Structural Failure, Product Liability and Technical Insurance

edited by
H.P. Rossmanith

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STRUCTURAL FAILURE, PRODUCT LIABILITY AND TECHNICAL INSURANCE

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PREFACE

Failure research and fracture mechanics technology have advanced to the stage where they are of direct engineering value for the prevention of sudden fracture in structures. This new technology forces an interdisciplinary system-type approach to failure prevention and it is mandatory that the technology stresses on the interaction between material properties, design, fabrication, inspection and operational requirements so as to enhance safe and reliable performance of engineering products.

The rapid rate at which modern technology is being developed has accelerated the manufacturing of engineering products and construction of large-size structures. With respect to possible damage of the structure the supplier and user should be aware of the current state of the art so that fracture mechanics can be fully utilized to produce a better product.

Ignorance of modern developments in fracture research may cause severe damage of constructions associated with possible loss of life leading to legal problems concerning guaranty, payment of damages, product liability and insurance. Advancement and results of fracture research offer new measures and guidelines for the conception and the extent of damage, the methods of damage assessment, the repartition of loss, the avoidance of damages and the insurance against losses. They will also influence the liability of the producer for the safety of his products.

In 1973, the American Society for Testing and Materials (ASTM) in its March issue of the Standardization News, entitled "Product Liability", calls the readers' attention to the new field of 'product liability'. The merging of the computerized precise world of engineering with the polymorphic societal world results in the emerge of a new engineering ethic, and the impact of product liability on engineering is impressively demonstrated by the fact that 27 out of some 70 pages of the March issue have been devoted to this important subject. During the very same month - March 1973 - a Short Course in Fracture Mechanics, Failure Analysis and Product Liability was offered by the Materials Research Center and Department of Metallurgy and Materials Engineering at Lehigh University, USA. The short course was designed for engineers and managers "...who have concern for the fracture of engineering components and their resulting legal consequences". Shortly thereafter failure analysis and fracture mechanics short courses were offered at numerous places in the industrial countries.

In 1981, an international seminar on "Failure Analysis, Fracture Mechanics and Technical Insurance" was held in Vienna, Austria. Overwhelming success of the seminar, close scientific cooperation of Dr.H.P.Rossmanith with Prof.Dr.G.R.Irwin from the University of Maryland over the past six years, and the conviction that the time was favorable to bring together engineering people, lawyers and technical insurers, gave the incentive to call for an international meeting. Participating experts presented and discussed recent advances in failure research and fracture mechanics as well as the impact of this technology on product liability with a firm stronghold on failure preventive design and manufacturing methodology, and legal and insurance aspects of product liability. The First International Conference on "Structural Failure, Product Liability and Technical Insurance" was held in Vienna, Austria, during the period of September 26-29, 1983, and was jointly organized by the Institute of Mechanics (H.P.Rossmanith), the Institute of Law (J.Kühne and M.

Straube), and the Institute for Testing and Research in Materials (T.Varga) at the Technical University of Vienna, Austria.

A significant number of internationally renowned specialists had expressed their deep interest to attend the conference and to present invited and contributed lectures. Industrial and governmental engineers, academicians, advanced technicians, scientists, technical managers, lawyers, and technical insurers representing 19 countries from all over the world took part in the sessions and discussions.

Concerning the merging of the technical and juridical fields this Conference can be said to have been a decisive milestone in the development of engineering. Hence, we shall attempt to highlight a few of the basic ideas of the subject.

In his key address to the Conference, A.A.Wells from The Welding Institute, Cambridge, calls the engineer's attention to the '*Fitness-for-purpose Concept*', an approach that has evolved in response to some of the lessons of structural failures, featuring the right level of material and fabrication quality for each application having regard to the risks and consequences of failure. The lecture also embraces the evolution of the design process, risk analysis and reliability engineering, non-destructive examination, codes and standards, and quality assurance - topics, that form the subjects of individual contributions.

The impact of fracture research on '*Failure Preventive Engineering* (FPE)'- a subject of great importance to anyone in the chain from the designer to the user and failure analyst in the process of design, development, fabrication, marketing, operating and scrapping of a product - is investigated in a paper by H.P.Rossmanith from the Technical University of Vienna.

