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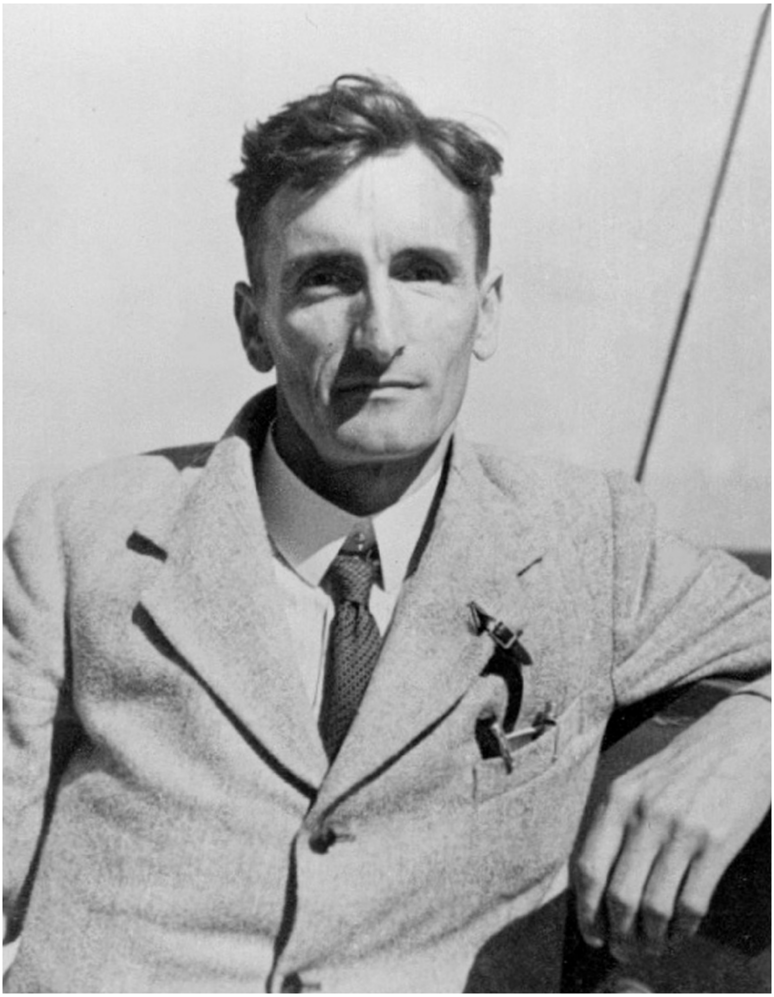
The Callendar Effect



Guy Stewart Callendar in 1934, about the time he turned his attention to the CO_2-climate question.

The Callendar Effect

The Life and Work of Guy Stewart Callendar (1898–1964), the Scientist Who Established the Carbon Dioxide Theory of Climate Change

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American Meteorological Society

The Callendar Effect: The Life and Work of Guy Stewart Callendar (1898–1964), the Scientist Who Established the Carbon Dioxide Theory of Climate Change

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Also available from AMS Books: *The Papers of Guy Stewart Callendar*, Digital Edition on DVD, James Rodger Fleming and Jason Thomas Fleming, Eds. (Boston: American Meteorological Society, 2007). This research-quality digital archive includes Guy Stewart Callendar's manuscript letters, papers, journals, documents, and family photographs.

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Dedicated to Anne and Bridget,
twin daughters of Guy Stewart Callendar

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Introduction

Guy Stewart Callendar (1898–1964) is noted for identifying, in 1938, the link between the artificial production of carbon dioxide and global warming. Today this is called the "Callendar Effect." He was one of Britain's leading steam and combustion engineers, a specialist in infrared physics, author of the standard reference book on the properties of steam at high temperatures and pressures, and designer of the burners of the notable World War II airfield fog dispersal system, FIDO. He was keenly interested in weather and climate, taking measurement so accurate that they were used to correct the official temperature records of central England and collecting a series of worldwide weather data that showed an unprecedented warming trend in the first four decades of the twentieth century. He formulated a coherent theory of infrared absorption and emission by trace gases, established the nineteenth-century background concentration of carbon dioxide, and argued that its atmospheric concentration was rising due to human activities, which was causing the climate to warm.

Callendar's contributions to climatology led the way in the mid-twentieth-century transition from the traditional practice of gathering descriptive climate statistics to the new and exciting field of climate dynamics. In the first half of the twentieth century, the carbon dioxide theory of climate change had fallen out of favor with climatologists. In the 1930s Callendar revived and reformulated this theory by arguing that rising global temperatures and increased coal burning were closely linked. Employed in defense research, and working from his home in West Sussex, Callendar compiled weather data from frontier stations around the world that clearly indicated a global warming trend in the early decades of the twentieth century. He also documented the retreat of glaciers. To support his hypothesis, he calculated the world use of fossil fuels, estimated carbon reservoirs and uptake by the biosphere and oceans, and compiled historical measurements that showed rising concentrations of carbon dioxide in the atmosphere. Callendar established the now standard number of 290 parts per million (ppm) as the background concentration of carbon dioxide in 1900 and estimated there had been a ten percent increase by 1938. Based on new work on the infrared spectrum and calculations of the absorption and emission of radiation by trace gases in the atmosphere, Callendar established the CO_2 theory of climate change in its recognizably modern form, reviving it from its earlier, physically unrealistic and moribund status. He concluded that the rising temperature trend was due to anthropogenic increases in the concentration of atmospheric carbon dioxide, primarily through the processes of combustion.

