FELIX JIRI WEINBERG
2 April 1928 — 5 December 2012
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Elected FRS 1983

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Felix Weinberg’s teenage years coincided with World War II. He spent much of the war in Nazi concentration camps, starting with Terezin in December 1942, followed by Auschwitz in December 1943, and finally Buchenwald, from which he was liberated on 11 April 1945. He joined Imperial College, London as a research assistant in 1951 and completed his PhD by 1954. He was appointed to a personal chair as professor of combustion physics in 1967, and he stayed at Imperial for his entire career. Weinberg was distinguished for his optical and electrical studies of flames and his pioneering development of innovative combustion methods. He invented a family of powerful optical tools in combustion, using both broad spectrum and laser light sources. His work on electrical diagnostics led to applications of electric fields to control combustion and to improved understanding of ionization and soot formation. He developed novel combustion devices that incorporated distinctive heat exchangers, thereby permitting the ignition and burning of very low calorific fuel–air mixtures. All of these works had a propelling influence on the global evolution of environmentally benign combustion furnaces. His wide-ranging service to academia, industry and scientific societies included visiting scholar appointments at universities around the world, consultancies for petroleum, chemical, aerospace and defence organizations, and active membership on committees and boards of governance for many scientific and professional bodies. He was author, co-author or editor of four books and well over 200 papers in the scientific literature.

THE EARLY YEARS, SCHOOLING AND CAREER SUMMARY

Felix Jiri Weinberg was born on 2 April 1928 in Czechoslovakia, his early childhood being spent in Ústí nad Labem, also referred to by the German name Aussig, in Sudetenland, where

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he is listed as a notable person of that town. Tragically, his teen years coincided with World War II, and he spent much of the war in Nazi concentration camps, beginning with Terezin in December 1942, followed by Auschwitz in December 1943, and finally Buchenwald, from which he was liberated on 11 April 1945. His mother and brother perished in the concentration camps, but he reconnected with his father in England, his adoptive country, on 15 August 1945, VJ day.

His early years are described comprehensively in his personal memoir, Boy 30529 (29)*, published in early 2013, just after his death in 2012. In his memoir, Felix takes us from an idyllic childhood in his hometown of Aussig, Bohemia, to his arrest as a Jew in December 1942 and through his time in the concentration camps of Terezin, Auschwitz-Birkenau, Blechammer and Buchenwald between the ages of 14 and 18. He was one of 900 children aided in their survival of Buchenwald by Antonín Kalina, a Czech citizen and Communist Bloc leader who is mentioned as ‘Righteous Among the Nations’ (10). Felix notes in his memoir that it was his ability to darn socks—‘It was a task I enjoyed—something to do with turning a one-dimensional thread into a neatly woven two-dimensional surface’—that was responsible for bringing him into contact with Kalina. The book ends with him reuniting with his father in England after the camps were liberated. As he wrote,

Unbeknown to me, sometime during the summer of 1945, the UK government agreed to admit 1000 orphans from Nazi concentration camps, provided they were under the age of sixteen. It was probably as well that I did not know, because I failed on both criteria. I was not an orphan and was over 17, and it would have never occurred to me that I might be able to hitch a lift. So the message that I was to present myself at an address in Prague for an immediate flight to England came as a complete surprise. I learned much later that there weren’t a thousand children camp survivors left (in the event not even 750 could be found) so there would be many vacancies. The planes were RAF bombers.

Felix had very strong opinions about ‘holocaust literature’, and he did not feel that his personal account should be considered part of that genre. Boy 30529 is 100% Felix, written in his voice, with his uniquely perceptive view of human nature and reality interwoven. It is fortunate that Felix resisted vehemently the editorial whims of the publisher so that his storytelling was left intact and authentic. He wrote:

Anyone who survived the exterminations camps must have an untypical story to tell. The typical camp story of the millions ended in death ... We, the few who survived the war and the majority who perished in the camps, did not use and would not have understood terms such as ‘holocaust’ or ‘death march.’ These were coined later, by outsiders.

