70th Anniversary of the German Creep Committee [1]

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Abstract
The German Committee on Creep Resistant Steels (Arbeitsgemeinschaft Warmfester Stähle (AGWS)) was founded in 1949 on the initiative of German power plant operators with the aim of gaining reliable material parameters for the construction of power plant components. Steel manufacturers and users commenced immediately with long-term creep tests at temperatures up to 600°C. Soon the need for long-term investigations at even higher temperatures became apparent. The German Creep Committee on High Temperature Alloys (Arbeitsgemeinschaft Hochtemperaturwerkstoffe (AGHT)) took up its work on July 31st, 1957. At the beginning, the testing program covered creep resistant steels as well as cobalt and nickel base alloys. More materials were subsequently added, and the temperature range was extended from 600 to 1000°C and above.
Since 2015 the two collaborative committees are joint in one organization which is called "Forschungsvereinigung Warmfeste Stähle und Hochtemperaturwerkstoffe (FVWHT)", focusing now on martensitic and austenitic steels as well as nickel base alloys. Performing jointly organized long-term tests over as much as 100,000 h is indispensable – the safe operation of power plants cannot be allowed to depend on extrapolation of long-term properties from short-term data only.
Even though the energy sector nowadays depends on many different sources conventional power plants are still essential on the world stage. Residual life analysis becomes more and more important, and also more complex loading such as creep fatigue interaction have to be addressed due to the flexible operation of power plants compared to the past. Furthermore, an important benefit is generated for high temperature equipment manufacturers too.

1. History

By the mid-1930s, German industry had become the world's first to introduce steam boiler plants with operating temperatures above 500°C. The design and rating of this equipment was originally based on short-term trials of about 50 hrs duration. Following a number of failures, it became evident that long-term tests of up to 50,000 hrs were necessary. Such tests were initiated at the Institute of Materials Testing in Darmstadt and continued throughout the war years.

After the end of the Second World War, a temporary research ban was imposed on German steelmakers, setting the industry back in comparison to its competitors abroad. As the reconstruction of power plants and production equipment began, Germany went into a phase of fast-paced industrial development. Efficiency improvements could only be achieved by increasing process temperatures and pressures. This resulted in higher

component temperatures with correspondingly more complex mechanical and corrosive loading. The idea to raise steam temperatures to 600°C and beyond emerged as early as in 1950, prompting materials manufacturers to develop new steel grades with ever better properties.
At the suggestion of the German Association of Large Boiler Owners (now VGB PowerTech), the working group on "Collaborative Fatigue Tests" was created in the Mechanical Properties Subcommittee in 1949 by a number of tube and pipe manufacturers, foundries, and forging producers. Since the intended long-term tests would also be of direct benefit for steel users, the latter readily agreed to participate in the collaborative test programme. In this way, the Collaborative Committee for Creep Resistant Steels was born [1-4]. Interest was focused on

- the long-term behaviour of various material classes > 100,000 hours;
- the determination of 1% creep deformation limits and creep rupture strengths at temperatures > 500°C;
- the determination of causes of brittle fracture;
- investigations of long-term microstructural changes;
- material behaviour under alternating loads.

At the first meeting on 17th of February 1950, the following tests on boiler and turbine steels (with different compositions and heat treatment conditions) were proposed:

- 500°C: St 45.25, 15Mo3, 13CrMo4-4, etc. (8 heats)
- 550°C: 13CrMo4-4, 12CrSiMo8, 2CrMo steel, 16Cr13Ni, etc. (16 heats)
- 600°C: 16Cr13Ni, 12CrSiMo8, austenite, etc. (16 heats)
- 650°C: 16Cr13Ni, austenite, etc. (9 heats)

Further materials were added later.

The long-term tests were carried out using multi-specimen testing machines at the Darmstadt Institute of Materials Testing and multi-specimen furnaces at Farbenfabrik Leverkusen. Automotive materials were subsequently added, and test temperatures were raised further. While it had originally been intended to determine characteristics for 100,000-hour load periods, progress in plant engineering technology resulted in a growing need for even longer test durations of up to 200,000 hrs. To allow for acceptable variations in chemical composition and heat treatment status, the test results obtained with the various heats were grouped into scatter bands.
Interest in materials for gas turbines and aircraft engines grew at the same time. Such materials were not produced by all member companies of the Committee on Creep Resistant Steels, and the temperatures at which they had to be tested were well above 800 °C, involving significantly higher costs. The parties involved therefore decided on 27th September 1957 to establish the collaborative Committee on High Temperature Alloys. Its test programme initially targeted heat-resistant steels as well as cobalt and nickel base alloys. Other materials were added later, and the temperature range was extended to above 1,000°C.
An overview on history is given in **Figure 1**.

