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OF

THOMAS MIDGLEY, Jr.

1889–1944

BY

CHARLES F. KETTERING

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Midgley's name is inseparably associated with four outstanding advances. The first was the discovery of the chemical antiknock agents. Tetraethyl lead, the principal one of these, has added immensely to the performance and efficiency of gasoline engines both in the air and on the ground. The second advance, which was necessary to the practical success of the first, was the extraction of bromine from sea water, in which it is present in the minute concentration of only sixty-five parts per million. The third was the utilization of fluorine to produce an altogether new series of refrigerating compounds, the only such compounds known which are stable, noninflammable, and completely nontoxic, and which are therefore indispensable in air-conditioning. An unexpected usefulness of these new compounds in World War II was as a means of dispersing insect repellents. That use had such a high priority over the original use that during the war the compounds were not generally available as refrigerants. The fourth advance was in the field of rubber, in which he extended the knowledge of the chemistry of vulcanization and of the fundamental composition of natural and synthetic rubbers.

Midgley also gave outstanding service to chemistry through the American Chemical Society, in which he was active for twenty-five years, having been a member of the Board of Directors from 1930 until his death in 1944, and chairman of the Board since 1934, as well as president of the American Chemical Society in 1944. All this is the more remarkable and creditable because Midgley's university training and his early experience were not in chemistry but in mechanical engineering.

Thomas Midgley, Jr., was born on College Hill in Beaver Falls, Pennsylvania, May 18, 1889. His father, Thomas

Midgley, Sr., was a prolific inventor in a variety of fields, but notably in that of automobile tires. And his mother, Hattie (Emerson) Midgley, was the daughter of James Emerson, inventor of the inserted-tooth saw. One of Midgley's earlier ancestors is believed to have been a trusted employe of the great James Watt. When young Midgley was about four, his family moved with him to Trenton, New Jersey, and two years afterwards to Columbus, Ohio. In Columbus, Midgley lived so many years at different times in his life that that city was always home to him, and he was living in the country near Columbus at the time of his death.

Midgley attended the public schools in Columbus until partly through high school. Always interested in athletics, he played on his high school baseball and football teams. When the spit ball first began to be used by baseball pitchers, Midgley and Sandford Brown, one of his teammates at the time and a lifelong friend, made a search for a substance to give the ball enough slippiness to make it have the maximum curving effect. Midgley hit upon the idea of using an extract of the inner bark of the slippery elm as an aid to that end, a practice which was later followed extensively by baseball pitchers.

Then in 1905 Midgley went to Betts Academy at Stamford, Connecticut, to prepare for college. At Betts Academy also he played both baseball and football, and in his studies he showed that he had an original turn of mind. In geometry, for example, he delighted to solve a problem by a method different from that illustrated in the textbook or from that demonstrated by the teacher. It was from his teacher of chemistry at Betts Academy, Professor H. M. Robert, that Midgley gained an interest in the periodic table which continued throughout his life and which later helped guide him to two of his most important discoveries. During the years of his chemical researches Midgley's interest in the periodic table caused him to carry a copy of it with him constantly. In his Perkin Medal Address in 1937—an address which he entitled "From the Periodic Table to Production"—Midgley told of the important place the periodic table had had in his chemical endeavors (46).* He said then that it had served as his guide in the latter and successful phase of the "fox hunt" which led to the discovery of tetraethyl lead as an anti-knock agent, and also that in the search for a nontoxic and noninflammable refrigerant it had pointed the way for him to make use of the unpromising but effective element, fluorine.

From Betts Academy, Midgley entered Cornell University, where he took the course in mechanical engineering. Dean Dexter S. Kimball recalls that during Midgley's years at Cornell he showed the great curiosity of mind which was so characteristic of his life. His interest in experimentation was so great that he did not have time for many of the usual student activities, although he did at one time organize an aviation club among the students. The club had no airplane, not even a glider, but it was perhaps one of the first such organizations to be formed. Midgley's absorption in making side excursions into other fields was such that it often interfered also with his attention to the routine requirements leading to an engineering degree. He was nevertheless a good student, and he was also one whose friendly ways made him many friends.

