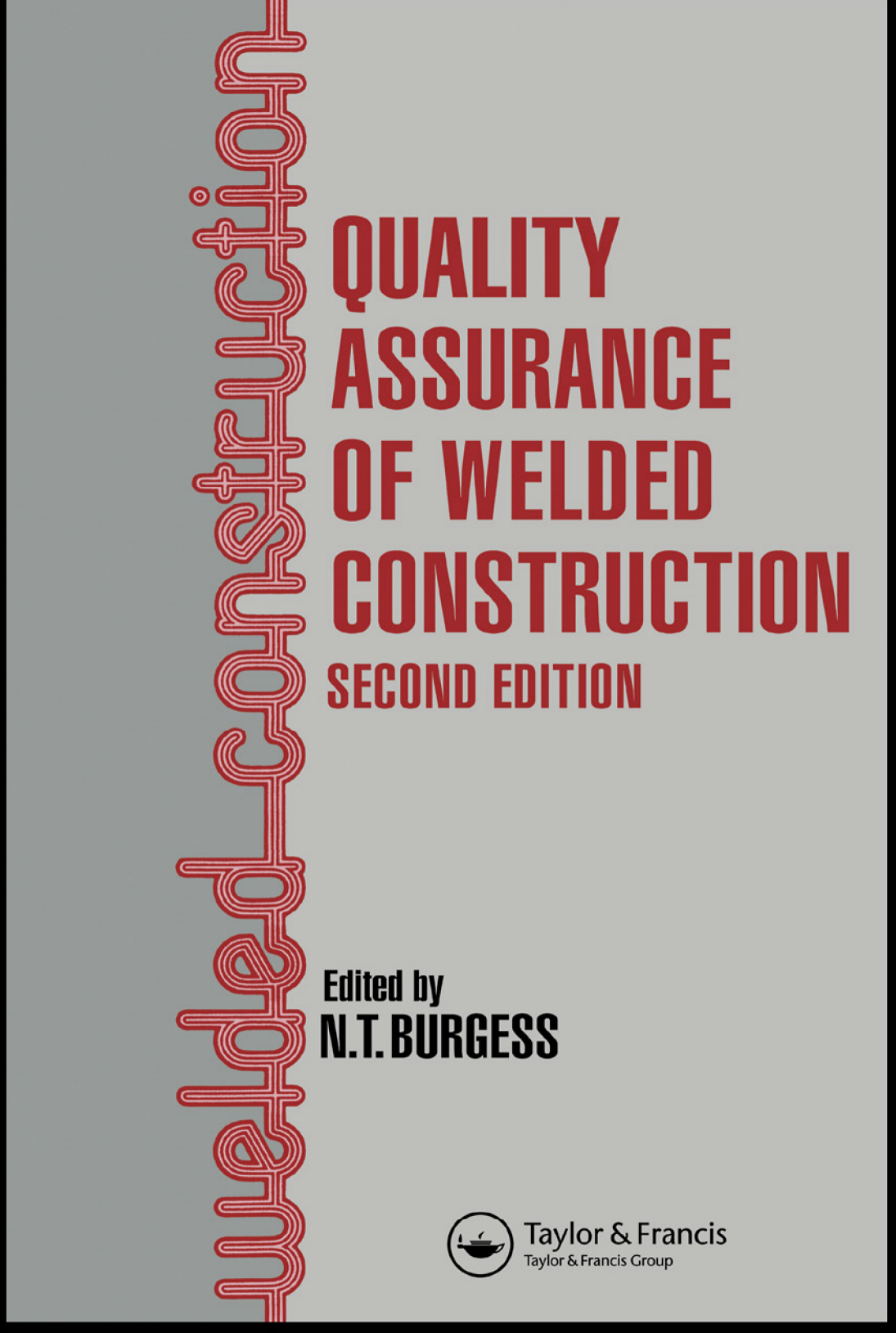

Quality Assurance of Welded Construction

Second Edition

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Preface to the Second Edition

Since the first edition of this book, most developments have been with the quality assurance element of its contents rather than with the welding technology part.

Of considerable significance to all parts of the construction industry, not least the fabrication side, was the issue of the International Standards Organisation's document ISO 9000 series, which effectively set the same quality management criteria worldwide. In the UK, this was issued as BS 5750:1987, and the subject is addressed further in this book.

