Air Products and Chemicals INC.

ESCAMBIA PLANT

INTEROFFICE MEMORANDUM

To: Distribution

Date: 3 December 1980

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From: B. A. Gebbia

Re: Process Hazards Review
Methanol Plant

The Process Hazards Review for the Escambia Methanol Plant is scheduled for December 8 - 12. Please plan to attend the review on each day from 8:30 a.m. to 4:30 p.m. Meetings will be in the old administration building conference room.

A Process Hazards Review of the Methanol Plant Revamp was completed in November and would be a helpful reference for these meetings. Also, guidelines for reformer design from PSG were developed for this review. Copies of both items are available from B. Gebbia.

The "What If" method will be used along with the fault tree analysis (for quantitative analysis where necessary) during this review. M. Brown will ensure up-to-date copies of the plant P&ID's are available for the meeting.

B. Cooley will serve as the review committee secretary.

B. A. Gebbia
B. A. Gebbia

BAG:dl

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→ Process Hazard Review

Reliability in Effluent and Water Treatment Plants

A. R. Churchley*

The value and importance of the continued operation of effluent and water treatment plant is often underestimated until a major breakdown occurs. Occasionally, in common with most other industrial plant, a relatively minor failure will cause an extensive shut down. It is usual that some plant equipment is more vulnerable in this respect than others and it is characteristic that there may be an imbalance in the reliability of components and processes making up the plant. In extreme cases, and at longer intervals, enforced shut down of the whole treatment facility may be expected to occur. Consequently, considerable benefits may be obtained from a study of the reliability *make up* of such plant.

The major effluent discharging industries are[1]: chemical, petroleum refining, electricity generation, iron and steel, paper and board manufacture, food processing, textiles (natural and synthetic), quarrying, gas and coke production, soap and detergent manufacture and brewing. Each of these industries produces one or more *liquid effluents* in large quantity.

Water is treated with any one of four objectives in mind, namely: treatment of fresh water for potable† purposes; treatment of sewage to yield innocuous effluent; treatment of industrial feedwaters; treatment of industrial waste for recycling or discharge. Each of these treatments has a different influent, is directed towards a different end product and is carried out in a different environment. With due regard to these differences, it may also be said that there are considerable similarities between them, for example, in all of these treatments settlement, dosing and mixing sometimes play an important role and filtration is often used to *polish* the end product. Even in sewage works where materials of comparatively high concentration can occur and complex reactions involving mixed biological, chemical and physical mechanisms are found, the same basic pumping, piping, valving and storage operations are used. All of the treatment processes ultimately rely on human supervision to manage, operate and maintain the plant, even on highly computerised units. No matter how capable the plants are of performing their intended task, as with any engineering process, they are also vulnerable to human and equipment failures.

The benefits of reliability studies may be condensed down to a simple statement of *reduced costs*. All enforced shut downs involve undesired expenditure. In the case of an industrial effluent treatment plant, its total failure could prevent production elsewhere in the works and incur heavy losses of profit. In the case of a water authority, a loss of facility causes inconvenience and

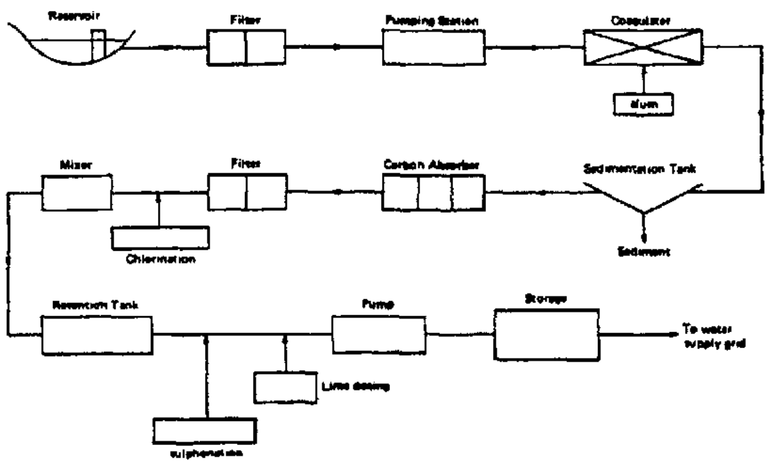

Fig. 1: Principal components of a potable water treatment plant.

* Dr. Churchley is manager of Safety, Availability and Reliability Assessment (SARA) Ltd., Warrington, UK.