After graduating from Cornell in 1911, Midgley went to work for the National Cash Register Company at Dayton, Ohio. There he was a draftsman and designer in Inventions Department No. 3. That department, which was then in charge of W. A. Chryst, was the same one in which I myself had begun work after leaving college seven years earlier, and in which the several improvements in the cash register which I had made were developed.

After working a year at the National Cash Register Company, Midgley left at the request of his father to assist him in an effort to improve cord tires and tread design. He thus

* Figures in parentheses are the numbers of the titles in the appended bibliography.

became before long chief engineer and later superintendent of the company formed to manufacture the improved tire. During that period Midgley's interest in the automobile and his experimental bent caused him to conceive a simple form of hydrometer for indicating whether automobile cooling systems contained enough alcohol in the winter time. His hydrometer was an unconventional one in that it consisted of two rubber balls of such difference in specific gravity that when put into a radiator fluid which contained the right amount of alcohol one of the balls would float and the other would sink. But, as the tire venture did not prove successful, the factory soon had to be closed, thus ending the hydrometer endeavor also and making it necessary for Midgley to look for other employment.

During his year at the National Cash Register Company, he had learned about the research which had been conducted under my guidance while I was head of Inventions Department No. 3. That recollection, together with the belief he had meanwhile come to have that research was the work he himself was cut out to do, caused him to make a decision which years later he said was the most important one of his whole life. He decided to try to get a job with me in the organization I had meanwhile developed, the Dayton Engineering Laboratories Company. So, as W. A. Chryst had meanwhile left the National Cash Register Company and had become chief engineer of this new company of ours, Midgley went to Dayton and asked him for an opportunity to help out in our research endeavors. It was thus that in 1916 Midgley became a member of our research staff and began then his long association with me and his remarkably productive career in research.

At that time Midgley was twenty-seven years of age, and his most highly productive work was done in the fifteen years following that time. Consideration of this circumstance may have caused Midgley to present as his presidential address before the American Chemical Society in 1944 a paper entitled "Accent on Youth" (56). In that address he included an analysis of a large group of outstanding inventions from the records of the United States Patent Office, which showed that 90 per cent of them had been made by men under 45. "It would seem foolish," he commented then, "to increase the time required for formal education beyond what it now is, since such increases would definitely encroach upon the most valuable years for actively prosecuting research and development." He said, though, that "being 27 and in uniform does not generate the genius of Napoleon."

Midgley's first job with us was to finish up a project already begun, the development of a built-in hydrometer for indicating the degree of charge in the storage battery of a Delco-Light farm lighting set. That job was quickly done and Midgley then asked, "What do you want me to do next, Boss?" That simple question and the answer to it turned out to be the beginning of a great adventure in the life of a most versatile man. So great did Midgley's love for research prove to be that shortly before his death he said that for him those next few years after he asked the question were like a story from the Arabian Nights.

Ever since we had put battery ignition and the self-starter on cars, the noisy bugbear of knock in automobile engines, which about that time had begun to be pronounced, had been blamed on the battery-type ignition. Some investigation of the subject had been made, but the starter and ignition business had grown so rapidly that for simple lack of time and hands the instruments and data were put away in a closet for future reference. When Midgley asked me that question, we sat down and talked about the knock in engines and why an exact knowledge of the cause was important. And I suggested that he get out those instruments, chief of which was an old Dobbie-McInnes manograph, put it on a Delco-Light engine and see what he could find out.

In that first investigation Midgley showed his most important characteristics as a research man—versatility and action.

The old manograph was not good enough to do just what was required. It did show, however, that the knock did not come from preignition, as was the common belief, but that it was caused by an abrupt rise in pressure *after* ignition by the spark plug had occurred. So Midgley said, "Let's make a better indicator to study it." And he proceeded to do that. Never did he say "This doesn't work," and stop there. Always he would say instead, "How can we overcome the difficulty and move ahead?"

The new knowledge gained in this work brought up the question, why does the abnormal rise in pressure after ignition occur and how can it be stopped? In talking over the problem we thought that maybe if the fuel were colored red it would absorb more radiant heat and evaporate more completely, thus preventing the rough combustion. This theory came to us then because we both happened to know that the leaves of the trailing arbutus are red on the back and that they grow and bloom under the snow.