The development in industry towards greater quality assurance is very substantial and, whereas in 1983 assessment of a manufacturer's capability was mostly left to the clients, particularly the major ones, in 1988, a significant number of fabricators have sought recognition for their quality management arrangements by obtaining certification from an independent third-party body. Indeed, 1988 saw the launch of the industry's own QA Certification Scheme by the British Constructional Steelwork Association, with several successful registrations. This new scheme (details from BCSA, 35 Old Queen Street, London SW14 9HZ) has its own Schedule which translates the more general requirements of BS 5750 (ISO 9000) to the particular needs of the fabricator and his customer.

This scheme, almost unique in the world, augments the more general schemes available from the other certification bodies in the UK, the BSI and Lloyds Register Quality Assurance Ltd. This trend is likely to have an impact in Europe now that the plans for a single market by 1992 have been announced. Construction products and certification figure prominently in the legislation.

The objectives for this book remain the same, but the opportunity afforded by reprinting has been taken to include new authors, new material and new ideas. In particular, there are now two chapters on design, both by a well-respected contributor who offers sound advice from a background which spans fatigue research, and offshore and structural consultancy around the world. Chapter 2 embellishes the traditional role of welded products design by sound quality advice. The organisation and execution of good design work is discussed along with education and training aspects, sources of information, etc.

In Chapter 3, more specific advice is given by the same author relating to design concepts, detail design and the critical parameters to be considered if quality weldments are to result. The requirements of Design Review, addressed in ISO 9000, are covered.

The opening chapter, now entitled 'Fundamentals', reiterates the earlier precepts since many of those improvements required are still overlooked in the rush to get certification. The bumper sized chapter on quality in shop operation remains at the 'heart' of the book, containing as it does experiences and recommendations of a well-established welding engineer turned quality executive!

Similarly, site operations are covered in Chapter 5, now enhanced by the author's direct involvement with one of the most important welded structures of our times—the revolutionary concepts in the Hong Kong & Shanghai Bank building. The essential topics of defects and inspection have been reviewed, essentially to

bring them up to date even though the topics and practices covered therein have changed little in the intervening years.

A new author for Chapter 8 on the critical subject of NDT has resulted in a new approach and some very valid observations and recommendations. Mr Mudge has crystallised for the reader the crucial arguments relating to design of joints for NDT purposes and the like, as well as reviewing, very thoroughly, all of the key NDT methods in the light of today's experiences. Of particular value is a very extensive list of references and a selection of international standards on NDT, nowadays a QA technique considered as an 'integral part of the fabrication process'.

The concluding chapter by Professor Rogerson brings the reader up to date with the relevant codes both in welding and in QA, although this scene is continuously changing.

The contributors hope that the extended coverage of the subject offered by the book will continue to benefit planners, spec. writers, managers, auditors and all those on the fringe of, but essential to, those principal people who have the responsibility for getting it 'right first time'.

N.T.BURGESS

Preface to the First Edition

The growing application of quality assurance both as a regulatory and contractual requirement and as a management discipline for the modern supplier has had significant impact on welding, the most important of the manufacturing processes.

At the same time, the uses of welding increase daily with the drive towards more economic construction for an ever widening range of industries. Problems with welded equipment still arise from a variety of causes, many of which are dealt with in this book. In the early days of welding both manufacturers and users were tolerant of fabricating and construction difficulties but this is no longer possible as the cost of failure, re-work and inspection increases. Further, the development of welding techniques themselves, the metals that can be joined and the range of thicknesses involved, have contributed more problems. There is a need to minimise at every point the influence of these factors on potential failure and on the avoidance of defects.

Quality assurance has developed as a total control concept without specific relevance to welding or indeed any manufacturing method, and it has demonstrated its value in maintaining and improving quality and safety standards, wherever possible in an economic fashion.

