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REVIEW

Collected Works of Theodore von Kármán, 1952–1963. Von Kármán Institute for Fluid Mechanics, 1975. 388 pp.

The first four volumes of von Kármán's *Collected Works* were published in 1956 (London: Butterworths) and were reviewed by G. Temple in what appears to have been (and appropriately so) the longest review in the history of *JFM* [**5**, 329–336 (1959)]. Temple opened with the statement that "while they are an astonishing tribute to the learning, insight, skill and energy of the author, they form only an interim report on his scientific activities, which are still continuing with unabated vigour and enthusiasm". He closed by pointing out that "they bring the tale only up to 1951 and that it is high time that we had a fifth volume".

We now have that fifth volume, published some twelve years after Kármán's death (as Rayleigh remarked on the tardy publication of Clerk-Maxwell's *Papers*, our "gratitude...is not unmingled with complaint"). It contains (Part I) eighteen scientific papers originally published during 1952–63, (Part II) eleven items "whose purposes [as judged by the editors] were more transient or whose lasting significance is more historical than scientific", and (Part III) a bibliography of Kármán's papers and a list of his honorary degrees, decorations and awards. I accept the judgment of the editors on the division between Parts I and II and note of the latter papers only that they document Kármán's role as a scientific statesman and provide full evidence of his celebrated wit and sure sense of history.

The scientific papers may be considered in five categories. The bold-faced numbers in parentheses are those assigned by the editors.

Combustion

Kármán's original scientific work during this period was (I believe most would agree) primarily in combustion and is represented by seven papers (**4**–**9**, **12**). He had been heavily involved in the development of rockets during World War II (in particular, he was the principal investigator of the U.S. Army rocket project at Caltech that ultimately became the Jet Propulsion Laboratory) and, as the editors remark, "was not at ease with the status of combustion research in the late 1940's. He found too few theoretical or experimental results in dimensionless form, he suspected that many arguments were unsound or were conjectures that posed as theories...So...with...able collaborators, he set about to introduce his own touch." At least five of the papers (**4**–**8**) contain original ideas that "affected permanently the direction of combustion research". The remaining two papers (**9** and **12**) are extended remarks at technical meetings. It appears (both from the editors' comments and from my own conversations with Professor Frank Marble) that the last paper (**12**) provides the only written record of Kármán's fundamental, but mainly unpublished, contributions on combustion instability in rockets.

Aerodynamics

Kármán is generally recognized as one of the two greatest aerodynamicists of the modern era (the other being his teacher, Prandtl), but it is probably fair to say that the aerodynamics papers in this volume do not rank in importance with either his earlier work or the present combustion papers. Three of them (**1**, **10**, **14**) are survey papers on high-speed aerodynamics that echo, but do not equal, his great 1946 Wright Brothers Lecture [*J. Aero. Sci.* **14**, 373–409 (1947); *Works* **4**, 271–326], even though the hand of the master is evident in almost every line.

"Dimensionless quantities in specific areas of aerodynamics" (**11**) also is a survey paper, from which I learned that the best known of all similarity parameters, the Reynolds number, was named by Sommerfeld in 1904. [Rouse & Ince, in their *History of Hydraulics*, credit Weber (1919) with naming both the Reynolds and the Froude numbers.]

Almost all of Kármán's papers exhibit, at least in their inspiration, a rather strong connexion with engineering, but "On the existence of an exact solution of the equations of Navier–Stokes" (**17**, with C. C. Lin) is, as its title clearly conveys, a singular exception – and not only by comparison with the papers in the present volume.

The formation of sand ripples has both fascinated and frustrated many aerodynamicists, including Kármán, as is evident from a rather brief paper in this volume (**3**) and from work carried out in 1937 and eventually published in 1947 (*Technion Yearbook*, 52–54; *Works* **4**, 352–356). Unfortunately, his 1937 statement that "the basic physical principles of the phenomena of transfer of solid particles by wind or water are as yet unknown" still holds.

The First Lanchester Memorial Lecture (**13**) might, I suppose, have been placed in Part II, but it seems appropriately placed in Part I, if only because of Kármán's incisive comparison of Lanchester's finite-wing theory with that of Prandtl.

Magnetohydrodynamics

In the late 1950s, perhaps in consequence of a sojourn with the Cornell group (headed by his former student, W. R. Sears), Kármán became interested in what is currently called magnetohydrodynamics, but which he preferred to call (more appropriately) 'magnetofluidmechanics'. According to the editors, he "often wondered 'whether magnetofluidmechanics was really engineering or only an indoor sport'"; nevertheless, he did write two papers on the subject. The first (**15**) deals primarily with the basic physics and demonstrates his customary insight. The second (**16**) deals briefly with applications, from electromagnetic pumps for liquid metals to ion propulsion, and informs us that Einstein proposed the use of a magnetically driven liquid metal as a refrigerator coolant.

Structures

Structural problems, especially of stability, remained of keen interest to Kármán throughout his life, and the last paper in Part I (**18**, with A. D. Kerr) deals with the instability of spherical shells under external pressure.

Aeroelasticity

Kármán's pioneering work on the aerodynamic instability of suspension bridges, stimulated by the Tacoma Narrows failure and perhaps not well known to *JFM* readers, is represented here by a report (**2**, with L. G. Dunn) on wind-tunnel investigations of scale models and includes a letter from Kármán that appeared in the *Engineering News-Record* of 21 November 1940, exactly two weeks after the original disaster. This letter makes a plausible case for simple torsional divergence and arrives at a range of critical wind speeds that is compatible with the observed value; however, the subsequent wind-tunnel tests leave little doubt that the actual instability was associated with vortex shedding (the editors do not comment explicitly on this discrepancy, but Professor Duncan Rannie informs me that Kármán soon eliminated the possibility of torsional divergence). Here again, it seems clear that Kármán was the first to identify a phenomenon of great technological importance and that, even more than in the example of combustion instability, the archival literature fails to provide an adequate measure of his contributions.

Earlier in this review I alluded to Rayleigh's review [*Nature* **43**, 26–27 (1890); *Scientific Papers* **3**, 426–428] of Clerk-Maxwell's *Papers*. Rayleigh closed his review with: "The reader of these volumes, not already familiarly acquainted with Maxwell's work, will be astonished at its variety and importance. Would that another ten years' teaching had been allowed us!"

The first sentence applies equally to Kármán, but whereas Maxwell (1831–79) died at forty-eight, Kármán was forty-nine when he left Aachen for Pasadena and lived almost to the age of eighty-two. This last volume of his works makes it amply clear that his scientific life was both rich and full to the end, for which we may all be grateful.

J. W. Miles