† Suitable for human consumption and for domestic use.

annoyance to the public together with consumption of public funds in restoration expenses. Furthermore, serious environmental and health consequences may occur. The consequences of failures may be severe. In a detailed reliability study ***fault tree*** techniques are used to estimate the frequency of such end events, and to highlight possible areas for improvement to reduce the frequency of their occurrence to an acceptable level. It is emphasised that these methods of reliability analysis are equally applicable to the other three kinds of water treatment facility for which different ***end events*** would be identified. ***Human error*** is not strictly an ***end event*** in itself but one element in a chain leading to a serious end event and it is often seen as a very immediate problem by plant management.

Figure 1 shows a typical treatment system. To ***invert*** this diagram into a ***failure logic diagram*** (or ***fault tree***), it is necessary to imagine that each of the stages shown does not perform in the manner intended. Some ingenuity is required on the part of the reliability assessor in order to foresee all the ways in which a given undesired end result may be reached. At the same time, some of the more likely combinations of events may be eliminated.

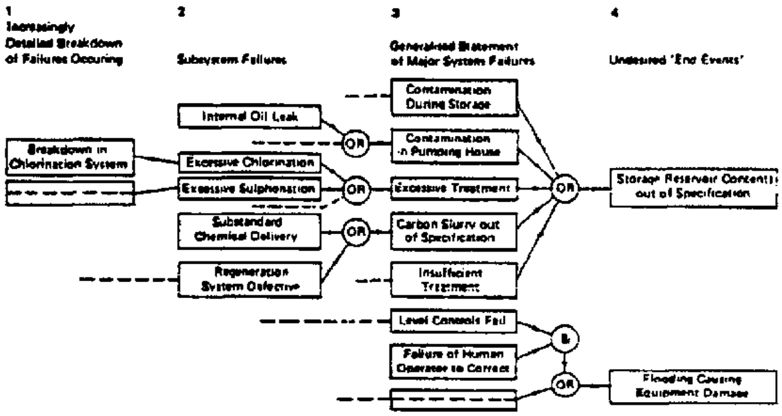

Fig. 2: An early stage in the construction of the failure logic diagram

To give an idea of the appearance of a failure logic diagram during the course of its construction, Figure 2 has been drawn. This represents a small and incomplete fragment of a much larger picture, which could easily run into tens of pages in the case of a ***real-world*** assessment. The columns drawn in Figure 2 (but not normally shown in such a diagram) indicate that the ***flow*** of the logic diagram occurs from a detailed breakdown of individual sub-systems, or component failures, through more generalised failures to the end event which they cause. It gives rise to a number of unanswered questions. How, for example, can the treated water be contaminated in storage? Can a severe oil leak in the pumping house cause serious contamination in the storage reservoir, or is this a comparatively trivial event? Are there other ways in which contamination can occur in the pump house? The diagram refers to excessive treatment by chemicals, but can under treatment occur? How is the treatment controlled? Questions such as these are best answered by the experienced management and operating staff responsible for the water treatment plant. This emphasises the need to build a good working relationship between the reliability assessor and the plant staff and management.

When the detailed assessment is prepared, the completed fault tree includes ***failure rates*** for individual equipment, in terms of failures per year. These ***failure rates*** may be deduced if sufficiently detailed maintenance records are available and some of this data may be available in the open literature, although good quality reliability data is often sparse or non-existent. One survey of ***instrumentation reliability*** in wastewater applications has been completed[2]. Most commonly a recognised data base would be consulted for suitable data, such as the Systems Reliability Service Data Bank. From the ***fault tree***, the areas most liable to failure may be deduced and the mean frequency of undesired end events determined. It is then possible to test various proposed improvements for effectiveness in reducing this frequency. In this way, a very useful cost/benefit analysis may be prepared for the improvement alternatives.

The *fault tree* and *failure rate* information assists in planning a number of maintenance functions, for example, spares holding and ordering levels may be optimised. Routine maintenance and inspection may also be planned so that a balance is struck between effort required and the acceptable frequency of end event. The mathematics required[3] to derive these benefits are a part of the skill of reliability assessment. To further exemplify the application of reliability techniques to water treatment and at the same time to introduce the *safety aspect*[4] a fault tree is constructed for *operator safety*, where sludge gas is generated in the following example.