In searching for a dye to color the fuel red and so to test our surmise, Midgley found no oil-soluble dye available there at the time, which happened to be on a Saturday afternoon. So he accepted iodine from the chemical store as a substitute. And, much to our astonishment, dyeing the fuel red with iodine did stop the knock completely. But was it the color or some other property of iodine? Red aniline dyes were soon obtained and tried with completely negative results. But colorless ethyl iodide did stop the knock, just as iodine had done. So evidently it was the iodine itself and not the color.

Of this new field Midgley then said, "No one knows anything about this problem. We must outline a whole series of experiments and find out if it is physics or chemistry." Unknowingly he began with that outline to become himself both a physicist and a chemist, but unhampered by the traditions of either. Our laboratory then was on the second floor of an old tobacco warehouse and not very well equipped, but that made no difference to Midgley.

By that time World War I was upon us, and Midgley then began to devote his efforts, along with men from the United States Bureau of Mines, to finding a better aviation fuel, one capable of giving higher engine outputs. The knock was limiting the power of the new Liberty engine. It was reported that the Germans had been using cyclohexane as fuel in their fighter planes. And, although the report was not true apparently, the work which Midgley and his group had done nevertheless made it appear that cyclohexane should make it possible to use considerably higher engine compressions, and thus give more power than the aviation gasoline of that time. So now Midgley turned chemist and tried to make cyclohexane by hydrogenating benzene which was readily available in quantity, but in doing so he experienced all the difficulties and disappointments of which he had been warned. However, Midgley was a tireless worker and long hours were common. So, after some months spent in overcoming obstacles, the most troublesome of which was the destructive effect of sulfur on the catalyst, the problems of hydrogenating benzene in quantity were solved.

Many barrels of this new fuel, which consisted of 70 per cent cyclohexane and 30 per cent benzene, were manufactured and tested successfully, both on the ground and in the air. That fuel was perhaps the first synthetic aviation gasoline. The end of the war came before the new fuel got into service, but out of that work and the investigation of other compounds which had preceded it came an important realization—the realization that it is the molecular structure of a fuel which controls freedom from knock, and not such physical characteristics as density and volatility, as had been supposed.

During World War I our laboratory was given also the job of developing an aerial torpedo similar to the buzz bomb of World War II. Midgley was assigned the additional responsibility of developing the control systems for that device. And the project, which proved quite successful, but which was not used in combat either because the time was too short, benefited greatly from Midgley's contributions to it.

In that war-time effort to hydrogenate benzene Midgley met with an accident which brought out an early instance of his originality and ingenuity. The fusible plug in a hydrogen tank blew out and spattered particles of the soft metal into the cornea of one of Midgley's eyes. The doctor, finding that the particles were located in places too delicate to permit being picked out, tried treatments to soften the cornea, but with little benefit. After some days of discomfort, Midgley himself conceived and tried—with the consent of his doctor—removing the particles by bathing his eye frequently with purified mercury. That experiment proved effective, and the eye was soon restored to normal. The ingeniousness of the treatment so impressed his friend and boyhood chum, E. J. Crane, now editor of Chemical Abstracts, that he wrote an account of it for Industrial and Engineering Chemistry.* And that account perhaps contains the first mention of Midgley's name in the publications of the American Chemical Society, where it appeared so frequently and with such high distinction in later years.

After the war we again took up in a serious way the search for a practical antiknock agent. Although neither the discovery of iodine as a knock suppressor nor the synthesis of cyclohexane for airplane fuel were put to practical use, they did have this important effect. They changed Midgley's principal interest and activity from the field of engineering to that of chemistry, as seeming to him by that time to be more interesting and important. And thus, being a very versatile person, he at length became one of the best informed, and surely one of the most creative chemists in the world.