The object of this book is to bring together, it is believed for the first time, the basic principles and techniques of quality assurance in relation to a specific area of industry, tailored to a major construction method. It has, within the confines of one volume, been difficult to decide what to include and what to exclude and since quality assurance can be said to embrace design phase and metallurgical aspects, as well as construction practices, it has only been possible to concentrate on the cardinal issues and on some valuable ideas from the contributors. Whilst the basic concepts and procedures contained herein are applicable to any welded construction the authors have in general been drawn from the ‘heavy’ end of industry and therefore examples and case studies referenced relate thereto. This will be very relevant to those industries that typically use pressure vessels, pipework, process plant, bridges, mechanical handling and like structures. As such, welding is most evident in the context of metal arc, inert gas, submerged arc and related methods, although resistance spot welding, for example, amongst other joining techniques, is not discussed. Since both quality assurance and welding principles span international boundaries reference is made where possible to internationally used specifications and practices from several countries.

The authors selected for this work have together and individually a vast experience of the application of welding in many industries, particularly those now grappling with the application of quality assurance. They are authorities in their own right and their backgrounds cover the academic field, research, manufacturing, design and consultancy. The Editor’s past spans the energy field including nuclear generation, the process plant industry and, more recently, the offshore oil and gas business. His opening chapter is intended to brief the unwary on some aspects of quality assurance that may not be apparent from the contract, the text books or indeed national standards.

It is generally accepted that up to 80 % of engineering problems are ultimately attributable to the design stage and in Chapter 2 Dr Jubb has provided some well-chosen examples of how welded design must take account of modern thinking and the latest knowledge. The author of the extensive coverage on manufacturing, Mr Gifford, had the benefit of working as a manufacturing welding engineer before becoming a QA manager and his insight into shop floor problems, particularly in the boiler and pressure vessels field, is extensive. Much welded work for the industries that form the basis of this treatise takes place at site, be it nuclear power station, oil refinery or gas pipeline, and to complement the workshop operations Mr Butler has provided direct experience of site practices with a bearing on quality assurance. A sound knowledge of the relevant artefacts is essential equipment for the practising quality assurance engineer and Dr Rogerson has succinctly reviewed the key information and commented on defect significance. This is particularly important in relation to acceptance criteria, which are discussed here and in other chapters. Inspection is the subject of many clauses in the national standards on welded plant and the author of this chapter has therefore limited his contribution to those aspects that have a strong bearing on quality assurance such as human aspects and qualification, referencing the techniques which are relevant.

The widespread use of non-destructive testing (NDE in many countries) has confirmed that when used correctly this is a major tool in assuring the quality of weldments. The emphasis in this chapter by Mr Jessop is not merely on techniques, as this can be studied from the textbooks, but on the limitations of the methods in relation to specific defects, and on the consideration of the scientific principles involved. Finally, since the core of a good QA programme rests on an understanding of what is considered ‘good practice’ between supplier and client, there is a review of standards and codes related to welding which highlights the strengths and weaknesses to which a QA man should address himself.

This then is a book about quality assurance in welding which indicates what is achievable and necessary rather than merely ‘How to make good welds’. As such the contributors hope that readers, whether they be quality engineers seeking a greater understanding of welding, or welding people faced with the needs of quality assurance, will be able to tackle their work more effectively.

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Fundamentals of Quality Assurance

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INTRODUCTION

Once the satisfactory design of a product or construction has evolved, and been detailed and checked, there is a need to specify quality characteristics against which to produce.

The quality of manufactured products is frequently dependent upon the effectiveness of the manufacturer's control of fabrication, inspection and testing operations. In consequence, manufacturers are responsible for instituting such controls over operation, processes and checking, as are necessary to ensure that their products conform to the specified requirements. Today, manufacturers are also often obliged to provide objective, verifiable evidence that they have carried out all necessary activities. This means that a supplier is expected to supply not only products and services but, in addition, proof that the product has been properly made and tested. A measure of assurance can be gained by (the customer) ensuring that everything necessary has been done to achieve the required integrity of each characteristic of the finished product. Thus, 'quality assurance'!

QUALITY ASSURANCE: DEFINITIONS

The generally accepted definitions of quality assurance (QA) and related terms are based on those promulgated by the International Standards Organisation, who issued ISO 8402 in 1986:

(1) *Quality.* The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs.
(2) *Quality assurance.* All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality.
(3) *Quality control.* The operational techniques and activities that are used to fulfil requirements for quality.
(4) *Inspection.* Activities such as measuring, examining, testing and gauging one or more characteristics of a product or service and comparing these with specified requirements to determine conformity.
(5) *Quality surveillance.* The continuing monitoring and verification of the status of procedures, methods, conditions, processes, products and services, and analysis of records in relation to stated references to ensure that specified requirements for quality are being met.

