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Management methodology for pressure equipment

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Abstract

Pressure equipment constitutes a significant investment in capital and a major proportion of potential high-risk plant in many operations and this is particularly so in an alumina refinery. In many jurisdictions pressure equipment is also subject to statutory regulation that imposes obligations on Owners of the equipment with respect to workplace safety. Most modern technical standards and industry codes of practice employ a risk-based approach to support better decision making with respect to pressure equipment. For a management system to be effective it must demonstrate that risk is being managed within acceptable limits.

Pressure equipment is operated and maintained by diverse groups within most organizations and central to ensuring statutory compliance and management of risk are well-documented and robust management systems that are clearly understood by all concerned. The management system must comprise elements for all stages of pressure equipment from design through fabrication, operation to disposal at end of life and include a strategy to manage non-conforming equipment.

Queensland Alumina Limited has developed such a management methodology and successfully implemented its use across the operation. This methodology is included in the Plant quality system and is regularly audited by the third party quality auditor and the Statutory Authority. The methodology contains all the fundamental processes for managing pressure equipment in accordance with best practice codes, interfaces with legislation, previous operating experience and the Company's safety and environmental systems, yet still allows effective use of the equipment to underpin the Company's production goals.

Introduction

In many modern manufacturing and processing industries pressure equipment is an integral and critical part of the production process. Boilers and unfired pressure vessels ranging from small air receivers of a few litres capacity to large volume boilers and pressure vessels of hundreds of cubic metres connected with kilometres of pressure piping are the heart of many process plants, particularly alumina refineries.

The very nature of pressure equipment and the potential energy stored in an operating vessel or piping system represents a significant safety hazard to personnel and the surrounding communities. Since pressure equipment was first used there have been on-going incidents where inappropriate management systems have resulted in incidents with sometimes devastating effect.

The consequential damage and loss of life that can occur when this type of equipment is not appropriately managed is all too evident in a number of disasters that have occurred throughout the world over the last thirty years. Incidents such as occurred at the Flixboro Nypro factory in England in 1974, the Longford Gas Plant in Victoria Australia in 1998 and the Gramercy Alumina Plant here in the United States in 1999 are just a very few recent examples where pressure equipment incidents have had a profound effect on the companies involved and the surrounding communities.

What most of these incidents have in common is not a lack of fundamental knowledge of how pressure equipment should be designed, constructed or operated but a series of basic organizational failures that did not respond to clear warning signs or learn from past experience. As noted by Andrew Hopkins in his book Lessons from Longford [1], "organization failures lie behind

most major accidents". If there is any lesson to learn from Longford and similar incidents it is that no company or industry has such a reputation or systems in place that it is immune to disaster if those systems breakdown or are ignored.

In addition to the safety and environmental risks that pressure equipment represents, this equipment also constitutes a significant investment in capital coupled with significant on-going maintenance expense to the organizations concerned.

For example, the replacement value of the Queensland Alumina Limited (QAL) plant in Gladstone Australia is four (4) billion Australian dollars. A significant proportion of this cost is represented by pressure equipment. Also approximately thirty (30) million dollars is budgeted annually for maintenance of pressure equipment. It is therefore critical to the economic viability of the organization that this equipment is managed in an appropriate way. The economic situation of many other organizations would similarly reflect or even exceed this level of economic criticality.

Overlaying these safety and economic considerations in most countries is that Statutory Regulation controls all aspects of pressure equipment design, installation, commissioning, operation, inspection and maintenance. At QAL we have nearly 900 Statutory registered pressure vessels on the site. This imposes another layer of compliance on the operators of plant. Statutory Regulations can be difficult to interpret and confusing at times further complicating compliance.

For any company to safely and effectively manage their pressure equipment in the current world operating environment it is imperative that a comprehensive and robust management methodology be in place and understood by all employees.

