QUALITY SYSTEMS - A REVIEW OF AS 2990 IN RELATION TO TENSION STRUCTURES

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SYNOPSIS: This paper provides an overview of AS 2990 - 1987, "Quality Systems for Engineering and Construction Projects". The philosophy, application and benefits of quality systems generally are outlined initially. The paper then reviews the categories of Quality System under AS 2990, selection of the appropriate category for given projects, examines the components of the quality system, customer responsibilities, and the contractor's responsibilities. The application of AS 2990 to tension structures is examined and conclusions and recommendations for the industry are outlined.

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INTRODUCTION

A quality ethos has not historically formed a major component of the Australian psyche. We have developed from a background of pioneers, of battlers, with an approach to our tasks of trial and error and learning by our mistakes as we progress. In the early period of our history, time was plentiful and labour was cheap, although lives were often at stake if poor quality results were achieved. As the nation developed we prospered on agricultural and mining industries, with local manufacturing showing sporadic development, at times leaping ahead of the rest of the world with brilliant insight, and at times in decline and under competition from either cheap labour or improved technology from overseas.

As we all recognise, Australia's future prosperity will depend on our ability to change and improve all of our areas of technological and economic activity, from mining and agriculture, to manufacturing, high technology in electronics, communications, financial services and personal services such as tourism and business travel.

The 'Clever Country' image is one espoused by our politicians, and the current increased retention rate at our secondary educational level, and the unprecedented surge in demand for places in our overcrowded tertiary institutions, is being touted as a sign that the Australia of the future will be populated by scientists, engineers, economists, accountants and hard headed business graduates. This is not necessarily the case, as most of the increased retention can be attributed to the current recession. In spite of Paul Keating's view, I do not believe this is the recession "we had to have". The recession to me is a result of the whole country being too willing to depend on the rest of the world to provide us with the quality components of our lifestyle, whilst we devoted our energies and finances to paper shuffling and speculation in non-productive, mainly property based assets.

Our future lifestyle will be determined by how well we develop our systems and improve our technology. These will depend to a large extent on how well we apply the principles of quality management, so the issues discussed in this paper are of vital importance to the future prosperity of the country.

QUALITY SYSTEMS IN GENERAL

Quality Systems in the general sense have been an inherent part of any manufacturing or production process since the Industrial Revolution.

The *philosophy* behind Quality Assurance and the various systems installed to assure quality is that there are significant benefits to both the customer and the manufacturer in the definition of the process whereby the customer gets what he has specified, with a high level of confidence and without undue faults or defects.

QUALITY SYSTEMS - WHAT ARE THEY AND HOW DO THEY WORK?

A *quality system* is much more than a check list completed by a bored employee at the end of the production process. A true *Quality System* is a complete approach, incorporating all of the following:-

- Management committment to quality
- Defined organisational structure with specific and separate authorities and responsibilities in relation to quality.
- Plans defined to meet specific levels of quality as defined by the customer or determined by the manufacturer.
- Procedures and Documentation to implement the quality plans, and keep records of the processes and results.
- Review, Surveillance and Audits to ensure the plan is working and all the requirements for quality are being met.
- Feedback into the system to continually upgrade and improve it.

Quality Systems may well require the philosophical committment of the customer as well as the manufacturer, and this will lead to significant *benefits* to both parties.

Benefits Of Quality General

- Satisfied customers will come back for further products.
- A reduction in product defect levels leads to increased efficiency and capacity in the production process.
- an assurance that the required level of quality is achieved will lead to a reduction in customer complaints and disputes.

Benefits For Membrane Structures

- Defined systems for assuring quality will lead to an increase in the overall quality of product from the industry with a positive cost-benefit to the industry.
- Uniform, defined quality procedures will increase customer perception of the industry as a mature, well organised component of the manufacturing and construction sector of the economy.