The search for a practical antiknock agent was actively pursued for three years more, with the customary difficulties and disappointments of such endeavors, before the discovery

* Industrial and Engineering Chemistry, *11*, 892 (September, 1919).

of tetraethyl lead. Many antiknock agents were discovered along the way—compounds of iodine, of nitrogen, of phosphorus, of arsenic, of antimony, of selenium, of tellurium—but every one had some limitation or shortcoming which prevented it from being used in a practical way. Even after the discovery of tetraethyl lead, the research was continued for about three years longer before the several problems of using lead in an engine had been solved in a satisfactory manner. Bromine was found necessary to the solution of one of those problems—that of preventing the formation of lead oxide during combustion and its deposition on valves and in the combustion space. Since it appeared that for the purpose bromine would be needed in amounts much larger than had ever been available before, an intensive search was made for further supplies of it. That hunt led to the research which demonstrated that bromine could be extracted from the sea, where it is present in inexhaustible amount, but in concentration extremely minute—a concentration of only 65 parts per million.

After the discovery of tetraethyl lead and the development of a satisfactory antiknock compound containing it, Midgley went to work on the job of introducing the new product to the public, an endeavor in which he met with, and finally overcame, many obstacles and much opposition. It was thus in his years of work on the antiknock problem that Midgley demonstrated unusual talents in all three of the important phases of industrial research: first, in original investigation or invention; second, in development or in conversion to the stage of practical usefulness; and, third, in selling the new thing to the public—or in some instances to management first.

Something of Midgley's showmanship or ability in salesmanship was seen by those who heard him, and saw him, give his scientific papers. In presenting the original paper on the discovery of the antiknock compounds, for instance, he made extensive and striking demonstrations of knock, both in a glass tube and in an engine, showing how knock could either be made worse or eliminated altogether by chemical means (4). So also, in presenting the first account of the research which yielded the fluorine-containing refrigerants, he demonstrated both their nontoxic and their noninflammable properties in one breath, so to speak. This he did by taking his lungs full of the vapor of one of the compounds and then softly exhaling it to surround and extinguish a candle burning before him (26).

After the sale of gasoline containing tetraethyl lead had been successfully established, Midgley went back to the research laboratory. The refrigeration industry was then in bad need of a new and better refrigerant, particularly one for use in air conditioning which would not take fire and which would be free of harmful effects upon people who might be exposed to it. Again with the periodic table as a guide, Midgley came to the conclusion that any *new* compound which could have suitable physical properties, would have to contain fluorine. And so, in spite of warnings about the hazardous nature of fluorine and of such misgivings as he himself may have had, he and his helpers prepared such a compound, dichlorodifluoromethane. This is the compound which today is commonly known as Freon, and it proved to have just the properties required. It is highly stable, noninflammable, and altogether without harmful effects on man or animals.

But he almost missed that important discovery; for, of the three or four small batches of the new compound made with the total available raw material of the time, only the first was not toxic to the animals on which it was tested. The others behaved just as everyone expected fluorine compounds to behave, that is, the animals exposed to their vapor quickly died. But that, as it was found later, was due not to the Freon itself but to an unsuspected impurity in the compound. Fortunately, though, it was the first batch which turned out well. In the toxicity tests made immediately on that first sample it proved so completely free of harmful effects on the animals used in the trial that in the final phase of the test all the nitrogen in the air the animals breathed was replaced with Freon vapor without harm to them. The fluorine-containing refrigerants, of which there are a number with different vapor pressures, have since been used extensively in the refrigeration and air-conditioning industry, and have completely filled the need for which they were sought. Also, the high volatility and completely nontoxic character of Freon made it the ideal substance to fill an unforeseen need. That was as a means of dispersing insect repellents in confined spaces, and during World War II it was put to extensive use for that purpose.

Midgley's extensive researches on rubber were undertaken because of a life-long interest in the subject, although that interest was heightened by high prices and a threatened shortage of rubber at the time. With the help of a few associates, he made extensive studies of the composition of natural and synthetic rubbers and of the chemistry of vulcanization. This work resulted in the publication of a series of nineteen outstanding papers. While nothing of a commercial character came of those researches, Midgley considered the work he did on rubber as the most scientific of all his endeavors. And among those informed in the field he received a great deal of recognition for it.