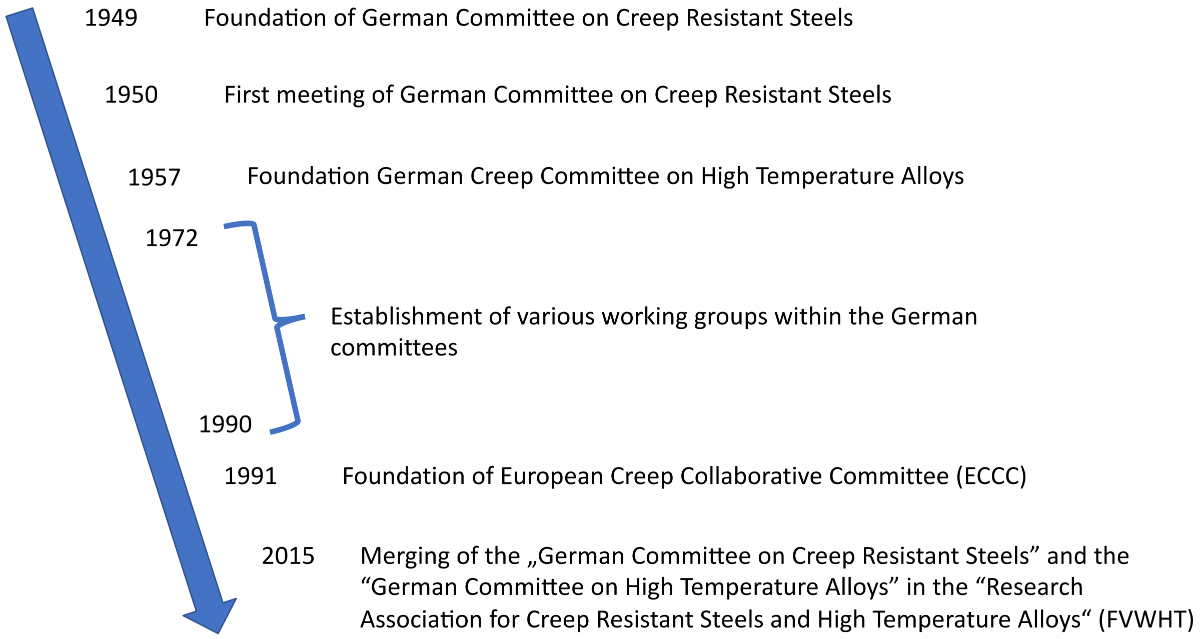

Figure 1: History of German Creep Group

Recognizing the value of this jointly organized work, more and more industrial companies began to participate in the long-term tests. To coordinate the large number of materials, various project groups were set up which determined and provided technical support for individual test programs. From 1949 to 2018, the German Creep Committee was managed by the Steel Institute VDEh, since 2018 the management of the FVWHT lies with the Forschungsvereinigung Stahlanwendung (FOSTA) e.V.
The civilian use of nuclear power and the development of the thorium high-temperature reactor raised a number of issues to be addressed by the manufacturers of creep-resistant materials. A cooperation extending over many years ensued between the Committee on High Temperature Alloys and the Juelich Research Centre. These activities ended in the late 1980s.
In the early 1990s, work commenced on the creation of European material datasheets. Until that time, a large number of national material datasheets for creep-resistant and high-temperature resistant materials had been in existence providing sometimes widely differing information. Standardization was urgently needed. The logical consequence was the formation of the European Collaborative Creep Committee (ECCC) in which European experts representing steelmakers and steel users have been cooperating closely to this day. Their joint review of national material data gave rise to the determination of scatter bands which are now harmonized at the European level and became the basis for today's standards. Concurrently, work was commenced to harmonize test procedures and evaluation methods.
Over the years the work of the two German committees AGWS and AGHT were organized very closely which led to the merging of the two collaborative committees in 2015 in the "Forschungsvereinigung Warmfeste Stähle und Hochtemperaturwerkstoffe (FVWHT)" which is now an independent association being supported by five organizations: Steel Institute VDEh, Bundesverband der Deutschen Gießerei-Industrie

(BDG), Forschungsvereinigung Verbrennungskraftmaschinen (FVV), FDBR e.V. – Fachverband Anlagenbau and the VGB PowerTech. The project groups of the AGHT were incorporated into the working groups of the AGWS, and the content changed from material-based working groups to product-based working groups.
The first main task of the FVWHT nowadays is the management, financing, and evaluation of the joint creep testing. Furthermore, it is steering publicly funded research projects which leads to a steady progress in knowledge for the member companies of the FVWHT and a close interaction with scientists at the universities.

