John Womersley: Applied Mathematician and Pioneer of Modern Computing

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John Womersley started his career in the 1920s and 1930s in applied mathematics and moved into managerial positions during World War II, just before the development of computers started in Great Britain (see Figure 1). Although he was a key player in the history of computing in the 1940s and 1950s, historians have mostly focused on the following generation of innovators. Womersley made both significant scientific contributions in applied mathematics and managerial contributions to computer innovation. He hired Alan Turing to design the ACE computer; he hired Donald Davies, who later invented packet switching, to work on ACE; and he hired Ray Bird to build the first small British computer for business use. However, Womersley remains unknown; for example, there are no easily available photos of him, and the engraving appearing here was difficult to find.

Womersley's career, which we outline in this article, reflected the major trends in British applied mathematics, statistics, and automated computation in the middle decades of the 20th century. He was an applied mathematician and then a manager of mathematicians and statisticians, in war and in peacetime. He was also involved at the beginning of electronic computers. However, he made a difficult career transition in the mid-1950s from second-level management back to very successful applied mathematics research. He then undertook what was possibly his most ambitious management position in the United States, but his work was cut short by his early death, only four years after Turing died.

Early Life and Education

John Ronald Womersley was from the north of England. He was the only child of George and Ruth Womersley, born 20 June 1907, in the town of Morley in Yorkshire, near Leeds, where his father managed a grocery store.[1] Morley has a long history back to Anglo-Saxon times, but in recent centuries, it was known for mining, quarrying, and textile manufacturing.

John Womersley was educated locally, culminating in Morley Grammar School. In 1922 he was awarded a Northern Universities School Certificate. In 1925, he was awarded a Cambridge Open Scholarship and the prestigious Royal Scholarship in Physics. He turned down Cambridge to study at the Royal College of Science, Imperial College, University of London. There he read "Pure and Applied Mathematics, Physics, Hydrodynamics, and the Kinetic Theory of Gases."[2] In 1929 he was awarded a BSc with first class honors in mathematics and became an associate of the Royal College of Science (ARCS), an honorary distinction.

He continued graduate study at Imperial, including hydrodynamics research, and in 1930 was awarded the Diploma of Imperial College (D.I.C.), equivalent to a master's degree. However, he had already decided to take up an applied mathematics research position in an area "close to home," both physically and metaphorically, in Manchester, about 60 km from Leeds.

Presumably he met his wife, Jean Isobel Jordan, before moving north, because she was a Londoner, working in commercial design and art. They married in

Background of John Ronald Womersley

Born: 20 June 1907, Morley, Yorkshire, UK

Education: Northern Universities School Certificate, 1922; BSc (first class honors, mathematics), Imperial College, University of London, 1929; Diploma of Imperial College (D.I.C.), University of London, 1930.

Professional Experience: Shirley Institute, junior research officer, 1930–1937; Ballistics Branch of the Research Department, scientific officer, 1937–1942; Wartime Ministry of Supply, assistant director of scientific research, 1942–1945; National Physical Laboratory, superintendent of the mathematics division, 1945–1950; British Tabulating Machines, director of research, 1950–1954; Physiology Department, Medical College, St Barthomolew's Hospital, research associate, 1954–1955; Analysis Section, System Dynamics Branch Aeronautical, Wright Air Development Center, section chief, 1955–1958.

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Hammersmith in 1931. Their first daughter, Barbara Jean, was born in Manchester in early 1932.

Applied Mathematician at the Shirley Institute for Fabric Research

The Shirley Institute was housed on the outskirts of Manchester in an elegant Victorian building, "The Towers," described as the "grandest of all Manchester mansions."[3] Originally a private residence, it accommodated the newly founded British Cotton Industry Research Association, named the Shirley Institute after the daughter of a major donor in 1920. The building still exists but has reverted to private ownership. The Shirley Institute is now, after several mergers, the British Textile Technology Group.

