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Thomas A. Jaeger - A remarkable civil engineer

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Synopsis

Thomas A. Jaeger was granted just 51 years of life. During his short lifetime, in an era marked by technological change, he made an unrivalled contribution to the development of nuclear engineering in the Federal Republic of Germany and provided lasting momentum to take the general assessment of constructional safety to new levels.

In the 1950s, having studied civil engineering in Dresden, he committed himself fully to the problems associated with nuclear engineering, a subject that had interested him since his student days. In so doing, he was navigating completely uncharted territory in an area to which he first had to give a name, shape and meaning - a task at which he undoubtedly succeeded. His unstinting efforts throughout the 1960s and 1970s had a powerful impact in Germany and far beyond. He possessed all the tools he needed to be so effective - truly extensive expertise, manuals and the excellent "Nuclear Engineering and Design" journal, which he himself founded. In 1971 he promoted the worldwide spread of knowledge by launching the series of SMiRT conferences ("Structural Mechanics in Reactor Technology"), which still live on today [1].

He spent the last 13 years of his working life at the Federal Institute for Materials Research and Testing (BAM) in Berlin; after his death the institute dedicated a commemorative volume to him, incidentally the only time it has ever granted such an honour to one of its leading lights.

1. The early years

Countless outstanding civil engineers have been mentioned and acclaimed in this present series of VDI-Gesellschaft Bautechnik, and yet only a few of them have been given as short a time in which to work and to achieve their visions as Thomas A. Jaeger.

Born in 1929 in Breslau, he was actively involved in the upheaval of the Second World War - as a so-called "Flakhelfer" ("flak helper"). Nevertheless, his family managed to escape from Breslau

and gain a foothold in the Soviet-occupied zone (later the "GDR"). He then started studying civil engineering at the renowned Technical University of Dresden in 1949, finally graduating in 1956.

It was during this time that he fostered numerous contacts with noted scientists and engineers all over the world, people such as W. Kliefoth, E. P. Blizard, A. Sawczuk and F. Schleicher, who were as a rule only too happy to address his questions and suggestions.
At the same time he had undertaken to review foreign - mainly English-language - articles for research projects at the TU Dresden where, at the time, major efforts were underway to try and rebuild lost links to international standards of knowledge. Many of these short papers were also taken by the civil engineering documentation centres at the Fraunhofer-Gesellschaft, and he was able to use the fees to improve his standard of living somewhat. Essentially, he read up on the field of atomic energy and safety in the building trade, acquiring a tremendous treasure trove of up-to-date knowledge in the process.

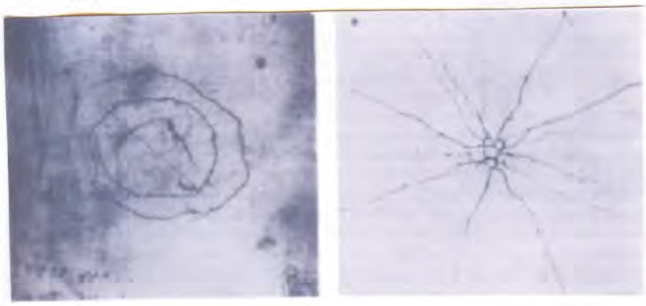
This is probably what also influenced the subject of his thesis, an unusual choice at the time: Investigations on the Limit Load Capacity of Reinforced Concrete Plates.

He himself identified the close examination of this subject as being of fundamental importance to his further development. He submitted two papers on the subject, in BAUINGENIEUR 31 (1956) and in BAUPLANUNG-BAUTECHNIK 10 (1956). After this "debut", F. Schleicher, who was at the time a professor at RWTH Aachen University and the publisher of BAUINGENIEUR, encouraged him to translate the newly published book by B. G. Neal: *The plastic methods of structural analysis*, which then came out in 1958 (Die Verfahren der plastischen Berechnung von biegesteifen Stahlstabwerken, Julius Springer; Heidelberg). There is no doubt that this achievement gave Jaeger greater status in Germany at that time, subsequently enabling him to address the complex issues of structural mechanics in nuclear power technology.

However, another volume, devoted more to the specific problems of reactor technology, was published prior to this as a product of extensive research and reviews: *Grundzüge der Strahlenschutztechnik*, (Principles of Radiation Protection Engineering), Springer, Heidelberg, 1960 [5] with a most interesting foreword by E. P. Blizard.

However, given the political circumstances in Germany, a move to West Germany was becoming inevitable and the entire Jaeger family left Dresden.

