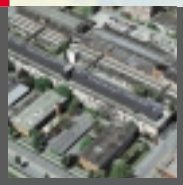
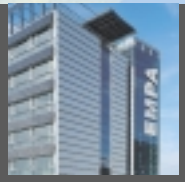
Annual Report 2001

Key areas
and
selected projects
of the year 2001





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Swiss Federal Laboratories for Materials Testing and Research EMPA A Reserach Institution of the ETH Domain

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Empa

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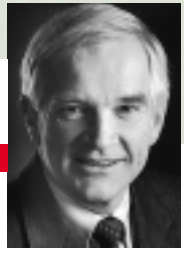
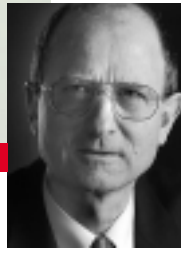


Louis Schlapbach



Urs Meier

Xaver Edelmann

Newly restructured and clearly positioned

Atoms can be put together in different ways to create bulk substances. For example carbon atoms can form soot, graphite, carbon fiber, diamond or carbon nano-tubes, each material having a different structure. Physical states can also be changed – graphite can be metamorphosed into diamond, or (more easily) diamond can be subjected to high temperatures to produce carbon. Antoine-Laurent Lavoisier successfully accomplished this in the 18th century using a large lens to concentrate the rays of the sun. The functional characteristics of a material are the result of the appropriate assembly of many atoms and the properties of the individual atoms themselves, producing, for example, a good conductor, a lubricating agent, or a beautiful glittering crystal.

A excellent analogy, in fact, for Empa itself! Our staff members supply the individual knowledge and ability. Together, they crystallize into that which Empa strives to be: a highly respected research institute. The development of this process was begun by Prof. Dr Fritz Eggiman, who led Empa from 1988 to 2001. His tenure was characterized by clarity of purpose, responsibility and judiciousness. We thank him sincerely for his extraordinary commitment.

With a new structure (planned and introduced over the period 2001/2002) comprising five science and technology departments plus a Logistics, Controlling and Marketing department, Empa has underscored its position in the Swiss research domain.

The two Federal technical Institutes, the ETH Zurich and EPF Lausanne, concentrate on fundamental research questions. The technical universities are responsible for product-oriented research and development. The four

research institutes of the ETH domain (Empa, Eawag, PSI and WSL) lie somewhere in between – they build upon the fundamentals and create an environment which encourages the application of basic research to practical problems. The Empa has the particular role to play in this environment: it is **the** research institute of the ETH domain for materials science and technology.

We have strengthened our research activities with three essential steps. First, we have defined key area programs, based on the ETH council's innovation and cooperation projects. These key areas include nanotechnology, adaptive materials, sustainability in the information society, materials for the protection and comfort of the human body, and technosphere/atmosphere. By concentrating our strengths we are creating synergies.

Second, we have allocated a substantial fraction of our resources to competitively selected in-house projects. The competitive nature of the selection process and the stringent evaluation by external experts have improved the quality of our research. Out of two selection series, only 20 projects were singled out and released for funding although 59 were submitted for consideration in the first serie and 80 in the second.

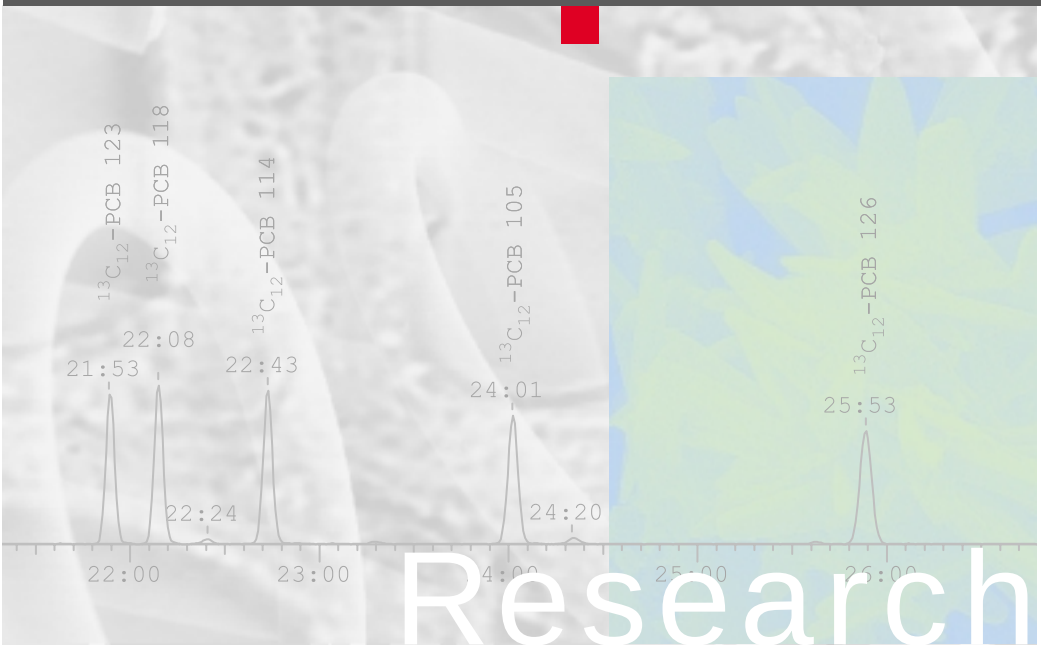
Finally – last but not least! – we are increasing the recruitment of staff who are particularly suited for research activities.

Empa is a partner of the institutes of the ETH domain and of the cantonal universities, the technical universities, industry and economy, local and federal authorities who have no laboratory facilities, and of the international science community. It is an established feature in the research landscape. Furthermore, Empa accomplishes valuable services as a nationally and internationally recognized neutral and competent materials testing institution. The research programs and selected projects described in this Annual Report offer the reader a glimpse of our work. For a more comprehensive and detailed scientific view please see «EMPA Activities 2001».

We hope you enjoy reading about our work!

On behalf of the Board of Directors

Louis Schlapbach, Urs Meier, Xaver Edelmann



Research programs

Nanotechnology
Protection, comfort and health of the human body
Adaptive materials systems
Technosphere – Atmosphere (TECAT)
Sustainability in the information society

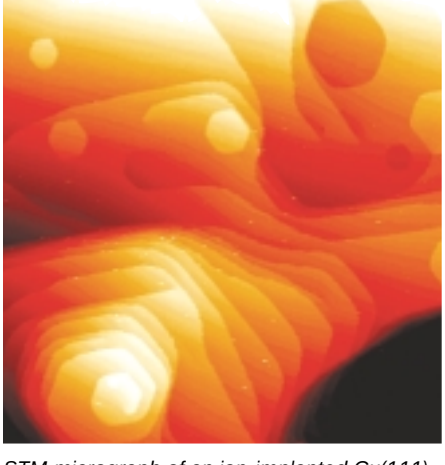
Material design on the nanometer scale

Empa is establishing a center for applied nanotechnology on the basis of the Innovation Program «Nanotechnology» selected by the ETH Board. This center of excellence is intended to promote practical implementation of developments and new findings in nanotechnology and will provide Swiss industry with orientated research and high quality services. Empa is contributing its extensive experience in surface and materials technologies, disciplines in which we have long been working in the nanometer range. The second year of the program, 2001, was a key phase: on the one hand, developments that were already under way were successfully consolidated, while, on the other hand, new challenges demanding innovation began to emerge from joint projects.

The essential factors in our success in nanotechnology developments are our familiarity with the materials sciences and our involvement in external research programs, in particular the NANO 21 Technology Orientated Program (TOP) launched by the ETH Board and Commission for Technology and Innovation (CTI), in which we are one of the leading institutions alongside EPF Lausanne and ETH Zurich.

Nanopowders for ceramics

In the «nanoparticle ceramics» research cluster, a feasibility study jointly carried out by Empa, a university and industry revealed that non-aggregated silica nanoparticles are ideal for use in dental composite materials (see also article on page 20). The great potential foreseeable for nanopowders in modern materials research and application encouraged us to set up a pilot-scale flame synthesis plant for production of various oxide nanoparticles. We have started developing work on a plasma facility for manufacture of non-oxide nanopowders, on the one hand benefiting from our specific process technology skills for the preparation of precursor materials and on the other hand, from our wide knowledge on characterization of nanoparticles deriving from combustion processes. The outlook for future industrial applications of tailored nanoparticle polymers and coatings is very promising.

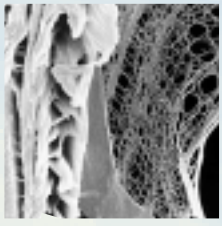


STM micrograph of an ion-implanted Cu(111) surface after partial annealing

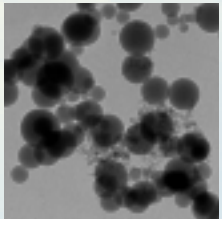
Nanostructured Surfaces

Research into specially textured surfaces with functional properties yielded important fundamental discoveries. Interest is focused here among other things on the effects of chirality (i.e. films generated either from left-handed or right-handed molecules) and mechanochromism (modification of the absorption spectrum under mechanical stress). In both cases, the emphasis is on exploiting the associated optical effects.

In the development of inorganic thin films, it proved possible to move on to heterogeneous systems (two-phase composites and multilayer structures), in which outstanding properties can be achieved by nanostructuring in the 10 nanometer range. Our long



Chemically treated wood cell wall: the fine cellulose fibrils, which impart strength to the wood, might be used for reinforced polymers.



TEM (Transmission Electron Microscope) micrograph of an unagglomerated, spherical SiO2 nanopowder produced by flame synthesis. (Joint project with the Institute of Process Engineering, ETH Zurich)

years of committed research has now obtained international recognition. Industrial applications in surface technology are close to reaching introduction, especially for components which are exposed to complex mechanical loads (see also article on page 32).

Outstandingly well equipped

We have achieved a major milestone in our instrumental infrastructure. In addition to a 300 kV transmission electron microscope (TEM), a unique focused ion beam (FIB) facility was commissioned in its own purpose-built user lab. This makes it possible to use an ion beam to carry out highly localized manipulations (such as deposition or removal of material) and precise shaping of TEM lamellae. X-ray tomographic microscopy (XTM), for which Empa was project manager, started operation at the materials science beamline of the «Swiss Synchrotron Light Source» (SLS) at the Paul Scherrer Institute (PSI). Together with the already successfully working environmental scanning electron microscope (ESEM), we are now outstandingly well equipped for in-situ experiments in the micro- and nanometer range. Furthermore, a special nanoindenter has recently been installed which is used to perform mechanical measurements on finely structured components. Another key beneficiary of our excellent instrumental equipment is our research activity in the field of materials and component reliability at small dimensions, which is associated with failure analyses and investigations of aging mechanisms on environmental exposure.