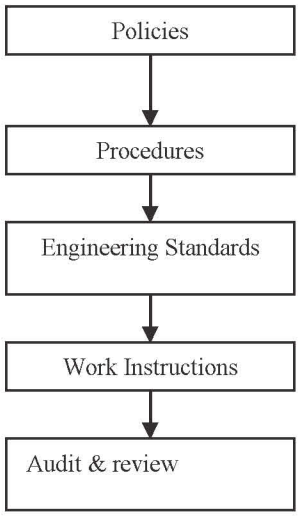
Fundamentals of the management methodology

For any management methodology to be successful it must include all the critical elements necessary for effective management of the pressure equipment, including complying with Statutory Regulation. Additionally it must be able to withstand independent scrutiny and audit and have a mechanism to include any learning from deficiencies identified.

Any procedures and instructions must be in simple language and easily able to be clearly articulated to all levels within the organization. In any large organization there are people whose educational standards range from basic numeracy and literacy to university level. There are people who are risk takers and will push the boundaries seeking to do things "better" and those who willingly comply with all standards and directions. There are people from differing ethnic backgrounds whose grasp of the language may not be as comprehensive as it needs to be. All these factors can work to undermine the effectiveness of any management system and the system must be all encompassing and address all the necessary criteria as well as being accepted by all levels within the organization.

It is imperative that all personnel have access to procedures and instructions at their place of work so they can be readily referenced. People will not track through computer systems to source information: they want it accessible and at hand when doing their assigned tasks. Underpinning the methodology has to be a knowledge retention system that ensure outcomes and any learning are captured and integrated into the system.

Queensland Alumina Limited developed a pressure equipment methodology based on the simple structure below -



Policies and procedures are as laid down by management and are the basis on which all systems within a company operate. They are the "givens" in terms of conducting the company's business.

With specific reference to pressure equipment there is a Policy approved by the Managing Director that defines management responsibilities and the methodologies under which this equipment will be managed. This endorsement by the Managing Director gives authority to the whole system.

Policies and Procedures specify the high level constraints under which an organization operates but specific detail on pressure equipment matters is specified in the internal Engineering Standards.

International and Australian standards contain a plethora of information on accepted practice that generally applies to a specific product or activity. Much of the information contained in a standard may not be relevant to a specific industry or alternatively there are industry specific conditions that may not be referenced in a standard.

QAL has developed a series of in-house Engineering Standards that contain the basic data from Australian and International Standards together with the requirements of Regulation but also include specific detail of requirements and conditions unique to the alumina plant. This suite of approximately fifty (50) documents, defines in specific detail what is acceptable practice and what variables must be complied with. These standards are the knowledge capture documents and clearly articulate what is and is not acceptable practice.

To ensure a ready reference for all Procedures and Engineering Standards pertaining to pressure equipment management, a Pressure Systems Manual has been developed. This manual is a controlled document within the Company's approved ISO 9001 quality system so up to date information is distributed to all manual holders and the third party auditors Lloyds Register regularly audit the system.

Multiple copies of the manual are available in all operating and maintenance sections. This ensures that the documents are readily available to all personnel at their place of work.

The pressure equipment management system is integrated in with the company's safety and environmental management systems and complements these systems.

Specific Elements

The fundamentals noted above show how the methodology is structured but within that structure are certain key elements that form the working heart of the program.

These key elements have lead to the success of the methodology at QAL and why we believe our methodology has been successful whereas others have failed.

Personnel

For any activity within an organization to be effective there has to be a "champion" to add focus and drive to that activity. This is particularly true for pressure equipment as it is too easy for the criticality of this equipment to be overlooked amid all the other challenges of daily production activity. This can lead to inappropriate decisions being made in the heat of the moment if this champion is not present. The specific role of a Pressure Systems Engineer is important in the organizational structure. The role must be primarily focused on pressure equipment matters and not be weighted so heavily with other responsibilities that the focus on pressure equipment is lost.

Independence from routine operational and maintenance roles is important for this "champion". Particularly when arbitrating on safety and integrity matters and as we will discuss later with issuing of Authorities to Operate, it is critical that shop floor personnel have confidence that decisions made are free of undue production and maintenance pressures and that a fair and unbiased perspective is applied.

The role must be recognized within the organizational structure as an important role, staffed by a competent senior engineer, who has the authority to establish acceptable standards and enforce the use

of the same. At QAL we have such a role, the Lead Asset Management Engineer, who is the "champion" for pressure equipment issues.