In the matter of recognition for his scientific endeavors, Midgley was particularly fortunate. He received all four of the most important medals for chemical achievement: the Nichols Medal of the New York Section, American Chemical Society, 1922; the Perkin Medal of the Society of Chemical Industry, 1937; the Priestley Medal of the American Chemical Society, 1941; and the Willard Gibbs Medal of the Chicago Section, American Chemical Society, 1942. For his pioneering work on engine indicators, The Franklin Institute awarded him the Longstreth Medal in 1925. He was elected to membership in the National Academy of Sciences in 1942. He also received the honorary degree of Doctor of Science from the College of Wooster in 1936 and from The Ohio State University in 1944. The citation read by Prof. William

Lloyd Evans at the time Midgley received the latter degree was in part as follows:

The research work of Mr. Midgley has received wide recognition, as is evidenced by the great number of distinctions which have come to him from those groups best qualified to evaluate his contributions to human knowledge. Through experience, the layman will also testify his indebtedness to one who has contributed so greatly to more pleasant and efficient living. He has made science a liberator, and we rejoice with him in the satisfactions that must be his in seeing the fruits of his labor. Posterity will acknowledge their permanent value.

Midgley had a large part in the business side of the industries which came out of his endeavors. He was vice president of the Ethyl Corporation from the time of its formation, as well as the first general manager of that company. As such he contributed a great deal to the success of the enterprise, both in solving commercial problems and in overcoming the prejudice against the new product which arose from fear that the use of lead in gasoline would poison people. He was vice president of Kinetic Chemicals, Inc., (Freon) and a director of the Ethyl-Dow Chemical Company (bromine from the sea). One of the satisfactions he had was that so many thousands of workers found employment in the new enterprises which grew out of the research endeavors in which he had such a dominant part.

Midgley was a strong believer in research and he did everything he could to advance its application. As a pioneer in research on fuels, he had a considerable part in the founding of some of the most important and productive research laboratories in the petroleum industry. He was for some years a director and vice president of The Ohio State University Research Foundation. In a paper entitled "The Future of Industrial Research," presented less than a month before his death, he said, "I am of the opinion that, as time goes on, more and more research of the fundamental type will be necessary" (57). As a means of helping to insure that there will be trained men to conduct such research, he advocated that "by ample fellowships both in size and number, it (industry) should encourage many young men to remain in educational work."

Midgley believed also in the importance and the soundness of the United States patent system. "I believe it is the purpose of our patent system," he said, "to stimulate competitive research on applied subjects. . . . To my way of thinking, . . . any increase of control over our environment, or beneficial alteration thereof, is invention. The method by which such results are obtained is of no importance." He was chairman of the executive committee and an active organizer of the Centennial Celebration of the American Patent System in 1936, and he performed the same function also in the celebration of the United States Patent Law Sesquicentennial in 1940.

Having been a many-sided person, Midgley did other things than those discussed above, of course, and a few instances of such further activity may be cited. He discovered one of the first known catalysts for cracking hydrocarbons, iron selenide, a catalyst which produced compounds of the aromatic type (15). In addition to his development of the Midgley optical gas engine indicator mentioned earlier (1), he directed the later development of the widely used bouncing-pin indicator (5). He was a pioneer in the investigation of engine combustion, first by visual observation of the flame through a window in the chamber, then by spectroscopic means (6), and finally by measurement of the amount of radiant energy emitted (16).

Midgley was a firm believer in the worth of scientific societies. He was a member of several such societies, including the National Academy of Sciences, the American Association for the Advancement of Science, the American Chemical Society, the American Institute of Chemical Engineers, the Society of Automotive Engineers, and the American Society for Testing Materials. He was a member also of Alpha Chi Sigma, Phi Kappa Phi, Tau Beta Pi, the Society of Sigma Xi, the

Chemists' Club of New York, and the Dayton Engineers' Club. He was an influential delegate to the International Congress on Chemistry, held in Rome in 1938.

Midgley's extensive service to chemistry through the American Chemical Society as a Director for 14 years, as chairman of the Board of Directors for 10 years, and as President in 1944, has already been related. In respect to that long and unselfish service of his, this was said in a resolution of his fellow Directors of the Society after his death:

His sound judgment, high ideals, alert energy, and kindly human contacts brought success to the American Chemical Society, raising the standards of the whole chemical profession and endearing him to his fellow Directors and to all who served with him. In the truest sense his life represented the best thought, far-reaching vision, and the most practical accomplishments in the field of chemistry of his day and generation.