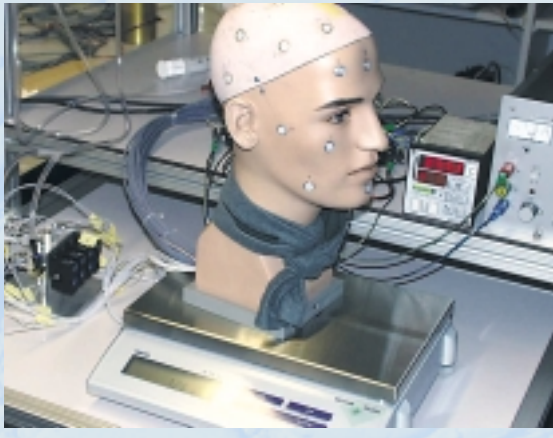
Nanotubes for electronics

New prospects are opening up thanks to our close link with the University of Fribourg, where interest is focused on the development of carbon nanotubes as ultra-high efficiency electron emitters and the controlled deposition of functional macromolecules onto surfaces as electronic circuit elements. Finally, the prospects to benefit from the special fine structures of natural raw materials look highly promising. In the area of biomimetics, or mimicking nature, cellulose fibrils might mechanically reinforce polymers, while selected cellular wood structures could be used in ceramized form, for example, for fine filters.

Walter Muster

Creating physical wellbeing with new materials

Freedom from bodily harm is essential to human wellbeing and is the basis of human performance. Innovative solutions to keep the body working properly and so improve quality of life are thus in demand. As part of its «Materials and systems for the protection, comfort and health of the human body» priority program, Empa is developing an interdisciplinary center of excellence which places great importance on researching and developing not only functional textiles and clothing but also materials for medical technology. The aim is to create high-tech solutions using modern coatings and nanotechnology.



As yet, relatively little research has been conducted into the mechanisms controlling the human body's temperature and release of moisture. There is insufficient data to indicate how the body and materials close to the body react to heat or humidity. Little is known about the influence of temperature and humidity on our perception of comfort either. To develop new clothing systems which assist the body temperature control to the greatest possible extent, it is essential to have an in-depth knowledge from two disciplines, firstly relating to the transport and storage of humidity and heat and secondly relating to human physiology. Simulations and specially-developed evaluation methods drawn from real-life conditions are helping us to gain a better understanding of the complex interactions involved.

Manikin SAM can even sweat

Areas of research to which we have paid particular attention are the construction of apparatus similar to the human body, intensive trials with test subjects and simulation models. For example we are having success with the Sweating Agile Manikin (SAM), an anatomically-shaped doll with mobile limbs and lots of sensors which, like a person, can release heat and even sweat. The researchers are working with cutting-edge software tools in order to model physical processes, such as heat and mass transfer under all possible conditions.

Developed by Empa: sweating head (top), sweating agile manikin SAM (below left) and sweating arm (below right)

Award by the Technology Center of Switzerland

Some newly acquired findings have been used in the development of new materials. Textiles with variable thermal insulation have been jointly developed with the clothing industry (see also article on page 30). This development was modeled on the behavior of birds. Birds ruffle up their feathers in cold conditions so that the air between the feathers insulates their body from the cold. Conversely, they hold their plumage tightly against their body when the weather is warm. This resulted in the concept of a jacket in which air can be pumped into the space between two membranes, the trapped layer of air protecting the body from cold external air. In a warm environment or during physical exertion, the air is let out of the jacket to avoid excessive sweating. All-year duvets could, for example, also be produced using the same principle. The concept/development of variable thermal insulation was awarded a prize in the «Technologiestandort Schweiz» (Technology Center of Switzerland) competition sponsored by the governmental economic promotion body.

We are also developing new materials for the care and hospital sector, for example, for the bedridden who often suffer chronic sores as a result of humidity and heat. «Tissupor» wound pads are the result of our cooperation with two textiles companies in eastern Switzerland, ETH Zurich and the Swiss School of Textiles, Clothing & Fashion (STF). The hard points on the pads are designed to stimulate the largely inactive base of chronic wounds, resulting in the formation of vascularised connective tissue. However, the wound pads have also proved successful in combination with other kinds of wound care (see also article on page 22). «Tissupor» was granted patent protection in 1999 in the «medical product with textile component» category and in 2002 was also awarded a «Technologiestandort Schweiz» prize.

How does he feel? Test person on the running track

Materials for biocompatible implants

Our new core activity is developing implants which are maximally biocompatible. The aim here is to control cell migration, proliferation and specialization in such a manner that the lost body function is regained. We are developing materials for biodegradable implants and investigating their biocompatibility. In order to create an ideal material surface, we carefully fashion culture dishes in the micro- and upper nanometer range, without modifying surface chemistry, investigate how to further optimize the functionality of these surfaces.

Another part of this program is research into protecting the elderly from injuries due to falls: novel hip protectors and specially designed flooring are intended to alleviate the consequences of an accident. Our research is not limited to textiles in contact with the body, but also addresses other material and system developments with the aim of reducing risks and ensuring wellbeing.

We are developing novel functional textiles using coatings and nanotechnology, working in interdisciplinary teams and with industry with the aim, for example, of achieving fire resistance or controllable optical and thermal properties.

Markus Rüedi

Adaptive materials systems

Attractive prospects for industry thanks to intelligently reacting materials systems

Innovative products help to secure, develop or win markets. When it comes to reducing vibration, ensuring nano-positioning or optimizing physical states in general, adaptive materials systems are of vital significance for future product development. On the basis of the adaptive materials systems innovation program selected by the ETH Board, Empa is developing a center of excellence in adaptive materials, structures and systems. This center is intended to promote the real-life implementation of developments and new findings and to provide industry with applied research and high-quality services.

Adaptive materials systems are capable of reacting autonomously to changes in environmental conditions in service and of adapting their properties appropriately. In general, this means adding sensing, actuating and information processing systems to the basic structure.

One of the cornerstones of the center of excellence is the synergetic combination of many individual developments already achieved. In addition to the classical materials science disciplines of metals, ceramics, polymers, fiber composites and joining technologies, this applies especially to the areas of sensing and actuator systems, optoelectronics, photonics and information and communications technology. Further important factors are not only our expertise in composite materials and joining technologies, but also the interdisciplinary areas of surface technology, micro- and nanotechnology as well as process engineering. Further major assets include our well-established collaboration with the Automatic Control Laboratory at ETH Zurich and the recently set-up cooperation with the Centre for Structure Technologies of the Institute of Mechanical Systems, also at ETH Zurich. The Automatic Control Laboratory and its control systems solutions will make a decisive contribution to the success of the adaptive materials systems center of excellence.

Knowledge transfer into real-life use

Basic research into adaptive materials systems has generated in-depth knowledge in individual, mainly isolated areas. However, very few of these findings have so far made their way into real-life use. Most of the research institutions which address this subject area are either unwilling or, due to inadequate contact with industry, unable to ensure knowledge transfer. The central aim of the center of excellence is to demonstrate to industry promising development opportunities for improved or novel products.

Adaptive materials systems are used wherever, as a result of ever more complex requirements, conventional solutions are reaching their limits because they are becoming too costly or the technical problems they generate are too great. It is thus essential to seek out simpler and more economic alternatives. Moreover, adaptive materials systems open up new applications which have not previously been achievable with conventional systems. For example, it is possible to carry out health monitoring of components and structures during production and in service in order to detect and analyze damage occurring due to external influences, materials fatigue, wear or corrosion. Integrating sensors into the structure makes it possible to

carry out permanent monitoring especially of critical systems, such as vehicles and bridges.

Materials adapt their properties appropriately

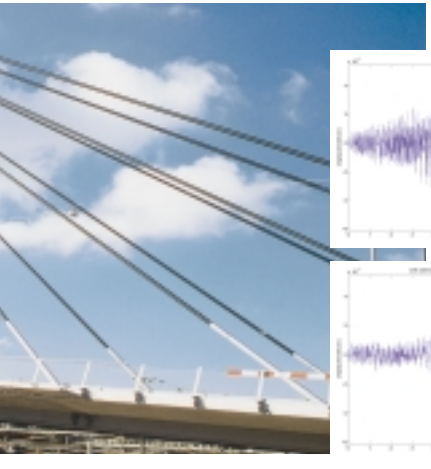
One wide area of application is the control of material parameters to tailor the properties of components and structures in service. For example, the use of electrorheological fluids permits electric field-controlled variation of elastomechanical properties (such as rigidity), a phenomenon which can be used to suppress vibration or absorb noise. As a result, it is possible to avoid costly constructions, especially in aerospace applications, but also in general vehicle construction. Purposeful modification of material properties, whether thermal (thermal conductivity), electrical (resistance, impedance) or optical (absorption behavior) thus provides many options for adaptive components and structures, for example to optimize the supply of light and heat in buildings (intelligent buildings).

Adaptive materials have many potential applications in medicine. One conceivable application is, for example, synthetic bones made from an implantable composite material which adjust themselves dynamically to changing loads, while another is flexible tracks for setting broken bones with which the healing process can be accelerated by careful modification of the stiffness of the tracks.

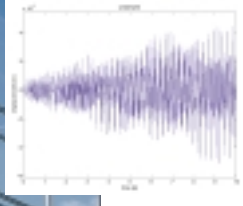
Macrosystems are being replaced by microsystems

We are reorganizing some of our departments as part of the development of the center of excellence: engineering designed for macrosystems is being replaced by engineering sciences for microsystems. Thanks to the diversity of the interdisciplinary skills that we have available all «under one roof», we will be able to make a sustainable and varied contribution to adaptive materials systems. One essential condition for moving on from development to production is a constant interchange of information between know-how suppliers, engineers and industry. The Empa Academy will be responsible for initiating, moderating and constantly updating this communication between the partners in the market place.

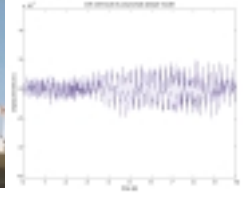
Prof. Urs Meier



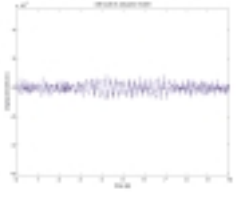
Cable-stayed bridge in Winterthur: Storchenbrücke



Vibrational behavior of an undamped bridge cable



Vibrational behavior of a semi-actively damped bridge cable



Vibrational behavior of an actively damped bridge cable

Technosphere – Atmosphere (TECAT)

Environmental and materials engineering join forces to protect the atmosphere

The TECAT Priority Program will in future ensure that Empa contributes even more to adequate knowledge and reduction of ground-level atmospheric pollution and emissions of global warming gases. Interest is primarily focused on pollutant flows at the interface between the technosphere and the atmosphere, on the processes that cause these flows and on the effects of the atmosphere after influence by human activity on materials and technical systems. Innovative systems are being devised to reduce not only the pollutant flows but also their impact.

The vigorous industrial/economic growth and technological advances made in the second half of the 20th century have brought about a massive rise in anthropogenic material flows into the atmosphere. The principal consequences are pollution of the atmosphere at ground level and the accumulation of greenhouse gases in the atmosphere. Moreover, the atmosphere also transports many pollutants into the soil and water. On the basis of our expertise, we will be concentrating on the following topics in TECAT: quantification of material flows impacting on the atmosphere, reduction of these flows by air pollution control and energy management measures, and the interaction between materials and atmosphere.