During the process of sludge digestion on any sewage works a gas mixture consisting mainly of methane and carbon dioxide is produced. Mixed with air, this sludge gas is explosive over a range of concentrations. Figure 3 shows a generalised *fault tree* leading to a safety hazard to the operator. The safety hazard to the operator arises from two main routes. The lower part of Figure 3 shows some of the ways in which an explosion may occur within vessels or pipework if an internal leak occurs. If an operator is present and an internal gas/air mixture has formed, then an internal ignition source causes an operator hazard. A hazard to plant and potential costs due to damage also exists, but this hazard would normally be dealt with on a separate logic diagram.

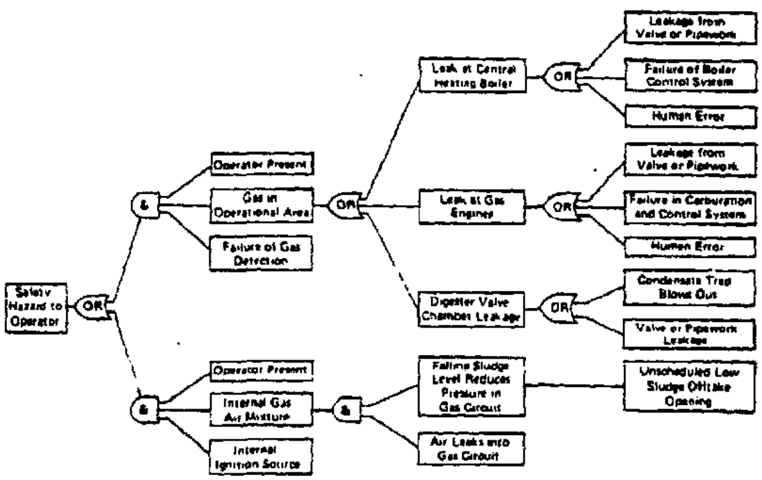

Fig. 3: A fault tree for operator safety

The internal gas/air mixture may result from a falling sludge level in the digester which reduces the gas pressure, any leaks in valves, flanges or vessels will then admit air. The logic diagram shows that both a leak and a pressure reduction must occur at the same time. Referring again to Figure 3, falling sludge level results from an unscheduled opening of the *low sludge off-take* in the digester, which could occur as a result of a control system failure, human error or a valve failure in the open position. With a little thought this fault tree can be extended further to cover the individual failures which may occur. The upper half of Figure 3 shows how gas may enter operational areas and cause a hazard to the operator if, for any reason, the gas detection system fails. There are two reasons why a hazard exists. Even though no ignition source is shown sludge gas is an asphyxiating mixture and the operator himself may cause an ignition since he is not normally expected to wear anti-static clothing or use spark-free tools. The remainder of the diagram shows some of the locations where leaks may occur, and general causes.

In this type of analysis the mean frequency of hazards to the operator may be assessed, and significant improvements are usually derived from the *failure logic diagrams*. The main difference in practice is that a much more comprehensive analysis is carried out. Liaison with management and staff is vitally important in the early stages, particularly when gathering data on how the plant works. Some of the sources and means of recording information are shown in Figure 4. When a complete description of the plant operation has been obtained and understood, *failure modes* can be deduced and *fault trees* constructed.

The configuration of the *fault trees* and the *failure rates* used are discussed

