In Memoriam Winfried Oppelt

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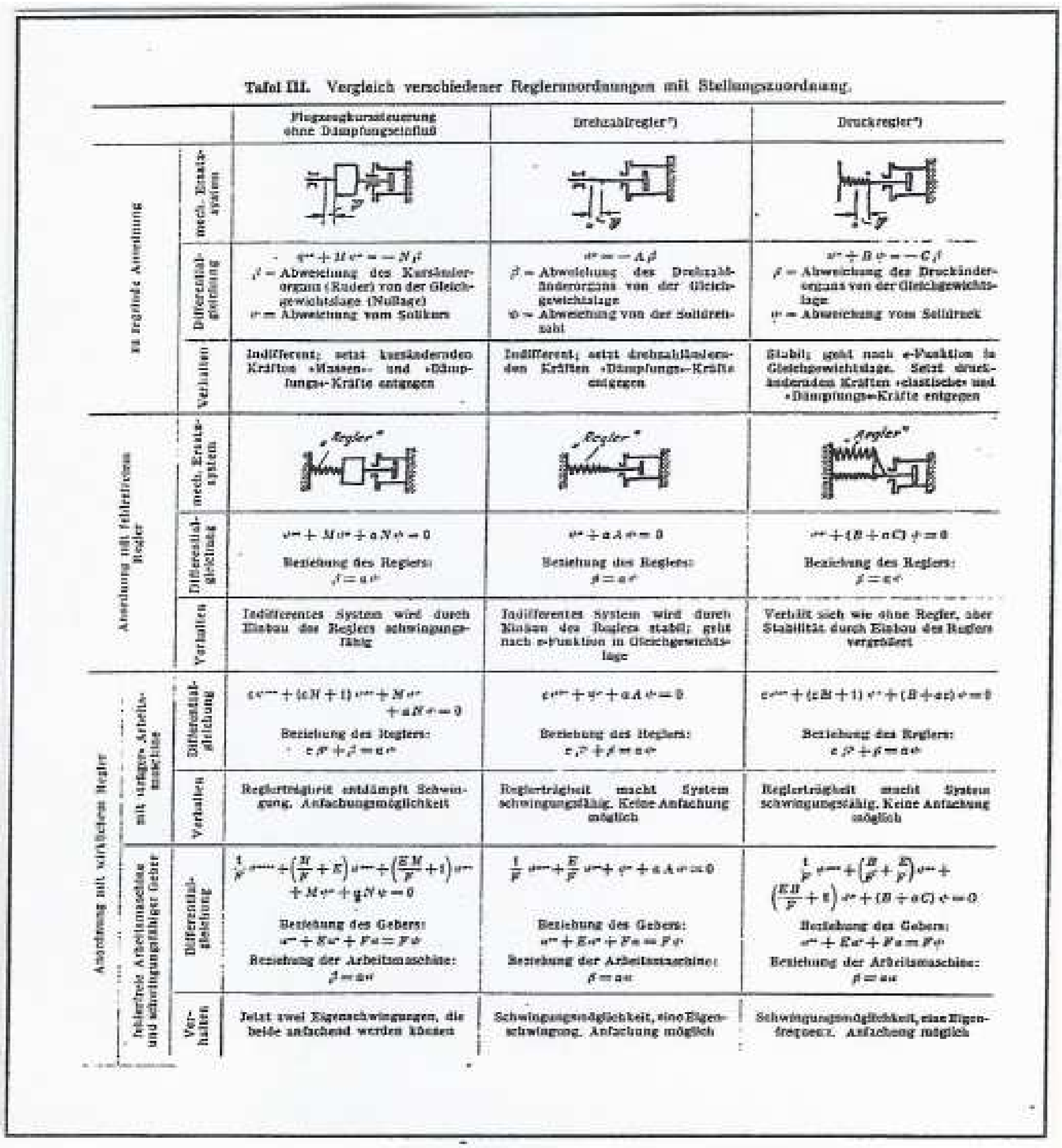
This special issue of **at** – *Automatisierungstechnik* is a celebration of the achievements of *Winfried Oppelt*, one of the great names of German control engineering. His reputation, and much of his work, will be well known to many readers of this journal, so in this introduction I shall not attempt to recount his biography in detail. Rather, I shall concentrate on the characteristics that, I believe, set him apart from other pioneers of the golden age of classical control.