Quantification of material flows of relevance to the atmosphere

One essential prerequisite for solving the problem is an awareness of the relevant pollutant sources and flows. With regard to the implementation of international agreements, such as the Kyoto protocol, it is not only the emitting processes which are of interest, but the regional origin of the pollutants is equally important. As part of a European project, we have been able to demonstrate the importance of the Jungfraujoch High Alpine Research Station in providing such elucidation. Its high-altitude location makes it possible to measure a time series of global background concentrations of substances relevant to long-term development. Moreover, its central European location means that, under appropriate meteorological conditions, the measuring instruments repeatedly record high levels of contamination in air rising from the ground-level atmosphere. Evaluating the measured data using MeteoSchweiz propagation models allows the measured peak concentrations to be assigned to individual source regions.
Last year, for the first time, we made use of satellite-based measurement data to characterize highly polluted regions as part of the European Space Agency's (ESA) Data User Program. These data are an ideal complement to the ground-based measurements. However, the limited spatial resolution and restricted availability of the data still limit the use of this future-oriented measurement method at present.

Air pollution control and emission abatement

Central topics that we are addressing in depth are engine combustion, engine emissions and the options for reducing such emissions. In the «clean engine vehicle» (CEV) project, we are working with industrial and academic partners to jointly develop an internal combustion engine-based vehicle drive that has an environmental impact no greater than that of an electric drive. In this project, a modern series-production vehicle is being converted to natural gas operation and its fuel consumption and pollutant emissions are being optimized by careful adjustment of the existing engine, control and exhaust gas treatment technologies.

Jungfraujoch High Alpine Research Station (Picture: Rail Corporation Jungfrau)

Climate protection and sustainable energy management

In its current report, the UN's Intergovernmental Panel on Climate Change (IPCC) considers that anthropogenic factors are making a substantial contribution to observable climate change. If the CO_2 concentrations in the atmosphere are to be stabilized at a sustainable level until 2050, there must be a sharp cut in the consumption of fossil fuels. The ways and means to achieve this are to promote and use renewable energy sources and to improve energy efficiency in energy conversion and use in the building and transport sectors. We are working on appropriate solutions in various areas:

Development and implementation work on sustainable systems and technologies, and thus low-CO_2 energy use in buildings, is geared to the «Minergie» and «Passivhaus» building standards. Over the past year, we have developed a method for assessing the overall environmental impact of a building and not just its energy use. We are working on the International Energy Agency (IEA) «high-performance vacuum insulation» project. There is great potential for using high-performance insulation technology both in new buildings and in renovation projects. Passive use of solar energy is an essential factor in a sustainable building. The IEA project «solar facade components» involves the development and evaluation of innovative window and solar protection products as well as transparent and thermal storage insulation. There are still huge potential energy savings to be made in the ventilation of residential buildings (heat recovery, demand-controlled mechanical ventilation). The lowest energy buildings are moreover heated only by means of ventilation. However, it is sometimes difficult to reconcile the requirement for internal air quality on the one hand with that for thermal and acoustic comfort on the other. In response, we are developing solutions in various projects, for example adaptive ventilation systems for apartments and thermal distribution potential of low-power output wood-burning stoves in passive buildings.

The size of the current and future CO_2 sink is being estimated for the forestry industry in Switzerland on the basis of consumption trends over the past 100 years. On this basis, it will be possible to use dynamic modeling to investigate the effects of any increases in consumption. We will consequently be able to put a figure on the potential reductions in CO_2 emissions arising from the replacement of materials and energy obtained from fossil resources with products made from renewable raw materials. We are working jointly with partners in the ETH domain on the EcoInvent 2000 project to develop the methodology and compile the data required to assess civilization's material and energy flows with regard to their impact on climate.

Interactions between materials and the atmosphere

Testing of the fire behavior of materials has in the past largely focused on flammability. As a result, little is known about the release of toxic or irritant substances. However, such information is of vital significance when selecting materials for use in densely occupied spaces, for example transport systems, concert halls or meeting places. Due to the complex processes which occur under thermal stress, emissions have to be investigated under conditions that match reality as closely as possible. The concept of the single burning item test and our analytical and materials science skills are a promising basis for the characterization and further development of the materials and systems in use today. We are currently carrying out a preliminary study with industrial support to clarify how this new area of activity should be developed.

Dr Peter Hofer

Sustainability in the information society

Getting more value while consuming less materials and energy – a contradiction in terms?

Our modern information or knowledge society is aiming to achieve «dematerialized» economic activity that can create ever more added value with less material and energy. However, the information and communications technologies required to achieve this themselves create new environmental and social risks. The tension between these conflicting interests means that there is an increasing need for reliable information. Empa is addressing this need with the «Sustainability in the Information Society» (SIS) innovation program selected by the ETH Board. In implementing this future-oriented, interdisciplinary research, Empa is combining its technological and environmental expertise.

On the one hand, decoupling economic growth from resource consumption and environmental impact should make it possible to ensure prosperity for an increasing number of people. On the other hand, the material and energy flows caused by the consumption of millions of short-lived information technology products are growing almost unnoticed into a new environmental problem. As yet, little attention is being paid to new economic and social risks, such as the rapid devaluation of acquired knowledge due to technical development or the exclusion of certain social strata or entire regions from enjoying the benefits of progress in information technology.

Research program with ambitious targets

Modern society faces the challenge of negotiating the narrow path towards sustainable development by resolving the tension between the hoped-for «dematerialization» and the new risks arising from information and communications technologies. This challenge increases the need for knowledge obtained by interdisciplinary research. In the information society, new demands are being placed on how we assess technological impact and the shape of future technologies. An integrated approach taking account of environmental, social and economic factors is the only way of benefiting from the sustainable development opportunities of the information society and minimizing risks. With the intent of responding to these requirements, we have set ourselves the following targets for the SIS program:

- to evaluate the opportunities and risks of information and communications technologies (ICT) for sustainable development
- to develop ICT applications that contribute towards a more sustainable mode of economic activity
- to refine research and development methods in the stated areas (life cycle assessment, modeling and simulation)
- to create databases for research and development in the stated areas (life cycle inventories)

Electronic media, virtual conferences – environmental opportunities?

In preparation of an international conference organized as part of the SIS program, alternative variants were compared with regard to use of resources and environmental impact. The variants compared were a conference without printed proceedings (papers published on CD) and a completely virtual conference taking place solely on the Internet. The life cycle assessment revealed that, depending upon many different factors, the comparison between print and digital media did not come down unambiguously in favor of electronic media. However, replacing air travel with telecommunications did bring about resource economies of one to two orders of magnitude.

Telecommunications and route planning – an ICT application for traffic optimization

Introduction of the distance-related heavy vehicle fee (LSVA) has made it attractive for Swiss transport companies to invest in more intelligent scheduling systems. The aim of a project sponsored by the Commission for Technology and Innovation (CTI), which is being conducted with the participation of the Solothurn and Basel Universities of Applied Sciences and Circon AG, is to develop an integrated solution for haulage companies to help them achieve savings in distances traveled. The vehicles, which are linked to the control center by an on-board computer, can be optimally scheduled using a method known as dynamic scheduling – even in response to urgent orders or sudden problems. The optimization methods under consideration are initially being tested with empirical data in a simulation model before going into service with pilot users.

Life cycle assessment (LCA) methods in the information society

Life cycle assessments, in which alternatives are compared using environmental criteria, generally assume functional equivalence of the alternatives. However, this approach is proving ever less fruitful when examining issues relating to new technologies, because technological change is characterized by new, previously unknown functions. Moreover, it should also be possible to take account of counter-productive feedback or «rebound» effects. In a recently started project, we are developing a new methodological approach, tailored to the requirements of the information society and based on time-use scenarios and considerations. This approach is initially being used in a study investigating why increased computer hardware performance (which has risen by a factor of approx. 1000 since the introduction of the first PC) has not brought about a comparable increase in either the productivity or environmental efficiency of working with computers.

National database of life cycle assessments

The most important basic data for LCA studies are the basic data compiled in life cycle inventories (LCI). For example, every LCA needs data about frequently used materials or forms of energy. The EcoInvent 2000 project, which we are coordinating with the participation of numerous Federal Agencies and institutions, has the aim of consolidating Swiss life cycle inventories into a common database.

Prof. Dr Lorenz M. Hilty

Selected projects

Ceramic nanoparticles for use in dentistry
Successful wound treatment
Post-strengthening of concrete structures
An environmental toxin that lurks in caulkings
Superconductor cable being put to the test
Jackets and duvets «ruffle up»
Insight into microstructures
A newt for potable water pipes
The bridge cable: how «healthy» is it?

Ceramic nanoparticles for use in dentistry

Background/Conception

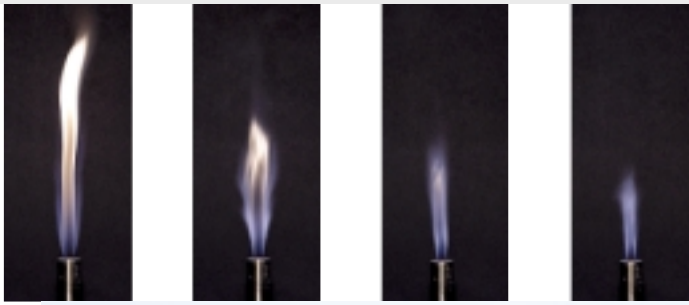
Optimizing nanoparticles for fillings

Nanoparticles are widely used in everyday applications. In the form of silicon dioxide (SiO_2) they are used as thickeners in paints, cosmetics and toothpaste or as binding agents in concrete. SiO_2 also functions as a filler in medicines, as a flow enhancer in powders or as a reinforcement of plastic elements. Titanium dioxide (TiO_2) nanoparticles act as UV-absorbing catalysers in suntan cremes and in paper coating and are also used as the white pigment in emulsion paints. Thanks to their properties, SiO_2 nanoparticles are also in demand for ceramic polymer composites that are used as a filling substance for teeth. For an optimum dental filling substance, the nanoparticles must ideally have the minimum possible diameter and be spherical in shape. The standard commercial SiO_2 nanoparticles used in filling material have a nominal diameter of 7 to 55 nanometers. Since the particles partly fuse together during synthesis, unsuitably sized particles of indefinite shape are formed, measuring from 200 up to 300 nanometers. Ways of avoiding these particle aggregates were sought.

Project

Research into the flame synthesis process

Intensive research was undertaken jointly by Empa and ETH Zurich to identify ways of influencing the formation of silicon oxide nanoparticles. The objective was to produce, non-aggregated, spherical SiO_2 nanoparticles with a mean diameter of less than 100 nanometers. A flame synthesis reactor constructed at the Institute of Process Engineering at ETH Zurich was used to carry out the tests. In this apparatus gaseous, hexamethyldisiloxane (HMDSO) was burnt in a methane flame, resulting in the formation of SiO_2 nanoparticles. The external shape of the particles is selectively influenced by specific burner configurations and the controlled addition of methane, oxygen and nitrogen.