Reviews of this book carry their own insights (e.g. see Purkiss 2013). There is no doubt that the years detailed in his memoir are at the core of Felix’s nature, and the experiences melded into his character. He viewed his life as the demonstration of a remarkable series of miracles leading him to the hopeful conclusion that even through such horror his life was a wonder. He concluded:

So, nine days after my 17th birthday, my life was given back to me. That took a long, long time to sink in. I am not sure it ever has, entirely. Come to think of it, the concept is meaningless, since I was no longer the same person. The camps changed me permanently.

* Numbers in this form refer to the bibliography at the end of the text.
Derek Bradley FRS provided this comment on the occasion of Felix’s eightieth birthday celebration:

His sufferings in the 1930s and wartime years were bad enough, but the coupling of these with the denial of a young person’s legitimate educational expectations was criminally severe. The associated suffering generated not only amazing fortitude, but also an extraordinary calm, thoughtful, rational person.

Felix’s view of his miraculous survival, the original working title of his biography being *Tragedies and miracles*, appears throughout *Boy 30529*. The book is unusual in that it is truly a memoir of his early years and, while the horror of the camps was a transformative experience, there is a much larger fabric of early life that is illuminated, and it is the entire early experience that ultimately resides in and creates Felix Weinberg FRS.

Having had no formal schooling since the age of 12, Felix took his first degrees from the University of London as an external student. He was not at the University of London itself (hence the external degree) because this was just post-war, and returning troops who had missed out on university education were given priority. He excelled in mathematics and science subjects, and, despite knowing little English, his hunger for knowledge and curiosity led to academic distinction even in English literature. He joined Imperial College, London as a research assistant in 1951, and completed his PhD by 1954 (figure 1). He was awarded the higher degree of DSc by the University of London in 1961 for his body of work using novel optical methods to analyse the structure of flames. He was appointed to a personal chair as professor of combustion physics in 1967 and spent the rest of his career at Imperial.

**Research**

Felix’s approach to research followed a general pattern. He found an unexplained phenomenon and became curious about its root physical cause. He then developed a guiding phenomenological construct and created a simple experiment to test a hypothesis regarding a dominant feature of the construct. He then evaluated the results of the experiments in comparison with other work to ensure consistency in the discovery, and then proposed new technological implications of his findings to motivate others as they embroidered details into the physical framework he laid out. His work is punctuated with significant books and review lectures that capture the state-of-the-art for posterity. While there is always plenty of rigorous mathematics, chemical kinetics and physics in all his studies, these elements are not the hallmark character of the work: rather, it was his physically astute view of what was happening in the system.

Felix’s creative and insightful approach to combustion science was recognized very early, as in his remarkably elegant ‘concept of a reaction system rate-controlled by a single chain branching and a single chain breaking step’ (4) and in his review and summary of the entire meeting of the British Section of the Combustion Institute in 1955 (5). He accomplished both of these demonstrations at the age of only 27, having just completed his PhD and recently married Jill Nesta Weinberg (nee Piggott), who would be his lifelong companion and life affirming foundation. Other examples of his keenly perceptive combustion physics viewpoint appear in his Imperial College inaugural lecture (10) and in his overview presentations on combustion, where the idea of fire is cleverly cloaked in a mythological context; for example,
his Royal Institution Thursday Discourse on 11 May 1972, ‘Old flames and the burning issues of today’ (12), begins with Prometheus and his theft of fire from Zeus for the benefit of humankind,

One of the charms of mythology is that it so often presents a scientific truth shorn of all its complexity and wrapped in a maximum amount of entertainment value . . . The victim of this theft—Zeus—was identified with lightning and thunderbolts. The most probable event which this legend beautifies is that lightning, i.e. Zeus, set fire to a tree . . .