AS 2990 - 1987 QUALITY SYSTEMS FOR ENGINEERING AND CONSTRUCTION PROJECTS

Australia can become the clever country - we have a diverse population who are prepared to work hard, who can be innovative and creative, and can develop sophisticated products with enough of an individual character to place them competitively in large and small markets around the world. Our own membrane structures industry is a prime example of this. Although we do not have a domestic manufacturer of architectural fabrics, we do have a number of innovative designers and fabricators who are taking a basic manufactured product and providing significant added value, with our architectural, engineering and fabrication input, to provide a world-class product for our domestic and export markets.

As part of our national and regional drive to improve our skills, improve our manufacturing base, consolidate our position as a significant exporter of design and engineering skills, and develop our position as an exporter of technology, particularly into our Asian region, we need to ensure the quality of our work and products is first class and equal to, if not better than, the rest of the world. The only way we can do this is by following a set approach to Quality Assurance, and then building on that in a step by step approach constantly improving in small increments over a period of time. AS 2990 is a significant step along this path, and combined with AS 1821 to AS 1823, Supplier's Quality Control Systems, can help us to improve our efficiency, our product and process reliability, and our standard as an exporter of high quality value added technological products.

However, be warned, any code of practice in such a broad area must, by its generalised nature, provide only a set of guidelines which form the basis for the development of an appropriate quality control system.

AS 2990 is intended to be applied to engineering and construction projects, and is written in a broad scope so that it can be applied to the whole spectrum of activities undertaken by the Project Industry, including.

- Mining
- Building construction
- Manufacturing facilities.
- Power station construction
- Infrastructure projects (railways, waste treatment, etc.)

Where AS 2990 varies from AS 1821 to AS 1923 and the accredited supplier program, is that its' specific application is for industries where procurement is undertaken on a project by project basis, as opposed to the procurement of products from batch production or mass production activities.

So therefore, whilst the manufacture of the architectural membrane material as supplied 'on the roll' would be subject to the requirements of AS 1821 to AS 1823, the design, fabrication and installation of most membrane structures can be controlled by quality systems developed under AS 2990.

CATEGORIES OF QUALITY SYSTEMS UNDER AS 2990

AS 2990 defines three categories or levels of quality system for the project industry. The lowest level is Category C, with increasing requirements for Category B, and the most detailed requirements for Category A.

Given that all clients have certain requirements for the quality and/or performance of a particular project, it is obviously necessary that these requirements are set out clearly in the contract documentation. For example, a client may require that a new building to be constructed for a certain design life, to meet certain physical conditions either to satisfy regulatory requirements or in excess of these (i.e. 100 year return storm, or ability to contain explosions, super flat floors for high bay racking systems, etc.)

The purpose of the various categories of Quality System in AS 2990 is:-

> "a) To provide the customer with assurance that the quality of product or service will be in accordance with contractual requirements;
>
> b) To place on the contractor the responsibility for achieving the required quality and then demonstrating that it has been provided."

Selection of a particular category is not intended to and does not change the contractual requirements to manufacture or construct a product or provide a service which meets specified requirements.

The quality system will only provide the means by which the customer can be confident that the specified requirements are achieved in a planned, systematic and documented manner.

Category C is aimed at providing objective evidence that contractual requirements are met.

Category B is aimed not only at providing objective evidence that contractual requirements are met but also planning and controlling the inspection and test verifications to provide this objective evidence.

Category A is aimed not only at achieving the requirements of Category B but also controlling the design and construction process to minimise the chance of any variation from the required quality.

SELECTION OF THE APPROPRIATE QUALITY SYSTEM CATEGORY

At the current time it is usual for the customer to define that he has a requirement for quality control, but it would be an educated client, or one with a reasonable level of technical or management advice, who would be able to properly select the appropriate level of quality system for their project. This is especially so given that the three basic levels (A,B and C) of Quality System Category can be, and quite often are broken down into several variations. These include:-

a) The Category C system without formal documentation of the system elements or a Quality Manual.

b) The Category C system with all the system elements documented and included in a Quality Manual.

c) The Category B system without the documented system element for manufacture and construction.

d) The Category B system including the documented system element for manufacture and construction, for those applications where manufacture or construction activities are complex.

e) The Category A system without the documented system element procedure for design assurance, but including design verification.

f) The Category A system with the documented system element procedure for design assurance included.