2. Organization of joint work

2.1 Member companies

The membership of the FVWHT is made up of material manufacturers and users. The manufacturer's side today comprises producers of tube and pipe, sheet metal, forgings, castings, and weld filler metal. On the user side are turbine and jet engine makers, boiler manufacturers, and power plant operators. Ranging in size from small and medium-sized enterprises (SME) to multinational groups, these member companies cover the entire production chain (28 companies in 2019).

2.2 Financial basis

At the time the Committee for Creep Resistant Steels was founded, steelmakers were aware that the projected long-term tests could only be funded through co-financing by the member companies. Steel users, expecting to benefit from the results as well, likewise contributed to the funding of joint tests. Therefore, the membership fees are used mainly for the financing of the joint creep tests, so all member companies are able to profit from the results. The not-for-profit (common interest) nature of the activities are laid down in FVWHT’s statutes. The FVWHT also initiates research programs for which external funding is obtained. In some cases, long-term tests are transferred to the collaborative committees following the expiry of interesting research programs in order to continue these projects out of own funds to the industrially required 100,000 and more hours.

2.3 Joint testing of materials

The tests carried out by the collaborative committees comprise mostly creep testing but also hot tensile, creep cracking, and strain cycling tests. Investigations are carried out with regard to both base materials and weldments, given that many components will undergo welding prior to use. To simulate real-life conditions, weldment samples are produced by the member companies in the intended material combination before testing is commenced. In addition, tests have been conducted to examine specific issues relating to the interaction between manufacturing processes and component properties.
The execution of joint tests is entrusted to testing laboratories. A key criterion for selecting these establishments is that only independent institutes or laboratories serving the material users should be commissioned to do the work. Today these are:

- the Institute of Materials Science at the Technical University of Darmstadt;
- the State Institute of Materials Testing in Stuttgart;
- the Siempelkamp Prüf- und Gutachter-Gesellschaft mbH, a Dresden-based testing and consultant experts' society.

In the collaborative committees' early years, the Max Planck Institute of Iron Research in Duesseldorf also contributed some of the necessary materials characterization expertise.

The collaborative committees strive to maximize the capacity utilization of the available testing facilities, using mainly multi-specimen machines. With this test method, long-term testing can be conducted cost-efficiently at multiple test temperatures and stress levels. Upon completion of a test, i.e. when the specimen ruptures or is removed on schedule upon reaching its specified service time or elongation, the next specimen is mounted right away. Tests can thus be offered more cheaply than individually commissioned one-off tests – this is a major financial benefit of joint testing. Several specimens can be arranged in series, combined into a strand via connecting elements, and loaded at the same time. More cost advantages are achieved in this manner. For exact mapping of a material's behavior in all three creep ranges, continuous strain measurement is the approach of choice. A particularly advantageous method is to record creep tests initially in single-specimen testing machines with continuous strain measurement and to transfer the specimens into a multi-specimen machine once the secondary creep range has been exceeded. Long-time tests can thus be continuously documented. The specimens are monitored without interruption, and test data are logged by a computer-aided system.

In total, the FVWHT has as of now well over 170 test slots in use at the testing laboratories in Darmstadt, Stuttgart, and Dresden. The longest test running at the time is a Ni-Co based alloy of type A617 at 700°C to characterize the creep strain behavior at low stresses, time > 263,000 hrs (30 years).

In addition to the tests financed via the FVWHT, member companies have repeatedly contributed results of so-called private long-term tests to the FVWHT's data, especially where scatter band evaluations had to be conducted for individual steels.

2.4 Data acquisition and joint assessments

In the early years, test data were logged using index cards and chart recorders. With the advent of electronic data processing technology, a central data computer was purchased at the Duesseldorf office in the late 1980s. It held the so-called ZSF Database, an ORACLE database system running on MS-DOS which permitted convenient data acquisition and analysis. The system operated reliably for many years until it became technically obsolete. Since its data visualization capability had become outdated as well, the ZSF Database was replaced with a new and advanced system - the LAMBDA Database - in late 2005. This system provides the necessary interfacing for an exchange and analysis of data with different evaluation programs.