For those who wish to find out more about his professional life, a wealth of information is given in [1, 2, and 3], and some milestones are also listed in Table 1.

1912	Born on 5 June in Hanau
1934	Graduated from *TH Darmstadt*, joined *Deutsche Versuchsanstalt für Luftfahrt* (DVL)
1937	Left DVL for *Anschütz* in Kiel; published seminal paper on flight control
1939-1944	Member of VDI committee on automatic control chaired by Hermann Schmidt
1942	Became head of a *Siemens* research department in Berlin
1943	Doctorate awarded by *TH Darmstadt*
1945	Joined *TH Braunschweig*
1947	*Grundgesetze der Regelung* appeared
1949	Joined *Hartmann & Braun* in Frankfurt; *Stetige Regelvorgänge* appeared
1952	Part-time teaching at *TH Darmstadt*
1954	*Kleines Handbuch technischer Regelvorgänge* appeared
1957	Professor of Automatic Control, Darmstadt
1967	Elected Fellow of IEEE
1971	Awarded VDI *Grashof-Denkmünze*
1977	Retired
1980	Awarded Austrian *Wilhelm-Exner-Medaille*
1981	Awarded GAIRN EEC Medal of London Society of Engineers
1982	Awarded *Aachener und Münchner Preis*
1999	Died on October 4 aged 87

Table 1. Some milestones in the life of *Winfried Oppelt*

As I remarked over twenty years ago, in the opening sentence of a report of an interview with him [3]: "*Winfried Oppelt* became a control engineer before control engineering had been heard of". He came from a physics and aeronautical engineering background, and worked on flight control systems as early as the 1930s. But the truly remarkable aspect of his early career is that he recognised the commonality of the dynamics of many different engineered systems, and the fact that a uniform approach could be taken to modelling – and, ultimately – controlling them. In 1937, long before most other engineers had begun to think in systems terms, he gave a conference paper, subsequently published as [4], in which he compared flight control to other systems, recognising such commonality in a range of applications (Figure 1).



Tafel III. Vergleich verschiedener Reglernordnungen mit Stellungszuordnung.