It should also be noted that even though a system element or procedure may not be documented, this does not automatically mean that the contractor does not, in fact, operate an effective quality system for that system element.

As far as the need for a specific quality system goes, the quality system is **not** an alternative to fully identifying and specifying the quality characteristics in the design documentation, but rather it provides the means by which the client can have a reasonable level of confidence that the contractual requirements are all met in a planned, systematic and documented manner.

AS 2990 provides a guide in Appendix B, to evaluating the project and determining the appropriate quality system category.

The relevant factors which need to be considered are:-

a) Complexity and maturity of the design, i.e. if the design process is either straightforward or is well proven by a number of years of usage, a lower category may be appropriate. On the other hand, if the design is complex and innovative (i.e. untried to any large extent) a more detailed Quality System may assist in ensuring the required results are achieved.

b) Nature of the manufacturing/construction process - is it a simple process using well proven methods (e.g. precasting of concrete components) or is it complex and intricate (e.g. the calibration and installation of a large number of sophisticated electronic components into a system or piece of equipment)?

c) Complexity of the product (e.g. concrete pipes or jet aircraft).

d) End use of the product or service (e.g. components for bridges giving farmers access over irrigation channels would require a different level of quality system than components used in a major road bridge over a busy railway).

Furthermore, if failure in service could have a significant economic impact or result in hazards to operators or to the public, then a high level of assurance is needed. On the other hand if failure is neither dangerous nor of economic significance, then standard commercial practices, without a formal contractor's quality system, may be quite adequate.

As an examination of the evaluation process, let us consider the example of a small fabric structure to be erected to a steel frame as an entrance feature and control station for a sporting facility.

The following factors are evaluated on a scale of 0 to 4 based on the characteristics of the particular project.

FACTOR		EVALUATION	
a)	Design process complexity		
	0 Design effort is minimal and simple		
	1 Design effort is significant but simple.		
	2 Design effort is significant and present some complexity.	2	Design effort is significant and present some complexity.
	3 Design effort is extensive or complex.		
	4 Design effort is extensive and complex.		
b)	Design Maturity		
	0 Proven design available		
	1 Combination of proven design elements for same application	1	Combination of proven design elements for similar applications
	2 Modification of proven design for a different application		
	3 Redesign of existing item for a different application		
	4 New design from first principles of a complex item.		
c)	Manufacturing/Construction complexity		
	0 Few simple processes required.		
	1 Significant number of simple processes required.	1	Significant number of simple processes required.
	2 Few complex processes required.		
	3 Significant number of complex processes required		
	4 Large number of complex processes required.		
d)	Product or service characteristics		
	0 Product or service has no close tolerance or interrelated characteristics.		
	1 Product or service has only a few close tolerance or interrelated characteristics.		
	2 Product or service has a few close tolerance or interrelated characteristics.	2	Product or service has a few close tolerance or interrelated characteristics.
	3 Product or service has a significant number of close tolerance and interrelated characteristics.		
	4 Product or service has a large number of close tolerance and interrelated characteristics.		

e) Economics

0	Results in negligible inconvenience or cost		
1	Downgrades the service of a facility to a limited extent and results in limited cost.	1	Failure would downgrade the facility to a limited extent and result in limited cost.
2	Significantly downgrades the service of a facility and results in serious cost.		
3	Seriously downgrades the service of a facility and results in a serious cost.		
4	Results in total loss of service of a facility and extreme cost.		

f) Safety

0	No risk to the health and safety of operating personnel	0	No risk to the health and safety of the operating personnel.
1	Results in limited risk to the health and safety of operating personnel		
2	Results in significant risk to the health and safety of operating personnel		
3	Results in undue risk to the health and safety of operating personnel and limited risk to the public.		
4	Results in undue risk to the health and safety of operating personnel and to the public.		
		7	Total of Evaluation Factors

Adding the values gives a total of 7, which, on review of Table 3 of AS 2990, indicates a Category C, with a written system element description.