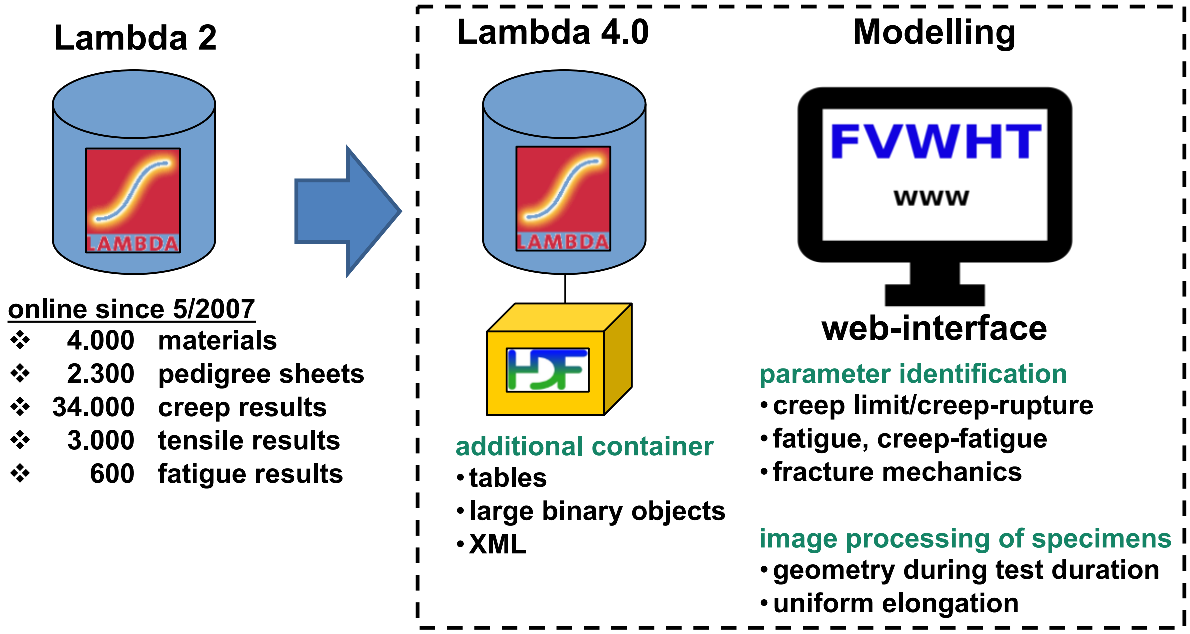

Figure 2: Database LAMBDA – overview of current and future features

Members of the collaborative committee can access the data online, and the information thus retrieved is virtually of same-day accuracy since raw data are transmitted continually to the central server from the measuring computers in Darmstadt. For the data analysis, the Darmstadt testing laboratory offers specialized software systems operated by skilled staff.
One key prerequisite for deriving scatter band data from various sources is that all parties involved abide by the Guidelines for the Conduction of Creep Tests developed by the Committee on Creep Resistant Steels. Consistent with modern quality assurance principles, these guidelines contain detailed definitions of the necessary material documentation, production, and testing procedures. An important aspect is the extensive pre-inspection of materials for compliance with standard specifications.

2.5 Joint research

Apart from the large industrial groups, few companies possess their own R&D departments which are in any case generally focused on typical development projects for in-house use. Small to medium sized enterprises frequently lack the budget to engage in joint research activities, e.g. in cooperation with customers. Such companies can, however, apply to a number of sources for funding to pursue developments jointly with users of their products. Forming consortiums is the task of the FVWHT. They in turn rely on the extensive experience of the testing laboratories when it comes to drafting the project applications. This pooling of capabilities ensures a high rate of success of the research project applications submitted. Providers of research funding are mainly

- the German Federal Ministry of Economics and Energy (BMWi) (AiF projects);
- the German Steel Application Research Foundation (AVIF projects).

The budget of these joint projects is usually many times higher than the budget of the FVWHT. The mix of large and smaller companies making up the working groups which guide a given project ensures a very practice-focused research approach backed closely by the committees' project groups. The members of the FVHWT thus contribute and profit directly to a project's success.

2.6 Presentation and publication of results

Selected project results are presented to the public at annual lecture meetings organized ever on the last Friday of November since 1975. These events are also attended and supported by experts who, although not members of the committees themselves, report on current results of their own work, thereby contributing to the experience sharing process [5].