		Flugzeugkurssteuerung ohne Dämpfungseinfluß	Drehzahlregler*)	Druckregler*)
Ungeregelte Anordnung	mech. Ersatzsystem			
	Differentialgleichung	$\ddot\psi + M\dot\psi = -N\beta$ β = Abweichung des Kursänderorgans (Ruder) von der Gleichgewichtslage (Nullage) ψ = Abweichung vom Sollkurs	$\dot\psi = -A\beta$ β = Abweichung des Drehzahländerorgans von der Gleichgewichtslage ψ = Abweichung von der Solldrehzahl	$\dot\psi + B\psi = -C\beta$ β = Abweichung des Druckänderorgans von der Gleichgewichtslage ψ = Abweichung vom Solldruck
	Verhalten	Indifferent; setzt kursändernden Kräften »Massen«- und »Dämpfungs«-Kräfte entgegen	Indifferent; setzt drehzahländernden Kräften »Dämpfungs«-Kräfte entgegen	Stabil; geht nach e-Funktion in Gleichgewichtslage. Setzt druckändernden Kräften »elastische« und »Dämpfungs«-Kräfte entgegen
Anordnung mit fehlerfreiem Regler	mech. Ersatzsystem	„Regler"	„Regler"	„Regler"
	Differentialgleichung	$\ddot\psi + M\dot\psi + aN\psi = 0$ Beziehung des Reglers: $\beta = a\psi$	$\dot\psi + aA\psi = 0$ Beziehung des Reglers: $\beta = a\psi$	$\dot\psi + (B + aC)\psi = 0$ Beziehung des Reglers: $\beta = a\psi$
	Verhalten	Indifferentes System wird durch Einbau des Reglers schwingungsfähig	Indifferentes System wird durch Einbau des Reglers stabil; geht nach e-Funktion in Gleichgewichtslage	Verhält sich wie ohne Regler, aber Stabilität durch Einbau des Reglers vergrößert
Anordnung mit wirklichem Regler: mit träger Arbeitsmaschine	Differentialgleichung	$c\dddot\psi + (cM + 1)\ddot\psi + M\dot\psi + aN\psi = 0$ Beziehung des Reglers: $c\dot\beta + \beta = a\psi$	$c\ddot\psi + \dot\psi + aA\psi = 0$ Beziehung des Reglers: $c\dot\beta + \beta = a\psi$	$c\ddot\psi + (cB + 1)\dot\psi + (B + ac)\psi = 0$ Beziehung des Reglers: $c\dot\beta + \beta = a\psi$
	Verhalten	Reglerträgheit entdämpft Schwingung. Anfachungsmöglichkeit	Reglerträgheit macht System schwingungsfähig. Keine Anfachung möglich	Reglerträgheit macht System schwingungsfähig. Keine Anfachung möglich
Anordnung mit wirklichem Regler: fehlerfreie Arbeitsmaschine und schwingungsfähiger Geber	Differentialgleichung	$\frac{1}{F}\psi'''' + \left(\frac{M}{F} + E\right)\dddot\psi + \left(\frac{EM}{F} + 1\right)\ddot\psi + M\dot\psi + aN\psi = 0$ Beziehung des Gebers: $\ddot\alpha + E\dot\alpha + F\alpha = F\psi$ Beziehung der Arbeitsmaschine: $\beta = a\alpha$	$\frac{1}{F}\dddot\psi + \frac{E}{F}\ddot\psi + \dot\psi + aA\psi = 0$ Beziehung des Gebers: $\ddot\alpha + E\dot\alpha + F\alpha = F\psi$ Beziehung der Arbeitsmaschine: $\beta = a\alpha$	$\frac{1}{F}\dddot\psi + \left(\frac{B}{F} + \frac{E}{F}\right)\ddot\psi + \left(\frac{EB}{F} + 1\right)\dot\psi + (B + aC)\psi = 0$ Beziehung des Gebers: $\ddot\alpha + E\dot\alpha + F\alpha = F\psi$ Beziehung der Arbeitsmaschine: $\beta = a\alpha$
	Verhalten	Jetzt zwei Eigenschwingungen, die beide anfachend werden können	Schwingungsmöglichkeit, eine Eigenschwingung. Anfachung möglich	Schwingungsmöglichkeit, eine Eigenfrequenz. Anfachung möglich

Figure 1. Table from *Oppelt*'s 1937 paper, comparing flight control with speed and pressure control

Incidentally, this paper also contained the germ of the describing function approach to non-linearities. *Oppelt* should be thus be credited with this alongside the independent work of *Goldfarb* (USSR), *Kochenburger* (USA), *Tustin* (UK) and *Dutilh* (France). With characteristic modesty *Oppelt* described his contribution to me in 1991:

> I replaced the output waveform of the non-linear element by a sinusoid with the same area over one period, rather than by the fundamental Fourier component, which subsequently became standard. I gave a paper on my method [at the 1951 Cranfield Conference], which I did not present very well, and which was criticised for not being properly justified [3].

It must have been rather daunting for *Oppelt* and a handful of other German colleagues to present papers at an international conference in the UK in 1951: looking at the conference proceedings after sixty years, however, they all seem to have acquitted themselves pretty well!