Midgley had, too, many interests outside the fields of his researches. He was a careful student of history and an investigator of many things in nature, one of which was the structure of ant hills. During the period of Midgley's active research, he took up golf as a means of getting out of the laboratory at intervals. Never having played the game before, he studied books on the subject and he talked to professionals on the mechanism of the swing. The result was that in a short time his golf score was down in the low 70's. Later, his observations of the deficiencies of greens set him to experimenting with grasses on his estate near Columbus. And soon greens experts from all over that area were coming there to see what he was doing, although by that time he himself had quit playing golf.

Midgley had a great fondness for music. He assisted some promising musicians to further their training. And once, when he came to know a young man who was working on an improved recording mechanism, he offered him his support, both technical and financial. The result was that, besides aiding in the project, he accumulated an extensive library of recordings, some of sports events, and some made from the wings of the Metropolitan Opera.

Midgley had also a liking for poetry and an aptitude for producing it himself. Some of his poetry was included in his Presidential Address to the American Chemical Society, "Accent on Youth" (56), and it ended with these two lines, lines which might well apply to Midgley himself:

Let this epitaph be graven on my tomb in simple style,
"This one did a lot of living in a mighty little while."

In the early fall of 1940 Midgley was struck by an acute attack of poliomyelitis, which, in spite of the care taken during his illness and of all the efforts made afterwards by himself and others, deprived him of the use of his legs and made him a semi-invalid. In typical spirit, Midgley computed afterwards the statistical probabilities of a man of his age catching polio, and his answer came out, as he expressed it, "substantially equal to the chances of drawing a certain individual card from a stack of playing cards as high as the Empire State Building." Nevertheless, he said, "It was my tough luck to draw it." But with characteristic courage and energy he continued in many of his activities in spite of the handicap right up until the time of his death, notably in his service to the American Chemical Society. He served also during World War II as vice chairman of the National Inventors Council and as head of one branch of chemical endeavor for the National Defense Research Committee.

On August 3, 1911, Midgley married Miss Carrie M. Reynolds of Delaware, Ohio. Two children were born to them, Jane (Mrs. Edward Z. Lewis), and Thomas Midgley, 3rd. All of Midgley's immediate family except his father survive him.

Midgley liked people of every class and profession. As he himself put it once: "I have always had a fondness for intelligent people." He had the ability to mingle with and to enjoy the company of people from all walks of life, and he would be as much interested in the philosophy of a cab driver as in the opinions of men in higher walks of life. Out of his manifold activities and associations, he made many friends, and he liked nothing better than being a host to them. To me personally Midgley was, throughout all those years, like a son or a brother. And he was held in the highest esteem by his associates everywhere.

Midgley died unexpectedly on November 2, 1944, at the age of 55. At his funeral, the minister read the familiar verse, "We brought nothing into this world, and it is certain we can carry nothing out." It struck me then that in Midgley's case it would have seemed so appropriate to have added this: "but we can leave a lot behind for the good of the world." And what Midgley did leave behind is a great heritage to the world from a busy, a diversified, and a highly creative life.

KEY TO ABBREVIATIONS USED IN THE BIBLIOGRAPHY FOLLOWING

A.P.I. Bul. = Bulletin of the American Petroleum Institute.
Chem. and Eng. News = Chemical and Engineering News. (Formerly News Edition of Industrial and Engineering Chemistry).
Ind. Eng. Chem. = Industrial and Engineering Chemistry. (Formerly Journal of Industrial and Engineering Chemistry.)
Ind. Eng. Chem., Anal. Ed. = Industrial and Engineering Chemistry, Analytical Edition.
J. Am. Chem. Soc. = Journal of the American Chemical Society.
J. Phys. Chem. = The Journal of Physical Chemistry.
Motor = Motor (New York).
S.A.E. Jour. = S.A.E. Journal. (Formerly Journal of the Society of Automotive Engineers.)

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