Thomas Jaeger had already made some preparations beforehand, partly through Max von Laue, with whom he was in contact through his uncle, the renowned physicist Rudolf Ladenburg, who had had to leave Germany in 1938 and who, like Einstein, went to Princeton. Although it was not feasible for a young engineer from East Germany to go and continue his studies in the U.S.A., Thomas Jaeger managed to join a DFG (German Research Foundation) research project that had been instigated by F. Schleicher but, the latter having died suddenly, was now being run in Berlin by Werne Koepcke, professor of concrete structures at Berlin TU. The topic of research was reinforced concrete plates and - naturally - their limit load-carrying capacity. Shortly before this, Antoni Sawczuk in Warsaw had made significant progress in work on the limit load capacity of orthotropic plates, about which he had kept Thomas Jaeger constantly informed, and he was now providing the experimental verifications in long series of tests, supplemented by practical calculations for orthogonally reinforced concrete plates subject to a variety of specifications, marginal conditions and loads. The fact that in highly complex cases the flexible hinge lines materialised as predicted in theory is remarkable in itself, particularly so in special cases such as loads on simply supported square plates subjected to centric point load: the locus diagram of the flexible hinge is a logarithmic spiral, picture 2. In 1963 Julius Springer then published *"Grenztragfähigkeit der Platten"* "Limit Load Theory of Plates" with the theoretical section by Sawczuk translated into German by Thomas Jaeger and the section that was largely consistent with his dissertation. The book remains a "classic" definitive work to this day.



Picture 2. Yield line pattern at the upper and rear face of a simply supported square reinforced concrete plate subjected to centric point load [4]

Armed with these findings, Thomas Jaeger was now able to take practical steps to address open questions on structural mechanics and structural reactor safety (a term he did not use until later).

1. Early work in reactor technology

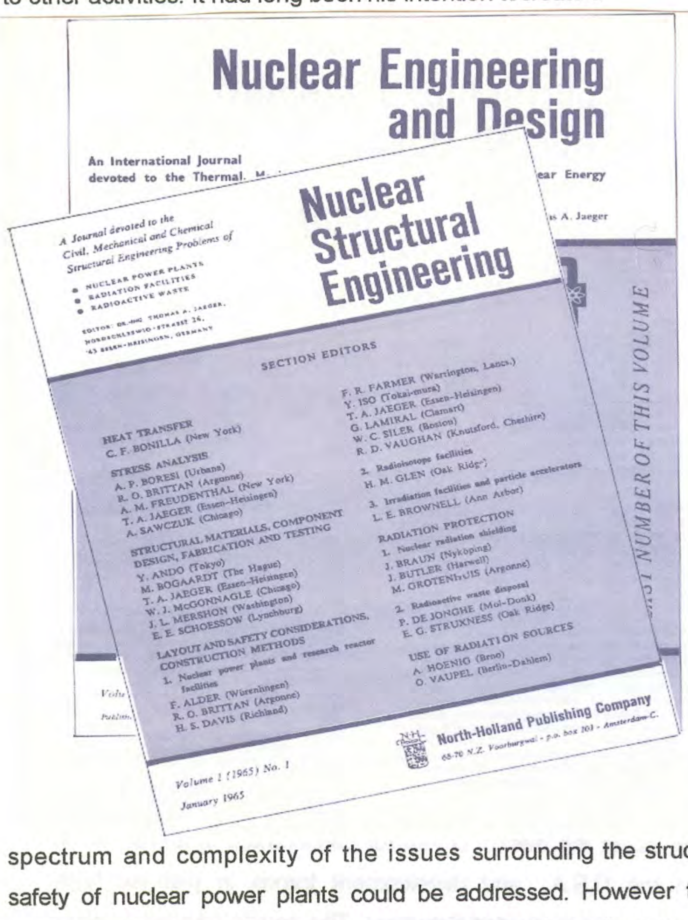
From 1962 to 1963, Thomas Jaeger spent a year with the Institute for Reactor Development at the Jülich Nuclear Research Centre (KFA), in those days a Mecca for everyone fascinated by nuclear technology. He had gone to the fledgling institute with the intention of introducing a consideration of the operational demands on reactor systems components when developing reactors. However, the way in which questions relating to the stability and durability of reactor systems parts were dismissed as unimportant by KFA development groups at the time left Thomas Jaeger very disillusioned. During this period he managed nonetheless to gather information about the design of reactor containment systems, which were then being worked on in the U.S.A., and development trends in planned high temperature reactors (pebble bed reactors by Rudolf Schulten). The pebble bed test reactor achieved criticality for the first time in 1966.

Closely linked to the high temperature reactor was the prestressed concrete reactor pressure vessel, which particularly aroused Jaeger's interest and then became the focus of his attention for a considerable amount of time. However, the KFA Jülich attached no importance to this issue, and Thomas Jaeger had no choice initially but to suspend his work on this aspect of reactor development, just as it was being viewed as a high priority in England.

It was only some years later that Thomas Jaeger, now working at the Federal Institute for Materials Research, was able to resume work on this topic and thus develop and manage a truly extensive R&D programme.

2. NUCLEAR ENGINEERING and DESIGN

His disillusionment with the limitation to development in Germany spurred Thomas Jaeger on to other activities. It had long been his intention tocreate a special journal as a forum in which the full spectrum and complexity of the issues surrounding the structural safety of nuclear power plants could be addressed. However this idea was not easily realised. The issue became even more pressing when, in 1963, a similar journal was proposed in the U.S.A. by the American Nuclear Society (ANS).