For most of the Second World War, *Oppelt* worked for Siemens in Berlin, particularly on torpedo guidance systems. But from 1939 onwards he was also a key member of one of the most remarkable committees in the history of automatic control. Established by *Hermann Schmidt* (another German pioneer of control), under the aegis of the VDI, the *Fachausschuß Regelungstechnik* (control engineering technical committee) examined the emerging discipline in detail over a period of several years, standardizing terms and definitions, and reporting some of the basic theory in a series of documents culminating in 1944 [5, 6].

Of the committee's work, *Oppelt* later wrote:

> I like to think back to the work of the specialist VDI committee. There prevailed an open-minded and free-thinking atmosphere, which promoted creativity. The entire field of control […] was discussed. This had, of course, very stimulating and far-reaching effects … [7]

And again:

> [The committee] was an astonishing experience for me – and for the other members as well – to be able to meet at that time and discuss technical matters without worrying about who was competing with whom. We produced a report at the end of the war on concepts and terminology in control engineering, which subsequently formed the basis of later work on the first DIN standard in control engineering" [3].

In the light of *Oppelt*'s later pedagogical work, it is not too fanciful to see his hand in the graphical explanations of process models in the final VDI report. Figure 2 is a compilation of these. Note how clearly the various elementary process models are characterised in terms of their step responses: a pure gain; a first order lag; underdamped second order; integrator; and integrator plus first-order lag.