In the next lecture, B.Ross of Failure Analysis Associates, USA, poses the significant and momentuous question "*What is a design defect ?*" and, after reflection on economic loss, insurance cost, product liability trends and risk of fatality, he relates salient details of a variety of design defects to case histories including disastrous failures such as DC-10 aircraft crash, Hyatt Regency hotel walkway collapse, VW fuel tank failure, etc.

H.J.Schüller of Allianz Center for Technology Ltd. (FRG) reports on *failure analysis and research as an active service in technology and insurance* performed at the AZT over the past 50 years. Particular emphasis is put on the insurer's active contribution towards stemming the increase of losses which have already reached threatening proportions.

One particular field of engineering, unfortunately associated with a steadily increasing degree of loss, namely *vehicle design, road building and safety equipment*, is the topic of a contribution by A.Slibar, Technical University of Vienna, Austria.

Failure analysis of metallic structures such as *aircraft parts, pipes, prestressed concrete structures, oiltanks, steam turbines etc* is highlighted in a number of distinguished papers. We bring the attention of the reader to the sequence of fine papers covering the *interaction between design and quality control* with special reference to *turbine and pump construction, the role of flaw tolerances* in preventing structural failure, as well as the *application of quality assurance systems* in the production of materials and components for application in diversive fields of engineering such as e.g. *large pressure vessels operating at low and high temperatures* and *biomechanical implants*.

The session encompassing the more technically orientated papers is concluded with a group of contributions featuring the *development of structural supervising systems, the realisation of structural reliability in the design stage* and miscellaneous problems of the *control of fracture in welded structures, the application of finite elements, void growth in structural steel* and the effect of environmental noise such as *sonic boom* as seen from the point of view of failure-inducement.

Numerous failure analyses and associated legal case histories are used to trace the development of product liability and product liability insurance. *The insuring of products liability in the United States* is reviewed by R.S.Cline of the University of North Carolina, USA. Special consideration is given to the causes and possible solutions to the problem. *The presentday situation of product liability insurance in Austria* as well as its *international relationship* are presented in two papers.

A remarkable contribution by F.Schubring-Giese of Allianz Insurance Ltd.(FRG) refers to the subject of *product liability insurance as seen from the view point of a German insurer operating on the international market-place*. The main points given prominence to are product liability insurance, product recall insurance, featuring multinational companies and German risks involved, European as well as U.S. product liability law. The importance and far-reaching consequences of *risk management within the framework of product liability* and *macroeconomic aspects of risk management* is illustrated in two remarkable papers by M.Gudenus of the Vienna University of Economics, Austria, and W.Eichhorn of the University of Karlsruhe, FRG. The following two papers are devoted to the *effects of self-insurance* and to *constitutional problems of dynamic reference*.

The final group of papers is concerned with a very delicate topic: inspection and failure of concrete structures. First, the problem of *material insurance coverage for cracks and defects in concrete buildings* is investigated and, secondly, *continuous inspection as a means of reduction of risk of fatal defects* as well as the *development of control plans for concrete buildings* is presented.

The selection of papers gives an excellent and general state-of-the-art review of the many facets of failure analysis, product liability and technical insurance, and their mutual interrelationships. The heterogeneity of the subject presented will be encountered in many places and situations. In view of the future development and role of product liability all participants have agreed on the need of close cooperation between engineers, lawyers and technical insurers. As a result of dissimilar and divergent terminologies and different ways of reasoning of the members of two professional groups the Conference exhibited a 'language-problem' which forms a major drawback to joint venture. The lectures and stimulated discussions at the conference have revealed the fact and left the impression that much work has to be done yet in forming a sound basis common to engineers and law people for improved understanding of mutual problems involved in common failure cases.

On behalf of the Organizing Committee I take great pleasure in expressing my sincere gratitude to Prof.Dr. G.R.Irwin for having brought to my attention the importance of the interdisciplinary interaction between failure analysis and product liability and technical insurance.