While Felix's research spans myriad combustion-related subjects, the highlights of his research roadmap concern three significant domains: 1. optical methods to evaluate flames; 2. effects of electric fields on flames; and 3. excess enthalpy combustion. All of these topics have their roots in his first decade as a combustion physicist, and he ultimately summarizes them in books capturing the state-of-the-art. *Optics of flames* (7), *Electrical aspects of combustion* (9) and *Advanced combustion methods* (20) provide Felix's illumination of these fields at the time. The latter, edited volume shows clearly the topics on which Felix concentrated. Although the authorship is distributed, there are chapters on fluidized bed combustion related to the excess enthalpy topic, the use of electrical aspects for augmentation associated with his plasma jets, and the effects of electric fields, which was one of the main topics throughout his career.
Optical methods

The optical methods that Felix pioneered and exhaustively implemented derived from the understanding that light is affected as it passes through regions of varying refractive index. Combustion systems, with their characteristically steep thermal (density) gradients automatically produce such variations, and they hence provide ideal objects for optical evaluation.

His PhD thesis, ‘An investigation into mechanisms of flame propagation in gases’ (1), and his first peer-reviewed combustion paper in 1953 (2) demonstrate and exploit optical methods in the evaluation of flame propagation. The optical methods were non-laser based, with a concentration on imaging and photography, as well as particle tracks. One marker of what was to come was Felix receiving a standing ovation when presenting his PhD work at his first conference. Showing how Schlieren techniques can be used to map flame temperature was a holy grail at the time. This was the launch of his interest and expertise in optical methods for characterizing flames, and he maintained a focus on thermally induced refractive index changes as the key feature in combustion, something that resulted naturally from self-sustained heat release reactions.

Beyond the significance of the content, Felix’s research approach and style are displayed prominently in his very first paper. The challenge for Felix was to measure flame propagation and structure, which required a sufficiently accurate means of measuring a thin reaction zone, where this zone is characterized by rapid changes in temperature. The refractive index is an excellent candidate because it varies with temperature and composition. The paper introduced the concept of a global reaction progress variable, labelled $\varepsilon$, in a thermal energy balance that linked the flame front structure to the gas temperature. From the paper (2):

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A thorough review of possible methods of high temperature measurement in gases has been made. Broadly speaking, the methods may be subdivided into three classes: those employing some material thermometer (including suspended particles); those using some emission from the flame; and those based on some property of the gas, such as density, refractive index or velocity of sound. Of these, the last was thought to be the least objectionable theoretically and the most suitable mechanically. The difficulty arising in the use of some property of the gas, however, is that the latter usually depends on composition as well as on temperature, and so varies due to reaction.

On the basis of such considerations, refractive index was chosen as the most suitable property. It can be measured to a high degree of accuracy by methods such as interferometry. Moreover, the use of a beam of light as a probe offers the possibility of producing an instantaneous map of refractive index distribution by means of a photograph. Finally, the variation due to composition change is generally small in comparison with the temperature variation.
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As an interesting side note, this paper also includes Felix’s derivation of a lever rule for the evaluation of thermal conductivity, which is still referenced today (Mathur et al. 1967; Saxena & Tondon 1971; Hosseini et al. 2020). Felix continued to use refractive methods throughout his research activities for identifying flame area and location, including subtleties arising in curving flame fronts. His first book (10), produced in the first decade of his research, collects his works and is written in a style that is playful and complex, while remaining clear and precise. His work in optical methods for flame evaluation continued to influence the field for decades, as is evidenced by his prominence in a review article from 1980 that surveyed all methods for determining the laminar burning velocity of flames (Rallis & Garforth 1980).
After the mid 1960s Felix’s optical technique publications gave way to research on combustion physics, but his use of refractive methods in novel ways continued throughout his career, including finally their use in combustion in microgravity (26).