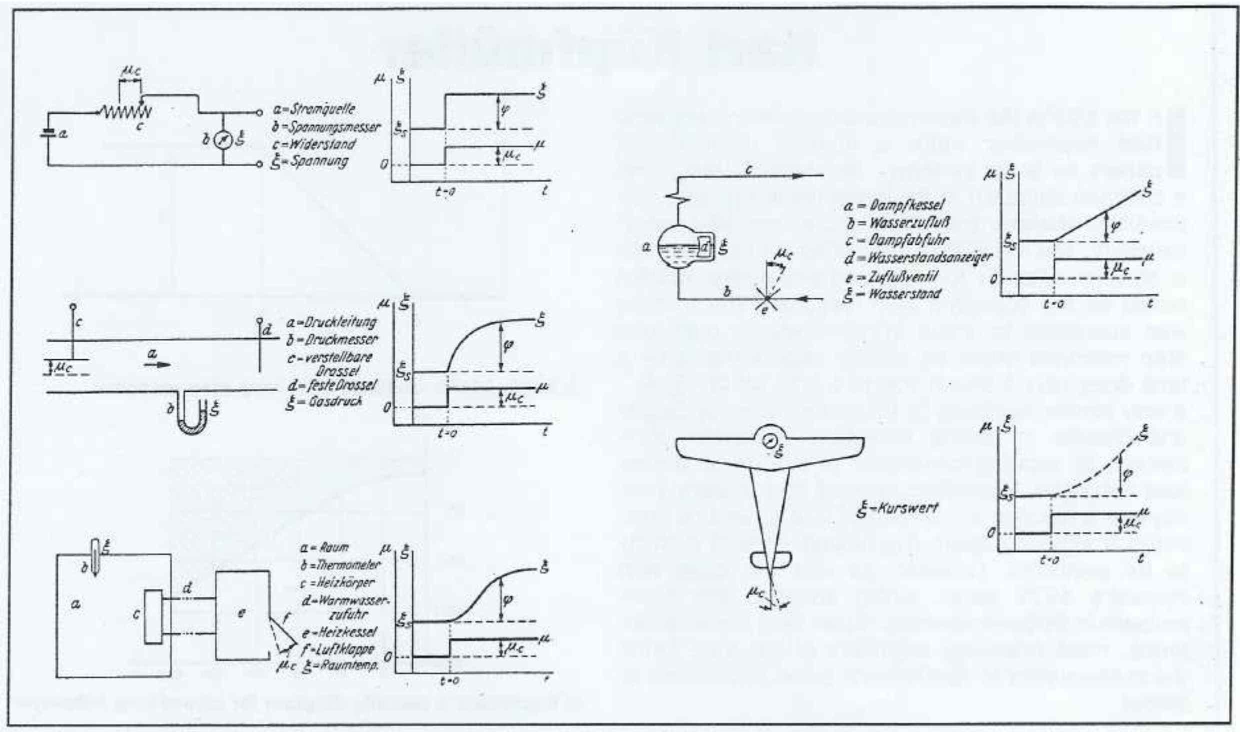


Figure 2. Process models from the 1944 VDI report

For a few years immediately after the war *Oppelt* lived quietly in Braunschweig, teaching at the university, and taking the first steps towards a renowned textbook on control engineering that was to be expanded and revised over the following decades. Two short introductory texts *Grundgesetze der Regelung* [Fundamentals of Control] in 1947 and *Stetige Regelvorgänge* [Continuous Control Processes] in 1949 were followed in 1954 by the renowned *Kleines Handbuch technischer Regelvorgänge* [A Short Handbook of Technical Control Processes], the fifth edition of which in 1972 ran to 770 pages (no longer so short!). This series of textbooks is truly remarkable [8]. *Oppelt*'s appreciation of systems thinking, already evident in his 1937 paper and his work in the VDI committee, finds its full expression in these books. Right from the beginning, he was aware of the difficulties that engineers from various specialist backgrounds were to have in making the interdisciplinary move that was to characterise mature classical control engineering. So he took great pains to give a wealth of examples, often illustrated by his own rather charming drawings, such as in Figure 3. The later editions of his text are still worth examining today, as an object lesson in engineering pedagogical writing. Various editions of *Oppelt*'s texts were translated into Czech, French, Hungarian, Japanese, Polish, Rumanian and Russian – but not, unfortunately, into English.

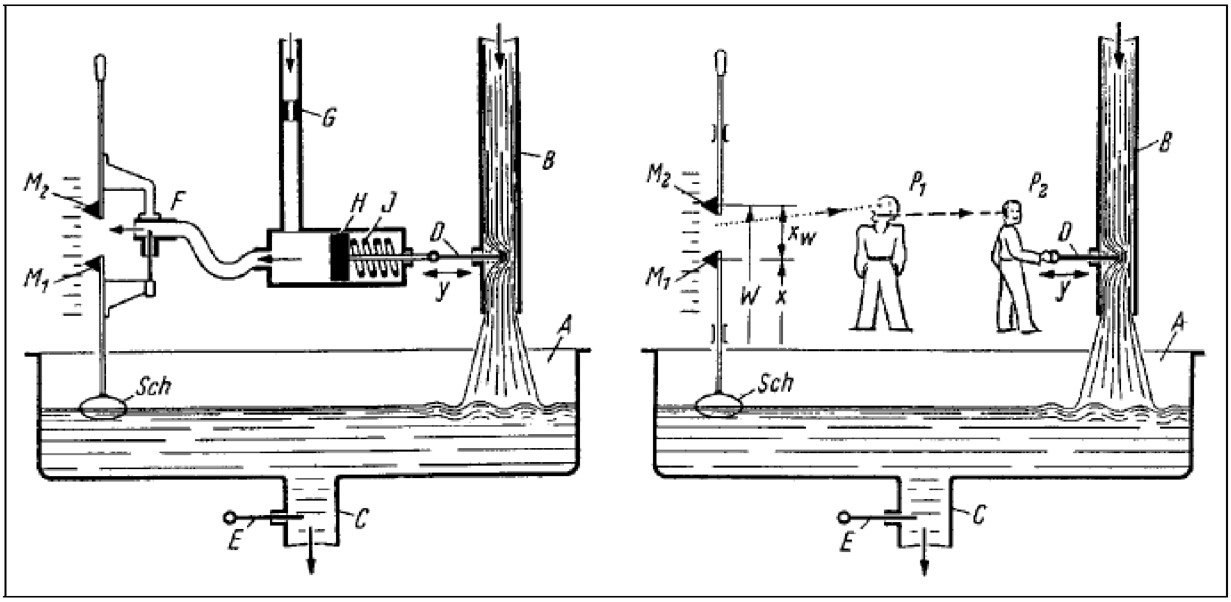


Figure 3. A typical hand-drawn illustration by *Winfried Oppelt* [2]