Finally, I wish to thank the following institutions and organisations for their assistance and cooperation during the conference and the preparation of these proceedings:

- Technical University of Vienna, Austria
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- Austrian Failure Analysis Associates (AFAA)
- Austrian Science Foundation (FWF)
- Carl Schenck AG, Darmstadt, FRG.

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Hans-Peter Rossmanith

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THE FITNESS-FOR-PURPOSE CONCEPT

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Fitness for purpose is deemed to be that which is consciously chosen to be the right level of material and fabrication quality for each application, having regard to the risks and consequences of failure; it may be contrasted with the best quality that can be achieved within a given set of circumstances, which may be inadequate for some exacting requirements, and needlessly uneconomic for others which are less demanding. The need for such an approach has already been seen with the development and application of fracture mechanics, but the paper draws attention to a wider scope which also embraces the evolution of the design process, risk analysis and reliability engineering, non-destructive examination, codes and standards, and quality assurance.

INTRODUCTION

At the time of his Presidency of the Institute of Welding (1960-61), Edgar Fuchs had been responsible for the specification and use of heavy welded plant in the chemical industry, characteristically operated at high and low temperatures, high pressures, and in conjunction with hostile environments. It had been his earlier experience that the consequences of failures in such plant were so costly as to justify the search for perfection in fabrication. Yet, in his Presidential Address (1961), he introduced the term and concept of fitness for purpose, and linked it with what was known of the significance of weld defects. His first example related to the development of porosity in MIG welded aluminium alloys which was then prevalent, and which called for much excavation and repair of welded seams. It had been concluded that this aspect of the search for perfection was totally misdirected, since no destructive test of those welded joints exhibiting moderate porosity could demonstrate a diminution of strength or ductility, whatever the loading condition. Indeed, the repairs were sometimes retrogressive, because they introduced new defects (lack of fusion, etc.) which did have a weakening effect.

As a result of sustained thinking on this topic he concluded that the most suitable quality of welding, even for onerous working conditions, was that which would emerge from all the evidence of mechanical, metallurgical and non-destructive testing (NDT) with the aim to establish the significance of defects. There is a profound difference between such a concept, and its precedent which aimed for the best quality that could be achieved with the available knowledge and means, regardless of application.

The very idea that all constructions contain defects has for long been repugnant to some, in recognising too readily that an ideal of perfection cannot be attained. The attitude is maintained in spite of recognition that acceptance of the alternative fitness-for-purpose concept entails an added responsibility, which is to assess the significance of defects, and to base inspections accordingly. Much has taken place since 1960 in the total development of welding technology to convert the fitness-for-purpose concept into a workable reality, but the old indiscriminate judgements do persist.

The positive argument in favour of retaining national standards based upon good workmanship rather than fitness for purpose is that the former impose a discipline upon craftsmen. As a particular case this cannot be denied in relation to those welding defects which are under the control of the welder, and rely upon manual welding skills for their avoidance. However, modern welding technology relies upon a wide range of supporting skills, for instance in choices of materials, welding processes and consumables, whose control is vested more in the welding engineer than the welding operator. Control of workmanship is then only a part of the total problem, as will emerge from this paper.

Cost escalations on projects both large and small have increasingly occurred in recent times. Some are related to management problems, and others to inflation over long periods of construction for large plants; it could be said in a few cases that an inadequate balance has been maintained between economy and safety. Lavish expenditure in the pursuit of quality may not always secure more than a diminishing return in terms of safety. The key to this dilemma now rests particularly with public perception: if the public is to be educated with respect to what can reasonably be expected in terms of safety from industrial projects and constructions, it is first necessary for the professional ethic to be clearly described, together with the working procedures which stem from it. This provides another objective for discussion in this paper.

In the contemporary scene the criteria for fitness for purpose are expressed more as a set of principles than as a movement towards more rigid specifications. It follows that the attempt is to define more closely some of those considerations which would formerly have been described as 'good workmanship' and 'sound engineering judgement'.