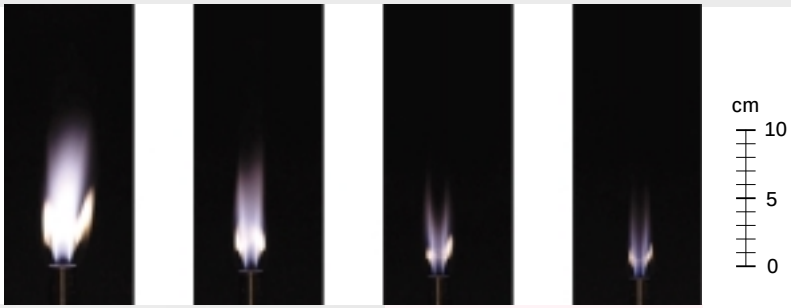


Specific burner configurations and their flame appearance: the core of the flame synthesis reactor

Optimized silicon dioxide nanoparticle shape

SiO_2 nanoparticles with a mean diameter of 10 to 80 nanometers were generated with the flame synthesis process. The particles' specific surface area was examined applying the BET method, and a transmission electron microscope (TEM) was used to investigate their morphology. It was found that monodisperse spherical particles had been produced instead of the aggregates at specific flame configurations under laminar gas-flow conditions at the burner outlet.

Dental filling substances manufactured by our industrial partner applying these optimized SiO_2 nanoparticles show significantly enhanced mechanical properties with regard to Vicker's hardness, bending strength, modulus of elasticity and consistency. The filling material with the non-aggregated, spherical particles is also exceptionally opalescent – for aesthetic reasons, a great advantage when used in dental applications.



Plans for a new nanoparticle plant for increased production

These heartening results prompted Empa to plan a flame gas synthesis plant with a higher production capacity than that of the ETH's largest device in order to close the gap between laboratory and industrial production scale. With the Empa plant it is possible to synthesize specific SiO_2 and TiO_2 nanoparticles, where production conditions are accurately controlled and a wide range of process parameters can be investigated. Special attention will be directed to the design of new burners. The construction of a second plant for continuous production of various oxide nanoparticles by a flame spray synthesis process has started.

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Successful wound treatment

Background/Conception

With improved material against chronic sores

The frightening figure of two million wound patients in Germany speaks for itself. Switzerland also has some 70,000 patients suffering from lower leg ulcers alone. In addition, there are also many people with restricted mobility due to age, disease or accident who are confined to a chair or a bed and so have to contend with bedsores. A joint project was set up to develop an improved wound dressing to treat the resultant chronic sores.

Treatment of chronic venous insufficiency with «Tissupor wound pads».

Project

«Tissopur wound pads» promote sore healing

With its partners, Empa developed the «Tissupor wound pads». The four-ply wound dressings are based on a novel mode of action. The high-tech embroidered fabric facing towards the wound has a three-dimensional surface texture. Tissue ingrowth and capillary vascularisation is promoted by various pore sizes of between 10 µm and 3 mm. The formation of granulation tissue is simultaneously encouraged. A spacer fabric next to the embroidered fabric withstands shear forces, applies compression and transports wound exudate into the superabsorber. The final ply is a dense knitted fabric which provides protection and controls moisture and gas transfer. The advantage resides in the mechanical stimulation of the base of the wound and activation of the wound healing process. Moreover, depending upon the patient, the dressing only needs to be changed once every 3 to 7 days, instead of several times daily.

The wound pads have also proved successful in combination with existing wound care concepts, for example being combined with vacuum sealing for the treatment of ulcers. These dressings can even stimulate tissue development in third degree burns prior to subsequent treatment by skin grafting, so giving the body the opportunity to regenerate «by itself» without foreign substances.

«Tissupor wound pads» are available in various sizes and with different printed patterns.

Industry, universities and hospitals

«Tissupor wound pads» were developed in a Commission for Technology and Innovation (CTI) project between Empa and the following partners: Bischoff Textil AG in St. Gallen, Flawa AG in Flawil, the Swiss School of Textiles, Clothing & Fashion (STF) in Wattwill and ETH Zurich. Clinical trials were begun in numerous hospitals in Switzerland and neighbouring German-speaking countries while the project was still under way.

Great interest and technology award

«Tissupor wound pads» aroused considerable interest in June 2001 at the 5th Congress of the German Society for Wound Healing (DGfW) in Ulm on the subject of «Structures and prospects for interdisciplinary wound management». The effectiveness of the new wound dressing in clinical use was demonstrated to German, Austrian and Swiss doctors and nurses who attended the Congress. The project was also awarded a prize in the Technologiestandort Schweiz (Technology Center Switzerland) competition in 2002. «Tissupor wound pads» are now patented worldwide.

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Post-strengthening of concrete structures

Background/Conception

High-performance composites for construction

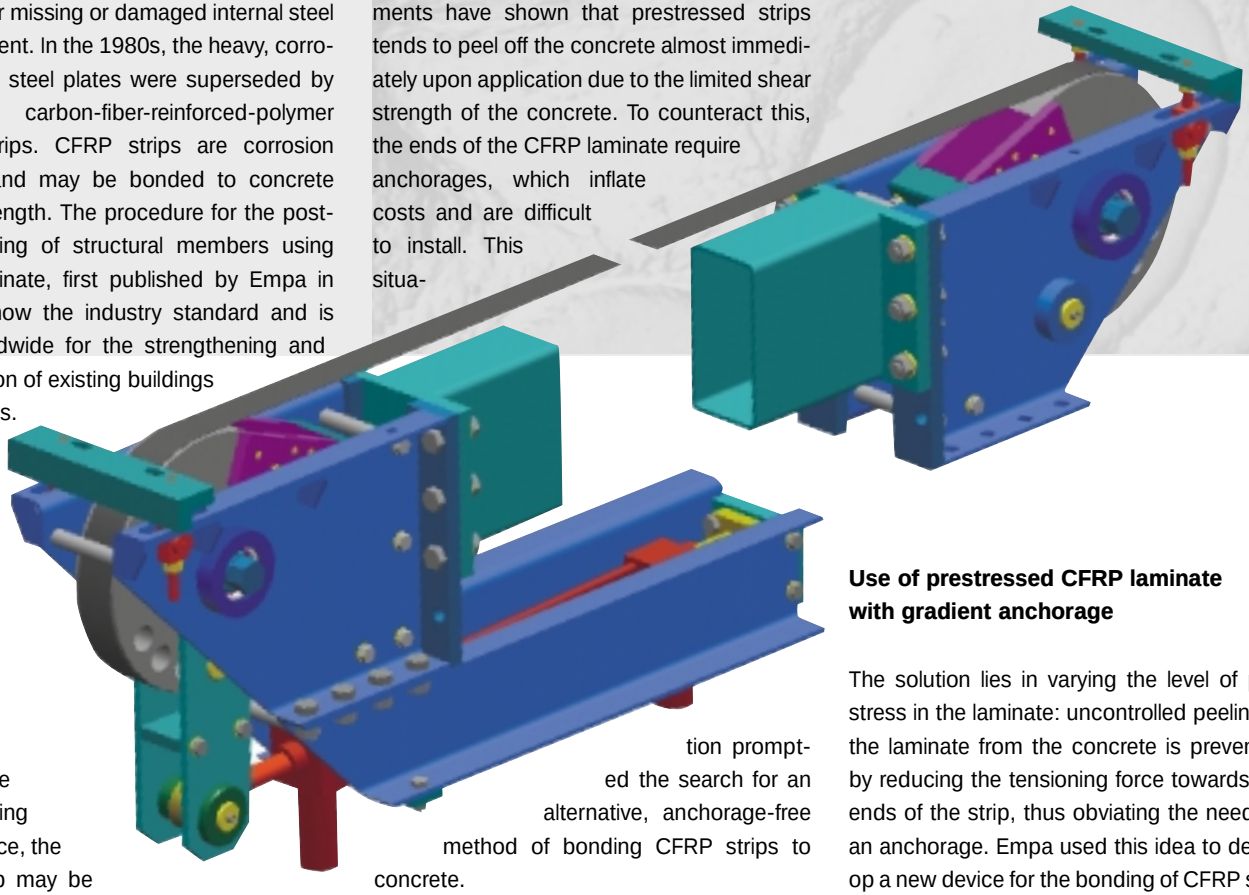
Steel-plate bonding has served as a method of strengthening concrete structures for over 30 years. The externally bonded plates compensate for missing or damaged internal steel reinforcement. In the 1980s, the heavy, corrosion-prone steel plates were superseded by lightweight carbon-fiber-reinforced-polymer (CFRP) strips. CFRP strips are corrosion resistant and may be bonded to concrete over any length. The procedure for the post-strengthening of structural members using CFRP laminate, first published by Empa in 1987, is now the industry standard and is used worldwide for the strengthening and rehabilitation of existing buildings and bridges.

To enhance strengthening performance, the CFRP strip may be prestressed prior to bonding. Deflections are reduced and the load at which cracks in the concrete occur is increased. The width of existing cracks is reduced and the fatigue resistance increased.

Project

However, while prestressing allows full exploitation of the material's most valuable property – its high tensile strength – experiments have shown that prestressed strips tends to peel off the concrete almost immediately upon application due to the limited shear strength of the concrete. To counteract this, the ends of the CFRP laminate require anchorages, which inflate costs and are difficult to install. This situation prompted the search for an alternative, anchorage-free method of bonding CFRP strips to concrete.

Scheme of the device for «gradient anchorage»

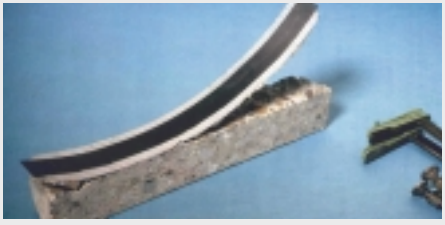


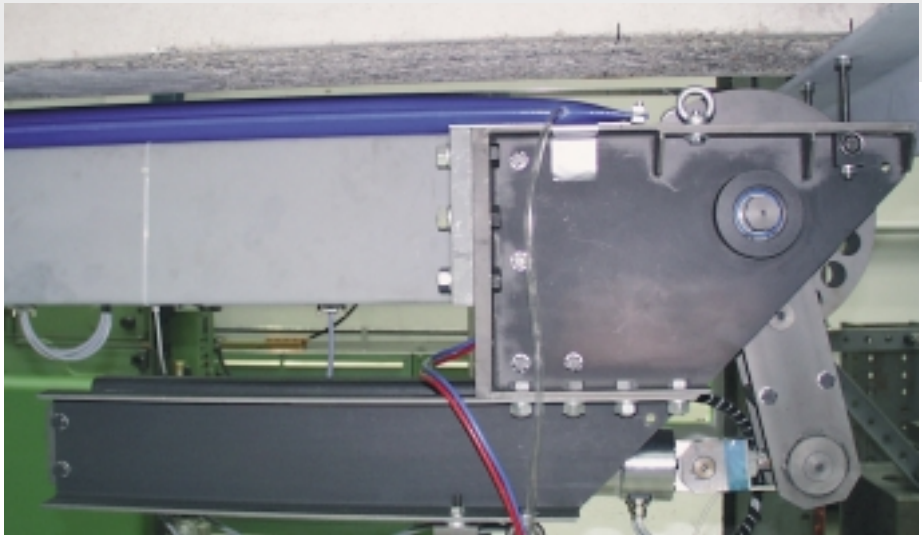
Use of prestressed CFRP laminate with gradient anchorage

The solution lies in varying the level of prestress in the laminate: uncontrolled peeling of the laminate from the concrete is prevented by reducing the tensioning force towards the ends of the strip, thus obviating the need for an anchorage. Empa used this idea to develop a new device for the bonding of CFRP strip to concrete in stages of varying prestress. This procedure is termed «gradient anchorage».