Picture 3. NUCLEAR ENGINEERING AND DESIGN

However, the Springer-Verlag publishing house, contacted by Jaeger repeatedly, took so much time that Jaeger wrote angrily in September 1963:
"I do not dare to assume that the Springer-Verlag was advised with a lack of appropriate knowledge in the case of my project, although one is sometimes quite impressed by the little understanding shown by natural scientists as far as technical questions are concerned."
In the end, however, he followed the advice of A. Sawczuk and contacted North Holland Publishing Company, where the decision to publish this journal was taken within a few weeks. It was not easy to assemble an editorial board with a wide range of expertise, but it was finally managed. In January 1965 the first edition of NUCLEAR ENGINEERING AND DESIGN appeared, under a somewhat different title to begin with.
It still remains **the** international journal in this field today.

3. Work at the Federal Institute for Materials Testing (BAM)

For a long time there was some uncertainty as to what career path Thomas Jaeger should follow, as he thought he should choose essentially between a university career or working in industry. Since 1958 however, he had stayed in touch with Max Pfender, President of the Federal Institute for Materials Testing (BAM) in Berlin, who offered him a responsible position in BAM. At the same time he gave Jaeger lots of time to work in other fields, thus gaining experience, and to get back to him in due course regarding the offer. Thomas Jaeger now took him up on his offer and, at the same time, put forward his idea of organising a series of international conferences designed to promote the urgently required spread of knowledge, which was developing everywhere. Pfender was not against the idea and, in the course of meetings in 1968, also agreed to allocate more staff to Jaeger, who could focus on it.
On 1 August Jaeger assumed the role of director of the sub-department "Load-bearing Capacity of Structures". The new employees were drawn from the ranks of his students in the subject of "Nuclear Structural Engineering" at the TU Berlin.
The effects of his initiatives quickly became obvious. As early as 1969, the annual report of BAM features two comprehensive pieces of work, which were produced in the field of nuclear structural engineering:
(a) Establishment of a basic programme for German research and development on prestressed concrete reactor pressure vessels (systems analysis and problem classification)
(b) Expert report on mechanical stresses on the core structures of the THTR pebble bed reactor
And the subsequent annual report gives details of three special projects, which had been successfully executed at BAM as part of a programme launched in the interim by the German federal government:

- Strength and failure of cementious concrete exposed to multiaxial loading within the temperature range from +20°C to +150°C.
- Investigation of content and transportation of moisture in concrete exposed to elevated temperatures
- Prestressed concrete reactor pressure vessel instrumentation

The R&D programme for prestressed concrete reactor pressure vessels had also been started up in numerous other places, and was to prove immensely successful under the continuous monitoring of a committee headed up by Thomas Jaeger.

The conferences initiated by Thomas Jaeger - of which more later - also took place in 1971 and then every two years, although they encountered considerable opposition from BAM rather than willing support.

The expansion of Thomas Jaeger's staffing contingent promised by the Federal Minister for Education and Science was a long time coming, and never reached the agreed scope. What's more, quite a few of the posts earmarked for Jaeger's group were actually allocated to other departments within BAM.

In a hidebound institution like BAM it comes as no real surprise that there was little enthusiasm for the activities of a certain Thomas Jaeger, whose field of work was characterised by interdisciplinary and international collaboration. And yet BAM gained clearly innovative impulses which have been pursued in quite a few areas, if somewhat hesitantly to begin with.

Jaeger frequently complained about pointless administrative procedure. He always saw much of it as superfluous from a professional point of view.

BIG SCIENCE

Speaking of BIG SCIENCE in connection with the field of civil engineering at BAM at that time may appear quite inappropriate, and yet Big Science evolved amidst the multitude of Thomas Jaeger's activities, first and foremost as a result of the very close collaboration with numerous institutions at home and abroad in dealing with highly complex problem areas. And, to be fair, in some cases Jaeger was able to fall back on great expertise at BAM.

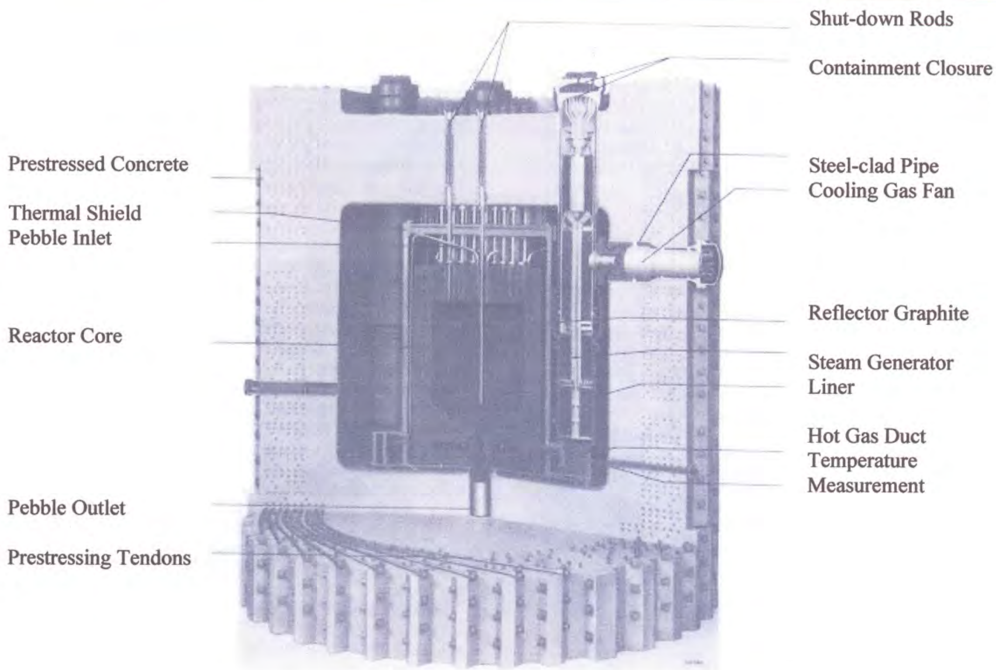
Prestressed concrete reactor pressure vessel