This is no more than a striving to do better and with more conscious articulation that which was done intuitively in the past. Thus, it was never customary to apply the same criteria to the selection of timber for a public utility pole in a country lane as to that for a sailing ship mast. The contrast was even wider between freestone for a rubble fill and squared blocks for ashlar masonry. The steel industry in a more modern context exhibits perhaps the most extensive hierarchy, with the highly refined and closely specified massive products for such as turbo-alternator rotors and nuclear high pressure vessels at the apex, and the more loosely specified products known affectionately in the U.K. trade as 'clog-iron' at the base for undemanding requirements. The monetary values of these products on a tonnage basis will vary by factors of more than 10. No well qualified engineer can afford to be ignorant of these distinctions: at one extreme he will risk failures and at the other he will unnecessarily waste the money of clients.

EVOLUTION OF THE DESIGN PROCESS IN STEEL STRUCTURES

Large engineering works in the 19th century and earlier were customarily conceived, planned, and executed by talented engineers as individuals, with few assistants and training on the job for those in a master and pupil relationship. Straightforward calculations were performed and confirmed by many tests on models. More complex calculations were pioneered in Continental Europe, and particularly in France, arising from the flowering of academic engineering science at the time of the Napoleonic Wars. The uses of elastic structural analysis and stress analysis were firmly entrenched everywhere at the commencement of this century. Knowledge had become firmly established at this time, but the base of experience tended to be broader in this field with independent contributions from the U.S.A, Japan, and elsewhere, as well as from Europe and Scandinavia. The complementary art of conceptual design of engineering works and structures can be separately distinguished and has more substance than is confined to structural analysis and strength of materials. It is closely allied to the practical limitations of construction, and to the organisation of large projects which developed extensively in the 19th century with the building of canals and railways, and has continued at an increasing pace ever since, notable through influences initiated in the U.S.A. Nevertheless, it is with detail design, analysis, and mechanical properties that we are concerned here.

These activities have been transformed in scope and importance during the past fifty years. In the first place, the capabilities of structural and stress analyses have increased by orders of magnitude through the application of numerical methods handled by digital computers. Experimental model tests have not disappeared, but have been progressively replaced by mathematical modelling. In the second place, mechanical testing has been modified by the orderly development of fracture mechanics methods, but an even more significant revolution has occurred with regard to the improvement of mechanical properties both in scale and consistency, through the development of metallurgical science. Two discrete sets of tools have been provided by and for metallurgists to make this possible. On the one hand wet chemical and similarly tedious methods of analysis have been supplemented by precise and automatic spectrographic methods, and a variety of other complements which provide not only instant readout but also data on molecular form as well as proportional atomic constituents. On the other hand the development of the whole family of electron microscopes has greatly increased the revelation of fracture surfaces, metallic microstructures, and other polycrystalline forms, so that the effects of impurities and contaminants as well as microalloy constituents have come into much sharper focus than hitherto. A similarly vigorous revolution, whose effects, both real and potential, are not yet so clearly evident, is now taking place in the methods of non-destructive examination. X-ray methods, long thought to be incapable of illuminating cracks, are increasing their ability to do so, and ultrasonic methods of great sensitivity are beginning to conform to the need for automatic recording. All these new methods for the analysis of metals and minerals have benefited metal processing, but nowhere has the effect been more profound than with regard to metal joining, welding, and fabrication.

This burgeoning of new tools and methods is only now being assimilated. A major effect has been to create a challenge to such intangible concepts as 'the responsible engineer'. The new methods of analysis, although they vastly supplement insight and capacity to control on a material basis, also require the services of an army of experts, and call for collective responsibility in implementation of a construction. Since no expert can readily be challenged in his own field, it might be expected that a side effect would be to retard the rate of construction and increase its costs, in exchange for an unquantified increase in safety and quality of the end product.

Assimilation into industry of the 'new metallurgy' has, in fact, been accompanied by several counterpart developments which help to optimise the advantages. These include risk analysis, fracture mechanics, non-destructive examination, computer-aided design, and quality assurance (QA). They are constituents which make up a total package of fitness-for-purpose design.