Whilst the role of a champion is important it is also vital to have a core team of specialists to support the champion role. At QAL this team consists of three (3) senior, experienced people supporting the Pressure Equipment Engineer: a Senior Engineer, Senior Materials Metallurgist and a Welding Co-ordinator. This group of people are a specialist technical resource, highly skilled in all matters associated with pressure equipment, design, operation and maintenance that oversee the Company's pressure equipment.

This dedicated group can also respond quickly to any matter requiring attention across all trade and engineering disciplines. The response is not tempered by other pressing commitments. Issues can be dealt with immediately and strategies developed to solve problems before they develop into incidents.

Standards

As important as it is to have competent personnel, it is also vital to have a mechanism to capture knowledge within the organization. Individuals cannot be present at every job every second of the day and documenting any outcome or learning is important for the future. At QAL this mechanism is the in-house Engineering Standards.

As noted previously these standards distil the general requirements of Australian and International Standards to specific clauses applicable to the alumina plant conditions while also acting as a repository for capturing previous experience and learning. Any parameters and technical data for all aspects of pressure equipment are contained in these documents. A fundamental requirement of these Standards is to present the data in clear and concise terms using tables and definitive statements so all can understand it.

The Longford Royal Commission noted that the safety management system in place was complex, repetitive, circular and contained unnecessary cross-referencing. These characteristics made the system difficult to comprehend by management and operating personnel.[2] At QAL we have sought to make our Standards concise and stand alone documents written in a language that is readily understood by all personnel.

This suite of documents covers all aspects of pressure equipment from design through to mothballing and removing redundant equipment. They are the core documents used daily within the refinery and are available throughout the plant on the intranet so current copies are available to every work group. These documents are being included in the SAP system so that standards can be directly linked to work orders thus further improving their access to all personnel at all levels within the organization.

The Standards specifically of benefit to QAL are the in-service inspection standards and those standards that deal with remnant life of ageing plant. QAL was the only high-pressure alumina plant in Australia for many decades and there was not a wealth of information pertaining to in-service inspections of this type of plant. Consequently we had to develop our own knowledge and ensure this was captured effectively. These Standards were also effectively the risk management documents for the plant. There is now a series of in-service inspections covering all pressure equipment.

Parts of the QAL plant are now approaching 40 years old and have been in continuous service for all that period. Management of remnant life issues associated with ageing plant is becoming an important consideration for our plant. A series of Standards has been developed and work is ongoing in this area to ensure that we understand the implications of ageing on equipment integrity, know how to manage the risks associated with ageing and capture this knowledge and develop strategies to ensure the integrity of the pressure equipment at all times.

As a means of keeping an up to date knowledge of latest standards development and being able to be actively involved in standards setting, QAL has representation on Committee ME-01 of Standards Australia through the Aluminium Council of Australia. This Committee is responsible for preparing all standards for pressure equipment in Australia and these standards are the ones primarily referenced in legislation in Australia. Being at the

forefront of standards development gives QAL the benefit that our in-house standards are always most comprehensive and up to date.

A presence on Welding Technology Institute of Australia committees is also maintained. These committees focused as they are on welding technology and practice also gives us the benefit that our in-house welding standards are comprehensive and up to date. Involvement with both organizations allows QAL to actively propose change and influence the direction standards take in order to minimize the negative impact on the operation but still maintaining high levels of integrity and safety.

Management of Change

Many incidents associated with pressure equipment have occurred because modifications have been made to the plant or process without fully taking into account all the foreseeable side effects or carrying out actions that could have been taken to alleviate unwanted side effects.

The Flixboro incident in 1974 is a classic example where an inappropriate piping modification was carried out. Investigations subsequent to the incident highlighted many issues, one being that while the people carrying out the modifications had practical experience and enthusiasm they had no professional training or competency to design the change installed and they had inappropriately used bellows at both ends of the bypass pipe. A correctly implemented management of change process where appropriate professional review was carried out could have prevented this situation and the incident may never have occurred as a result.

No one person can know everything about a plant's operation. Some aspects of the operation require specialist knowledge and those with that knowledge will quickly recognize a deficiency that others will ignore because they "do not know what they do not know."[3] The purpose of a Management of Change process is to ensure that competent people for all aspects of the change carry out appropriate review.