Until recently, G. S. Callendar had been largely overlooked by historians and scientists. He was a quiet, family oriented man, an avid sportsman, supremely competent, widely published and cited, yet unassuming. He received few special honors, held no academic appointments, and left relatively few letters and no personal journals. His scientific papers, although considered valuable, were in danger of being scattered, damaged, and lost. No one in the climate research community had any photographs of the man or his family. Under these circumstances, preparing his biography and a digital archive of his papers were daunting tasks. Callendar's life was reconstructed from a variety of sources including scientific correspondence and notebooks, family papers (graciously provided by his daughter Bridget), and the well-documented life of his father, the famous physicist Hugh Longbourne Callendar, who nurtured his son's career and introduced him to the technical elite of England.

Callendar was a Fellow of the Royal Meteorological Society and served on its council. He was also a Fellow of the Glaciological Society. He counted many distinguished scientists as his friends, colleagues, and coworkers. He received a first-rate technical education and entered into collaborations with

Britain's technical elite on steam research and the infrared spectra of complex molecules. His work on the thermodynamics of steam was foundational for steam-plant design calculations in Great Britain for more than three decades. His papers on the infrared properties of trace gases drew rave reviews from leading meteorologists and climatologists and influenced the later development of the field. His work in defense-related research in two world wars and the cold war was directed, wherever possible, toward non-violent ends.

The legacy of Guy Stewart Callendar continues through the Callendar Effect, influencing scientists of his own and subsequent generations and now historians of science to examine the paths by which we have arrived at our current state of climate knowledge and apprehension.[1] This volume provides an overview of his life and times and introduces an optional digital archive of the Callendar Papers. I hope that it provides the reader with deeper perspectives on an earlier era in science and engineering, allows a glance into Callendar's personal life and accomplishments, and stimulates both broader awareness and further research on the life and work of this unpretentious, but creative and fascinating individual.

The Callendar Effect: Climatic change brought about by [anthropogenic] increases in the concentration of atmospheric carbon dioxide (CO_2), primarily through the processes of combustion. The actuality of such changes was proposed in 1938 by the English scientist G. S. Callendar, son of H. L. Callendar. *See also* greenhouse effect.

—*Encyclopedia Britannica*

CHAPTER ONE

The Early Years to 1930

> The Callendar boys shared their father's love for science and engineering, while sister Cecil cultivated the arts.
>
> —Leslie Callendar

Guy Stewart Callendar was strongly influenced by his famous father, who nurtured his son's scientific and extracurricular interests and served as his mentor. Hugh Longbourne Callendar, first son of the Reverend Hugh Callendar and Anne Cecilia Longbourne, was born April 18, 1863, in Hatherop, Gloucestershire and was christened May 24, 1863, in his father's church.[1] Following his father's untimely death in 1867, young Hugh was nurtured by both the Callendar and Longbourne families and developed a very protective attitude toward his mother and siblings.

From early childhood Hugh was a self-motivated learner: precocious in languages and mathematics, with a knack for technical matters. His skills were cultivated at a young age by a private tutor.[2] By age 10, he had constructed a number of technical devices, including a Rhumbkorff induction coil, a Wimshurst electrostatic generator, and a telegraph network that he used for communication around the house (having taught himself Morse code).[3] At age 11, with the assistance of his maternal uncle J. V. Longbourne, Hugh entered Marlborough College. Hugh's interests and hobbies included astronomy, nature study, competitive shooting, gymnastics, football, and handicraft. Some of the younger boys at school believed that he controlled the weather because he was put in charge of the barometer in the house.[4] He constructed an automatic wind recorder and designed a fountain pen using an angular glass tube and a rubber stopper. His mother liked the pen so much, she used one for her letter writing for more than 60 years. He also devised a system for testing sight and color blindness.

Cambridge Years

Hugh Callendar entered Trinity College, Cambridge in 1882. During his university years, Callendar reportedly studied 10 to 12 hours a day yet still reserved two hours for afternoon sporting—he excelled in tennis, gymnastics, lacrosse, and shooting. To boost his efficiency, he devised a method of speed writing, subsequently known as the Cambridge system of shorthand, teaching the system to his friends and associates, as well as publishing several books about it.[5] Earning first class honors in Classics (1884) and Mathematics (1885), Callendar began experimental work in physics at the Cavendish Laboratory with Professor J. J. Thomson.[6] The two men greatly influenced each other. Thomson learned Callendar's shorthand system and used it for note taking throughout his life. Callendar followed Thomson's suggestion to study the problem of metallic resistance thermometry, a decision that shaped the rest of his career.

The Platinum Resistance Thermometer and Related Inventions

In 1885, after eight months of extensive experimentation and research in cramped quarters at the Cavendish Laboratory (he used a windowsill as a workbench), Callendar developed an accurate platinum resistance thermometer suitable for high temperature measurements (Figure 1.1). Compared to earlier devices, it had an extended temperature range and held its calibration over time. According to Thomson, Callendar "gave to physics a new tool to determine temperature with an ease and accuracy never before obtainable. . . ."[7]

In Callendar's original design, coils of fine platinum wire were wound on thin mica plates connected to silver leads. He added annealed pure platinum contacts and corrected for errors made by other scientists in the relationship between temperature and resistance. Callendar presented his findings to the Royal Society of London on June 10, 1886, and patented his thermometer the following year.[8] Arguably the most significant invention of his career, Callendar's new thermometer was able to measure temperature