3. Project groups – focus of current work topics

The basis of joint activities, now as before, consists in the in-depth work conducted within the project groups. Their tasks comprise the joint definition of testing plans which is not always easy in view of the very heterogeneous interests involved. Test parameters (test temperature, stress, duration) are defined and combined into a test schedule. These documents, together with the pre-testing certificate drawn up to characterize the material, provide a complete description of the joint test to be conducted. Following joint approval, the specimens are fabricated and tested then. The test results are discussed and jointly analyzed by experts. Safeguarded long-term data for the materials investigated are the result of this work.

The work of the project groups is coordinated by the Steering Committee. This body meets all 6 month and defines the budget for tests, decides on new test programs and research projects, coordinates national and European standardization activities, and reports on the cooperation with international organizations. For work performed within the ECCC, test programs forming the German contribution are defined. Finally, the annual lecture meeting is prepared.

A number of specialized project groups made up of experts from the respective manufacturing and user companies have been set up within the FVWHT for the various product forms, testing tasks, and open research topics.

Table 1: Current working groups of the FVWHT

Project Group	Founded	Subject
W1	1975	Creep resistant tubes, pipes and plates
W2	1981	Creep resistant cast materials
W3	1975	Creep resistant forged materials and bars
W10	1980	High temperature behaviour under changing loads
W11	1983	Relaxation behaviour
W12	1972	Residual service life
W13	1965	Testing technology and analytical issues
W14	1982	Creep crack propagation
W15	1990	Committee on creep resistant steels

While the project groups W1, W2 and W3 deal with the steering of the long-term tests, the project groups W10 to W14 monitor publicly funded research projects and other general topics with the view of industry and the later applicability in real products. Some key activities of the project groups are outlined in the following (**figure 3**).

	Component	Material Properties							
		0.2 Yield strength	Creep elongation limits	Creep rupture strength	Relaxation behaviour	Crack resistance	Crack growth	High Cycle Fatigue	Low Cycle Fatigue
Turbine	High Pressure rotors and casings	X	X	X		X	X	(X)	X
	Bolts	X	X	X	X				
	Valve casings	X	X	X					X
	Blades	X	X	X				(X)	
	Blades root		X	X				X	X
Steam generator, pipes and tubes	Membran wall	X		X					
	Superheater tubes		X	X					
	Live steam pipes	X	X	X					X
Others	Weldments			X		(X)			X
		W1-W3			W10-W15				

Figure 3: Overview on the current working groups focus in FVWHT, example for power plant applications

Project group W1 - Creep resistant tubes, pipes and plates

Its activities started out with investigations into low-alloyed ferritic materials such as 15Mo3, 13CrMo4-4, 10CrMo9-10 with a view to including these grades into national standards. The project group continued to perform creep tests on unalloyed steels and alloyed Mo and CrMo grades for boiler making and pipeline applications. The group also cooperates closely with ECCC-WG3A, e.g. in creating data sheets for the materials X10CrMoVNb9-1 (P91), X10CrWMoVNb9-2 (P92) which are soon to be released by ECCC as a new revision.
Furthermore, project group W1 has creep tests running on materials such as Alloy 617, C263, Sanicro 25, and USC DMV141.

Project group W2 - Creep resistant cast materials

Casting alloys were the first materials examined by this project group which started its activities when the foundries organized within BDG joined the FVWHT. Its initial work

consisted in the analysis of test data relating to 1CrMoV steel GS17CrMoV5-11 and similar-metal weld joints. Today this project group examines the long-term properties and weldability characteristics of creep-resistant ferritic/martensitic steel castings and also determines weld strength factors. Coordinated long-term characteristics determined by this project group have been used as input for the steel castings standard DIN EN 10213, among others.
Current testing activities relate to similar-metal welded joints (same-type and mixed combinations) of 9% Cr steels, e.g. P91/GS17CrMoV5-10 and CB2/P92 weldments.

Project group W3 - Creep resistant forged materials and bars
This project group examines the effects of production and processing operations on the long-term behaviour of low and high-alloyed creep resistant steels for heavy rings, discs, and shafts used in turbine industry. Current tests involve forged rings and shafts as well as forgings made of materials such as F92, FB2, and tests on A286 are being prepared.