Electrical aspects of combustion

Felix’s first foray into the subject of flames and their electrical response (6) was inspired by prior work of Calcote (1948), and may have originated from discussions that occurred during the third international combustion symposium that both Felix and Calcote attended. Two important discoveries that caught Felix’s imagination came from Calcote’s paper:

It is concluded that the observed effect of an electric field on a n-butane-air flame can be almost completely explained by a mechanical interpretation. The high concentration of ions in the inner cone, adduced from these experiments, is evidence for chemi-ionization and the non-equilibrium conditions existing in the flame front.

While earlier researchers in the field of electrical properties of flames branched off toward chemi-ionization chemistry, the topic that became the focus for Calcote (1957) and van Tiggelen (Deckers & van Tiggelen 1957), Felix remained fascinated with the physical ion wind component. As he noted (6):

the results of preliminary experiments, have prompted the authors to investigate the possibilities of using the movement of ions under the action of fields and the associated body forces on the gas as a potential tool contributing to the management of some combustion processes. Examples are modification of volumetric heat release rates, heat transfer and carbon deposition from flame gases and the isolation of some intermediates.

Words to this effect appear in all subsequent research into the physical impact of ion movement in flames. Felix boils the results down to a concise and natural consequence that guides his further evaluation. He realizes that for many, perhaps most, applications, the details are not important since the overall phenomenon is governed by a dominant process. In chemi-ionization, for example, there is a great deal of discussion describing the potential pathways within the flame for creating ions, but in the end the only thing that matters for ion-driven wind is the production of a single long-lived ion (H$_3$O$^+$), and the maximum potential for creating that ion. He found that the ion production depends on temperature and the carbon influx into the flame. This realization informs all his subsequent studies, including his interest in heat recirculation as a means of increasing the temperature (and hence the chemi-ionization) in flames.

While he was not the first to present the fundamentals of the ion-driven wind, Felix refined the understanding of the phenomenon to its essence. The ion-driven wind is based on a body force, meaning force per unit volume, that depends on the ratio of the ion current density $j$ to the charged species mobility $K$, $F_{ion\_wind} = j/K$. It is then straightforward to evaluate the potential effects of the ion-driven wind on combustion systems. All that is needed are estimates of the ion current density, which depends on the production of ions by the flame or injected into the system from an external source, and the mobility of the charged species. Understanding that the mobility of electrons is several orders of magnitude higher than that of any ion produces the insight that the electrical body force does not depend on electrons, although it might depend on electron attachment forming negative ions. Felix made this insight
clear from the 1950s, but it continues to appear as a ‘surprising’ conclusion in some of the most recent publications on the topic.

Felix’s interest in applying the fundamental discoveries in electrically driven flames led him to a practical study in which the maximum potential for the electric-driven wind is analysed (8). The velocity of the ion-driven wind results from this force acting over a distance $L$, and depends on the density $\rho$ of the driven gas:

$$V_{\text{ion\_wind}} = \sqrt{\frac{F_{\text{ion\_wind}} L}{\rho}} = \sqrt{\frac{j L}{K \rho}}.$$

This work was part of a sequence of papers with James Lawton culminating in 1969 with publication of their treatise on the subject, *Electrical aspects of combustion* (9). A few additional papers regarding electric field effects driving ion winds in flames continued through the 1970s, but, for the most part, the treatise contained everything that was known at the time. Although studies continue on the electrical aspects of flames, surprisingly little has been added to the understanding contained in that book (9), leaving only applications developed by subsequent generations of technologists.

Unfortunately, and as can be seen from an order of magnitude analysis using the above equations, in the face of buoyancy, the ion wind, or ion-driven wind, is generally not significant in modifying combustion at a level for major direct practical impact. Hence, Felix changed direction to understanding the increase of the effect due to increasing the concentration of ions. The intentional creation of plasma is one such mechanism, and this led Felix to a series of studies on plasma jet igniters and the enhancement of combustion and thermal processes using plasma. This included a study with A. K. Oppenheim (14), which led to Oppenheim’s enthusiastic adoption of the technology and its potential for combustion control (Cavolowsky *et al.* 1987; Oppenheim 1993). Highlighting the potential practical implementation of these plasma arc technologies, two patents were issued with Felix as inventor (17, 18).