Womersley spent seven years at the Shirley Institute. He was involved in research on cotton spinning and the drafting of fibrous materials. He developed an automatic yarn regularity tester with his colleague G.A. Foster. He worked on the stability of spinning spindles, the diffusion of wax in cotton hair, and the properties of almost-periodic functions.[2] It was a productive time, resulting in internal reports and external publications, mainly in the *Shirley Institute Memoirs*. One of these, "The Application of Differential Geometry to the Stress-Strain Relationships of Cloth," was considered significant enough to be reprinted in the *Journal of the Textile Institute* and to be included, with another article by F.T. Peirce, in a slim paperback as late as 1978.

During this time, Womersley also became interested in practical computation. He made the acquaintance of New Zealander L.J. Comrie (a chemist and astronomer, later to found the computer bureau Scientific Computing Services[4]) and spent one month at the Nautical Almanac Office, London, learning Comrie's computation and numerical analysis techniques.[2] He used the Manchester Differential Analyzer and published another important and much-referenced paper on the numerical integration of partial differential equations, as coauthor of Douglas R. Hartree of the University of Manchester. Womersley was described as being "always good company,"[5] and developing friendships with such distinguished people would later do his own career a great deal of good.

Womersley's position at the Shirley Institute was as a junior research officer. However, by the end of his tenure, he supervised two laboratory assistants and was beginning to be recognized as an up-and-coming talent.

Figure 1. John Womersley engraving.

Move to Government Service

With hostilities looking imminent, Womersley was recruited for military research. There were two distinct phases to his work, but there was a single progression of his career. From February 1937, he was a scientific officer in the Ballistics Branch of the Research Department (later the Armaments Research Department) at Woolwich, with manager C.A. Clemmow, the superintendent of Ballistic Research. Woolwich was the sobriquet for the Royal Arsenal, located at Woolwich in East London, and it performed ammunition proofing and explosives research for the British armed forces. Thus, the Womersleys returned to London, which presumably pleased Mrs. Womersley, living closer to her own family. Initially they lived at Bexley Heath, fairly close to work. Later, their house in Charlton was destroyed by bombing, and they were evacuated to Cambridge in 1940. Womersley lived on Cherry Hinton Road for a month, and then the family found a house in the village of Great Shelford, before moving back to London in late 1942 as the danger from bombing receded.

Womersley's work at Woolwich had two aspects: general computation, and mathematics and statistics applied to ammunition proofing. On the computational side, he began to make a copy of the Meccano

Differential Analyzer, but Woolwich was severely damaged by bombing in the very first air raid of the London Blitz in September 1940, and his work was destroyed before completion. He was involved in setting up computing facilities for Woolwich, in the sense of "computing" at the time—banks of desk calculators with human operators.

His initial applied research was in "internal ballistics." After the outbreak of war in 1939, he began a large-scale statistical survey of cordite proof and gun proof. He specialized in work on mathematical statistics between 1940 and 1942, publishing an internal report, "The Statistical Analysis of Variations in Muzzle-Velocity at Cordite Proof and Gun Proof."[2] He later claimed that he worked on "Analysis of Small-Arms Firings and Studies of Variations in Performance of Loading Machines in Filling Factories," and this led to managing a "Staff of 40, supplemented by outside contracts for computing."[2] There must have been overlap between this position and his next appointment.

Assistant Director of Scientific Research at Wartime Ministry of Supply

In May 1942, Womersley received a major promotion to assistant director of scientific research at the wartime Ministry of Supply. The Ministry of Supply was an enormous department of the UK government, formed in 1939 to coordinate the supply of equipment to all British armed forces (except for aircraft and the supply of the Royal Navy). During the war years, its headquarters were at Shell Mex House in the Strand, London.

Womersley was effectively in command of computing, statistical, and mathematical research at the Ministry of Supply, reporting to E.T. Paris, controller of physics research (later chief scientist at the Home Office, Whitehall).[2] He summarized the work in his curriculum vitae (CV):

> Setting up and Chief of Advisory Service on Statistical Methods and Quality Control Advice and Assistance to Government Inspectorates, Research Establishments, Factories and Contractors on the use of Statistical Methods in Research, Development, Production and Inspection of warlike stores.
>
> Organization was in four sections:
>
> Advice to and investigations in Government Filling Factories concerned with the filling of ammunition.
>
> Advice to and investigations in engineering factories.
>
> Advice to and investigations in Government Inspectorates.
>
> Fundamental Research. Over 50 reports issued, many containing original research. Its Fundamental Research included independent discovery of Sequential Analysis and new methods of Multi-factorial experiment planning.[2]

He claimed that his staff included 28 graduates in science or mathematics and was proud that he had "personally recruited and trained" many, "qualified statisticians being very scarce." To see the scope of this job note that, throughout the country, Woolwich supervised more than 40 Royal Ordnance Factories and Filling Factories, some owned by the Ministry of Supply and others by private industry. Among other things, his department produced the UK's first booklet of advice on quality control for manufacturing engineers.