Project group W10 - High temperature behaviour under changing loads
Dedicated to the examination of creep behaviour under variable loads and of creep fatigue characteristics, this project group currently deals with the following topics in publicly funded projects:

- Quantification of notch support effects for cast steel components against the background of more flexible power plant operation (AVIF A310)
- Lifetime and damage mechanisms of thick-walled housing components made of modern cast steel operated at variable loads (AVIF A307)

Project group W11 - Relaxation behaviour
This project group deals with questions concerning the relaxation behaviour. Currently the following publicly funded project is worked on:

- Inspection concepts for high temperature flange and bolt connections in flexible plant operation (AiF 20088)

In addition to the supervision of research projects the creep and relaxation tests on Nimonic 101 and Nimonic 80A financed by the FVWHT are supervised.

Project group W12 - Residual life time of components
For power plant operators it is very important to be able to judge the in-service behaviour of components exposed to high temperatures and pressures. This group initially dealt mainly with remaining service life assessments and damage development studies in low-alloyed ferritic steels but today it also studies time-related defect formation patterns on the new 9-12%Cr steels within the framework of research projects. The current research project is

- Determination of the remaining service lifetime for critical components of existing power plants with flexible operating cycles (AVIF A302)

Project group W13 - Testing technology and analytical issues
This group develops and updates recommendations for the execution and assessment of high-temperature tests. Such recommendations are anchored in the FVWHT guidelines and are key to obtaining reliable and comparable characteristics from the different German test laboratories. Issues relating to the international harmonization of test and evaluation procedures are also addressed by this project group. Long-term

archiving with the help of the LAMBDA database system, which was developed "in-house", assures the online accessibility of valuable long-term data to members of the FVWHT at any time. Project group W13 thus serves as an important link between research, test, and interpretation functions within the collaborative committees.
Current research projects are

- Advanced methods for the reliable determination and evaluation of creep elongation and creep rupture values (AVIF A 297)
- Robust Fracture Deformation Parameters (FVV own funding and AVIF A314)
- Continuous development of evaluation and modeling tools (material testing 4.0) (FVWHT own funding)

Project group W14 - Creep crack propagation
In this project group research programs aimed at describing the creep cracking behaviour and propagation patterns of creep-resistant materials are addressed. Since crack behaviour could not be computed until the 1970s, components were designed and rated on an empirical basis, often resulting in an excessive consumption of material. The project group examines approaches for assessing creep crack initiation and propagation.

- Assessment of defects in welded joints for power plants under flexible operation (AVIF A 300)
- Simulation of the crack behavior of coarse-grained nickel alloys at high temperatures (AiF 19226)

Project group W15 - Committee on creep resistant steels
Established as the professional forum for the study of creep-resistant steels in the former GDR, the technical committee reorganized in 1990 and has since been dedicated to promoting experience sharing among steelmakers, power plant manufacturers as well as power supply companies. Lecture meetings are organized at the sites of regional power technology providers. While in terms of subject matter this project group is assigned to the FVWHT, it operates as an entirely independent organization and is managed by the Dresden test laboratory.

4. International cooperation

The member companies of the collaborative committees operate not just in Germany but in Europe and overseas as well. This reflects the global positioning of the country's steelmakers and steel user community. Their involvement in various research projects and professional circles provides the members of the collaborative committees with ample experience-sharing opportunities. Although the raw data collected by the committees are not disclosed, evaluation output data are compared to the information obtained in other projects. This practice enhances the validity of the results obtained and allows researchers to establish internationally supported, characteristic design and rating parameters which may serve as input in the preparation of European Standards and other normative specifications.

4.1 Cooperation with the ECCC

In response to the growing importance of the European Standards system, the European Collaborative Creep Committee (ECCC) was founded in the 1990s on the initiative of the German Collaborative Committee on Creep Resistant Steels and several experts and companies in the UK [3]. A number of industry specific working groups conduct confidential assessments of specific materials. Besides these, there is an open group which directs their activities towards drawing up European testing and evaluation guidelines. To this end, resources have been obtained from three successive European research funding programs from 1991 to 2005. After funding from the European commission ceased in 2005, ECCC continued on a voluntary basis, but some momentum was lost. Since 2011 ECCC activities are funded again through Joint Industrial Projects (JIP), i.e. ECCC is financed through member companies. Each JIP lasting three years. The JIP3 is currently underway with approx. 30 partners.