RISK ANALYSIS AND RELIABILITY ENGINEERING

These are two aspects of quantification which address the same problem from different ends, and which had their origins in Scandinavia and the U.S.A, respectively. Long before it became customary to grace such studies with specific names, the engineering insurers and classification societies worldwide compiled statistics on the incidence and manners of failure of engineering structures. Excellent work was published and updated from time to time. Specific families of structures were isolated and firm data now exist for aircraft, for fractures of ship hulls and oil storage tanks, and for pressure vessels. The populations of structures in service and therefore at risk over periods of, say, twenty years are sufficiently large that the observed failure rates are as regular as mortality rates, and small changes of rate can be perceived. These changes are mainly downwards, in spite of considerable improvements of service performance over corresponding periods. It is abundantly clear that public tolerance has much to do with the setting of acceptable casualty rates, and that these latter diminish as the number of human beings exposed in a potential casualty becomes larger. A comparison of the data from the several classes above leads to the elementary supposition that an acceptable probability of structural failure is that for which the associated human casualty rates approximately match the risks of death and injury from natural causes. However, the public perception of risk is strongly biased (Warner and Slater (1981)) to accept the familiar (motor bicycles and common diseases) and reject the unknown but dreaded risks (nuclear incidents, crashes of large aircraft), irrespective of the actuarial data.

It follows that experimental observation of structural casualty rates should have been supplemented in due course by attempts to calculate them in advance, as for instance in the case of nuclear pressure vessels. Risk analysis has developed from this, and it attempts to compute the overall risk of failure from constituent parts, using statistical and probabilistic methods. The methods first developed in Denmark have taken account of pressure vessel loading, notch toughness and its scatter, characteristic populations of cracklike defects, and efficacy of NDT methods in finding these defects. The value of these methods is best seen when sensitivity analyses are superimposed upon them, since these show where efforts to improve can best be applied. It is of interest to the metallurgist that one of the most required developments is shown in this way to be the improvement of the consistency of notch toughness properties.

The parallel approach known as reliability engineering is believed to have been developed in connection with electronic components for use in aerospace equipments. Standard failure rates have been compiled for such as resistors, capacitors, and transistors, and these can be synthesised to predict failure rates for circuits, both singly and in array. More recent applications have been made to measurement and control units used in the gas and petroleum industries.

It is the experience of this author that the benefits of making use of risk analyses by calculation are obtained at no great cost other than that of the determination of standard deviations on measured mechanical (and other) properties (which require permutation in any case for purposes of quality control). The benefits include the assignment of meaning to occasional low results, and identification of areas where improvement leads to no more than diminishing returns. Risk analysis falls within the province of the engineering designer, and can assert a strong influence on the rational determination of fitness for purpose.

FRACTURE MECHANICS

The main circumstances of the development of fracture mechanics, especially linear elastic fracture mechanics (LEFM), are by now very well known. The objectives have been summarised by the author (Ford et al (1981)) in the following terms:

"<u>The aim</u> of using the fracture mechanics approach to fracture control in engineering structures is to determine the loading (applied, thermal, residual stress, etc.) at which a pre-existing crack of given size will extend in the most vulnerable mode (brittle, ductile tearing, fatigue, stress corrosion, high temperature creep). <u>The means</u> involves:

1. the determination of loading conditions for crack extension in a sharply notched specimen by using the appropriate material and environmental conditions (temperature, loading rate, gaseous and electrochemical surface condition, pressure)

2. the provision of a stress analysis embracing the sharp notch in both distribution and scale, and the effects of shape and loading conditions."

It may be added in amplification of these stated principles that the first objective is to measure the fracture toughness of the material under precisely standardised conditions, and the second objective is to estimate the driving force at the postulated crack, wherever it may be found in the structure and whatever might be the most onerous conditions. The fracture toughness will exceed the estimated values of driving force under safe working conditions, subject to margins which relate to previous experiences.

Thus, fracture mechanics was specifically developed to help the engineer to determine the significance of defects in terms of susceptibility to fracture, and to reinforce judgements on the necessity to repair defects once they had been detected. Its relevance to fitness for purpose is self-evident.