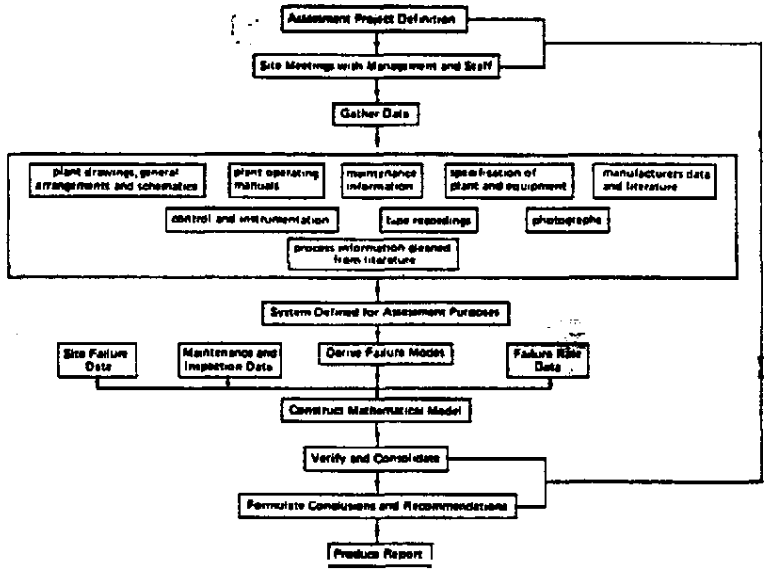

Fig. 4: Typical assessment procedure

with plant management to ensure that errors and omissions are removed and that there is no conflict with practical plant experience. Finally, the work is written up as a report. The conclusions contain suggestions for improvement and recommendations for optimal routine maintenance testing and inspection. Some reliability studies have already been carried out in the field of industrial feed-waters but it is likely that considerable scope for reliability improvement exists in this area, particularly on the newer, more highly automated plant. The differing types of treatment plant, ***(potable, sewage, feedwater and industrial wastewater)*** share in a common need for reliability and many similarities exist between their equipment and control systems.

In all cases, a lack of reliability can be translated into **increased costs.** Improvements in reliability will **increase availability,** reducing losses and important benefits may be seen in the **maintenance function. Safety** may also be improved by increased reliability and, in some cases, an analysis is carried out with this sole objective in mind. The day may come when **reliability** is regarded as an **ingredient of plant success** which has the same importance as the hardware from which the plant is constructed. **Reliability** today is a ***quantitative discipline,*** rather than a ***black art,*** and may be considered as a commodity which can be purchased through the services of the reliability consultant. In the future, increased reliability will undoubtedly be demanded from water treatment plants and this article is intened to show that reliability engineering assessments would be of value in all the water treatments discussed. Hence, in future, we are likely to see increasing use being made of ***reliability prediction techniques.***

Probably the most important message that the reliability engineer would wish to convey is that **reliability engineering is already well developed in many of the engineering industries and it is now ready to take on the challenge of water treatment industries.**

References

1. Royal Commission on Environmental Pollution. Chairman Sir Eric Ashley. 3rd report September 1972. Cmnd 5054 HMSO.
2. Molvar, A. E. et al. How reliable is instrumentation in wastewater applications? Instruments and control systems. October 1977 p29.
3. Green, A. E. and Bourne, A. J. Reliability technology, Wiley Interscience, reprinted March 1977.
4. Health and Safety Commission, consultative document. Hazardous installations (notification and survey) regulations, 1978.

Acknowledgement

This is an abridged version of the paper that first appeared in the Effluent and Water Treatment Journal of May 1979. Quarterly Digest wishes to thank the editor for giving permission to make use of it.

Courses on Reliability Technology

The **National Centre of Systems Reliability** runs a number of regular and short specialised courses on various aspects of **Reliability Technology. Some** courses are held at Liverpool University, some at the Centre's headquarters at Culcheth and others (by arrangement) at an organisation's own premises.

A number of courses are constructed as ***standard packages*** whilst others, particularly short courses of one or two days duration, can be tailored to meet the specific requirements of individual organisations.

Standard courses include:

An introduction to reliability assessment — theory and practice
Location: Liverpool University
Duration: Two weeks
Frequency: Twice per year, Spring and Autumn
Topics: Mathematics of probability, Probability distributions, Reliability testing and maintenance, Equipment failure analysis and prediction, System reliability analysis and synthesis, Data banks, Case studies, Tutorials, Project work and Workshops.

An introduction to the reliability evaluation of engineered systems
Location: Culcheth
Duration: Two days
Frequency: Several times per year
Topics: Need for reliability evaluation, Quantification of reliability, Active and passive systems, Simple probability concepts, Reliability parameter evaluation, Synthesis of system reliability, Data requirements, Case histories and Tutorials.

An introduction to fault-tree methodology and applications
Location: Culcheth
Duration: Two days
Frequency: Two to three times per year
Topics: Need for fault-tree analysis, Various methods of approach, Reliability and probability aspects, System evaluation, Logical analysis and Boolean algebra, Fault-tree symbolism and methodology, Cut-sets, Fault-tree evaluation, Computer program strategies, Case studies and Tutorials.

Basic reliability calculations
Location: Culcheth
Duration: Two days
Frequency: Two to three times per year
Topics: Historical development, Basic probabilistic concepts, Reliability in time domain, System reliability parameters, Simple distributions, Mean-time to failure, Failure-rate, Unavailability, Probability of failure, System reliability calculations, Series systems, Parallel systems, Majority-vote systems, Tutorials.