His department, initially designated SR1e and later SR17, was based at Berkeley Court, opposite the Baker Street tube station. Staff were mainly actuaries and young mathematics students from Cambridge. Recruitment took place at "a mysterious address near the Strand. Womersley provided the new unit with a sense of direction, firm support, and the warmth of his personality… [he] contributed much to the strong esprit de corps."[6] SR17 notably nurtured a fundamental research team led by the statistician George Barnard, including important mathematicians such as Dennis Lindley and Peter Armitage, who later had major influences on the study of statistics and probability.

Womersley's management style seems to have been to appoint competent section leaders or managers and let them get on with the job. Dennis Lindley, for example, reports "very little contact with him," either at SR17 or later at the National Physical Laboratory (NPL).[7] He provided cover and support as necessary. In any case, he must have been good at his job because he was one of only two candidates invited to apply for his next position at NPL. In fact, at the end of 1944 and beginning of 1945, he was still officially employed by the ministry.

Superintendent of Mathematics Division at NPL

Womersley's next role as the first superintendent of the mathematics division of NPL

has earned him the most recognition. In particular, he hired Alan Turing (Figure 2) to build ACE (Womersley actually suggested the acronym of Automatic Computing Engine), and he was still superintendent when the Pilot ACE started up. However, being the manager of the designer of the ACE was not Womersley's main accomplishment. More importantly, he was responsible for the set-up and initial operation of the British government's first national computing center. This story is well known, thanks to research by David Yates[8] and Mary Croarken,[4] so we will focus on Womersley's role.

During 1943, those involved in computation for the British war effort recognized that they needed help that could best be provided by amalgamating their efforts. An interdepartmental committee was set up by the Department of Scientific and Industrial Research (DSIR) to study the matter. Womersley was among the 20 committee members, and one of only three representatives from the Ministry of Supply, indicating the level at which he was operating. The committee delivered its report to the DSIR Advisory Council on 10 May 1944,[9] endorsing the creation of a "Central Mathematical Station." High-level considerations led to its being a division of NPL at Teddington, on the southwestern edge of London. Briefly, the functions of the division were as follows:

- Research into new computing methods and machines, including the design of new computing devices.
- Encourage the development of new computing methods and machines by the dissemination of knowledge, including creating a library.
- Deal with statistical problems from industry, especially in application to industrial research.
- Examine the need for and, if necessary, prepare mathematical tables.
- Provide computing services for government departments, industry, and universities.
- Act as consultant for government departments, industry, and universities on the use of mathematical and statistical techniques.

This was intended to be *the* British government's center of computation. It was necessary to appoint a suitable superintendent of the new division to get it started. Two people were invited to apply, Womersley and Donald

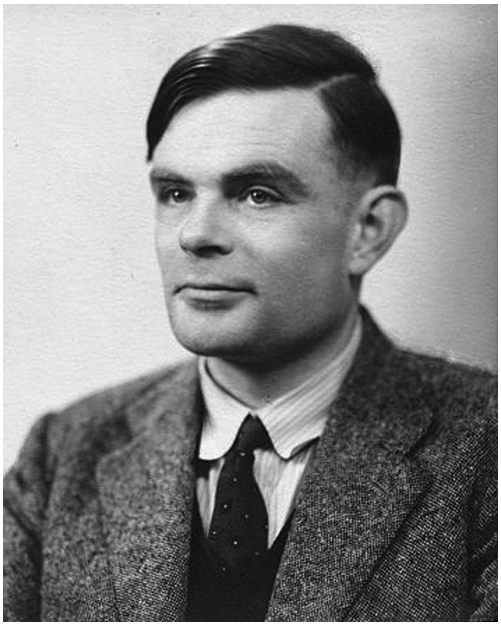

Figure 2. Alan Turing, 1951. (Courtesy of National Physical Laboratory.)