Felix returned to the field of electrically forced flames by concentrating on combustion in domains where the electric body force dominates. This occurs especially under microgravity conditions since the density-driven body force is then absent. The initial brilliant proof of concept experiment demonstrating how electric fields can control flames in microgravity was carried out with his colleague Fred Carleton in an aircraft flying in a parabolic trajectory that produced extended periods of microgravity (21). The images from this paper show very clearly that a candle flame in an electric field at zero gravity has the same appearance as candle flame without electrical influence in Earth gravity, except that the flame burns aligned in the direction of the electric field. This study showed that for flames of this size the electric body force and the buoyancy body force are nearly matched. This led Felix to consider how electric fields might be used to simulate microgravity conditions in 1g, how electric fields could be used for extinguishing flames in microgravity, how to create an all-electric burner for combustion without buoyancy without any moving parts and, finally, the detailed evaluation of the effects of electric fields on microgravity flames. These last studies continued long after Felix’s death (Chien *et al.* 2019; Tinajero & Dunn-Rankin 2019).

*Excess enthalpy combustion*

As with other major research themes in Felix’s career, the seeds for the use of preheated reactants to reach combustion regimes not possible from unperturbed reactants started very
early, with his first paper published in *Fuel* in 1955 (3). Although this topic began for Felix in the mid 1950s, he did not make significant contributions to it until the early 1970s. His optical methods and electrical aspects in combustion dominated his first two decades of research. It was the electrical augmentation of combustion, however, that seems to have triggered Felix’s return to the concept of excess enthalpy, or highly preheated reactant combustion.

A subtle but deceptively simple concept lies at the heart of his work in what he termed ‘excess energy’ combustion. The concept relies on the recognition that the heat release from combustion reactions provides an increase of energy input in addition to the enthalpy of the incoming reactants. This means that the final temperature from the process is adjustable by both the chemical enthalpy of the reactants and the level of their preheating. With his penchant for physical analogies, Felix referred to this as a thermal dam to raise the temperature level of incoming reactants (12). His son, Peter, recalls an alternative analogy:

Although we must have been young at the time, I distinctly remember him [Felix] explaining the Swiss roll burner to us (he was deeply in love with it) and using the analogy of a train on tracks that came over a hill. It took some energy to get the first few carriages over the hump, but once that was achieved, they pulled the rest of the train over the hill, giving back the energy they had been given.

Once recognizing this phenomenon, it is possible to envision a broad array of methods for feeding back combustion energy to the reactants in order to expand reaction domains, increase combustion stability and potentially reduce harmful combustion emissions. In his eightieth birthday celebration address at Imperial College, Felix described how the excess energy approach could further aid the environment by burning very low calorific gases, including those coming from the rear end of intensively-fed cows. The concept of excess energy, or excess enthalpy as it came to be known, spawned what is now the enormous research field of highly preheated air combustion (Tsuji *et al.* 2019), including mild combustion (Cavaliere & de Joannon 2004). This latter review article credits Felix with initiating the field in 1986 with Combustion in Heat Recirculating Burners chapter in *Advanced combustion methods* (20), but it is clear that Felix’s conceptualization of the excess enthalpy approach predates that chapter by decades.

The specific implementations of preheated combustion can be traced through the Swiss roll burner, which first appeared in recirculating fluidized bed combustion, to spouted bed fluidization and then to a revival of the Swiss roll with compact combustion and thermoelectricity applications (27). It is interesting that a recent paper (Terletskii 2018) has a title and content almost the same as the extended comment from Felix and his co-author Don Hardesty (13) published 42 years earlier. The number of review articles that start with Felix’s early work is remarkable, the field of excess enthalpy in combustion being another example.