The issue of quality and quality activities has moved ahead since the publication of the first edition of this book in 1983. Most industrialised countries are party to the ISO series of standards ISO 9000, issued in 1987, which set down criteria applicable to any product or service. Welded constructions are no exception

and, indeed, because welding remains such an important manufacturing tool it has always been subject to a great deal of attention in relation to welding quality. However, the emphasis in welding, as with other manufacturing processes, is now on the prevention of problems, rather than their detection.

Thus, quality management is now a normal part of the management process used increasingly to distinguish good companies from bad, and successful business from failure.

These basic definitions go to make up the subject of Quality Engineering—that branch of engineering which deals with the principles and practice of product and service quality, assurance and control.

A quality engineer may need to be qualified in some or all of the following aspects:

(1) Development and operation of quality assurance and control systems.
(2) Development and analysis of testing, inspection and sampling procedure.
(3) An understanding of the relationship of human factors and motivation with quality.
(4) Facility with quality cost concepts and techniques.
(5) The knowledge and ability to develop and administer management information, including the auditing of quality programmes to permit identification and correction of deficiencies.
(6) The ability to arrange appropriate analyses to determine those operations requiring corrective action.
(7) Application of metrology and statistical methods to the analysis of quality parameters for both control and improvement purposes.

THE BACKGROUND TO QUALITY ASSURANCE

Quality assurance concepts grew out of quality control which, in the stage of industrial development after the Second World War, became a necessity in many industries. In the USA the use of statistical techniques, particularly in the continuous production industries, telecommunications, etc., was a prime tool in measuring the performance of processes, men and machines. It was possible to predict the likely level of defects in a given situation and therefore attempt to prevent or reduce them. Quality control, as a management or production discipline, became standard practice in the USA and, later, in Japan, although application to ‘one off’ structures, power stations, oil refineries and the like was much slower. In many countries the development of quality control practices progressed through defence equipment to electronics generally, nuclear plants and conventional power stations and to many critical structures.

The incentive for manufacturers to reduce defects, and therefore costs, led to extensive development of quality control, except perhaps in those industries where the purchaser has traditionally taken some responsibility for quality control. In ‘one off’ and heavy engineering industries, often involving welded construction, customer inspection, or rather witnessing inspection, has been the convention and it is claimed by many that this led to minimum quality control efforts by respective manufacturers. This appears to be true when compared with industries supplying retail or consumer outlets, where market pressures forced a tighter control of quality aspects of the product. ‘Quality control’, as a tool for suppliers, therefore preceded ‘Quality assurance’ for customers. (Quality control has been used since the 1940s as a term to include all methods used to control quality, including inspection and non-destructive testing (NDT).)

‘Quality assurance’, on the other hand, is a term which has grown in the Western world mainly since the 1960s. The term connotes much broader concepts of quality and reliability achievement and involves action by, and responsibilities on, the purchaser/user. (The Allied Quality Assurance Publications (AQAPs) used by NATO are customer-produced requirements that formed the basis for many similar customer-related requirements.)

In welded construction, many aspects of controlling quality have been developed inherently or instinctively, e.g. the selection and use of correct and proven welding parameters. Indeed, resistance spot and similar automatic methods have always lent themselves to quality control—to the exclusion of individual weld inspection.

The extensive use of welding as the most important constructional method and the rapid developments in welding technology itself are two factors that have inevitably contributed to engineering quality problems. Other factors are the more onerous service required of many welded structures or components, the progressive reduction of safety margins and the use of more economic or conservative design criteria, as well as developments in materials to be welded.

Problems with welding, both during manufacture and in service (by way of failure), have led, over the years, to a tremendous growth in weld inspection (often on a 100% basis) by customers as well as manufacturers, as an obvious, although sometimes misguided, defence. Third party inspection (by the State, an approved body, or by inspection organisations) has flourished in most countries and in direct relationship to the increase in use of welding. This is especially noticeable in the heavy engineering sector, power plants, oil refineries, ship building and so on, particularly where pressure plant and other potentially dangerous equipment is being constructed. Unfortunately, much of this effort has been ineffective, or indeed counterproductive, and throughout this book there are indications as to how this situation can be improved.