At QAL there is a documented management of change procedure that applies generally across all the operation but specifically dovetails into any changes proposed for pressure equipment. This structured approach requires sign-off by all interested parties from Operations, Maintenance, Engineering and Safety whenever a change is proposed. By following a rigorous and documented procedure all aspects are considered and any unwanted side effects can be controlled.

Authority to Operate System

One key tool of pressure equipment management at QAL is the Authority to Operate (ATO) system. This system is enacted whenever it is necessary to continue to operate non-conforming equipment. It is important here to understand the difference between unsafe and non-conforming equipment.

Unsafe equipment must never be operated except to the extent critical to render it depressurized and safe. There can be no compromise in this regard. There may be situations also where pressure equipment does not comply with Statutory Regulation and again in this situation the equipment must not be operated.

There can be occasions however when pressure equipment may not comply with in-house standards but would be safe for continued operation for a short duration until maintenance repair can be effected. Alternatively a scheduled inspection may be overdue or inconclusive in its findings.

In this situation the equipment owner must review the current plant conditions and if after exhausting all alternatives (eg. shutdown of the equipment, bypassing the equipment while repairs are carried out, having inspections conducted, etc) may request an ATO be issued. An ATO is always a last resort, short-term option for operating non-conforming equipment and therefore has a defined duration after which it lapses and the equipment must be removed from service.

As an example, a pressure vessel has localized erosion on a section of the wall resulting in it being below the minimum practical thickness as specified in the Engineering Standard. Plate to effect a replacement of the eroded wall is not immediately available and needs to be sourced from a Supplier. Bypassing the affected vessel until the plate arrives would adversely impact on the operation of other surrounding equipment. For maximum

efficiency maintenance resources, particularly certificated Welders, need to be planned and mobilized to reduce downtime while the vessel is removed from service. This is typical of a situation where the equipment owner may consider requesting an ATO.

An assessment of the erosion would be carried out against AS 3788, a risk assessment conducted, the conditions applying considered, alternatives to keeping the vessel operating investigated and if these were all favorable an ATO could be issued for a short period to allow planning and procurement to proceed and disruption to the operation eliminated or reduced.

Situations where an ATO is required involve operation outside of routine conditions and as such there are multiple factors needing evaluation, not the least of which is the legal implications of continued operation of equipment known not to comply with the Company's documented standards. For this reason access to and use of an ATO is strictly controlled. The Regulator has audited the ATO system and given endorsement to it.

An ATO can only be issued by a select few technical experts within the organization: the Lead Asset Management Engineer, the Engineering Superintendent or their immediate nominated proxies. In QAL there are only four (4) people with the authority to issue an ATO for pressure equipment. It is important to note that all are technical experts in their field with many years alumina plant experience and none are directly responsible for production output. Every attempt has been made to maintain the impartiality of the person issuing an ATO from the normal production and maintenance pressures.

The Lead Asset Management Engineer maintains a database of current ATO's and this information is available to all operating crews and management. Inclusion of ATO information in a weekly report ensures all know of the current situation and management control is maintained.

Approved Suppliers of Pressure Equipment

Important as it is to maintain control over any operating equipment within the plant, it is equally important to have confidence that external Suppliers are competent to carry out their duties and supplying fit for purpose equipment. With increased use of outsourced Supplier strategies it is common to engage external organizations to fabricate and maintain pressure equipment. While many external organizations claim to be experts in pressure equipment manufacture and repair many do not have the resources, systems or competent personnel to undertake the complexity of work found in an alumina refinery.

At QAL we have recognized this and implemented a strategy to approve Suppliers of pressure equipment. For a Supplier to be approved they must successfully complete a technical audit in addition to the routine commercial assessments. No Supplier can be engaged to supply pressure equipment unless they are included on the approved listing.

An internal standard based on the recommendations contained in AS/NZS ISO 3834.2 has been developed which defines criteria against which any proposed Supplier is assessed. The criteria have been specifically tailored to suit the alumina refinery environment. The assessment seeks to determine a Supplier's capacity to carry out the work in relation to workshop facilities, cranes, tooling, welding equipment etc; their technical capability; the competency of their people, particularly their Welders and Welding Supervisors and finally their quality system, documentation and record keeping.