Sadler, another Yorkshireman, who ran the computing center at the Nautical Almanac Office of the Admiralty. They were both interviewed, and Womersley was offered the position, which he immediately accepted. No doubt he was preferred because he had already shown that he could create a computing center quickly and likely because of the quality of his technical work in the Ministry of Supply. Sadler seems to have been ambivalent, later stating "I was invited (by Sir Charles Darwin) to apply for the post of Director of the Mathematics Division; I reluctantly applied, but was glad that I was not faced with the decision as to whether to accept or not."[10] It should perhaps not be forgotten that Sadler took over Comrie's job when the latter was summarily ejected from the Nautical Almanac Office in 1936, and Comrie seems to have supported Womersley; these personalities moved in a small world. Nevertheless, Sadler was not entirely gracious about being passed over, also stating that "Womersley was not very successful and he did not stay long," a questionable assertion as we shall see.

Although appointed in September 1944, Womersley did not officially take up the position until May 1945. He remained on the Ministry staff but must have transferred his efforts, for he submitted a report to the NPL Executive Committee in December 1944[11] in which he laid out initial plans. He was keen

that the Mathematical Division should develop new machines—he was aware of the potential of electronics, although had no knowledge then of Colossus or US developments. He was sent on a fact-finding mission to the United States on behalf of the Ministry of Supply and DSIR in February through April 1945. As *the* British computing representative in the US, he was given a grand tour of their facilities. He learned about the ENIAC, Aitken's Harvard machine, Stibitz's machines, and the initial plans for EDVAC. He thought that the Harvard machine was like "Turing in Hardware," perhaps impressed by its large tape readers.[12] He soon wrote a paper for the journal *Mathematical Tables and Aids to Computation* titled "Scientific Computing in Great Britain" that summarized the precomputer state of numerical computing in Britain, giving prominence to the work of Comrie and showing that he was well aware of what had been achieved.[13]

When he returned from the US in May 1945, the new NPL division and Womersley's appointment were announced. He set up the Mathematics Division with four sections: General Computing Section, Punched Card Section, Differential Analyser Section, and Statistics Section. He set about hiring staff and transferring groups from other branches of the government. He was particularly keen on starting an electronic computer project. He was aware of Alan Turing's work (claiming to have read his theoretical paper by 1938) and that his ideas could be applied practically, and he was now aware of EDVAC. In June he was introduced to Turing via Hartree. He invited Turing to his house, gave him a copy of von Neumann's EDVAC report to read and then hired Turing himself to run the "ACE section" to work on the development of an electronic computer. All sections of the Mathematics Division were under way by 1946. By this time, he and Jean had two more daughters, Ruth and Marion, and they were living in the Wimbledon Common area, close to Teddington, as they had since 1942.

Most interest in Womersley's tenure as superintendent of the Mathematics Division of NPL has centered around the ACE project, but this was only part of his job, and it has been described in detail by Jack Copeland.[14] Let us consider Womersley's achievements overall. Mary Croarken poses this question: "Did the NPL Mathematics Division succeed as a Central Mathematics Station?"[4] She gives a generally positive answer.[4] For Womersley's point of view, we can read his claims in his CV as to what occurred during his time as the first superintendent of the new division:

> Designated Superintendent September 1944. Prepared estimates for succeeding financial year and took up duties April 1st 1945. Laid down organization, recruited staff, organized research program in Numerical Analysis, Digital Computers, and Mathematical Statistics. Provided computing services [to] government scientific establishments and industry Built up Division from nothing to a staff of 60 and a budget of $200,000 p.a.
>
> During this time the Division produced some thirty papers on numerical analysis, established the largest punched-card installation in Europe devoted entirely to scientific computation, and completed the Pilot Model of the Automatic Computing Engine, a high-speed digital computer with mercury delay-line storage.[2]

Overall, it seems that Womersley was successful within NPL and externally. For example, in 1947 he visited the US as the UK official delegate to the World Statistics Conference, chairing the Quality Control and Industrial Statistics meetings. However, there were some hiccoughs that deserve comment.