Other combustion topics

In addition to Felix’s main combustion research, he also contributed interesting sidelight topics, always triggered by his curiosity. For example, he co-authored a paper with Sir Alfred Egerton FRS on cigarettes as devices permitting continuous and stable smoulder combustion with regulated burn rates by the inhaling smoker—at a time when the health effects associated with tobacco smoke were not a paramount concern (Egerton 1963). Bob Dibble was a National Science Foundation post-doctoral fellow at Imperial College in 1976, and he and Felix showed that it was possible to support a flame on a laser beam, observing that the P(16) line of the
CO₂ laser at 10.59 microns had a strong overlap with an ethylene absorption. They were able to heat ethylene to a high enough temperature that it burst into flame above an ethylene and air burner. As with many of Felix’s curiosity-driven explorations, this early informal and unpublished study germinated and then percolated into his later work on the ignition and stabilization of flames using radiation, particularly focused laser radiation.

Felix’s last research publication appeared in the Proceedings of the Thirty-Fourth Combustion Symposium (30), bookending his contribution in the Fourth Symposium (2), with 30 symposia and 60 years of combustion physics in between.

Two colleagues at Imperial College deserve special mention as they played an extensive role in Felix’s post-1970s research. First is the selfless Alan Jones. Alan’s first research with Felix was using shear interferometry in 1971, and they published together periodically for nearly 20 years (11, 22). Though Alan’s research evolved more in the direction of light scattering and particles, he remained a core member of the Combustion Physics Group, including providing an educational article on the subject (Jones 1985). Alan matched Felix’s gentle demeanour and they shared an office as emeritus faculty. Felix relied on his unwavering support.

The second was Fred Carleton (16, 30), who for more than 30 years was the man behind the laboratory implementation of Felix’s ideas, including keeping graduate students safe. Fred could extract remarkably reproducible experimental data from the museum of equipment in Felix’s laboratory. Their teamwork was incredible, with a daily sharing of the latest results, discussions of what physical discovery they illuminated, and any further measurements needed to write up for posterity. Fred worked with Felix to the last.

**Family and interests**

There is no doubt that Felix’s achievements were possible only with the extraordinary support provided by Jill, his inexhaustibly conscientious and generous spouse of 52 years (figure 2). Felix and Jill met when they were both studying at South West Essex Technical College, where Felix was working for his external degree from the University of London. Jill was studying French, English literature, and geography. She was a good French speaker and an avid and informed reader of classical and modern literature ever after, as well as a committed theatre attendee. She was the daughter of a baker and the first person in her family to go on to higher education. Felix and Jill were married in 1954, the year Felix completed his PhD, and raised three sons: twins Peter and John born in 1958, and Michael born 11 years later.

Felix and Jill often went on long cycle tours to see the country, staying in bed-and-breakfast places. Subsequently the bikes were changed for a motorbike—a passion Felix kept going even post-retirement with his Honda 440 Four superbike. An earlier bike used for their touring adventures was a Francis Barnett, and Jill used to tell stories of using her hairpins to de-coke the cylinders. Perhaps this was an early introduction to combustion research!

Jill Nesta Weinberg (nee Piggott) took care of everything that might intrude on Felix’s focus and creativity. From a daily packed lunch and quiet time for meditation to permitting risky behaviours such as archery in the back garden, Jill’s influence was monumental. Felix was the first to recognize this unflagging support when he explained that Jill and he had an agreement that he would be the first to die since it was obvious that Jill could survive without him, but the converse was not at all clear. When Jill sadly predeceased Felix, he found himself rediscovering all the things that she had quietly been taking care of.
Felix loved nature in all its forms, a passion he attributed to walks with his father, and one that he passed on to his own children through holiday camping adventures. He never tired of the magnificence of flora and fauna, whether it be closest to home in Richmond Park (figure 3), or further afield snorkelling with his son John in the Red Sea, watching the magnificent buzzard hawks in California or paddling in the waterways of the US southeast.