Specific criteria addressed are:

Contract and design review	• Capability in terms of experience, equipment and personnel to undertake a defined scope of work. • Possession of the relevant welding standards.
Subcontracting	• A written approval from the Owner shall be obtained for all sub-contracted welding activities.
Welding personnel	• Records maintained for all welders including certificates and qualification records as nominated by Engineering Standard QP50-007-02. • Welding supervision as defined by this

	standard shall be part of the organization. Lines of authority for the Welding Supervisor shall be documented and provided to the Owner. The tasks and responsibilities of the Welding Supervisor are defined by ISO 14731 and summarized by Attachment 6.2.
Inspection and testing.	• An Inspection and Test Plan (ITP) developed for each task and endorsed by the Welding Supervisor on completion of the work. • NATA-endorsed laboratories used for all non-destructive testing to assure weld quality. • A link between NDT test results and maintenance of welder qualification should be demonstrated.
Equipment	• Welding machines, cutting equipment, jigs and fixtures, cranes, safety equipment, rolling and bending equipment and automated welding equipment that are necessary to undertake work on pressure equipment shall be in use. • Documented plans for the maintenance of essential equipment. • The refurbishment of heat exchanger shells requires an adequate enclosed workshop space, rotators and submerged arc welding machines.
Welding activities	• Production plans that sequence the welding requirements of the work scope are required. • Qualified Welding Procedures in accordance with AS 3992 with supporting test certificates for NDT and mechanical tests. • Welder qualification tests to demonstrate the welder's ability to satisfactorily apply the qualified welding procedure.
Welding consumables	• Specified responsibilities for the control and storage of consumables.
Parent materials	• Identification, storage and traceability shall be demonstrated.
Post-weld heat treatment.	• Records from any specified heat treatment kept and are traceable to the welding operation.
Non-conformance and corrective action	• A system for repairs and rectifications that records traceability and re-test results.
Calibration	• Record the availability of testing instruments such as electrical tong testers, temperature measurement devices and pressure gauges.
Identification and traceability	• Documented systems and knowledge of identification of piping in accordance with Engineering Standard QP50-007-02.
Documentation	• Endorse the relevant quality records.
Quality records	• Systems that retain qualified welding procedures, welder certification details and welder qualification records. • An ability to compile Manufacturer's Data Reports. • Retention of quality documents for a minimum period of five (5) years.
Relationship to Welding Service Provider	• Employee or retained for a fee as needed. • Part-time or full-time.
Contract review	• Experience in fabricating or refurbishing pressure equipment. • Knowledge of the welding capability of the work group.
Design review	• Access to relevant welding standards. • Review joint location with relation to the design requirements, access for welding, inspection and testing arrangements, weld joint details, quality and acceptance requirements for welds.
Materials	• Know the system for identification, storage and handling of the specified parent materials and welding consumables.
Production planning	• Establish suitable qualified welding procedures. • Verify the qualification of welders with regard to suitability and validity. • Confirm the suitability of welding jigs and fixtures, welding and assembly sequences for the structure, welding inspection requirements, environmental conditions, health and safety.
Equipment	• Confirm the suitability of welding and associated equipment.
Welding Operations	• Review joint preparation, fit-up and cleaning, application of the specified welding process parameters, application of any intermediate testing, welding sequences, post weld treatments • Prepare production weld tests as required.
Testing	• Visually examine the work to verify completeness of welding, dimensions and joint appearance. • Verify all NDT results. • Re-assess repaired welds. • Record all corrective actions.

Successful completion of this audit will result in the Supplier being included on the approved list. Inclusion in this listing is subject to a three year sunset clause and any Supplier is liable to re-audit during or after the three years to reassess their capability though in practice this is rarely required as on-going involvement during the period allows continuous assessment of their capability.

The audits generally are conducted using internal resources but third party assessors can be engaged if circumstances dictate. The Welding Technology Institute of Australia (WTIA) has carried out assessments when required especially in dispute situations when a Supplier has challenged the outcome of our assessment.