An introduction to fault modes and effects analysis (FMEA)
Location: Culceth
Duration: One day
Frequency: Two to three times per year
Topics: Need for FMEA, Various methods, Fault analysis and classification, FMEA methodology, Tabular presentations, Codes, Case studies and Tutorials.

Computer codes for system reliability analysis
Location: Culcheth
Duration: One day
Frequency: Once per year
Topics: Need for codes, Strategies of approach, Common aspects, Review of codes available, Examples of application, Advantages and disadvantages of methods.

Tailored short courses or presentations (half to two-day duration) on subjects which include:

Reliability evaluation techniques; Reliability data acquisition and analysis; System reliability modelling; Availability modelling; Common-mode failure analysis; Mechanical reliability analysis; Human reliability factors; Software reliability

with other subjects in the field of reliability technology which may be included to meet particular requirements.

For further technical information or discussions on particular aspects please contact.

Mr. A. J. Bourne, B.Sc., C.Eng., M.I.E.E. M.Inst.M.C., F.I.Q.A., Manager, Reliability Technology, National Centre of Systems Reliability, U.K.A.E.A, Wigshaw Lane, Culcheth, Warrington WA3 4NE. Telephone: Warrington 31244, Extension 345,

or for further details of, and applications for, the two-week standard reliability course and other standard courses please contact:

Miss Mary Sutton, National Centre of Systems Reliability, U.K.A.E.A., Wigshaw Lane, Culcheth, Warrington WA3 4NE. Telephone: Warrington 31244, Extension 318.

Comment

Mr. G. Volta,† an additional comment on "Computer Programs for Fault Tree Analysis" (by Andy Cross*, Quarterly Digest, January 1980).

I think it will be of interest to SRS and fellow Associate Members to know about the computer programs developed and in regular use at the Joint Research Centre, Ispra and freely available to all the European organisations through the JRC Eurocopi Service.

The following table lists five programs, which I think will be of interest, under the same headings as used by Andy Cross so that these, too, can be added to his list.

PROGRAM NAME	FAULT TREE CONSTRUCTION	FINDS MINIMAL CUT SETS	RELIABILITY CHARACTERISTICS	COMPONENT IMPORTANCE	ANALYSIS OF DATA DISTRIBUTIONS	COMMON MODE IDENTIFICATION	FAULT TREE GRAPHICS	REFERENCE
AWE-1		●	●	●				M. ASTOLFI "Programs AWE-1, AWE-2 and BRUNA for the calculation of system availability. Calculation methods and how to use" EUR 5638 e (1976)
AWE-2		●	●	●				
BRUNA		●	●	●	●			
DYCOMICS		●	●	●		●		M. ASTOLFI, F. NALDI "DYCOMICS Program. How to use." EUR 5811
SALP-3		●	●	●		●		M. ASTOLFI, S. CONTINI, C. L. VAN MUYZENBER, G. VOLTA "SALP-3. A computer program for fault tree analysis" EUR 6183 EN

Computer programs for fault tree analysis.

See also COMMENT in the April 1980 Quarterly Digest by Richard Storck of the Institute of Engineering, Technical University of Berlin.

† Commission of the European Communities, Joint Research Centre, Ispra, Italy
* Reliability Research Engineer, Reliability Technology Research Unit, NCSR.

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Personaltities

Mr. E. S. London

Director and founder of Hazards Evaluation and Loss Prevention (Consultants) Limited, 40 Bewsey Street, Warrington, U.K.