The concept of defect tolerance has been well established by observation over the past two decades of the behaviour in service of welded structures containing cracks (Wells (1979); Burdekin (1963)).

Although fracture mechanics has become widely known, the usefulness of the approach is confined at present to the control of notch ductility or fatigue crack growth rates in a relatively narrow range of structures of high expected performance, usually associated either with high strength materials or heavy sections. The main reason for this is related to the employment wherever possible of materials, typically ferritic steels, at temperatures and strain rates so that they are above a transition temperature, and therefore exhibit a high margin of tolerance with regard to fracture risk.

The accurate measurement of fracture toughness by fracture mechanics methods is more difficult in the circumstances of superior toughness, and the tests are relatively costly to perform. Such measurements are beyond the range of LEFM and require the use of the crack opening displacement or J-integral criteria. Furthermore, the measurement specimens require in many cases to be of full-section thickness to make valid measurements. It is also necessary in most of such cases to make use of the full resistance curve, taking slow crack growth into account to the point of instability, to mobilise the very high values of fracture toughness which characterise modern steels of very high qualities.

The favourable economics of such approaches are well established for high performance structures, and there are no valid alternative procedures for them. Conversely, these procedures are inappropriate for most constructions of a largely repetitive character, for which there are serviceable, empirical alternatives in control through Charpy V notch impact testing, together with correlations with performance of similar constructions in past service. This dichotomy can be regarded as temporary since valid and characteristic fracture toughness values will become available as standard data in the course of time, although this state of affairs does not yet obtain. Despite many careful attempts up to this time it has proved to be relatively unsatisfactory to rely upon empirical correlations between the results of valid fracture toughness tests and those of Charpy V notch impact tests.

NON-DESTRUCTIVE EXAMINATION

Structural defects must first be detected and sized by NDT before their significance can be assessed. The methods that are characteristically employed, e.g. X and radiography, magnetic and penetrant testing, and ultrasonics, have all now been in regular service for more than thirty years, but it would be inappropriate to assume that any one of them has yet reached full development, or will lapse into disuse. The importance of magnetic and penetrant testing for surface defects has been emphasised in the light of much careful fatigue testing of fillet welds, which has demonstrated the vulnerability of the latter in circumstances of repeated loading. This arises from the coincidence of superimposed geometric and metallurgical discontinuities at their edges, or toes, to the extent that incipient or very shallow cracks are often present from the time of manufacture. These cracks are readily detected by one or the other of these methods of NDT, and their effects can also be ameliorated by various surface dressing techniques. Such treatments have proved to be of use in the construction of welded steel ocean platforms, particularly those destined for the North Sea where wave loading fatigue effects are present, and in which fillet welded joints are commonplace at the nodes of tubular constructions.

Recording techniques associated with radiography have been improved to such an extent in the recent past that it is no longer held to be conventional wisdom that cracks cannot be detected by this method. The long recognised advantage of radiography has been the acquisition of permanent visual records, which are suited to the proof of contractual obligation. Ultrasonic observations were earlier regarded as complementary in this regard, in that the method making use of reflections can exhibit considerable sensitivity, but is sometimes lacking in certainty of detection. The method is also penalised by scatter and absorption when associated with coarse microstructures, such as sometimes arise with austenitic materials. There are also difficulties in distinguishing legitimate signals from background noise levels. In spite of these limitations ultrasonics has become the principal tool for sizing defects. Considerable progress has also recently been made in overcoming a similar problem with the transmission of television images through space, through the conversion of data to digital form, coupled with signal processing by numerical methods. Recent attempts to apply similar techniques to ultrasonic imaging have been encouraging (Hanstead (1981)), and should further assist in defect sizing as an adjunct to the application of fracture mechanics.

Ultrasonic imaging offers a powerful technique for the acquisition of permanent data, even in its present state of development, and has led to the concept of 'fingerprinting' important structures fabricated by welding at the time of commissioning, and at infrequent intervals during service, so that the degree of quiescence or alternative growth of incipient defects can be observed. This technique develops in importance where there are repeated loads which can cause fatigue but where a long service life is also envisaged. Fingerprinting was devised for the special case of nuclear reactor pressure vessels, but is becoming justified for wider application.