Admiral Rickover, in his now famous 1962 address to the 44th Annual Metal Congress in New York, said ‘The price of progress is the acceptance of more exacting standards of performance and relinquishment of familiar habits and conventions rendered obsolete because they no longer meet the new standards. To move but one rung up the ladder of civilisation man must surpass himself.’ He followed with a catalogue of quality problems besetting the nuclear industry (particularly in nuclear submarines) at that time. The author believes that this paper was a turning point in the move towards quality assurance around the world, subsequently to be taken up in most technological industries and in many countries.

Some of the best publicised failures, such as that of the Kings Bridge in Melbourne in 1962, demonstrated a serious lack of quality control. Several pressure vessel failures during tests in the UK and elsewhere during the 1950s and 1960s had direct or indirect relevance to a lack of quality control.

Rickover also reported further on serious deficiencies in U.S. manufacturing practices: ‘During the past few years, hundreds of major conventional components such as pressure vessels and steam generators, have been procured for naval nuclear propulsion plants. Less than 10% have been delivered on time. 30% were delivered six months to a year or more later than promised. Even so, re-inspection of these components after delivery showed that over 50% of them had to be further re-worked in order to meet contract specification requirements’.

And again: ‘there are 99 carbon steel welds in one particular nuclear plant steam system. The manufacturer stated that all these welds were radiographed and met specifications. Our own [U.S.Navy] re-evaluation of these welds—using correct procedures and proper X-ray sensitivity—showed however that only 10% met ASME standards; 35% had defects definitely in excess of ASME standards and the remaining 55% had such a rough external surface that the radiographs obtained could not be interpreted with any degree of assurance.’

Serious failures and delays in the UK power programme due to poor quality control blighted the construction programme of the 1960s. Excessive failure levels in welds made by oxy-acetylene welding, by flash welding, at attachments to boilers, and with defective boiler tubes, as well as large turbine castings, were reported. Since the worst performance came from conventional power plant components rather than nuclear items, the initial corrective programme was in that sector. Major failures associated with welding have been experienced by most industries.

In recent times, so much has been learnt and applied that these failures and problems as mentioned above are rare. Pressures today stem from ‘economic’ factors—manufacturers can no longer afford to make defective goods, especially when competition from the international market is common. In addition, the growth of welded items in nuclear power stations, offshore structures, highways and bridges requires continuous attention to those elements of good practice that are implicit in the phrase ‘quality assurance’.

QUALITY ASSURANCE: A GROWING REQUIREMENT

Some of the reasons why quality assurance is required by purchasers and plant users are:

(1) The recognition that inspection and tests alone do not *prevent* defects—they may not even prevent them getting into service.
(2) No one can *inspect* quality into a product—it has to be designed or built in.
(3) It costs more to make defective welds than good ones, and someone has to pay for those defective goods.

Control of quality must be planned and organised, just like any other business parameter.

It is clear that, because of the nature of welding operations, inspection (including examination) and monitoring surveillance will be necessary. However, it is fundamental to quality assurance that ‘quality is best controlled by those responsible for the product and by those closest to the point of manufacture’. This must mean the supplier himself and not the purchaser. (This aspect is dealt with further in Chapter 7.)

This is particularly important today, since product liability concerns many countries and many industries. The responsibility for accidents resulting from poor quality design and manufacture is generally placed with the designer or manufacturer.

Whose Responsibility is Quality Assurance?

Basically, a quality assurance approach by an industry, a user or a supplier requires at least:

(1) A top management policy decision, followed through to line management.
(2) A quality assurance specification or programme identifying the ‘management’ criteria.
(3) An obligation to evaluate and audit control processes, procedures and instructions as a preliminary to quality control surveillance.

There is no single factor in the avoidance of failures in welded construction; many different factors may be involved, not only within a particular company, but outside, with suppliers, sub-contractors, customers, inspection authorities, etc. What can be achieved is a more disciplined approach to all quality related activities from ‘cradle to grave’ of a product or component. This includes the salesman who should not

TABLE 1