E. S. (Selwyn) London, C.Chem, FRIC, who trained at Manchester College of Technology, started his career in chemical plants in 1939 with Jos. Crosfield & Sons Ltd., in Warrington, where soaps and edible oils were processed. In 1941 he moved to a government war-gas factory in Runcorn and later to one in North Wales. After the war he joined Ward, Blenkinsop & Co. Ltd., at Widnes, where fine and pharmaceutical chemicals were made. He than turned to heavy organic chemicals, dyestuffs intermediates, insecticides, etc., with Hickson & Welch Ltd., at Castleford, Yorkshire. In 1948 Mr. London was invited to join the UK Ministry of Supply's Atomic Energy project (now the UKAEA) as a plant manager on the Springfields plant in Lancashire. In 1950 he moved to their Windscale works in Cumbria, where he managed each of the new irradiated fuel reprocessing plants in turn. Selwyn considers the pioneering period from 1948 to 1956 as the most exciting of his career and considers himself fortunate to have been one of the few involved in separating out the first batches of British plutonium produced in the old Windscale Atomic Piles. Great things were accomplished then despite shortages of people and knowledge. In 1960 Selwyn moved to the UKAEA's Health and Safety Branch (now the Safety and Reliability Directorate) There he helped to develop and introduce the modern plant assessment methods and procedures still used throughout the nuclear industry and rapidly being adopted by non-nuclear concerns. He became Head of Chemical Plants and Laboratory assessments, but in 1978 Selwyn left to form his present consultancy He is also a director of Safety, Availability and Reliability Assessments (SARA) Ltd., which, together with "HELP", provides a complementary consultancy service in safety and reliability assessments that is available to all Selwyn is also a founder director of the Warrington Research Centre, one of Europe's foremost fire testing and consultancy organisations.

Mr. N. Jones

Senior consultant with Hazards Evaluation and Loss Prevention (Consultants) Ltd., 40 Bewsey Street, Warrington, UK.

N. (Noel) Jones, L.R.S.C., began his career in 1941 with Courtaulds Limited, Flint, North Wales, UK, where they manufactured viscose rayon. From 1944 to 1948 he served in the Aircrew Branch of the Royal Air Force after which he returned to Courtaulds Limited as laboratory assistant, then shift chemist and finally production foreman. Mr. Jones joined the UKAEA in 1958 at the Dounreay Experimental Reactor Establishment, Thurso, Caithness, Scotland, as an analytical and development chemist in the irradiated fuel reprocessing laboratory. During this period Noel had been studying Chemistry at Thurso Technical College and in 1964 he gained corporate membership of the Royal Institute of Chemistry (now the Royal Society of Chemistry). In 1966 he took over technical management of an integrated Nuclear Fuel Reprocessing Plant and the associated Highly Active Liquor Evaporation and Storage Complex. Noel joined the Systems Reliability Service, at its inception in 1970, as a Field Engineer. He was actively involved in development of the SRS Data Bank, in the organisation of Event Data Collecting schemes at Associate Member's works, the supervision and guidance of engineering students abstracting reliability data from maintenance and operational records at chemical plants throughout the UK and, latterly, he was engaged on SRS reliability assessment project work. In 1975 Noel transferred to the Chemical Plants, Labroatories and Transport Section of the Safety and Reliability Directorate (SRD) where he carried out quantitative safety assessments of new chemical plants He also advised design engineers working on new plants and represented SRD by serving on Safety Working Parties Noel joined his present company in July 1979.

Dr. A. R. Churchley

Senior consultant with Safety, Availability and Reliability Assessments (SARA) Limited, 40 Bewsey Street, Warrington, UK.

Dr. A R. (Andrew) Churchley, BSc. Tech., Ph.D., C.Eng., M.Inst.E., A.I.Inf.Sc., graduated in Fuel Technology and Chemical Engineering from Sheffield University in 1967. His research work concerned oscillating combustors for gas turbines, in conjunction with the National Gas Turbine Establishment, Pyestock, Hampshire. During this period Dr. Churchley gained experience as an engineering consultant through his association with the development department of the National Carbonising Company, North Nottinghamshire Division. In 1970 he joined the engineering department of that company as a project engineer, constructing Europe's most modern low temperature smokeless fuel production plant at Snibson, Leicestershire, UK. At this time he became a chartered fuel technologist and, later, he became research leader in the Scientific Services Department, improving the quality and profitability of smokeless fuel production In 1973 Andrew joined Unilever Research at Port Sunlight, Wirral, Merseyside as an Information Scientist He built up a practice serving the diverse interests of Unilever engineers including, significantly, a group of reliability engineers He became editor of Safety News, an international publication with world-wide circulation, and assumed responsibility for the laboratory data preparation group Andrew joined AE Electronics, a reliability engineering consultancy based at Stockton Heath near Warrington, in 1978 where he was engaged in studies of water treatment plant In May 1980 Andrew joined his present company which is the sister company of Hazard Evaluation and Loss Prevention (Consultants) Limited. He has presented a number of technical papers at National conferences and symposia and published reliability papers in the technical press (see elsewhere in this edition of Quarterly Digest). Amongst his spare time activities Andrew is a keen radio "Ham" and he operates station G4EAQ.