All reminiscences of Felix remark on his gentleness and humanity. He was far more than a research advisor for the students he guided. As Winston Wong recalled: ‘Felix knew that I was alone in London. During the years between 1972 to 1975 when he was my PhD supervisor, he was not only my mentor on combustion physics and laser interferometry, he was more like my father.’

**Personal philosophy and world view**

One of the outstanding features of Felix’s influence was his personal philosophy, which extended beyond physics and into a world view whose heart was in curiosity. In this role he shared his more spiritually driven thoughts. As already mentioned, this wonder found its way into his popular technical presentations and discourses, including his inaugural lecture (10), his Royal Institution discourse (12), the Institute of Physics Lecture and the University of California Irvine Chancellor’s Distinguished Fellows Lecture.

Felix also shared more directly philosophical views, and these views provide a further window into his approach to life and science. For example, he wrote an undated and unpublished essay, ‘A dedication to natural philosophy’—a small part of which appears in the final chapter, ‘Natural philosophy’, of *Boy 30529*—which shows the awe and honour Felix felt about understanding the physical world. In this essay he wrote:

I suppose we all start life assuming everybody thinks as we do. It took me a long while to realise that, if a strange object fell from the sky, only a small subset of people would need to know what
it was and where it came from. There would be many others who would want to worship this miraculous apparition, litigate about the damage it caused and its ownership, or chop it up for any valuable contents to sell.

There is a genuine major difference here between the arts and sciences. In science, it is not necessary to be a genius to add some small but useful piece to cumulative knowledge and share in the glory of understanding its entirety . . . the main reason for gradually becoming a mere spectator in the arts was the sheer triviality of anything I could possibly produce in that field ranked against the revelations of physics.

Felix always valued intellectual modesty, as much for practical reasons—you learn more by listening than talking—as for a recognition of societal kindness. His semi-humorous article on this subject, titled ‘The infallibility syndrome’, first appeared in the Imperial College student newspaper and then later in Physics World (24). In it he noted:

Although the infallibility syndrome (IS) is known to afflict popes and, occasionally, senior members of the constabulary and prime ministers, the subject of this discourse is its development in academics, especially those active in the physical sciences. . . . Victims of IS are generally unaware of their condition; early symptoms include spectacular displays of unreasonable self-assurance combined with a plethora of dogmatic pronouncements. . . . There is probably no cure for full-blown IS but research has revealed methods of delaying its onset. They are all based on medieval memento mori devices designed to promote falling off pedestals and deflating one’s ego.
Felix had a long-standing interest and practice in meditation. The ultimate goal for Felix included the practical benefit of reaching more deeply into his own mind. As can be seen, he was rooted in the physical world and looked on its phenomena (particularly combustion) with joy and wonder. As described in his Physics World article of 1994, ‘Superstitious pigeons in a model world’, he viewed direct apprehension of these phenomena, either by theory or experiment, as truth, while he evinced some scepticism of models (25). The caution Felix provides is not to say that he eschewed all modelling, and in fact many of his publications relied on it, but rather it is a defence of experimental observation as glorious discovery without playing second fiddle to models.

**Legacy**

Derek Bradley FRS, another pillar of the British Section of the Combustion Institute, was a comrade in experimentation and a complement to Felix in his areas of expertise. Although they have only one formal collaborative publication (19) together, they continually attempted to set combustion on an organized course. For example, their 1991 treatise, ‘Combustion terminology: a disaster area’, was published as a Combustion Institute NewsFlash, and although only the rough manuscript remains, the work was sufficiently influential that it is referenced in the ‘Gas explosion handbook’ (Bjerketvedt et al. 1997).