If one is in favour of the move towards gas-cooled high-temperature reactors, then the need for prestressed concrete reactor pressure vessels (if this simplified term may be used) is obvious, indeed imperative. Thomas Jaeger had been well aware of this fact for a long time, and his intentions regarding his activities at KFA Jülich were in line with this awareness. As early as 1958 he had written the following in a report in BAUINGENIEUR:

"In nuclear power systems using gas for heat transfer the increase of net power of the reactor system at a given maximum permissible temperature of the fuel elements is proportional to the enlargement of the reactor core diameter and the increase of gas

pressure. Thus, the design of the pressure vessel becomes the main point in the design of the entire nuclear power plant... .
When constructing ... the reactorsat Marcoule, France, an alternative solution (instead of steel vessels) was adopted for the design of the pressure vessel. Instead of meeting the three requirements: pressure resistance, impermeability to gas and radiation shielding as usual by using a steel pressure vessel surrounded by a concreteshell as radiation shielding, the French associated pressure resistance with radiation shielding by using a prestressed concrete pressure vessel and attained impermeability to gas by an inner steel lining... .
Prestressed concrete seems to offer a maximum of technical possibilities: great freedom of design, the possibility of realising vessel measures and pressures which cannot beachieved when using steel vessels as well as safety, and all this at relatively low costs.
"

Thomas Jaeger had been quick to realise that there was a great deal of potential in the concept of a prestressed concrete vessel, and it comes as no surprise that he found it fascinating, picture 4.
Fundamental political changes were occurring at around the same time as Jaeger started his work at BAM in 1968. Clear priority was allocated to research and development, whilst traditional outdated structures were seen to stand in the way of effective research. As a result, just months after joining BAM, Jaeger was commissioned by the federal government to draw up an R&D programme for prestressed concrete reactor pressure vessels. He had just been able to appoint a gifted young engineering scientist and the two of them, in conjunction with a hastily assembled group of experts, succeeded in compiling an unusual programme. Thomas Jaeger describes the concept at the "Second Information Meeting on Prestressed Concrete Reactor Pressure Vessels" in autumn 1969 in Brussels as follows:

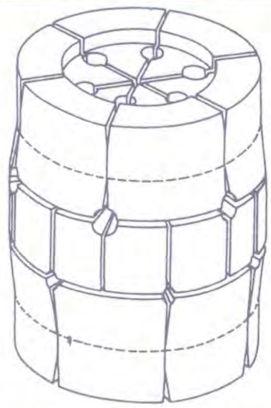


Picture 4. Model of prestressed concrete vessel of the 300 MW-THTR nuclear power plant at Schmehausen (Hamm-Uentrop) (Photo: HRB Mannheim)

> *"Essentially, the conception of this programme intends to put as much stress as possible on basic research. It is a regrettable fact that research carried out up to now is in most cases related to special projects ... so that the transferability and general applicability of results at international level is considerably limited. There is no evidence of future-oriented and effective utilisationof the large fund of research support. "*

Such a basic criticism of policy, characterised by a lack of any concept of allocation of research funding, could not be expected from the people who were rooted in this system.
And yet where can one find the kind of individuals who have not lost their independence within the system?
Research work on the project yielded the expected results in a relatively short time. The numerous contributions on the subject to the SMiRT conferences (of which more later) are testimony to this.
Mention must also be made of the fact that some significant contributions to the research project came from BAM, in particular the instrumentation designs for thedifferent areas of the

vessel and the proposed solutions for problems with the stability of the cement under three-axial stress and elevated temperatures, picture 5.