Working Groups of ECCC are
- WG1 – Data Generation and Assessment Procedures
- WG3A – Ferritic steels
- WG3B – Austenitic steels
- WG3C – Nickel base alloys

One important task of FVWHT's project groups is to mirror the ECCC's work. This is especially in view of the fact that several member companies cooperate in both organizations. ECCC activities are reported, assessments obtained in the FVWHT and ECCC are compared, and new ECCC test programs are initiated. Key products of this cooperation include
- ECCC Recommendations
  - Volume 1 - Overview
  - Volume 2 - Terms and terminology
  - Volume 3 - Recommendations for data acceptability criteria and the generation of creep data
  - Volume 4 - Guidance for the exchange and collation of creep data
  - Volume 5 - Guidance for the assessment of uniaxial creep data
  - Volume 6 - Residual life assessment and microstructure
  - Volume 7 - Guidance for the assessment of creep crack initiation in test pieces and components
  - Volume 8 - Guidance for the assessment of multi-axial creep test data
  - Volume 9 - High temperature component analysis
- ECCC Data Sheets
- European Assessment Methods

4.2 Cooperation with NIMS / Japan
Intensive experience-sharing is currently being pursued with the National Institute for Materials Science (NIMS) in Tsukuba, Japan. This institute develops materials for use in e.g. power generating equipment. Up-to-date findings are regularly exchanged at joint workshops. This process is lead managed by the Stuttgart and Darmstadt test laboratories which, in conjunction with NIMS, organize the events and the associated experience transfer. Invited participants from industry take part and discuss the findings and scientific conclusions.

5. Benefit of the joint work approach
The activity of the FVWHT is focused on investigations of established materials with the aim of confirming their long-term performance characteristics. These data supplement existing scatter band assessments and also indicate trends, e.g. concerning the long-term behavior of welded joints, or the influence of heat treatment.

In individual cases, long-time testing is conducted jointly by manufacturers and users as part of the material approval process. The material characteristics obtained are made available to all member companies of the FWVHT, given their relevance for design. The evaluation results of the test programs were originally summarized in the committees' so-called "Ring Binder".
A publication of assessment data in form of separate material data sheets was postponed in favor of the ongoing standardization work and data sheets published by ECCC after gathering creep data from additional sources besides the FVWHT and its members from other European countries. These data have been incorporated into numerous European and international standards. Via standard committees the collated long-term material characteristics are harmonized once again with the stakeholder community, i.e. steelmakers, steel processors, steel users and certification societies.
It should also be mentioned that new findings on long-term testing technology gathered by the research laboratories are incorporated into the relevant testing standards via the Materials Testing Standards Committee of the DIN Institute.
In recent years there have been great advances in evaluating and modelling of material behaviour. The FVWHT working groups have made their contribution and have carried out diverse research projects. Many of the achieved results will also be of benefit for the FVWHT members as the FVWHT finances a running project that uses the existing tools for a continuous improvement and enhancement of data analysis in the age of the so-called Industry 4.0.
However, despite all progress achieved in modelling and extrapolating long-term data, the analysis of long-term tests and the resulting conclusions remain the cornerstone of all present and future work aimed at providing reliable technology for our society that is still needed in the time of a more and more diverse energy mix resulting in more complex challenges.
The test programs conducted to date by the FVWHT have without exception provided a wealth of valuable material data for the design of components made of creep-resistant steels and high-temperature alloys, and these data are being used directly in practice. Optimum utilization of materials, efficient use of resources, and sustainability can only be achieved through safe design and reliable service life time. This wealth of material data can only be financed by cost sharing through this common work.
Selected results of the joint scientific and practical work are presented and discussed with users at the FWVHT's annual lecture meeting. This is one means by which the FWVHT is the platform for precompetitive collaborative work which gives engineers the chance to interact with experts along the whole process chain and to improve it.
The continuous progress in science is finding its way to industry by the interaction between universities and companies that is possible through the activities of the FVWHT and the technical and application-oriented discussions within this community.

6. Summary and Outlook

Although in our day and age data appear to be readily accessible online at any time, a great deal of effort is still required to produce well-founded, reliable, and representative data. Collaborative endeavors offer many benefits even today. This is demonstrated by the achievements of the FVWHT. Over the past seven decades the successful work has been a key driver of the industry's ability to catch up quickly with the international state of technology after the Second World War and to attain the leading position it holds to this day. The results of practice-focused joint research projects have been speedily implemented.