The Differential Analyzer Department did not work out as intended. Initially NPL used the Manchester machine, which was moved to NPL at Teddington. The exciting prospect was a new differential analyzer that was to be the largest ever built. It was decided that the machine should be built by industry, and in May 1947, Womersley went with Arthur Porter (an expert from the Ministry of Supply) for a week's visit to Göttingen in Germany to discuss whether it could be built by the company Rechenautomaten GmbH of Hans Bückner (Askania). The ministry issued a contract to this company later in the year. Because of internal German science politics, the contract was passed on to Schoppe & Faeser in Minden. What a controversial decision to use German technology and engineering so soon after the war!

NPL took over the Schoppe & Faeser contract in 1949. It was intended that NPL should not be directly involved in building the machine, but they definitely became involved and parts of it were made in England. There were considerable delays, and the machine was not installed until 1954, at which point it was already obsolete. It was decommissioned in 1958.[15]

The other computing project at NPL was, of course, ACE, which Copeland has described in detail. What is evident is that

the project would not have got under way without Womersley's involvement. He got Turing interested and hired. He then presented Turing's proposal to the NPL board, submitted a supporting document and spoke eloquently and strongly in favor, showing that he really understood where Turing was "coming from."[16] He invented the name Automatic Computing Engine as a hat-tip to Babbage. He supported Turing by finding staff and support for the project from other institutions. He gave a presentation on the ACE project to Imperial College, the result of which was Donald Davies (see Figure 3) applying to work on the project and being appointed to do so. Womersley described the ACE project to Hans Billing on his visit to Göttingen and thus inspired Billing to develop his own line of computers.

Of course, the ACE project did not go according to plan either, and it was already the third modern computer in Britain when it finally ran in 1951. Turing left after two years and worked at Manchester instead, after a year at Cambridge. It is hard to blame Womersley for these delays and events. They seem to have been caused by factors beyond his control—politics in the Post Office (initially intended to build ACE) and higher-level machinations involving the Director of NPL Sir Charles G. Darwin. However, Womersley does seem to have somewhat lost interest in the project,[17] although he presumably still provided managerial support. He does not even appear in the official photographs taken when ACE was "unveiled."

It is well known that Turing took a dislike to Womersley.[18] Womersley was generally regarded as very likeable, and he must have got on well with Turing at first, given that he supported him so strongly. Perhaps the issue stems from Harry Huskey's year at NPL. From the start, Womersley was interested in a small-scale pilot project and gave Huskey the okay to go ahead with the pilot while Turing was away, and Turing was apparently very annoyed. It might also have had something to do with the appointment of Davies, who spent some time finding and correcting errors in Turing's famous 1936 paper. Whatever the cause, there does not appear to have been any animosity on Womersley's part.

The people who continued the ACE project regarded Womersley highly,[19] but somehow the belief arose that he was a technical ignoramus. We have seen that was clearly not the case as he was an accomplished applied mathematician (and he understood serial computers enough to be granted a patent later). There is a much-repeated story of a wager among the ACE team that Womersley would not write down a mathematical formula for an entire week, and he apparently did not. This seems to be a misunderstanding of his role; at NPL he was a second-level manager and not involved with project details unless requested. He probably "had his fingers burned" by getting too close to Turing. Anyway, it was certainly, from his perspective, time for a change by 1951.

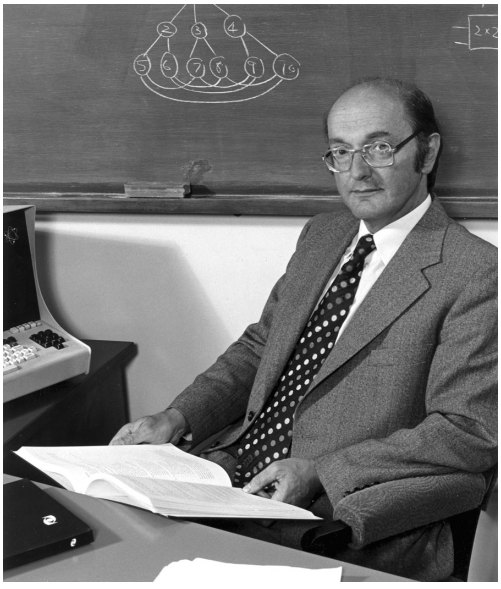

Figure 3. Donald Davies, circa 1980. (Courtesy of National Physical Laboratory.)