QUALITY ASSURANCE

Of all the modern aids to fitness-for-purpose design and construction the simplest and possibly the most useful has been the development of QA concepts and methods. Quality assurance is the system of organisation which joins them all together, and is still best described as the provision of a standard of good housekeeping.[1] The need for QA arises firstly with the growth in complexity of modern construction and production sequences, coupled with the requirement on behalf of a purchaser for independent verification that all the specified sequences have taken place correctly and in the right order.

Quality assurance methods have their roots in the design process, at which stage the needs and objectives are defined. The interpretation at present embraces the proper selection of methods for structural analysis and design, authentication of design data, and independent checking of calculations, including those making use of computers.

Nowhere is the need for good QA methods more acute than in the deployment of correctly chosen materials, which should also receive the correct treatments during manufacture. The system is therefore applied with uniform attention, firstly in design, then from the stores where the materials and components are first accumulated and disbursed, through the production operation to final inspection of the finished product. It embraces evidence of calibration of the production equipment and the instrumentation used for quality control. It also embraces a sufficient documentation of the work as it passes through the production stages.

Quality assurance procedures supplement the necessary activities of inspectors such as those employed by insurance bodies and classification societies. They are based upon the creation at each plant of a quality assurance manual, prepared by the staff of the plant to satisfy the needs of inspection.

The Quality Assurance Manual aims to describe in detail the design and manufacturing capability of a plant in terms of its skills, resources, and ability to control them, and therefore commences with staff and organisational pattern, including the skills and qualifications of many individuals. It goes on to describe in detail the resources and facilities, both general and specialised, from buildings to individual plant items. It takes account of training facilities and those for acquisition of expertise from outside sources. Considerable attention is given to facilities for measurement, including those associated with machine tools and manufacturing equipment, and those in supporting laboratories. This includes the arrangement for calibration, both within the plant and outside, to which references are made on a routine basis or otherwise. Design/production organisation and documentation methods are set down. Inspection facilities, the methods that are used, their characteristic performances and the associated documentation systems are obvious candidates for detailed attention. The Manual is examined by a responsible outside body both at the outset, and at intervals thereafter; it is also updated when significant changes occur. Omissions and modifications are required to be dealt with, and the outside body conducts and maintains an audit to ensure that the Manual corresponds with actuality.

The QA Manual becomes the basis upon which customers assess the capability and suitability of a potential contracting firm, and government departments and multinational companies were the first to demand and encourage the use of this approach and to conduct their own audits. The necessity for multiple audits has been diminished in one field in Britain by the founding of the Pressure Vessel Quality Assurance Board (PVQAB), and its affiliation with the Institution of Mechanical Engineers. It is not therefore a government body, but is fully recognised by the Health and Safety Executive. The duties of the compact staff, answerable to the Board, centre upon the appointment of auditors to act at companies seeking and extending recognition, and to ensure that the auditors operate impartially and are themselves suitably qualified. The auditors are drawn from the skilled and experienced staffs of engineering insurers and classification bodies. The advantage of the system to the participating manufacturing companies, including those concerned as subcontractors, is that the need for multiple audits is diminished. Its success will otherwise depend upon the capability to satisfy customers for equipment whose standards have already been created by previous experience. The PVQAB should provide for users of British Standards the facility which has hitherto been provided by the American Society of Mechanical Engineers for users of the corresponding US Standards, a service which has proved to be of such value that it has penetrated many countries of the world, and is well known for its pragmatism.

It should be emphasised that these systems take care of the need for organisation of quality assurance and provide for its audit; they do not diminish the need on behalf of the customer to make use of independent inspection, which may be provided as before by the insurers and classification societies, nor do they replace internal inspection during the progress of work. The systems do provide unambiguous evidence of what is expected in manufacture, and how it is to be attained.

CODES AND STANDARDS

Nothing that has been described diminishes the need for effective national codes