman, Imperial Chemical Industries Metals Ltd.
- John Joseph MacDonald, Chief Steward, Merchant Navy.
- Donald McDougall (Junior), Skipper of a Motor Boat.
- Miss Mary McGregor, Overlooker, J. & P. Coates Ltd.
- John McGuffie, Assistant Foreman Plumber, Barclay Curle & Company, Ltd.
- Alexander McIntyre, Boatswain, Merchant Navy.
- Nicol McKechnie, Boatswain, Merchant Navy.
- Frank Cantwell Mackenzie, Curator of Original Documents, Hydrographic Department, Admiralty.
- William Berry McLaren, Chief Pharmacist, Medical Branch, General Post Office.
- Bernard McLaughlan, Able Seaman Lamp-trimmer, Merchant Navy.
- Miss Marion MacLennan, Acting Sub Postmistress, Lochboisdale, Isle of South Uist.
- Miss Elizabeth McMeekin, Forewoman, Imperial Chemical Industries (Explosives) Ltd.
- Alan McPherson, Dock Labourer, Glasgow Dock.
- Donald McPherson, Boatswain, Merchant Navy.
- Neil McTaggart, Boatswain, Merchant Navy.
- Thomas Blackburn Maddison, Acting Foreman, Machine Shop, Darlington, London & North Eastern Railway Company.
- Jean Sarah Malloy, Sergeant-in-charge, Women Police, Glasgow.
- Harold Stocks Marsden, Group Leader, Civil Defence Motor-cycle Messenger Group, Leeds.

- Gordon Percy Albert Marsh, Charge Engineer, Ferry Dock Pumping Station, Dover. For services to Civil Defence.
- Edward John Marsh, Principal Foreman, Royal Aircraft Establishment, Ministry of Aircraft Production.
- John Edward Marsh, Storeman "A," Anti-Aircraft Command, War Office.
- Robert Martin, Chief Baker, Merchant Navy.
- Harry Matcham, Chargeman of Acid Mixers, R.N. Cordite Factory, Holton Heath.
- Audrey, Mrs. Mather, Librarian and Entertainment Organiser, Catterick. For services to the Forces.
- Horace Melbourne, Chief Cartage Supervisor, Marylebone, London & North Eastern Railway Company. For services to Civil Defence.
- Helen Rae, Mrs. Mellis, Centre Organiser, Women's Voluntary Services for Civil Defence, Clydebank, Dunbartonshire.
- Thomas Inglis Russell Melville, Section-Leader, Western (No. 2) Area, Scotland, National Fire Service.
- Charles Edwin Miles, Foreman, Electrical Assembly and Wiring Shop, Cinema-Television Ltd.
- Albert Reginald Millar, Employed in a Department of the Foreign Office.
- Harry Miller, Inspector (Engineering), Telephone Manager's Office, Lincoln.
- William Henry Miller, Temporary Chief Inspector, Oxford City Police. For services to Civil Defence.
- Dorothy, Mrs. Milne, Canteen Manageress, Royal Ordnance Factory, Ministry of Supply.
- John Mitchell, Chief Warden, Civil Defence Wardens Service, Londonderry.
- Charles William Moller, Works Manager, Plessey Company, Ltd.
- Alfred Molyneux, Able Seaman, Merchant Navy.
- Ernest Monk, Foreman, Royal Gunpowder Factory, Ministry of Supply.
- Thomas Monkhouse, General Foreman, Metropolitan-Vickers Ltd.
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