TABLE 3
QUALITY SYSTEM CATEGORY SELECTION

Value Range	Quality System Category
19-24	A, with design assurance
13-18	A, excluding design assurance
8 to 12	B
5 to 7	**C, with system element descriptions**
0 to 4	C, without system element descriptions

As a double check, consider the broad outline description given in AS 2990 for this classification.

> "System Category C with system element descriptions is suitable for relatively simple manufacturing/construction processes such as custom machining, light fabrication or assembly and installation. It is particularly applicable where a potential risk to safety exists or where failure would have significant cost."

The relevant comment about this structure is that failure, whilst not being particularly dangerous or expensive, would be highly embarrassing and could have consequential effects on later projects. In this case, a Category C system with documentation would appear appropriate.

As another example, the design and construction of a new chemical processing plant, of significant cost and using new processes involving potentially toxic materials, may be rated as follows:-

a)	Design process complexity	4
b)	Design Maturity	3-4
c)	Construction Complexity	4
d)	Product Characteristics	3-4
e)	Economics	4
f)	Safety	4
	TOTAL	19

i.e. the highest level of quality system would be appropriate, Category A with Design Assurance. Again the broad outline description of the type of projects warranting this Category, i.e.

> "Custom designed high technology products requiring extensive design effort by the contractor which have many complex manufacturing/construction processes and where failure in service could result in extreme cost and undue risk to health and safety",

closely reflects the project being evaluated

QUALITY SYSTEMS

Having established the requirement for a *"Quality System"* on a given project, and the "category" of that system, let us now examine exactly what the quality system comprises.

At this stage a few definitions and interpretations of various phrases and jargon are appropriate:-

"Quality System" - The organisational structure, responsibilities, procedures, activities, capabilities and resources that together aim to ensure that products, processes or services will satisfy stated or implied needs.

"Quality System Element" - The administrative activities affecting quality that need to be implemented and controlled to ensure that the product or service meets specified quality requirements.

These elements include items such as the tender and contract, inspection and test plans, inspections at the various stages, identification, traceability, records, nonconformance, corrective actions and Quality audits.

Description - a document stating the purpose and scope of an activity, detailing who is responsible for what, and outlining what has to be done to complete it.

Procedure - a document that specifies, as applicable, the purpose and scope of an activity; what shall be done and by whom; when, where and how it shall be done; what material, equipment, and documentation shall be used; and how it shall be controlled.

The difference between a *description* and a *procedure* is primarily that a description outlines what has to be done to complete an activity, whereas a procedure defines exactly what shall be done, i.e. a procedure is much more rigourous than a description when it is applied to a quality system element. Procedures are required for Category A system, descriptions are required for Category B and (when specified) Category C systems.

Procedures and descriptions perform similar functions for the various categories of quality system (A,B or C).

Inspection and Test Plans (ITP's) - documents which describe the inspections, tests and verifications for the product or service specified in the contract.

Non conformancies - any areas of the contracted works which do not meet the required specifications or acceptance criteria (i.e. faults).

The requirements of the various categories of Quality System and their requirements for documentation and implementation are summarised in the table below.

