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# REPORT ON AN INTERNATIONAL EVENT

## Safety of Industrial Automated Systems: Learning from Mistakes—Innovative Safety Technology—Focus on the Human Factor

The second international conference on Safety of Industrial Automated Systems was held in the Beethovenhalle in Bonn, Germany, from 13th to 15th November 2001. The event was organized by the BG Institute for Occupational Safety and Health (BIA) in conjunction with the ISSA Machine and System Safety and Research sections, and by the Health and Safety Executive (HSE, UK), the Institut National de Recherche et de Sécurité (INRS, France) and the Institut de Recherche Robert-Sauvé (IRSST, Quebec, Canada). It was attended by 250 participants from 16 countries.

The conference focussed upon the use of new technologies for the safe design of machine and plant control systems. The subject was not restricted to the reliable design of automated systems alone, but was extended considerably by the subjects Learning From Mistakes and Focus on the Human Factor. The systematic inclusion of human interests, abilities, and limits (human factors) was also regarded in the specialist discussions as a component worthy of particular attention.

The next conference will be held in October 2003 in France (www.inrs.fr). The conference proceedings of the second conference (in English) can be ordered for a nominal fee from BIA.

### Learning From Mistakes

Innovative safety technology in all its complexity presents not only opportunities, but also risks for occupational health and safety. The new issues must therefore be accompanied by prevention measures as and when they arise. Case studies on particular items of automation equipment, as well as general accident and fault statistics, are useful for this purpose. Accident statistics from which accident black spots in the industrial sector can be identified are of primary interest to researchers. They enable trends to be recognized and key areas for prevention work identified. General statistics may however be difficult to apply in practice during the study of accidents which may vary widely in their technical and nontechnical origins. Detailed knowledge of faults is a useful tool for practitioners, such as designers, in the design and use of automated systems.

A British accident study (1984–1991 and 1997–2001) of over 284 accidents on automated systems showed clearly that 65% of all accidents could be attributed to machinery and plants that were not adequately designed for the work process. The study revealed a significant increase in the accident risk in particular where unanticipated work was involved, such as the rectification of faults, and in cases of incorrect human behaviour. The conclusions drawn from these statistics are supported by conclusions from the other papers on the subject of learning from mistakes. Even though the theoretical knowledge available in standards and other relevant documents has for some years paid systematic attention to human failings in the design of safe systems, all speakers criticize the lip service paid to detailed practical implementation. Information gained from mistakes should be exploited as a basis for prevention activity. A Polish paper proposes that a global database be created to which all designers should have access. Such a database, containing input from research institutes and industry, is currently being set up in Poland. As faults are often to be found in the details, this database will not only describe general methods, but will also contain detailed data on known potential sources of faults. This enables knowledge of faults to be exploited better in practice rather than merely being recorded in the statistics. A French project has taken the same route: Data specific to accidents and faults arising in the use of complex programmable logic controllers are collected in this case. The ways in which safety-related protective equipment may be employed incorrectly or dangerously are presented for practitioners by way of a number of illustrative examples. Papers from Finland and Germany showed this with an impressive wealth of detail, and with corresponding proposals for remedial action.

## Innovative Safety Technology

The database of faults referred to in the previous section can be described in the broadest sense as a record of as-is states from the past. When new technologies are employed, prediction of how a system must or should behave is an important task of Occupational Health and Safety experts and designers. A significant component here is the assessment of opportunities and risks associated with the use of new technologies for which there is no past experience to draw upon. Risk analysis is one element of this assessment. Risk analysis methods are repeatedly the subject of debate. They were for example under scrutiny at the beginning of the second main theme of the conference, Innovative Safety Technology. Some papers indicated that methods the results of which were intended to further the safety-related reliability of a safety system were, in some cases, not yet adequately developed. Even where normative regulations have existed for years, their implementation in practice is often not reproducible. In addition to providing examples that attempt an exact risk analysis, the majority of those present warned, both in papers and discussion, that a global project is urgently required here in order to promote a reproducible measure of safety. This measure must, however, remain financially and technically achievable. It should be noted that the need for such a risk analysis project has already been recognized by standards authors.

At this point, the conference participants were provided with a technical treat. In addition to the state of the art, high-tech developments of the future were presented in three subthemes: control system design, bus systems, and protective devices. This theme in particular was also supported by exhibitors from industry, who had the opportunity to present their very latest products.

Innovative safety technology is currently the driving force behind the new design of machine workplaces. The subtheme of Control System Design was introduced by reflections on the part of standards authors in Europe and the USA that designers should be provided with assistance in systematically implementing the required safety concepts and safety requirements. The integration of safety in modern control systems for robots and machine tools and in electric drives generally exhibits tendencies that deviate fundamentally from the path followed for safety systems in the past. The emphasis is no longer on enclosure of the working areas by tiresome doors, gates, and working instructions, but rather on highly intelligent machine controls that reliably meet the needs of the operator. Working hand-in-hand with the robot, without compromising safety, was one of the safety technology highlights. Complex machine tools and trains of machines in which up to 360 axes are interconnected have already been implemented with safe technology and without the production process, and therefore productivity, being impaired. High-dynamic linear drives, comparable to the drive employed on the prototype Transrapid rail system, with an acceleration of up to 32 g, are controlled safely, and brought to a standstill in an emergency with minimum overtravel.