As is clearly reflected in co-authored publications, Felix had an immense influence on a group of combustion researchers from around the world. Bob Sawyer (15) refers to the particular group from the USA as Felixfila Americanus. Figure 4 shows the youthful Felix at the Fourteenth Symposium at Penn State in 1972, after receiving the Silver Medal with Felixfila Americanus Michael Fox. His many contributions have produced international recognitions of distinction, which are listed below.

Felix was instrumental in setting up the Institute of Physics Combustion Physics group and a fellowship of the Institute of Energy. Together with the spectroscopist Professor Dick Gaydon, he founded a school in combustion physics at Imperial College that lasted for a quarter century, and he trained a number of researchers who now occupy top positions in this subject around the world. He also served as a board member of the Combustion Institute and was an honorary board member of the British Section of the Combustion Institute even after his formal membership term was completed. In his honour, and recognizing Felix’s commitment to youthful intellectual achievement, the Combustion Physics group of the Institute of Physics has established the Felix Weinberg Prize, an award for the best paper presented at the group’s Early Career Young Researchers meeting.

Felix is remembered as an originator of the field of combustion physics, but it was his remarkable personality that is his most enduring legacy. Felix was, like many of those curious physicists who influenced him, a complex individual but one with a unique capacity to extract the purest essence of a problem and resolve it simply. He possessed an ability to understand the mathematical complexity underpinning obtuse reacting flow systems while reveling in the joy of simple experiments and physical analogies. He has written two remarkable remembrances (‘Alfred Rene Jean Paul Ubbelohde’ (23) and ‘Alfred Gordon Gaydon’ (28)) which display his attention to scientific depth and his inimitable writing flair.

The best way to know Felix’s scientific artistry is to read his work. So it is with Felix the person; he defies unidimensional description, and this memoir can provide only some of
Figure 4. From left: Michael Fox, Felix Weinberg, Heinz Wagner and William Avery at the Fourteenth Combustion Symposium held at Penn State in 1972.

the themes of his life and research contributions. Fortunately, even scratching the surface is illuminating because, with few exceptions, he published only when he had collected a significant body of information to stand the test of time.

AWARDS, HONOURS AND PUBLIC APPOINTMENTS

1961 DSc, University of London
1967 Professor of Combustion Physics, Imperial College, London
1972 The Silver Medal (with Mike Fox) of the Combustion Institute ‘for an outstanding paper from the previous Combustion Symposium’
1980 The Bernard Lewis Gold Medal of the Combustion Institute for the ‘adaptation of physical measurements to flame processes’
1983 Fellow of the Royal Society
1988 The Rumford Medal of the Royal Society
1990 DSc Honoris Causa from the Technion, Haifa
1991 The Italgas Prize for Energy Sciences
1998 City and Guilds, Senior Awards to High Level Achievers
1999 The Smolenski Medal of the Polish Academy of Sciences
2000 University of California Irvine Chancellor’s Distinguished Fellow
2001 Elected Foreign Associate, US National Academy of Engineering
2005 The Huw Edwards Award from the Institute of Physics
Supplementary Material

Additional text, including appreciations from his colleagues, can be found at https://doi.org/10.1098/rsbm.2021.0012.

Acknowledgements

Many individuals have contributed their memories of Felix, and communications with them have enriched the portrait shared here. In addition, there are several ‘in memoriam’ documents in Felix’s honour, and some of the material from them (Kandyoti & Michels 2013; Lindstedt & Dunn-Rankin 2013) has been used in this document, but all of them deserve further study. Thanks to Peter Weinberg for sharing personal memories, Derek Bradley, Don Hardesty, Bob Sawyer and colleagues at Imperial College, particularly Fred Carleton, and Alan Jones, Rafael Kandiyoti and Hans Michels for providing their thoughts.

The portrait photograph was taken in 1983 and is © Godfrey Argent Studio. All other photographs were kindly provided by the Weinberg family.

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