SYSTEM ELEMENT REQUIREMENTS AND THEIR DOCUMENTATION

System element	Category A		Category B		Category C	
	Clause	Procedure	Clause	Description	Clause	Description
Tender and Contract	3.1	A	4.1	B	5.1	C
Design Assurance	3.2.1	A C/R	4.2	N/R	5.2	N/R
Design Verification	3.2.2	A	4.2	N/R	5.2	N/R
Documentation	3.3	A	4.3	B	5.3	N/R
Measuring and Testing Equipment	3.4	A	4.4	B	5.4	C
Procurement	3.5	A	4.5	B	5.5	N/R
Inspection And Test Plan(s)	3.6	A	4.6	B	5.6	C
Incoming Inspection	3.7	A	4.7	B	5.7	C
In-process Inspection	3.8	A	4.8	A*	5.8	C
Final Inspection	3.9	A	4.9	A*	5.9	C
Inspection Status	3.10	A	4.10	A*	5.10	N/R
Identification	3.11.1	A	4.11.1	A*	5.11.1	A*
Traceability	3.11.2	A C/R	4.11.2	A* C/R	5.11.2	A* C/R
Handling and Storage	3.12	A	4.12	A*	5.12	N/R
Manufacture/Construction	3.13	A	4.13	A* C/R	5.13	N/R
Special Processes	3.14	A	4.14	A*	5.14	N/R
Packaging and Shipping	3.15	A	4.15	A*	5.15	N/R
Records	3.16	A	4.16	A*	5.16	C
Nonconformance	3.17	A	4.17	B	5.17	C
Corrective Action	3.18	A	4.18	B	5.18	B
Customer-supplied Products or Services	3.19	A	4.19	A*	5.19	A*
Statistical Techniques	3.20	A	4.20	A*	5.20	N/R
Quality Audits	3.21	A	4.21	B	5.21	N/R

LEGEND (FOR PROCEDURE AND DESCRIPTION COLUMNS)

A — Category A procedures apply.

A* — Category A system elements documented as descriptions rather than procedures (less than Category A).

B — Category B system elements documented as descriptions rather than procedures (less than Category A*).

C — Category C system elements documented as descriptions when specified in the contract (less than Category B).

C/R — To be documented and implemented only when specified in the contract.

N/R — No requirement to be satisfied.

As can be seen there is an increasing requirement in the various elements for which procedures or descriptions are prepared, and for the relevant documentation to be prepared and maintained. A detailed description of what has to be carried out to satisfy each system element is provided in the code. The amount of detail required to satisfy the requirements of each system element decreases with the reducing categories, from A to B to C, and are fully defined in the various sections of AS 2990, Section 3 for Category A, Section 4 for Category B, and Section 5 for Category C.

CUSTOMER RESPONSIBILITIES

For the quality system to be effective on a project, it needs planning and commitment to its implementation, from the customer, starting at the earliest time of inception of the project.

As has been stated before, the implementation of quality systems do not replace the need to fully define the requirements for project quality in the tender and contract documents. Once the customer has determined the appropriate category of quality system to be implemented on his project, it is also essential to ensure that tenderers are fully aware of the customer's requirements and in particular have the commitment, intention and resources to fulfil the Quality System Requirements, before awarding the Contract.

Customer's responsibilities - in section 1.4.1., include:-

a) Evaluation and selection of contractors
b) Specification in the tender and contract documents of the required scope of the work and the quality system to be implemented.
c) The carrying out of surveillance and audits to ensure the contractor is conforming to the standard.
d) The certification of customer supplied products, and
e) Evaluation of the contractor's quality system as it relates to products manufactured for stock and not specifically for the project.

These requirements seem quite straightforward, but it is essential for the smooth operation of the quality system that the customer ensure the contractor is fully conversant with the requirements of the Code, including management requirements, provision of quality management personnel, and in particular any areas of the chosen quality system category which are only required **when so specified.**

This will remove any ambiguity and eliminate the possibility that the quality system allowed for by the contractor in the tender does not meet the expectation of the customer.

For example, at Category C, the following system elements are all required to be implemented but are only required to be documented as descriptions when specified in the contract.

- tender and contract review
- calibration of measuring and testing equipment
- inspection and test plans (although it should be noted plans are required to be prepared, but not necessarily submitted to the customer)
- incoming inspections
- inprocess inspections
- final inspections
- traceability
- records
- non conformance

(The descriptions of each system element would define at a minimum its purpose and scope and an outline of what should be done).

Thus we can see that if the customer requires substantial documentation in these areas it must be specified in the contract. If it is not specified, then the only requirement on the contractor is to prepare (but not submit) inspection and test plans and make the records of those inspections available to the customer.