Director of Research at British Tabulating Machines

Britain had never had an office automation industry to the extent of that in the United States. There were two main data processing equipment vendors, Powers-Samas and, with rights to make and sell IBM equipment, British Tabulating Machines (BTM). Unfortunately for both of these companies, at the end of 1949 IBM dropped BTM as their agent and started their own subsidiary in Britain.

This was a potential disaster for BTM because it was weak on research and the use of electronics. IBM had announced a popular device called the IBM-604 Mulitiplying Punch, and BTM had no equivalent. The top management team realized that they needed to get into research and the possible design

Figure 4. Advertising material for the Hollerith electronic computer (HEC).

and manufacture of electronic devices, even computers. They needed someone to manage this modernization process. Womersley was suggested and approached, and he accepted this new challenge in September 1950. He was appointed the research manager at BTM's factory at Letchworth, reporting to Technical Director C.G. Holland-Martin. Womersley was particularly pleased that the position included a large company house at "Corrie Wood, Hitchin Road, Letchworth, Herts." At the time, he still had three growing daughters at home, although the eldest was on the verge of starting university.

Womersley stayed in this position until July 1954. He described his accomplishments thus:

> Direction of electronics laboratory, concerned research electronic digital computers [sic] for business applications and electronic equivalents of conventional punched card accounting machines.
>
> To direct and supervise all scientific research. To build up a research Laboratory to be particularly concerned with electronics, to enable the company to develop electronic digital computers for business uses. To study business mechanization and direct the company's research effort along fruitful lines. Set up lab with 30 staff, built two pilot models of small digital computers. Supervised 5 graduates, 15 non-graduates.[2]

The course of events at BTM had some interesting twists and turns. Womersley emulated his ACE technique of hiring a capable young practical scientist and leaving the details to him. He presumably asked around for suitable candidates and, no doubt through his contacts at Imperial College, was recommended a recent master's student named Raymond Bird. He tempted Bird with the prospect of working on an electronic multiplier and soon had him hired at BTM Letchworth. BTM did produce a successful electronic multiplier embedded in its BTM 541, 542, 550, and 555 calculators, but this was a project already under way at the time of Bird's appointment.[20]

Because of rumors of IBM commercial computers, BTM wanted to investigate this new phenomenon, but it was mindful that any computer suited to its customers must be relatively inexpensive. To get Bird up to speed, Womersley set out to visit the existing computer projects in the UK with him. Womersley must have had access to an adequate budget and could have taken the train because he did not drive or own a car. However, Bird, newly married, had a motorcycle with a sidecar. So we have this image of the new junior employee on a road trip to visit all the sites with his manager, a large man (182 cm., 95 kg.), crammed into the sidecar. Not the way BTM did business normally! There is also a peculiarly British class issue here, with higher managers at BTM usually being "upper class" and having gone to the right schools, whereas Womersley was a grammar school boy from the industrial North; perhaps he felt that a sidecar was just his level in the austerity of post-war Britain.

In any case, it turned out that all the university projects were of high cost, with the exception of that of Andrew Booth at Birkbeck College, who made a series of slow but inexpensive computers based around a magnetic drum memory. So it came about that BTM sponsored a project to build a version of Booth's computer APEC, called APE(H)C, with Booth as a consultant and Bird as the designer and manager.[21] The prototype computer, renamed the Hollerith Electronic Computer (HEC, Figure 4), was exhibited in 1953 and sold with limited success (four sales). Later a further redesign called the BTM 1201 was produced and eventually sold as a product in the second half of the 1950s. (Incidentally, Bird came to an arrangement with Booth that his redesign could be written up as a doctoral thesis, and he was awarded a PhD in due course.) This turned out to be a suitable BTM response, for its customers, to the IBM 650, also a drum-based computer.