Optimum bonding of prestressed CFRP laminates to concrete

The device comprises two rotating rollers connected by a steel beam of suitable length. Each laminate end is wrapped roughly three-quarters the way round one of the rollers and clamped in position at its extremity. The CFRP strip is then tensioned by turning one or both rollers. The laminate is coated with adhesive and fixed to the structure temporarily together with the tensioning device. The adhesive of the center section of the CFRP strip is cured first. The prestress is then eased somewhat and the adjoining sections either side are cured. After that, the prestress is again slightly reduced and the next sections cured. This procedure continues until the entire laminate has been fixed. The tensioning device can then be removed. Separate heating devices in each section allow localized temperature control to influence the curing process of the adhesive.





The special device for «gradient anchorage» allows to bond prestressed CFRP strips to concrete without their peeling off (small picture above)

Award of Techtextil Innovation Prize

The gradient anchorage method for CFRP laminates has made expensive, corrosion-prone end anchorages unnecessary. Moreover, the automated application techniques permit substantial savings in time and money on strengthening and rehabilitation.

The presentation to Empa of the international Techtextil Innovation Prize at the world's largest exhibition for technical textiles is proof that this is a new technology with an exciting future. In awarding the 2001 Innovation Prize in the «New Applications» category, the Organization Committee paid tribute to Empa's «exemplary development work in the field of technical textiles».

The award provides an added incentive to forge ahead with developments in the field of high-tech materials. Given the numerous bridges that will need strengthening over the next few years, there will be no shortage of demand. At the same time, the new methods may also lend themselves to other applications such as the conservation of historic structures and strengthening of structures in earthquake-endangered areas.

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An environmental toxin that lurks in caulkings

Background/Conception

Working off the PCB heritage

Until the use of polychlorinated biphenyls in open systems was prohibited in 1972, PCBs were often used as aging-resistant plasticisers in caulking compounds for expansion joints in concrete buildings. PCBs had proven to be poorly degradable, dioxin-like environmental toxins which could be released from the caulking compounds containing them into the indoor air for inhalation by the room's occupants. After the discovery of caulking compounds with PCB contents in excess of 30% in various public schools in Switzerland, the Swiss Agency for the Environment, Forests & Landscape (SAEFL) set up a national working party. The intention was for various aspects of the problem to be tackled by representatives from cantonal and city authorities, the Swiss Federal Office of Public Health (SFOPH) and Empa with the aim of measuring levels of contamination and investigating their impact on legal and health issues.

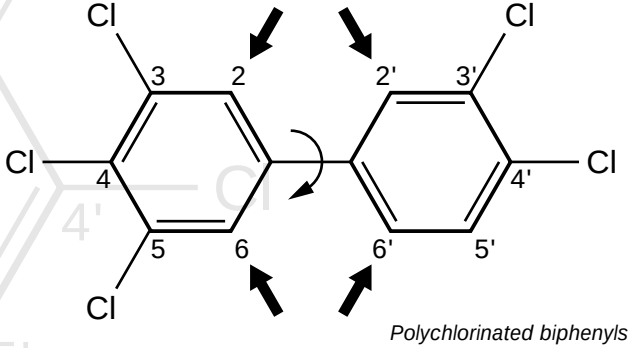
Projects

Measurement of coplanar polychlorinated biphenyls (PCBs) in indoor air

Switzerland did not have the data on which to base a toxicological risk assessment and to set tolerable PCB concentrations for room air. Dioxin-like, coplanar PCBs occur only in trace quantities and reliable determination is thus generally beyond the capabilities of routine analysis. Empa developed a highly sensitive measurement method based on gas chromatography and high-resolution mass spectrometry. Using this method, it has been possible to push detection limits for coplanar PCBs far lower than previously published values.

Quality assurance of the chemical analysis of PCBs in caulking compounds

Since measuring PCB levels in air was entirely new in Switzerland, and there was little experience of analyzing PCBs in caulking compounds, Empa was requested to examine quality assurance issues relating to PCB analysis. Empa organized an interlaboratory test, in which 17 laboratories took part.

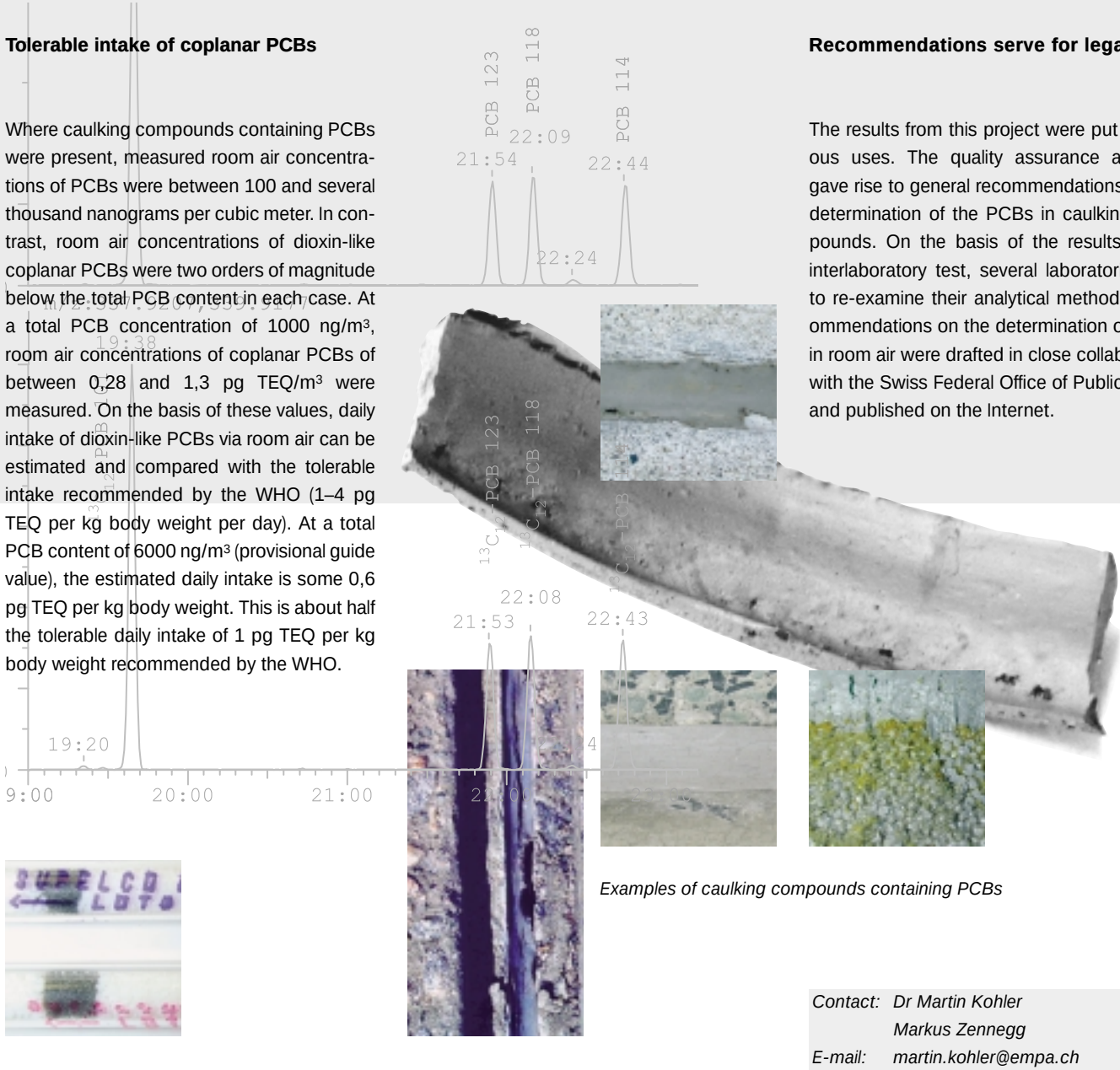


Polychlorinated biphenyls (PCB)

Results

Tolerable intake of coplanar PCBs

Where caulking compounds containing PCBs were present, measured room air concentrations of PCBs were between 100 and several thousand nanograms per cubic meter. In contrast, room air concentrations of dioxin-like coplanar PCBs were two orders of magnitude below the total PCB content in each case. At a total PCB concentration of 1000 ng/m³, room air concentrations of coplanar PCBs of between 0,28 and 1,3 pg TEQ/m³ were measured. On the basis of these values, daily intake of dioxin-like PCBs via room air can be estimated and compared with the tolerable intake recommended by the WHO (1–4 pg TEQ per kg body weight per day). At a total PCB content of 6000 ng/m³ (provisional guide value), the estimated daily intake is some 0,6 pg TEQ per kg body weight. This is about half the tolerable daily intake of 1 pg TEQ per kg body weight recommended by the WHO.



Examples of caulking compounds containing PCBs

Benefits

Recommendations serve for legal bills

The results from this project were put to various uses. The quality assurance activities gave rise to general recommendations on the determination of the PCBs in caulking compounds. On the basis of the results of the interlaboratory test, several laboratories had to re-examine their analytical methods. Recommendations on the determination of PCBs in room air were drafted in close collaboration with the Swiss Federal Office of Public Health and published on the Internet.