Picture 5. Yield line pattern of a prestressed concrete reactor pressure vessel (from : Konstruktiver Inieurbau, Reports, Issue 12, Essen 1915)

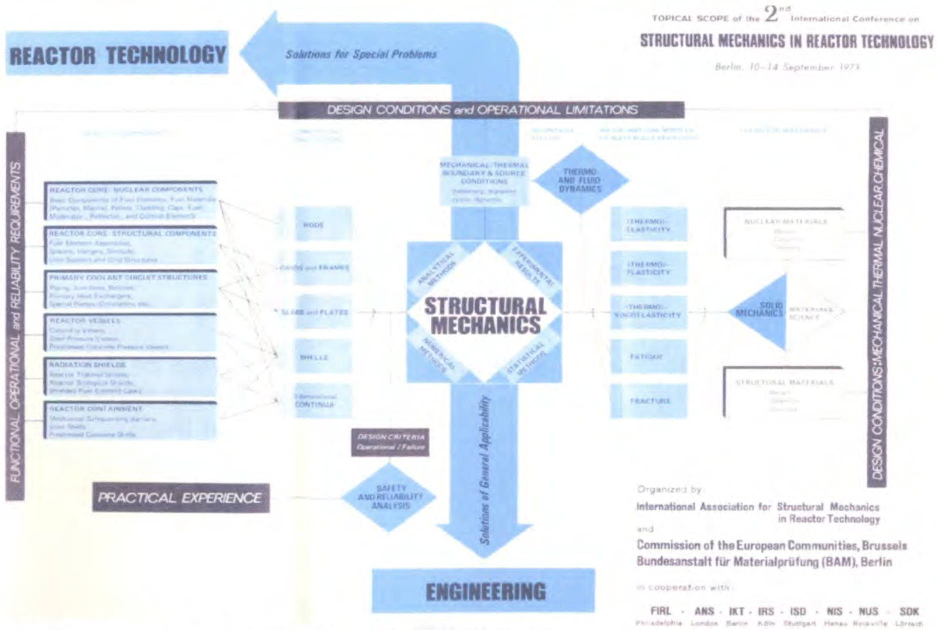
External influences on nuclear power plants

On the absolute insistence of Jaeger, the inclusion of so-called "external influences" on nuclear power plants in safety assessment terms had to be given the priority that was due to them as possible catalysts of "common failure scenarios": earthquakes and impact of an aeroplane crash.

Both areas produced comparable R&D concepts, whilst the problems associated with - earthquakes drew authoritative advice from abroad. One of the most comprehensiveR&D programmes examined the problems caused by the impact of an aeroplane on a reinforced concrete container. This particular project was studied extensively by German institutes and companies and won them such acclaim that it was even used as the basis for a joint Japanese-German R&D project in the late 1990s.

4. SMiRT – conferences

The "International Conferences on Structural Mechanics in Reactor Technology", or SMiRTConferences for short, were destined to become **the** central lynchpin of Thomas Jaeger's work, picture 6. As has already been mentioned, Jaeger was already toying with the idea of a series of events before he joined BAM, and its president at the time, Max Pfender, encouraged him in this plan. It is unlikely that anyone would really have expected the first major conference to be held just three years after starting work at BAM, although a minimum of two years was needed to prepare for an international event with many hundreds of participants. To organise a conference for the very first time would normally take a few years.



Picture 6. Topical scope of the SMiRT conferences with what was later to become the logo: the double-headed arrow [2]

Nothing was certain to begin with. Before he could even begin, Jaeger took out a not inconsiderable personal loan. Friends and colleagues from the editorial board of NUCLEAR ENGINEERING and DESIGN proved to be most helpful, indeed the conference would not have been feasible without the preliminary work done by the journal, picture 7. A preparatory international event held by the American Concrete Institute (ACI), which took place at BAM on Jaeger's suggestion in October 1970, ended in great success, which augured well for the larger conference.

Nevertheless, it was not possible to achieve financial backing of any kind, not even any of the basic sponsorship requested from the federal government. In the end, the Commission of the European Communities (CEC) absorbed all the costs for the preprints and proceedings and provided some organisational support. Then, a few weeks before the conference, the Senate in Berlin approved funding, albeit a sparse amount.

Picture 7. Strategy meeting to prepare for SMiRT 1. From left: Zenons Zudans, J. R. Feldmeier, Thomas A. Jaeger. John. H. Argyris

And so became reality the vision of Thomas Jaeger to bring together colleagues working in nuclear power technology, and to set up a much-needed association for thoseconcerned with the safety of nuclear power plants. There are extensive reports on the idea for these conferences but, unfortunately, insufficient space for them here. Feedback from official bodies may be used to speak for others:

The Federal Minister for Education and Science wrote:

"Dear Colleague !

My collaborators as well as some relevant German institutions informed me of the exceedingly great success of the First International Conference on Structural Mechanics in Reactor Technology initiated and organised by you. Even during a stay abroad, my attention was drawn to the excellent standard of this congress. With this congress, you delivered not only a valuable scientific-technical contribution, but you also considerably contributed to increase the prestige of the Federal Republic of Germany in the field of reactor technology...."

And Otto Kellermann, Head of the Institute for Reactor Safety (IRS), Cologne, wrote:

"I would like to take the opportunity to let you know that your conference was the best-organised meeting I have ever participated in. The arrangement of all lectures and sessions according to a clear basic concept as well as the technical and social

programme impressed me in the same way as did the excellent proceedings of the conference ."