A number of eminent control engineers of the post-war period took a keen interest in the wider applications of control theory, and *Oppelt* was no exception [9]. In the mid 1950s the VDI held a number of conferences on the non-engineering applications of control. In April 1954, for example, there was a two-day meeting on biological control mechanisms in Darmstadt [10] and in March 1955 a similar one in Essen on the links between processes in economics and those in engineering [11]. At both events *Oppelt* gave introductory talks, setting the scene for the ways in which control engineering ideas could contribute to an understanding of biological and economic systems respectively.

From 1957 onwards *Oppelt* occupied the Chair of control engineering at Darmstadt Technical University, where he was a huge influence on a whole generation of German control engineers, and built up one of the foremost German centres of control engineering for both teaching and research. His teaching was characterised by technical interdisciplinarity and advanced practical work for his students [1]. However, he retained an interest in non-technical applications of control theory in such areas as cybernetics, biology and economics. In 1970, for example, he co-editored a collection, *Mensch als Regler* [*Man as regulator*], that reported work of the 1960s (mainly from Eastern Europe) covering both humans within a control loop and control systems within the human body [12]. The book received a somewhat belated, but highly favourable, review in IEEE *Transactions on Systems, Man and Cybernetics* in 1974 [13]:

> The emphasis of this book is on modelling, in the precise engineering sense, of a variety of phenomena that are regulated by a human being consciously or unconsciously. With minor exceptions, there is no attempt to justify the models or demonstrate their usefulness in medicine, ortheses, prostheses, or other tasks. However, the book's most valuable asset is the integration of engineering sciences and biology to a very sophisticated and effective degree. For those who know the fundamentals of system theory and can read German, this book not only provides pleasure and inspiration but also vistas of future work in understanding the human organism.

In 1984, well into his formal retirement, he published another cybernetic examination of human behaviour: *Über das Menschenbild des Ingenieurs: eine Bestandsaufnahme und offene Fragen bei der kybernetischen Modellbildung menschlichen Verhaltens* [An Engineering View of Human Beings: current situation and open questions in the cybernetic modelling of human behaviour]. In this text, which originated in an address the previous year to the prestigious academic scientific society *Wissenschaftliche Gesellschaft der Johann Wolfgang Goethe-Universität Frankfurt*, he considered the application of engineering models and analogies to the nervous system and the brain. In later life *Oppelt* continued to be fascinated by such applications of control, cybernetics and systems theory to biology, and continued to work – and publish – on such matters, including hypnosis, until shortly before his death. He also published two important historical papers in English that brought to an international readership many aspects of his lifetime's experience in control engineering [7, 14].

Winfried Oppelt was one of a group of eminent control engineers from Germany, the United Kingdom and the United States, who emerged from the Second World War with a burning desire both to disseminate the novel ideas about automation and control that had been forged during the conflict, and to apply them in areas other than technical systems – and a belief that automatic control could be a benefit to post-war society. In all these countries, engineers were coming to terms with what they had done, within or without the armed forces, as part of the war effort. The late 1940s and early 1950s saw a rash of textbooks, conference papers, and journal articles on the new discipline in its native technical terrain [15]; but only a few engineers (*Norbert Wiener*, *Hermann Schmidt*, *Arnold Tustin*, for example) made significant advances beyond the purely technical [9]. *Winfried Oppelt* was one of that distinguished company.

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