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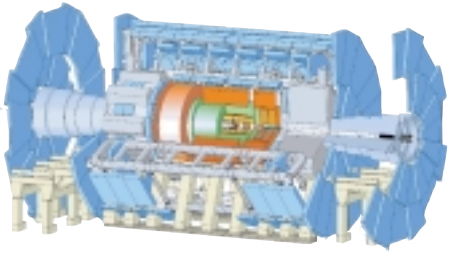
Superconductor cable being put to the test

Background/Conception

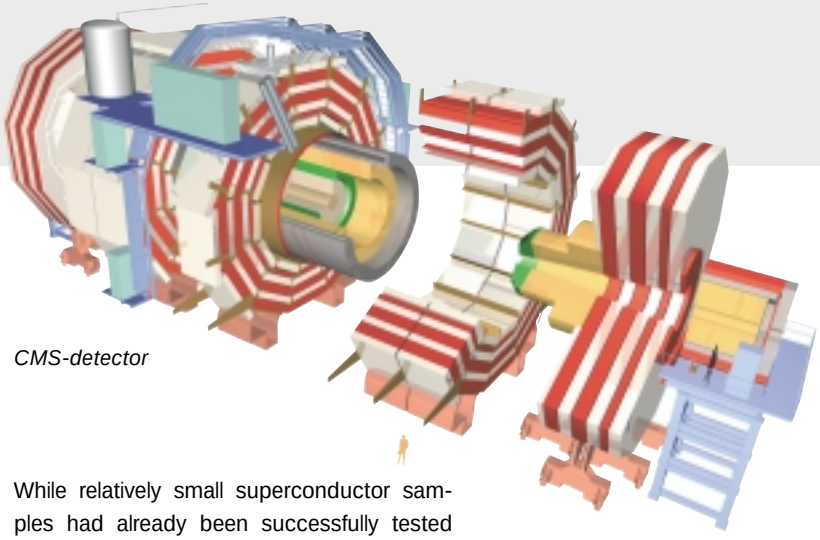
Superconductor stabilization for the particle accelerator at CERN

Construction is under way on CERN's new Large Hadron Collider (LHC) particle accelerator in Geneva. Very powerful magnetic fields are required in the CMS (Compact Muon Solenoid) and ATLAS (A Toroidal LHC ApparatuS) detectors in order to detect charged fundamental particles. These magnetic fields are produced, as in the case of the CMS, by a massive coil wound from a continuous superconductor cable 50 km in length. Superconductors are very sensitive and thus require electrical, thermal and mechanical stabilization. The superconductive flat band cable is thus first cased in an extruded sheath of high-purity aluminum. In a second step, the sheathed cable is then mechanically stabilized on both sides with a high-strength aluminum alloy.

Since the consequences of bonding defects could be disastrous, a reliable monitoring method must be used both during coextrusion and during reinforcement by electron beam welding to test whether the metals have been properly bonded together. While that may sound relatively simple in theory, it is difficult to carry out in practice: the individual cable sections are some 900 or 1800 meters in length for ATLAS and as much as 2,5 km for CMS.



ATLAS-detector



CMS-detector

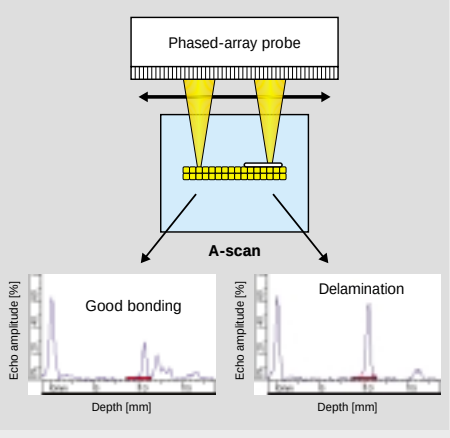
While relatively small superconductor samples had already been successfully tested under laboratory conditions at Empa using an ultrasound scanner, mechanical scanning was not feasible for the long superconductors. ETH Zurich thus commissioned Empa to develop a new testing system.

Project

Phased array system instead of mechanical scanning

Working with industrial partners, Empa designed and built a phased array ultrasound monitoring system consisting of two multi-element transducers combined with a 128-channel ultrasound system. The ultrasound beams generated by the system can be moved to and fro electronically and precisely focused on the interface between the superconductor material and the aluminum.

The sound waves are reflected differently by bonding defects than they are by a proper bond. This phenomenon forms the basis of the method: if the instrument measures and displays a changed, higher amplitude, a bond defect is most probably present. Thanks to newly developed software, detailed interpre-



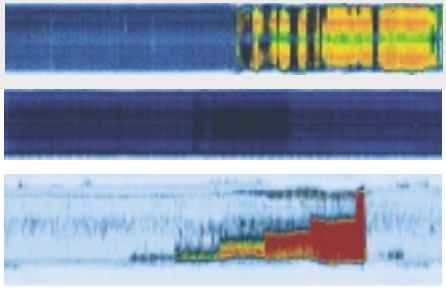
Analysis of the extrusion. Right: bonding defect (delamination)

tation of the echo and amplitude is possible. This software allows more precise identification of the type of defect and diagnosis of the defective bond.

Because scanning with the phased array system is one hundred times faster than conventional, mechanical ultrasound scanning, this test procedure can be easily integrated into the production process. The previously extruded or reinforced superconductor band runs past the test station at a speed of 1,5–3 m/min. However, as soon as a suspicious amplitude appears on the screen, an alarm is triggered and, in an emergency, the production process can be halted.

International collaboration

Two ultrasound phased array systems were designed and built in collaboration with R/D Tech (France) and Marti Supratec (CH). One of the systems is mobile and is used alternately in the Nexans plant in Switzerland and the Hydro Aluminium plant at Seneffe in Belgium. A second, stationary, system has been installed at Techmeta in France.

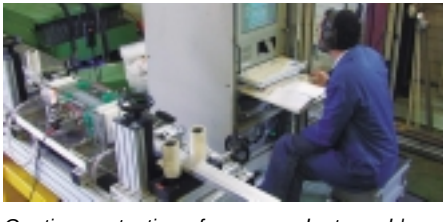


Ultrasound images, taken with the phased array system

Range of use to be extended

By the end of 2001, more than 100 km of the aluminum sheathed CMS and ATLAS superconductors had been inspected in various batches at the production facilities at Cortaillod in the canton of Neuchâtel and Seneffe in Belgium. By the end of the year, 7,5 km of the electron beam welded conductor had been tested at Annecy in Haute Savoie, France.

Successful application of the phased array system is an important step forward in non-destructive ultrasound testing because using multi-element transducers has considerable potential for ensuring rapid, improved and, ultimately, cheaper testing. As a result, non-destructive testing will be feasible not only for superconductors but also for other materials. The range of potential applications is huge: ultrasound testing can be used both on very small electronic components and on very large parts for power generation, railway and aerospace engineering.



Continuous testing of superconductor cables during production

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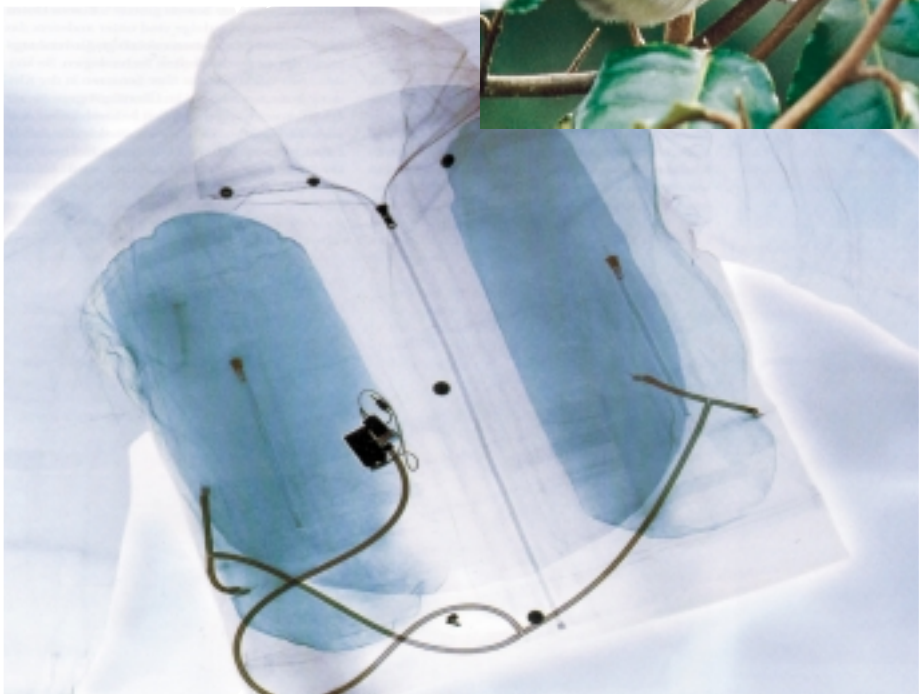
Jackets and duvets «ruffle up»

Background/Conception

Textiles with variable thermal insulation

The clothing industry is forever striving to improve the wear comfort of its products. This comfort is primarily determined by three factors – weather, level of activity and air temperature and humidity – and the better the clothing is adapted to these factors, the greater the comfort. Optimum thermal insulation is one vital element in the equation and should be variable depending upon weather conditions and physical activity.

Items of clothing that adapt to the prevailing conditions thus offer advantages. Phase change materials (PCM) are one known solution, but products exploiting the «bird effect» developed by Empa are entirely new. The principle was modeled on observations of bird behavior; in cold conditions they ruffle up their feathers so that the air between the feathers insulates them from the cold. Conversely, in a warm environment, they flatten their plumage tightly against their body.



Projects

Pumps provide the appropriate air volume

With a commercial partner from the clothing industry, Empa has developed jackets for winter use in which a miniature electric pump draws air between two membranes. In this way, the air, together with the down located between the membranes, provides optimum protection from the cold external air. In a warm environment, or on physical exertion, the air is removed from the jacket, so preventing excessive sweating.

The same principle may also be applied to all-year duvets. Depending on the season and temperature in the bedroom, the duvet must provide a completely different thermal insulation if the bed's occupant is to be kept neither too hot nor too cold. Thanks to the double

Best wear comfort at the finger tip
(Picture: Sympatex)

membrane system and the down between the membranes, the thermal insulation provided by a duvet can be varied over a wide range by pumping air in or out by means of an electric pump, so automatically adapting it to ambient conditions. A temperature sensor monitors room temperature and controls the necessary level of thermal insulation; it's even possible to set a personal temperature profile.

For outdoor and indoor applications

Empa's partner for the development of jackets with variable thermal insulation is Sympatex Technologies in Wuppertal (Germany).
The partner for duvet development is BSS Thermo-Bettwaren AG in Stein am Rhein (Switzerland).

Aiming at market-readiness

Prototypes are currently undergoing further development in the laboratory and in field trials. The aim is to achieve market-readiness by 2003.
The project concept was awarded a prize in the 2002 «Technologiestandort Schweiz» (Technology Center Switzerland) competition and was thus presented to a wide audience at the Hanover Fair (Germany) from 15 through 20 April 2002.

Prototype of a duvet with a thermal insulation system: filled with air (left), without air (right)

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Insight into microstructures

Background/Conception

Morphology and properties of thermally sprayed coatings

There are different methods to thermally spray materials onto a surface. Even if the coating composition is the same, it turns out that the resulting coating properties depend on the deposition process. The coatings differ in porosity, corrosion and wear resistance as well as in electrical conductivity and in elasticity. These differences result from diverging microstructures with constituents ranging in size from sub-nanometers up to several hundred micrometers.