Picture 8. SMiRT 1, 1971. Reception held by the Senate in Charlottenburg Palace, Berlin (from left: Senator König, Zenons Zudans, Thomas A. Jaeger, Frau B. Jaeger, K. Brandes, Frau E. Brandes)

It was during this first in a series of SMiRT conferences that the "International Association for Structural Mechanics in Reactor Technology" (IASMiRT) was founded, which organised future conferences, held every two years.

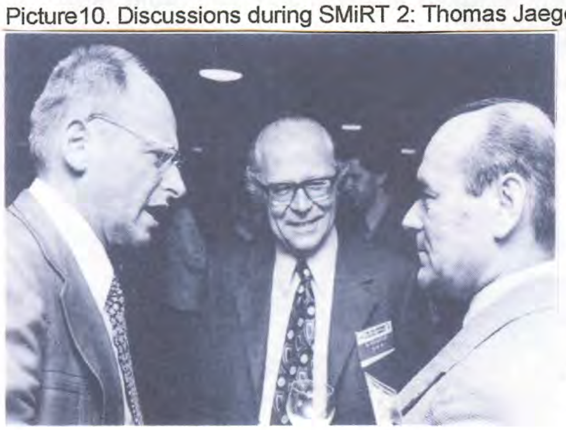
Picture 9. A H. Hadjian, who was to organise SMiRT 10, held in Anaheim, CA, during SMiRT 1 in front of the conference venue, the Kongresshalle in Berlin

This also removed the problems that were caused by the fact that Jaeger worked at the Federal Institute for Materials Testing, a body overseen by the Federal Ministry of Economics. From then on, Thomas Jaeger was able to operate very freely under the umbrella of IASMiRT, something that soon proved to be absolutely essential.

It was indeed significantly easier in the run-up to the next SMiRT conference, held again in Berlin in 1973, to obtain backing from the federal government and the Senate in Berlin, with the CEC now also proving to be reliable, and yet, after numerous engineering scientists from all over the world had responded to the call for papers, there were numerous withdrawals on the part of the U.S.A. The American administration had claimed that too much knowledge, including some of the information that reached Thomas Jaeger, had flowed from the U.S.A. to Europe for the first conference. The accuracy of such assertions is open to debate.

Thomas Jaeger decided to take drastic measures. On 16 April 1973 he wrote a letter, taken very seriously, to the American president, in which he explained in detail the origins and aims of SMiRT conferences, setting it all within the context of that era's political scene - a document of excellent technical-scientific diplomacy. This was of course done under the umbrella of IASMiRT. Whether the letter ever reached the president is open to question. However, it certainly caused a rethink in other areas; many of the withdrawn papers were resubmitted.

Picture10. Discussions during SMiRT 2: Thomas Jaeger with G. Schuster (CEC) and Antoni Sawczuk



The lists of delegates for SMiRT 1 and SMiRT 2 read like an international Who's Who of structural mechanics and reactor technology.

The third and fourth conferences were held in London and San Francisco.

The number of participants rose from an initial 800 to 1200. The 5th conference came to Berlin again, and was to be Jaeger's last. In spite of serious illness he was full of vitality, but he died a year later. At the last conference he was able to attend, it was decided to institute a **Thomas A. Jaeger - Prize** for outstanding contributions by young engineering scientists, and this has been awarded by the CEC on the occasion of SMiRT conferences ever since.

The tradition of SMiRT conferences lives on to this day, and remains dedicated to its mission of bringing together engineers and scientists in this vitally important field - the safety of technical systems - from all over the world.
The 20th conference in the series will be held in 2009 in Espoo, Finland.

5. Duties with the Reactor Safety Commission

It is an essential principle of engineering that the engineer - unless he does engineering purely as a science unrelated to practice - assumes, indeed must assume, very real responsibility. The engineer is held to account if his construction fails, whether it's because of design faults, unfounded assumptions during construction and layout of the facility or because of negligence during operation. Last but not least, human lives depend on equipment, machines and structures fulfilling their functions reliably.
There is arguably no doubt that this responsibility weighs all the more heavily with highly complex nuclear power plants than with conventional technical facilities. Thomas Jaeger accepted this responsibility when he answered the call to be appointed to the Reactor Safety Commission (RSK). The RSK is the advisory body on reactor safety for, and appointed by, the responsible federal government minister.
In 1970 Thomas Jaeger was appointed to the RSK for the first time. At the time a significant change was becoming apparent in this field: previous appointments had mainly been experienced experts, most of them elderly, who relied on their wealth of experience to assess the technical risks associated with new technology. This had not always achieved the desired aim, as much of their experience arose from working with quite different kinds of technologies. For some time prior to 1970, Otto Luetkens, who had written books on frameworks and mining subsidence, was on the RSK for civil engineering matters. They now had the right man for the job, an expert with in-depth knowledge of the latest issues relating to the demands placed on structural plant components and how to deal with them.
Jaeger essentially found himself at odds with the RSK from the start of his work there. As much as he was capable of shedding light on and identifying physical and technical interconnections, he refused in equal measure to show even the slightest understanding for the priority so often given to purely judicial or even administrative arguments.
The relationship between the amount of effort put in and the improvements in technical safety that were actually achieved gave rise in Jaeger to a gradual sense of resignation, having spentmany years doing his utmost to improve the structural safety of reactors.
At times Jaeger overemphasised the problem slightly, in order to be understood:

"Although a realistic analysis of the mechanical behaviour of nuclear power plants for regular operation is much simpler than calculations ... for highly transient dynamic accident conditions or external events, defects have occurred in the past, during normal

operation, requiring additional safety equipment. However, as much more care is required in reactor technology than in any other high technology (with the exception of space technology), the frequency of defects which have to be repaired is rather surprising. By the way, in this connection, there is a remark by Norman. C. Rasmussen (Combustion, 1974): 'Probably one of the most serious issues that the intervenors (critics of nuclear power) can raise today, with good statistics to back their case, is that the nuclear power plants have not performed with the degree of reliability we would expect from machines built with the care and attention to safety and reliability that we have so often claimed'. "

Thomas Jaeger was never able to summon up any understanding of the mainly bureaucratic obstacles placed in his way. He wrote about this directly to the Federal Minister of the Interior:

"A considerable barrier against the realisation of science and technology is ... aphenomenon, known in American literature as "principle of avoidance of cognitive dissonance". Cognitive dissonance is a phenomenon that affects both individuals and groups; those who experience it attempt to minimise internal conflicts by rationalising mistakes in decisions already made."

This makes it very difficult to learn from wrong decisions in the past, even though it is actually quite common in business and politics - where there is no real responsibility!

Thomas Jaeger took up his duties with the RSK at a time when the Commission was faced with a host of new challenges. Of fundamental importance were any questions connected with the new reactor types of the high-temperature reactor and the fast sodium-cooled breeder reactor. Around 1970 prototypes of both power reactor systems were commissioned: the 300 MW thorium high-temperature prototype power plant (300 MW-THTR) at Hamm-Uentrop and the prototype of the fast sodium-cooled reactor (SNR 300) at Kalkar.

However, whereas the high inherent safety potential of the THTR aroused such great interest on the part of Thomas Jaeger that he organised his own actual activities around it - for instance, the R&D programme for prestressed concrete reactor pressure vessels on the one hand, and the testing of reactor core structures on the other, referred to in section 3 -, his interest in the SNR 300 centred around its numerous physical and procedural features.

A whole new set of problem areas was addressed as he sparked off contemplation of so-called external influences, such as earthquakes and aeroplane crashes. It soon became evident that no provisions whatsoever had been put in place to cope with these profoundly damaging scenarios, and that Germany did not have the engineers needed to handle these matters. Thomas Jaeger attempted to remedy these shortcomings by organising some special events, with top experts from theU.S.A., with great success (seminar 1978 at BAM).

Shortly before that he had arranged a seminar entitled "Reliability Analysis of Systems and Components of Nuclear Power Plants", which was essentially organised by N. C. Rasmussen (author of the well-known Rasmussen Report in the U.S.A.) and A. M. Freudenthal. The subject of the probabilistic analysis of the safety of technical plants had also been paid scant attention for quite some time.

This period also marked the foundation of the German Society for "Earthquake Engineering and Structural Dynamics" (DGEB), although this did not take place until after Thomas Jaeger's death.

7. Teaching born of inner conviction

Since his time as a postgraduate student at the TU in 1963, Thomas Jaeger had given lectures in the Faculty of Civil Engineering on *Nuclear Structural Engineering*. Lectures were given at the Institute for Nuclear Technology on *Reactor Design and Radiation Shielding* subsequently. At the beginning of the 1970s, Thomas Jaeger and Klaus Brandes took joint responsibility for lecturing duties.

Then, from autumn 1974, he spent a semester as visiting professor at the MIT School of Engineering lecturing on *Structural Mechanics in Reactor Technology.* This series of lectures introduced the subject of *Structural Mechanics in Nuclear Power Technology* at MIT. A year later he then lectured on the subject again, at the University of California in Los Angeles (UCLA), in his capacity as visiting professor.

A. F. Keil, Deacon of the School of Engineering at MIT, wrote regarding this matter to the President of BAM:

> *I have received numerous outstanding reports of the quality and organisation of these lectures, as well as of Professor Jaeger's outstanding competence in this field. These comments have been given to me by members of my faculty, who are experts themselves in the field of structural mechanics....*

In a letter about his teaching activities, Jaeger wrote:

> *I regard my special disciplines as only being suitable for postgraduate studies for especially talented students who are particularly trained in the field of structural fundamental subjects. It seems rather sure that the reorganisation process (in the universities) leads towards emphasising the fundamental engineering sciences... and towards shifting specialisation... to postgraduate studies. It seems, however, that my perspective lies only in the field of postgraduate studies.*
>
> ...
>
> *My former enthusiasm, which was nourished by the impulse for the new technical special field, has now been replaced by a motivation nourished by the conviction that I am performing something very useful.*

Thomas Jaeger mentored and supervised numerous doctoral theses, still acting as an examiner at home just weeks before his death.