Common to all new technologies is that new developments in machine construction are being accompanied in particular by modern intelligent control concepts with integrated safety technology. In addition to the central controllers, control systems with remote intelligence are also of decisive importance in the machinery concept of the future. Reliable transmission of data between these remote safety units is becoming increasingly important in this context. Communication is assured by bus systems, which combine high flexibility, programmable wiring without physical intervention, and rapid diagnostics in the event of a fault. The second subtheme, “bus systems,” deals with means for safe design of these systems. A number of different functional standard bus systems are available on the market. The same trend can now be observed in the area of safety bus systems. The objective is on the one hand to provide as safe and as reliable transmission as possible of sensor and actuator data (sensor/actuator bus) in the field, and on the other to transmit large volumes of data (field bus). Ethernet, a bus system that has been employed for some years in industry, is also increasingly being used in safety bus systems. At the same time, all user organizations and safety bus system manufacturers are currently developing harmonized concepts for the integration of the most diverse components for the system integrator. Laser scanners for example are to be configurable directly and in a standard environment through the user interface of the bus system. The user-friendly standard interface will be available for configuration and maintenance even of complex safety drives. Safety concepts for the safeguarding of standard bus systems have been developed over a number of years. These concepts, together with a facility for evaluation of the quality of data transmission, were presented by German and American representatives.

In the Protective Devices subtheme, cutting edge developments were presented such as a French camera system for detection of human beings, to be used for safeguarding escalators. Reports were also presented on experience with the use of modern sensor technology such as light barriers, laser scanners, and passive infrared protective devices. Camera systems in particular appear to be poised to assume an important role, as was evidenced by the ensuing discussion. From a safety perspective, cameras can potentially be employed for the surveillance of large areas. As the entire machine environment can be monitored, the systems will be able, within a few years, to detect faults at an early stage and to shut down the plant or machine if required by the circumstances. The distinction between a human being and a moving product can be integrated automatically into the system. This task can be accomplished at present only by light barrier systems with muting and blanking facilities, the flexibility of which is substantially inferior. The absence of moving parts, the use of cheap mass-produced products from the multimedia sector, and finally, imitation of the human visual apparatus, are further reasons for camera systems with imaging functionality to replace or supplement other protective devices in the future.

Modern safety developments are also coming to fruition in fluid technology. A paper from Germany described an example involving hydraulic proportional valves with safety responsibility. Such valves will increasingly be able to assume the safety-related functions in future.

The conclusion from the innovative safety technology theme is that in addition to the central controllers as the “brain” of the machine, nervous systems, that is, bus systems, senses (modern sensors for personnel detection), and intelligent actuators are available or will become so in the near future, and will serve as elements of a high-technology concept.

## The Human Being at the Centre

In the face of the full range of possibilities presented by technology, innovation should not become an end in itself. The emphasis in the third theme, Focus on the Human Factor, was a systematic consideration of the interests of human beings. This theme was divided into three subthemes, namely Maintenance, Training, and Operation/Man-Machine Interface.

By way of introduction, a French paper demanded that issues of human concern be addressed in a general fashion. Greater importance must be attached to aspects of occupational psychology. Not only technical solutions, but also organizational solutions in which greater consideration is given to human interests contribute towards increasing the safety of machinery. Safety, it was pointed out, is not only the domain of engineers, but must also be supported by ergonomists and psychologists.

The human influence was examined in various situations in the first subtheme, Maintenance. Remote maintenance of machines is a topical issue here. A catalogue of measures for the safeguarding of remote maintenance describes in detail how the activities of personnel and the machine controller are to be safeguarded in order to prevent faults and accidents.

In the Training subtheme, measures for the remote control of mining plants comparable to those described for remote maintenance were presented from a Canadian perspective. The focus here is upon training personnel in safe planning and implementation of complex technologies. The last two papers show clearly that not all tasks can be fully automated, and that human beings must always be included in the safety concept. This confirms, first and foremost, the aforementioned principle described of a generalized approach for the consideration of safety concepts. Human beings, both users on the one hand and designers, integrators, and maintenance personnel on the other, require training.

A further Canadian paper describes how the training of all parties involved is becoming substantially more complex owing to the increasing complexity of the systems. This leads to problems that exacerbate the task of the developer. A new approach containing two essential principles, a technical and a field aspect, is proposed here for the training of designers. The objective is, by playing through the widest range of scenarios, to exploit the experience thus gained in order to transfer competencies to the area of application concerned. This method differs from conventional training, and has been employed successfully in Canada since 1999.

The third subtheme, Operation/Man-Machine Interface, revealed a plethora of different possibilities and problems associated with improving the operability of machines. Japanese innovations in the area of freely configurable control elements, which enable uniform user interfaces to be designed for machine controllers, were described, as were completely new approaches, for example voice control of machines. Concepts for safeguarding remote controls for complex machines serve first and foremost to make machine operation easier. A German paper dealing less with the technical and more with the psychological limits of multifunctional (joystick) controls demonstrated that the design of complex interfaces must be accompanied by occupational psychologists. Some developments currently distributed combine up to 15 control functions in one and the same element. A field and laboratory study on earth-moving equipment revealed that operation of between one and four functions on the same control element is well within the capacity of a human operator. The paper demonstrated that the user's concentration begins to drop considerably however as soon as six or more functions are combined on one control. This simple example shows that the limits of technical solutions may be reached if the human factor is not also considered systematically.

## Summary and Future Perspectives

The most important conclusions and the focus for the future are that

- In the main, the opportunities presented by the use of new technologies outweigh the risks;
- Innovation must be shadowed by prevention;

- Human factors must be integrated into system design earlier and with greater emphasis. The interaction between users and the system, the transfer of expertise from the manufacturer to the operator, the creation of collective competencies, and increased consideration of repair, maintenance and servicing, from the design stage onwards, are particularly relevant here;
- There is a need for the pooling of experience at international level;
- Solutions of new problems are necessary, such as remote control and remote diagnostics of systems, verbal communication between human beings and systems, and the development of new sensors for distinction between persons and product.

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