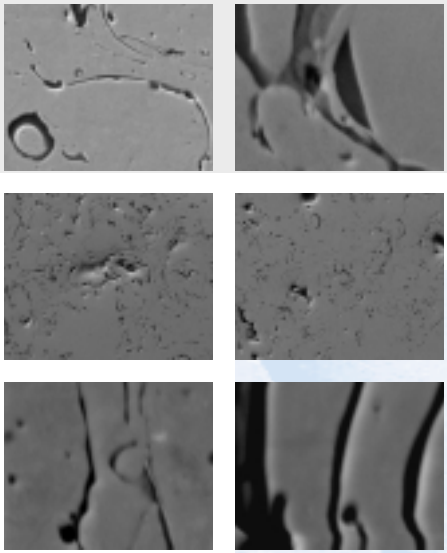
In order to better understand the relation between thermal spraying techniques and the microstructure of the coatings the project «Thermetcoat» (Thermally Sprayed Metallic Coatings) was set up. During the project analysis methods were used to reveal the coatings microstructures. Furthermore, physical and chemical investigation methods were developed or improved in order to determine the coating properties relevant to applications.

Partners

Switzerland and Czech Republic joint in the EUREKA project

Research institutes and company laboratories involved beside Empa in the three-years project:

- Paul Scherrer Institute (PSI), Villigen
- Sulzer Metco AG, Wohlen
- Institute of Plasma Physics (IPP), Prague, Czech Republic
- Škoda Research, Plzen, Czech Republic



Scanning electron microscopy micrographs of details of the microstructure of thermally sprayed nickel alloy-based coatings

Project

Thermal spraying processes

Thanks to the international nature of the project and to the materials technology know-how at Empa, it was possible, in an initial step, to create a large variety of nickel alloy-based coating samples. Empa deposited flame and plasma sprayed coatings in atmospheric environment and vacuum, respectively. In a second step, the coatings were investigated using an ingenious coating analysis with new measurement devices and methods such as neutron small angle diffraction, ultrasonic surface investigations and mechanical microindentation methods. In particular, the recently at Empa developed edge toughness measurement method revealed the fracture mechanical properties of the coatings.

Assessment of coating anisotropy

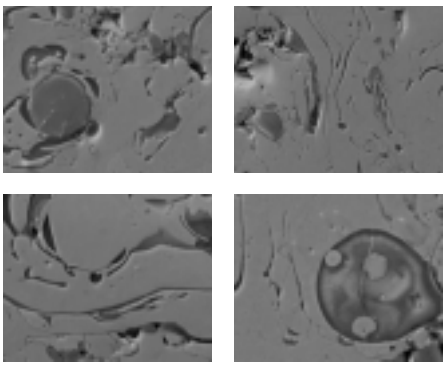
The coatings are anisotropic materials that have different chemical and physical properties in different directions. Electrical current, for example, is not transmitted equally well in all directions and the strength values also vary.

Analysis of edge toughness by combination of micro-mechanical tests and scanning electron microscopy

In order to characterize anisotropy and voids, small angle neutron scattering (SANS) in collaboration with PSI was used. In the framework of a common Phd-project between Empa and ETH Zürich the method was for the first time applied and further optimized to metallic thermal spray coatings.
To show how anisotropy and voids in the coating are related, research focuses on the system of pores, cracks and voids and their distribution in terms of size and orientation. Coating types, for instance, can be distinguished by volume and shape of their pores.

Tailored properties of thermal spray coatings

More knowledge about microstructures helps researchers to develop thermal spray coatings more quickly and at lower cost. However, the knowledge is also useful for industry because it enables the production of reliable coatings of predictable quality. Customers looking for coatings with highly specific properties for parts or components should not be forgotten. For instance, the object can be a huge water turbine for a power station with strict erosion or corrosion tolerances or a tiny component in the electronics industry that requires a specific electrical conductivity. This know-how not only enables the manufacturer to find the material with the right chemical composition but also the suitable thermal spraying method and the best process parameters for the coating.



Scanning electron microscopy micrographs of details of the microstructure of thermally sprayed nickel alloy-based coatings

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A newt for potable water pipes

Background/Conception

How can corrosion damage inside potable water pipes be discovered?

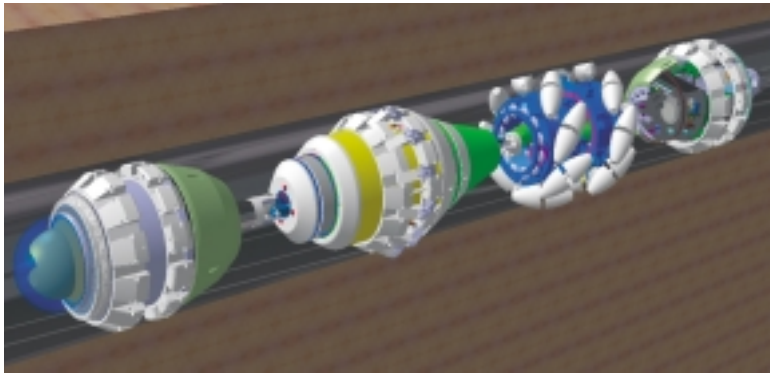
Corrosion in cast iron pipes for potable water ultimately results in pipe breakage that may cause costly damages. Water suppliers thus often replace their pipes earlier than required, sometimes as much as 15 years before replacement is actually necessary. In order to save costs and materials, a solution was sought to take a snapshot of the condition of cast iron pipes in a simple and non-destructive manner.

First rough drawing

Project

An ultrasound newt dives

If you want to know the extent of corrosion in water pipes, the best thing to do would be to look inside the pipes. This is easier said than done. Most water pipes are buried underground and cannot be simply checked. The WAPISMO (Modular Water Pipe Inspection System) project team thus designed an ultrasound inspection robot which can be submerged in water-filled pipes and uses ultrasound to image the pipe walls with a resolution of 2 mm x 2 mm. The newt will move through the pipes and check pipe walls carefully for internal and external corrosion, spongy solidifications and cracks.



The model – generated by computer

Implementation

Design of an articulated robot

The major challenge consists in fitting all the functions in the given small volume. The robot newt must also be able to move smoothly through straight as well as curved sections of pipework. As the robot passes through the pipe, it makes ultrasound measurements, records the condition of its surroundings also with a monitoring camera and transmits the data back to a mobile measuring station. Geometrically, the best solution is a series of interconnected modules. The following closed systems will thus be installed in four segments:

- power supply and data transfer system
- actuation system
- rotating ultrasound sensor system
- vision system

The robot is controlled from the mobile measuring station in a van over a special hybrid electrical and fiber optic cable.

Input of Empa expertise

Communication module

Empa contributed to the mechanical design and construction of the robot modules. The Empa team was also in charge of the design and installation of all optical systems, including not only data transfer and communications via optical fibers, but also contactless, optical transmission of the ultrasound measurement data from the rotating to the static part. In addition, Empa was responsible for the camera and illumination system, which should detect obstructions in the pipe and, if required, may also record an image of the pipe wall damage found by the ultrasound system.

A joint project between industry, municipal utility and research

Partners from Switzerland and Germany decided to join forces to design and produce the ultrasound robot.

Innotest AG, Eschlikon
ultrasound system, overall system, technical project management

Von Roll Infratec, Oensingen
technical consultancy, inlet sluice, mobile test pipe system

Zurich water supply utility, Zurich
technical consultancy, inlet sluice, mobile test pipe system

Zurich University of Applied Sciences, Winterthur:
IMS, Institute of Mechatronic Systems
robot control, interaction of individual modules, fail-safe system, administrative project management

IzfP, Fraunhofer Institute of Nondestructive Testing, Saarbrücken, Germany
ultrasound system: hardware and software

Empa, Dübendorf
mechanical design, manufacture, optical communications, data transfer and camera system

Financial support: BBT-CTI 4337.1

Routine examination by water suppliers

In the final phase of the project, application tests will be performed in a mobile test pipe system. Once this testing is complete, it is planned to market the technology. The underwater robot will then give public and private water suppliers the opportunity to check the condition of their water pipes non-destructively. Overall maintenance costs can be kept down because the newt provides data to decide whether the pipes need to be replaced or whether they are still safe.

Potable water

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«Check-up» of bridge stay cables

Background/Conception

Non-destructive in-situ testing of bridge cables

Major installations must be tested regularly to ensure their fitness for service, a requirement which also applies to the cables for cable-stayed bridges. Over the past few years, Empa has developed an elegant non-destructive method for testing the carrying and traction cables of aerial cableways. Using induced magnetic fields, flaws in the cables are detected before they become dangerous. The scaled up version of the testing device used for cableways is expected to be suitable for the inspection of stay cables.

Project

Magneto-inductive evaluation of thick cables

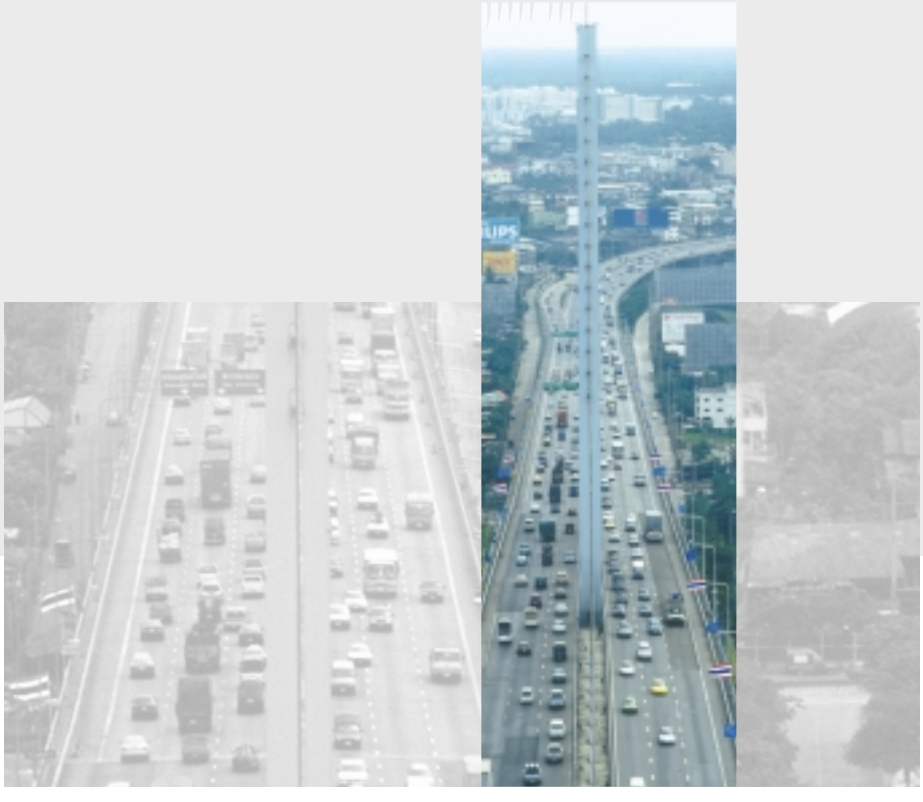
The aim of the project was to develop this method so as to permit non-destructive testing of large-diameter cables (diameter greater than 100 mm). In order to make sure that the complete cross-section of the cables is inspected, it is necessary to attain magnetic saturation also in the center cable cross-section.