Womersley found time to keep up with developments. In January 1951 he attended a conference in Paris on "Les machines à calculer et la pensée humaine" [Calculating

Machines and Human Thought].[2] This was a remarkable meeting, attended by the leading lights of cybernetics (Norbert Wiener, Ross Ashby, and Grey Walter) and neurology (W.S. McCulloch) as well as computer pioneers (Aiken, Booth, Kilburn, Wilkes, and Williams). In September 1951, Womersley visited the Burroughs Adding Machine Co. in the US on behalf of BTM. Although he managed resources, Womersley apparently kept his distance from details of the BTM computer development. Nevertheless, he is listed on an interesting patent describing mixed-base serial arithmetic[22]—this was when the UK still used pounds, shillings, and pence. The ability to handle mixed bases was included in the successor to the BTM 1201, the ICT 1301.

His hope of setting up a research center to investigate future products seems to have come to little at this stage, and the ICT 1301 was actually made by General Electric. (It was a couple of years too late to compete with the IBM 1401.) In any case, Womersley found a new interest: "Spare time activity during this time has included some original work on the hydrodynamics of blood-flow in the larger arteries."[2]

Research into Mathematical Haemodynamics

Womersley's eldest daughter Barbara was by then a medical student at St. Barthomolew's Hospital in London. She possibly drew her father's attention to the research on blood flow being carried out there by Donald A. McDonald. This rekindled Womersley's interest in applied mathematics, and he became involved at the Physiology Department in the Medical College of St. Barthomolew's Hospital from July 1954 to July 1955, where he was a research associate, funded by the Medical Research Council. As he said:

> Temporary arrangement to fill in time whilst awaiting completion of arrangements to come to WADC [Wright Air Development Center] under present contract. Fundamental Research – a mathematical investigation of the oscillatory flow of blood in the larger arteries, studied as a problem in hydrodynamics. Five papers published, clearing up a problem which had remained unsolved for a generation.[2]

This interim work took place while he was negotiating a move to the United States. However, his return to applied mathematics was highly successful and led to a series of papers that have been widely referenced. Along with McDonald, he is recognized as one of the founders of mathematical haemodynamics. Later, McDonald also emigrated to the US and eventually produced his foundational book *Blood Flow in Arteries*.[23] The first edition was published after Womersley's death and was dedicated to Womersley. McDonald worked on a second edition but died before it was published. A decision was made to include his photograph (as an engraving), but because the book was dedicated to Womersley, it was also necessary to include a similar engraving of him. This is the only publicly available portrait known. McDonald's book has been through many editions and is still in use today (although without the portraits.)

Chief of Systems Dynamics at Wright Air Development Center

The Wright Air Development Center (WADC), located in Dayton, Ohio, had decided that it needed a center to study "systems dynamics" (essentially, an applied computing research center) and was looking for someone to get it going. Womersley already had a good reputation in this area, and Howard Aiken suggested him as a possible candidate. The Aeronautical Research Laboratory's Directorate of Research Clarence Ross made initial contact on 13 September 1954. On 21 October 1954, Womersley wrote accepting what must have been initially an informal offer, considering that the formal decision was made to offer him the position on 19 November 1954.

Womersley had to go through the formal process of applying for the job because it was necessary to show that there was no suitable American candidate. He prepared a CV and nominated as referees Howard H. Aiken, Samuel H. Caldwell (professor of electrical engineering at the Massachusetts Institute of Technology), and Samuel S. Wilks (professor in the Department of Mathematical Statistics at Princeton University). Womersley was hired under a scheme called "Operation Paperclip," whereby European scientists and engineers (mainly German, such as Wernher von Braun) could be brought into the US and set to work quickly. The corresponding list of "Foreign Scientist Case Files 1945–1958" held by the US government archives shows 41 pages of overwhelmingly Germanic names (including, surprisingly, Konrad Zuse).[24] Womersley stands out as one of the rare English names on the list. His resulting personnel file[25] has been a major source for the present article.

From the computing point of view, we must remember Womersley as a pioneer computer initiator rather than a designer.