The FVWHT's extensive database and the results of "private" long-term tests carried out at a number of member companies supplement one another ideally; both are indispensable for the reliable determination of scatter bands. The trustful cooperation between material producers and users, from the start of the production process onwards, prevents the selection of unsuitable materials and manufacturing processes and ensures that only materials with assured long-term characteristics will be employed. The FVWHT's work can therefore be rightfully considered part of the quality management and improvement process, eliminating, as it does, the need for much additional testing. All this has enabled the users represented in the collaborative committees to produce internationally competitive power generating and/or high temperature equipment.
Reliable long-term characteristics of highly creep resistant materials are indispensable for the design and operation of fossil-fired power stations with highest efficiency and lower CO_2 footprint helping to preserve the natural resources. The same applies to high-temperature alloys for jet engines. Due to the challenges of the more diverse energy production the requirements on the materials change as power plants operate with more flexible load and temperature cycles than in the past which the materials will have to withstand. These are questions that the FVWHT has made and will make a decisive contribution. Open questions such as the creep testing of additively manufactured materials (AM) will be addressed soon so that the members of the FVWHT can benefit from knowledge created here in order to make their companies prepared for future demands.
Globalization also presents new challenges for the collaborative committees. With steelmakers and steel users now operating globally, international technical exchange has gained more importance again. The FVWHT became involved in European and international cooperation schemes so that it can be reported back to the relevant working groups in order to generate well-founded technical answers to global challenges. To continue the successful work undertaken in the past, the proven concept of bringing together manufacturers and users of materials and of maintaining a steering committee to guide the FVWHT's activities is all the more essential today. If this is safeguarded, the FVWHT will continue to address upcoming questions in a changing and new industrial environment and to operate for the benefit of all their members now and in the future.

List of abbreviations

AGHT	German Creep Committee on High Temperature Alloys / Arbeitsgemeinschaft Hochtemperaturwerkstoffe
AGWS	German Committee on Creep Resistant Steels / Arbeitsgemeinschaft Warmfester Stähle
AiF	Arbeitsgemeinschaft industrieller Forschungsvereinigungen "Otto von Guericke" e.V.
AM	Additive Manufacturing
AVIF	German Steel Application Research Foundation / Forschungsvereinigung der Arbeitsgemeinschaft der Eisen und Metall verarbeitenden Industrie e.V.
BDG	Bundesverband der Deutschen Gießerei-Industrie e. V.
BMWi	German Federal Ministry of Economics and Energy / Bundesministerium für Wirtschaft und Energie

DIN	Deutsches Institut für Normung
ECCC	European Creep Collaborative Committee
FDBR	FDBR e.V. – Fachverband Anlagenbau
FOSTA	Forschungsvereinigung Stahlanwendung e.V.
FVV	Forschungsvereinigung Verbrennungskraftmaschinen e.V.
FVWHT	Forschungsvereinigung Warmfeste Stähle und Hochtemperatur-werkstoffe
LAMBDA	Data bank of FVWHT for data storage and data evaluation
NIMS	National Institute for Materials Science, Japan
SME	small and medium-sized enterprises
VDEh	Steel Institute VDEh
VGB	VGB PowerTech e.V.
WGxxx	Working group in ECCC
ZSF	Zeitstandfestigkeit / creep strength

Literature

[1] This article is based on: “60th Anniversary of the German Creep Committee”, I. Steller, W. Bendick, T.-U. Kern, K. Maile, M. Monsees, A. Scholz on the occasion of the 2nd ECCC conference, 21. – 23. April 2009, Dübendorf, Switzerland

[2] J. Ewald, W. Bendick, J. Granacher, K. Maile, K.H. Mayer, B. Melzer, W. Rohde, E. Tolksdorf: 50 Years of Joint German Activities in the Area of Creep Resistant Materials, High-Temperature Materials and Design International Colloquium on the occasion of the 50th Anniversary of the German Creep Committee, 23. November 1999, Düsseldorf, Germany

[3] D.V. Thornton, J. Ewald: Future Aspects on Joint Activties – Activities of the European Collaborative Creep Committee, High-Temperature Materials and Design, International Colloquium on the Ocassion of the 50th Anniversary of the German Creep Committee, 23. November 1999, Düsseldorf, Germany

[4] J. Ewald, W. Bendick, K. Jäger, G. Gnirß, R.-U. Husemann, K.-H. Mayer, B. Melzer und E. Tolksdorf: Fünf Jahrzehnte Arbeitsgemeinschaft für warmfeste Stähle – Notwendige Auslegungsdaten für den langfristig sicheren Betrieb bei hoher Temperatur-, 21. Vortragsveranstaltung Langzeitverhalten warmfester Stähle und Hochtemperaturwerkstoffe, Tagungsband, Düsseldorf: Stahlinstitut VDEh, 1998, S. 27/38

[5] Tagungsbände der jährlichen Vortragsveranstaltungen „Langzeitverhalten warmfester Werkstoffe und Hochtemperaturwerkstoffe“, diverse Jahrgänge seit 1975