Development

From a permanent magnetic device to an electromagnetic coil

Due to the thickness of the cables, a strong magnetic field is needed in order to obtain a thorough magnetization. Permanent magnetic devices showed to be not suitable for the magnetization of stay cables because of their weight and the difficulties operating them. The device developed for the inspection of stay cables is based on the use of an electromagnet where the magnetic field is generated by the circulation of a strong current in a copper coil. So far a precise indication of the number of detected flaws as well as to their position along the axis of the cable can be given. The amplitude by which the signal varies at a flaw allows conclusions to be drawn as to the approximate size and position of the flaw. Additional development is currently being carried out to refine the methods used for the analysis of the raw data.

Electromagnetic testing device, mounted on a stay cable of Rama IX bridge in Bangkok



Cable-stayed bridge in Bangkok

Empa used the principle of magneto-inductive condition testing on the 15-year-old Rama IX cable-stayed bridge in Bangkok to test the bridge's cables, which are up to 167 millimeters thick. Testing was carried out by fitting the cables with a coil, which moves along the cable. A magnetic field was induced inside the cable by the current circulating in the coil. The coil was powered by truck batteries, which, together with a computer for data gathering, were carried in a gondola that accompanied the measuring instrument as it traveled along the cable. Although installation was time consuming, the actual measurement only took between 5 and 15 minutes depending upon the length of the stay cable. Wire breaks within the cable were to be expected wherever the magnetic field lines were deflected.

Cutting-edge methods in international use

Evaluation of the data from Bangkok is complete. The conclusions are positive, because the method proved to be of practical use. Overall, the method has proved effective. It is planned to develop software tools for evaluating the large volumes of data generated in further projects as efficiently as possible. It is also intended to extend this bridge testing method still further to include the cable anchorage as well.

Participation in the IMAC project of the European Union's 5th Framework Program is currently in preparation; collaborative testing is being planned with the Joint Research Centre JRC at Ispra (I).

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Empa

in figures

Personnel
Finances
Investment
Scientific output

Empa in figures

Personnel

On 31.12.2001, Empa had 771 members of staff, 14 more than the previous year. The absolute number of women has remained constant, but has declined slightly in percentage terms from 24.7% to 24.4%. One piece of good news is that one more woman has been appointed to a senior management position. The proportion of foreign staff has risen by 2.25% relative to the previous year and is now 17.25% or 133 members of staff.

Establishment at 31.12.2001 *(previous year's figures in brackets)*

Location	Women	Men	Total establishment
Dübendorf/Thun	125 (124)	464 (438)	589 (562)
St. Gallen	63 (63)	119 (132)	182 (195)
Total	**188** (187)	**583** (570)	**771** (757)

During the report year, Empa was host to 16 doctoral students, 18 postdoctoral students and 49 trainees. In addition, Empa also supervised 17 (23) diploma students from ETH Zurich, universities and universities of applied sciences. The number of apprenticeships available fell slightly to 31 from the previous year's number of 33.

Finances

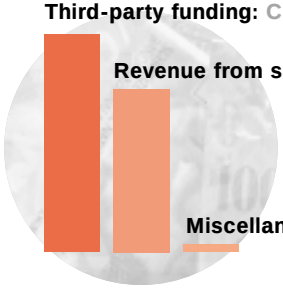
Revenue from services amounted to CHF 14.9 million in 2001, a rise of CHF 1.2 million compared to the previous year. Receipts of third-party funding rose by CHF 0.8 million to CHF 19.9 million from the previous year's high level of CHF 19.1 million. At CHF 9.6 million, commercial research accounted for around half of the third-party funding. The other half was accounted for by funds from research promotion institutions such as the Commission for Technology and Innovation (CTI) and the Swiss National Science Foundation (SNSF) (CHF 2.7 million), departmental service research and public funding (CHF 5.8 million) and European research programmes (CHF 1.8 million).
Total revenue of CHF 35.5 million covered some 28% of total expenditure of CHF 124.8 million. The Federal government provided CHF 89.3 million of total funding requirements. Of total expenditure, CHF 109.9 million went on current activities, while CHF 14.9 million were invested in buildings and equipment.

Investment

Total spending on building was CHF 5.3 million in 2001 (CHF 11.3 million in 2000), some CHF 1.4 million under budget. Available funding was not completely spent in part due to economies and in part due to project postponements. In addition to capital spending on building, CHF 1.2 million were spent on maintenance.
Total investment in movables was CHF 8.7 million in 2001. Some 130 orders of a value exceeding CHF 5000 were processed, four of which were WTO tenders. CHF 0.9 million were also invested in informatics hardware.

Income: CHF 35.5 million

Third-party funding: CHF19.9 million

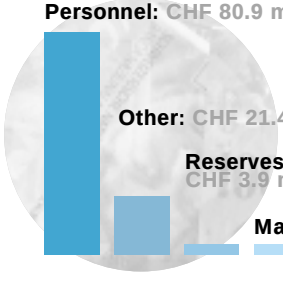


Revenue from services: CHF 14.9 million

Miscellaneous: CHF 0.7 million

Expenditure: CHF 109.9 million

Personnel: CHF 80.9 million



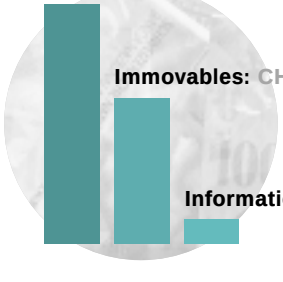
Other: CHF 21.4 million

Reserves: CHF 3.9 million

Materials: CHF 3.7 million

Investment: CHF 14.9 million

Movables: CHF 8.7 million



Immovables: CHF 5.3 million

Informatics: CHF 0.9 million

Key financial figures

(in CHF million)	2001	2000
Income		
Revenue from services	14.9	13.7
Third-party funding	19.9	19.1
Miscellaneous	0.7	1.4
Total income	**35.5**	**34.2**
Expenditure		
Personnel expenditure	80.9	79.9
Materials expenditure	3.7	6.0
Other operating expenditure	21.4	16.6
Reserves for current projects	3.9	4.7
Total expenditure (current activities)	**109.9**	**107.2**
Investment		
Immovables	5.3	11.3
Movables	8.7	4.8
Informatics	0.9	0.4
Total investment	**14.9**	**16.5**
Total expenditure	**124.8**	**123.7**
Federal government's financial contribution	**89.3**	**89.5**

Scientific output

The number of publications fell slightly over the year, but a 10% rise in the number of peer-reviewed publications was recorded. In addition to reviewed publications, papers published in specialist journals without peer-review also play an important role. Because of the disciplines which Empa focuses upon, engineers are a major audience. It has been shown that knowledge transfer to engineers is more effective in readily comprehensible, practically-oriented publications than in peer-reviewed scientific journals.

Initial and continuing training events also experienced strong growth, largely due to the successful expansion of the activities of the Empa Academy in its second year of existence.

Substantially more patent applications were filed in 2001 than in the preceding year, but the number of licence agreements and spin-offs/start-ups stagnated. One success was, however, when, after prolonged negotiations, the «test materials» group with its 13 staff was spun-off to form a corporation as a management buyout.

Roland Knechtle

Scientific output

	2001	2000
Publications:		
• peer-reviewed	67	60
• the others	303	315
Initial and continuing training events	71	47
Patent applications filed	14	6
Licence agreements	6	6
Spin-offs/Start-ups	4	5

Empa

organization

Management and departments
Organs
Profile

Management and departments

Prof. Dr Louis Schlapbach
CEO

Prof. Urs Meier
Deputy

Walter Muster

Advanced Materials and Surfaces

Dr Peter Richner

Materials and Systems
for Civil Engineering

Markus Rüedi

Materials and Systems for
Physical Protection and
Comfort of the Human Body

Dr Xaver Edelmann

Information, Reliability
and Simulation Technology

Dr Peter Hofer

Mobility and Environment

Roland Knechtle

Logistics, Controlling and Marketing

Organs of Empa

ETH council

The ETH council has overall responsibility for the management of the ETH domain, which incorporates the two Federal Institutes of Technology (ETHZ, EPFL) and the four federal research institutes (PSI, WSL, Eawag and Empa).

Chairman: Francis Waldvogel, Prof. Dr med., Genf
Delegate and Vice-Chairman: Stephan Bieri, Dr oec. publ., Zürich
Members: Martine Brunschwig Graf, lic. oec., Genf
Monica Duca Widmer, Dr, dipl. Ing. ETH, Manno
Jean-Marie Pierre Lehn, Prof., Nobelpreisträger, Strasbourg
Jacques Rognon, Dr sc. nat., Corcelles
Heinrich Rohrer, Dr sc. nat., Nobelpreisträger, Wollerau
Alois Sonnenmoser, Dipl. Ing. HTL, Baden
Iris Zschokke-Gränacher, Prof. em. Dr phil., Basel

Advisory commission

A body of leading personalities which advises the ETH council and the Empa management on fundamental concerns.

Chairman: Peter Loew, Dr, Basel
Members: Peter Edelmann, Wetzikon
Dieter Landolt, Prof., Lausanne
Markus Oldani, Dr, Baden
Max Oppliger, Dr, Zürich
Gustav Pfister, Dr, Männedorf
Anton E. Schrafl, Dr, Zürich

Industry commission

A body of 20 members drawn from industry, trade, the services sector, consumer groups, technological institutions and governmental authorities, both national and international. The industry commission is active in the fields of knowledge and technology transfer and in the dissemination of research, and it facilitates cooperation with the economic world and the regulatory authorities. The members are represented by delegates.

Chairman: Bernhard Bischoff, St. Gallen
Members of the Board: Peter Edelmann, Wetzikon
Xaver Edelmann, Dr, St. Gallen
Rosmarie Rüegg-Marti, Wittenbach
Albert Wyss, St. Gallen

Creative interface: research, development, testing and knowledge transfer

Empa is a Swiss technology institution forming part of the «ETH domain» (domain of the Federal Institutes of Technology). It specializes in applied research and development as well as sophisticated services in the field of sustainable materials science and technology. Its core activities are innovative collaboration with industry and public institutions to ensure the safety of humankind and the environment, knowledge propagation and university-level teaching. The Empa Academy disseminates the latest results of our work at events and in publications. The focal points of our activities are: modern materials and their surfaces, construction materials, materials that protect the human body and ensure its wellbeing, information, simulation and reliability technology, and mobility and the environment. Approximately 770 employees work in over 30 specialist fields on interdisciplinary customer-specific service assignments, partnership-based development projects and nationally and internationally funded research projects. 34 sections are EN 45000-accredited and agreements with counterpart institutions in other countries ensure that Empa's investigative, testing and certification activities are recognized throughout Europe and beyond.

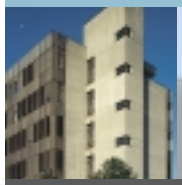
Swiss Federal Laboratories for
Materials Testing and Research

Eidgenössische Materialprüfungs-
und Forschungsanstalt

Laboratoire fédéral d'essai
des matériaux et de recherche

Laboratorio federale di
prova dei materiali e di ricerca

Institut federal da controlla da material
e da retschertgas



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