CONTRACTOR'S RESPONSIBILITIES

The contractor is responsible for the planning, development and maintenance of the quality system which will assure that the contractor's obligations under the contract are carried out. In particular, this requires establishment of management policies, definition of responsibility and authority for quality systems, appointment of a representative for quality, and assignment of personnel for inspection and monitoring who are independent of those carrying out or responsible for the work.

In other works the contractor needs to provide management support and additional personnel whose sole responsibility is the monitoring and maintenance of quality systems. For Categories A and B the contractor is also required to prepare a Quality Manual, defining;

- the system and its application
- management responsibilities and organisation
- procedures and/or descriptions of the relevant quality system elements
- review procedures

In addition to the above the contractor may be required to monitor his subcontractors and ensure that their works are also covered by AS 2990 or other appropriate standards.

APPLICATION OF AS 2990 TO TENSION STRUCTURES

1) Is AS 2990 the appropriate Code?

Since tension structures tend to be designed on a project by project basis, most structures do come within the scope of AS 2990. Proprietary items such as smaller shade structures and demountable buildings, produced in a batch or mass production process, would not be covered by AS 2990, but if quality systems are required by clients to be in place, then the other codes such as AS 1821 to AS 1823 would be applicable.

2) Selection of the category of Quality System

Obviously the category of quality system is determined by the client, but I strongly believe that the MSAA should be considering this as well, to present a united approach to customers, and to avoid unnecessary detail in the quality system installed. Obviously the category will vary with the size, use, cost and public profile of a particular structure, but it would certainly be worthwhile for the MSAA to be examining the various types of structures and placing them into recommended categories which are appropriate to the complexity and level of risk inherent in the particular project.

3) Subcontractor's Responsibilities

A third point of interest is that a significant proportion of the work performed by our industry is of a subcontract nature, and as AS 2990 does require the head contractor to ensure that all products and services conform to contract requirements (in Categories A & B systems, at least), there may well be significant demands placed upon a membrane subcontractor to meet the quality system requirements of the head contract. Therefore it is essential for the subcontractor to be informed of these requirements, and it should be a standard condition of tendering that the customer or head contractor is required to fully inform the membrane fabricator of any quality system requirements and categories to which the subcontractor must conform.

4) Management Responsibilities

We all need to be aware of the requirement of AS 2990 for a committed management approach to quality systems, for defining a structure including responsibility and authority within our organisations, and for the assignment of personnel to perform witnessing, inspection or monitoring of the work. These personnel are not to be involved in directly performing or supervising the work being carried out. This will in many small organisations be a difficult or expensive requirement to satisfy.

5) Finally, since I believe Australian Industry is heading more and more towards a controlled, quality orientated approach to its products, we will all need to develop Quality Manuals and put in place Quality Systems. Whilst a design office may formalise these systems still in a fairly general way, I belive it will be wise particularly for the fabricator members of our organisation to develop a common approach.

This has significant advantages, including:-

a) Sharing of what can amount to a significant cost.
b) Providing a common approach to customers so that there is no confusion and so submissions and tenders can be compared on an "apples for apples" basis as far as quality systems are concerned.
c) Setting standards which can be introduced into the industry at our initiative, so that we are seen to be showing the way on quality, rather than having possibly unsuitable or onerous provisions thrust upon us.

CONCLUSIONS AND RECOMMENDATIONS

1. AS 2990 provides a significant step in the formalisation of an Australian approach to ensuring quality of Engineering and Construction Projects.
2. The code provides an outline for management structures and systems to be set up, to assure customers that their requirements for quality, as defined in contracts they let, are being met.
3. There are a number of areas open to interpretation unless the specific requirements of the customer in relation to the various categories of quality system are spelt out.
4. There are significant advantages to the membrane structures industry in adopting a unified approach and taking the lead in the application of AS 2990 to the membrane structures component of the construction industry.
5. I recommend that a subcommittee be set up to develop the thoughts outlined in this paper and to generate discussion and comment from within our industry and from our customers.