8. The crossroads between technology and risk

Thomas Jaeger had always wanted to be able to devote more time to the issue of technical safety. He was never allowed to do so, and yet his actions in themselves contributed greatly towards the safety of technical systems and a much-needed heightened general awareness of the issue. In some lectures and articles, however, he made it clear what the problems were and - in what was to be his legacy - left them behind. Two extracts from these texts should be quoted here in conclusion.

Nowadays it seems to me that the risk problem in technology has turned out to become one of the most pressing questions concerning the whole of industrial development. This problem is of fundamental as well as of highly practical importance. The answer to the question "How safe is safe enough?" requires a combination of reflective and mathematical thinking as well as the integration of technological, economic, sociological, psychological and ecological knowledge from a superior point of view.

One should suppose that such a complex and urgent problem concerned with the relations of being and consciousness of man towards his environment should call the philosophers on the scene. However, taking this presumption, one feels disappointed, and one is astonished about the fact that among the great number of philosophers there are only a few who try to gain a certain degree of understanding or show deeper interest in technology. It appears, however, one can hardly find concrete attempts to comprehend this problem. The few philosophers who share this interest seem completely prejudiced by arguments, which are variously emotionally loaded and concern the general being of the phenomenon of "technology", where different schools of idealistic thinking and rationalistic-empirical conceptions oppose each other. (Schweizer Archiv für angewandte Wissenschaft und Technik 36 (1910), p. 201-201)

With our technology being subject to ever new developments, the question "How safe is safe enough?" keeps coming up daily. So far this question was mostly handled in apragmatic way and in general gradually rectified in a slow process of adaptation to the system of social values and evaluations. Safety in many branches of our technology was traditionally developed in a dynamic process of adaptation. At the same time a gradual correction of risks was effected by a public alarmed (by major accidents or ecological disasters such as water pollution) - although with a considerable delay - but still these corrections did not meet the anticipated requirements. Sometimes risks occurred on account of certain egotistical business interests or also for lack of oversight of technical systems; this had to be corrected.

Reckless business behaviour and egotism of interest groups, of course, has to be counteracted on a legal and political level, and we cannot afford to allow potential and immediate hazards to happen due to gross misinterpretations of technical risks or lack of *system oversight, especially with the present state of this technology and its widespread use. The traditional saying "you learn the hard way" has to be discontinued and replaced by a more far-sighted, more comprehensive and more profound analysis of safety problems than has been practised so far. For this, the establishment of admissible risk values and an analysis methodology becomes necessary.*

Definition of acceptable and admissible values concerning technical risks, either for individuals or for society, contain, as well as a benefit/risk analysis, the consideration of individual and social-psychological factors. A combination of the above-mentioned different categories represents a major problem for industrial technology and the economy as well as society. We are talking about the individually and socially acceptable *compromise to answer the question "How safe is safe enough?". To answer "absolutely safe" is inadequate, because there is no absolute safety. To answer "as safe as possible" is no answer either, because with money and engineering efforts each technical risk can be reduced, but along with it the question arises whether this financial and intellectual potential could not have been deployed more effectively some other way for mankind's well-being. It is my opinion, however, that in each individual case one has to investigate whether a risk considered acceptable can be reduced even further with relatively little effort; for example ALAP ("as low as practicable"), a concept developed by the U. S. Environmental Protection Agency. ...*

The accomplishment of this task requires an intellectual methodology that integrates technical, economic, ecological, sociological as well as psychological understanding together with an evaluation modus. (Technisches Sachverständigenwesen, VDE-Verlag, Berlin, 1978, p 129-150)

9. Looking back, looking forward

This development, addressed and ultimately desired by Thomas Jaeger, is still barely underway and we can only understand it as a commission to continue further along this path.

The technical problems that occupied him are still there, although slight progress can be seen. The SNR 300 came to an end in his lifetime. Highly rated by Thomas Jaeger, the pebble bed reactor (THTR), a prototype of which was tested for several years, is being developed in some countries. Some time ago the Chinese government announced its intention to build a whole series of these reactors.

Nuclear power is the subject of new discussions in what is now a different context; can there be technology without risk?

Closing remarks

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In 1979 Thomas Jaeger was awarded the Distinguished Service Medal of the Federal Republic of Germany at the instigation of the Senate in Berlin. He, probably more than anyone else, had truly earned such an honour. He had become a civil engineer because he had been prevented from studying physics in the former GDR. Although he had not built great bridges or towers, he had been able to combine his fascination with physics, particularly nuclear technology, with a knowledge of structural engineering in such a way as to achieve remarkable things in a brand-new field. As a result of his unique achievements, he was able to attain worldwide recognition and a high degree of prestige, even under what were at the time difficult conditions for German engineers.

Every era brings new challenges for engineers, challenges that can no longer be overcome by standard training alone. Success can only come in an interdisciplinary and international environment and is no doubt one of our greatest challenges. Thomas Jaeger was a shining example in how to take on and overcome them.

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