In June 1955, Womersley's appointment was approved as a mathematician at $9,600 per year, and the family was given authorization to travel to the US. This took place via Bad Homburg in Germany, where they were cleared medically. The family arrived at the Idlewild airport in New York on 25 July 1955.

Womersley took up the position as "Chief, Analysis Section, System Dynamics Branch Aeronautical." This seems to have been a fairly senior appointment with considerable responsibilities. He participated in discussions and planning for setting up the new branch for the System Dynamics mission and, on 18 May 1956, was made acting chief of the Analysis Section, System Dynamics Branch, Aeronautical Research Laboratory, under Col. A.L. Lingard, the chief of the Aeronautical Research Lab.

He must have done well, for within a year he was invited to change from "Paperclip" to normal status with a permanent position. This involved resubmitting his CV. On 1 July 1956 he was given "normal" status and promoted to the rank of supervisory mathematician at $11,610 per year. His title was "Branch Chief, Systems Dynamics Branch, Aeronautical Research Laboratory, WADC, WAFB" under Owen L. Koontz, Major, Executive Officer. Later, on 23 September 1956 he was promoted to "Supervisory Aeronautical Research Engineer (Flight Systems)," with his pay increased to $12,690.00 per year. This seems to have been a reclassification and renaming of his existing position.

All seemed to be going well in the new job but then disaster struck.

Womersley's Early Death

On 28 May 1957 Womersley was forced to request a leave of absence and relinquish his position because he needed treatment for cancer. Leave was granted from 1 June 1957 to 1 December 1957. He had operations in London and was able to return to work in September 1957 but at the lower grade of mathematician at $11,395 per year. However, the cancer returned and he died on 7 March 1958.

As fairly new immigrants to the US, his family was left in a difficult situation, despite lump sum payments from accumulated annual leave and the Federal Employees' Group Life Insurance. His eldest daughter Barbara had chosen to practice medicine in London. However, the rest of the family elected to stay in the US. His wife went to university and trained for a career as an art teacher—she survived in Dayton until 1996. At the time of this writing, the Womersleys were survived by two daughters and had six grandchildren living in the US and Canada.

Womersley's death was marked by obituaries in *The Times*[26] and the *Journal of the London Mathematical Society*[5] by F. Smithies and in *Nature* by Sir Charles Darwin.[17] These seem to give a fair description of his life and contribution, except perhaps for Smithies' underestimating the importance of his mathematical talent. To quote Darwin,

> The general impression that Womersley gave was his sense of adventure in all the work he was doing. He was always looking for something new to undertake, sometimes be it said a little at the expense of the actual work in hand. I really only saw the fringe of his work during the War, but he seemed to impart a most refreshing breadth of outlook into what might have been just a dull routine…
>
> We must grieve at the loss of a very able man, whose intellectual adventures had already carried him far over the fields available to a mathematician. It is idle now to speculate how much farther he would have gone if he had been granted the normal span of human life.[17]

Now, with the benefit of another 55 years, how should we evaluate Womersley? He was clearly gifted, but so were many other mathematicians who have passed by without close examination. As an applied mathematician and haemodynamicist, Womersley will always be remembered because the dimensionless number in his fundamental equation has been termed the "Womersley number"—not many mathematicians are honored with their own number! This work is often cited to this day.

From the computing point of view, we must remember Womersley as a pioneer

computer initiator rather than designer. Ray Bird said it well: "Womersley was a stimulator and an encourager."[27] He actively initiated the first project in Britain to build a modern computer at NPL, and he initiated the development of suitable computers at BTM, leading eventually to the 1201, the most widely sold of the early British computers. He also had an excellent record in hiring outstanding staff, such as the statisticians Armitage, Barnard, and Lindley; luminaries like Bird, Davies, Wilkinson, and Woodger; and of course Turing. He was not involved directly with computer design, but without his contribution, those early projects would not have started or would have been very different.

Womersley's career epitomized how numerical and statistical methods came into widespread use from the 1930s, in Britain as in other Western countries. It also showed how this development stimulated both applied mathematics and electronic computation, for both military and civilian purposes, as the computer age began. Womersley seized opportunities as they arose, but he never forgot his background as a mathematician.

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