Initially there was resistance from Suppliers when this approach was implemented because they thought that compliance would place them at a commercial disadvantage, however experience has shown this not to be the case and in some instances compliance with QAL systems has had the spin off advantage of opening a door of opportunity for Suppliers to engage with other organizations.

Communications

The importance of communication in the management process cannot be understated. Communication is a well establish pillar of management philosophy but not always handled well, however if a pressure equipment management methodology is to succeed those working within the Plant have to have confidence in the decisions being made and the standards being enforced. Communication and keeping an "open door" policy are vital in gaining and building that confidence. If there is an appearance of secrecy or withholding information, particularly safety based information, then the methodology will not gain acceptance.

Communication has to occur both within the organization and with others in the industry and pressure equipment operators generally. We can all learn from each other and it is important to share knowledge and findings of investigations among all users of pressure equipment. As Trevor Kletz notes, misquoting the well known words of poet John Donne, " No plant is an Island entire of itself; every plant is a piece of the Continent, a part of the main. Any plant's loss diminishes us, because we are involved in the Industry; and therefore never send to know for whom the inquiry sitteth; it sitteth for thee"[4]

Within QAL open communication is encouraged. Alumina Producers working within the process plant are encouraged to contact the Lead Asset Management Engineer regarding any issues of concern or for clarification or explanation of any actions taken. Training sessions are regularly conducted with the crews on pressure equipment Standards and how the equipment is managed. Alumina Producers have been involved in the auditing process on occasions as a means of further improving their understanding of the equipment but more importantly the management systems underpinning the operation.

One aspect of the management system that can generate concern from time to time is the ATO system. On occasions it has been necessary to explain to individuals and crews why an ATO has been issued and the basis of the assessment. By having an understanding of the process and having access to the technical expert issuing the ATO, there has been excellent acceptance of ATO's by the Alumina Producers.

There are advantages in maintaining channels of communications with other alumina refineries and pressure equipment users generally. It provides a network of contacts whom more often than not can assist in resolving problems in our own operation. At QAL we have actively maintained contact with our Owners' alumina plants, other large-scale users such as oil refineries as well as universities and research organizations, all to mutual benefit. We can learn from their experiences and work and similarly they can learn from us which overall leads to a safer environment for all.

Audit and Review

For the methodology to continue to be effective there has to be continuous improvement and checks and balances in place to ensure we are doing what we say we are doing. The system is therefore subject to regular audit and review both internally and from external sources.

Annual internal audits of the pressure system are conducted and reported through the management structure to Owner level. These audits cover aspects ranging from the physical condition of the equipment as assessed against prescribed criteria through to compliance with the inspection standards and the underlying systems of management.

The audit provides a "snap shot" in time of the condition of pressure equipment and is a useful vehicle in identifying deficiencies in both the equipment and the underpinning

management systems. The findings of the audits are actioned through the SAP management system and responsible people are allocated and held accountable to have the recommendations completed and signed off by the Lead Asset Management Engineer. This ensures that recommendations are not "forgotten" and appropriate action is taken.

Selected people within QAL conduct the audits however from time to time, external experts, including personnel from our Owner's organizations, have been used to provide a fresh perspective. Our quality system assessors Lloyds audit the Policy and Procedures on a regular basis. This gives an independent and thorough assessment of compliance and generates recommendations for improvement that are actioned through the quality system.

A periodic review is also important because no system is perfect and standards are constantly evolving and changing as new knowledge is attained and processes develop. Any system that is static will become irrelevant and quickly lose effectiveness. The review process has to be honest and inclusive and challenge the accepted norms.

At QAL we have a process, mandated in the Policy, for periodic review and updating of the management system. Standards are constantly being revised and updated but the underpinning systems themselves have to be scrutinized and when necessary updated.

Conclusion

"What has happened before will happen again. What has been done before will be done again. There is nothing new in the whole world." [5]

By having a structured methodology that clearly defines requirements and has supporting systems in place to ensure compliance, risks associated with the operation of pressure equipment in the alumina refinery can be controlled and managed in accordance with best practice so the company's production and safety targets can be supported.

Acknowledgement

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