Hazardous Chemicals Process Equipment: Assuring Quality From Design Through Installation

By David E. Hendrix

The Hendrix Group, Inc., Houston, Texas

Third International Conference on Improving Reliability in Petroleum Refineries and Chemical Plants

Marriott Houston Westside
Houston, Texas
November 15-18, 1994

Organized by
Gulf Publishing Company
and
HYDROCARBON PROCESSING
Hazardous Chemicals Process Equipment
Assuring Quality From Design Through Installation

by

David E. Hendrix, P.E.
The Hendrix Group, Inc.
15823 N. Barkers Landing
Houston, Texas

Abstract

The OSHA 1910.119 Process Safety Management standard has caused many chemical facilities to rethink how they manage the mechanical integrity of processing equipment. Many facilities have developed written programs for complying with paragraphs (j)(1-5) of 1910.119, Mechanical Integrity, governing the inspection and testing of existing plant equipment. Fewer companies have developed procedures for complying with paragraph (j)(6), Quality Assurance, requiring written procedures for assuring the suitability of purchased fabricated equipment. This paper discusses an integrated approach, based on ISO 9000 concepts, for assuring the quality and suitability-for-service of purchased process equipment intended for hazardous chemicals service. The approach is based on developing a capital project or equipment item QA plan incorporating one or more of the following elements: (1) assigning criticality ratings to equipment items, (2) use of technical specifications to mandate minimum fabrication, testing, and inspection requirements, (3) establishing minimum quality and inspection requirements for engineering design/construction contractors and equipment fabricators, (4) and performing audits to assure that the QA plan requirements are being implemented. The individual elements of the program can be tailored to meet both the requirements of large capital projects and individual equipment purchases.

Introduction to 29 CFR 1910.119

OSHA first published a proposed process safety rule on July 17, 1990 and began public hearings on the proposed rule which produced over 4000 pages of testimony. In February 1992 OSHA issued its final regulations under 29 CFR Part 1910, titled Process
Safety Management of Highly Hazardous Chemicals. The Process Safety Management (PSM) rule took effect on May 26, 1992 and specifies the implementation of management systems to govern the manufacture, processing, and storage of 130 specific chemicals above defined threshold amounts, and of flammable liquids or gasses at quantities of 10,000 pounds or more. Exemptions to the rule are provided for hydrocarbon fuels used for heating, retail facilities, oil & gas operations, and remote facilities. Its requirements are designed to minimize the consequences of a catastrophic release of toxic, reactive, flammable, or explosive chemicals. The impetus for the rule was based on the catastrophic explosion and resulting deaths associated with several highly publicized industrial accidents, including the Bhopal, India incident in 1981 that resulted in the deaths of over 2000 people.

The centerpiece of the rule is based on process hazard analysis, or HAZOP, a systematic analysis of failure scenarios and the identification and implementation of the safeguards to be implemented to assure that those identified potential failure mechanisms do not occur. Staged deadlines for conducting HAZOPS were established, with 100% compliance required by 1997. Other sections of the rule established requirements for: (a) process safety information, (b) employee involvement, (c) operating procedures, (d) training, (e) contractor requirements, (f) pre-startup safety review, (g) mechanical integrity, (h) hot-work permits, (i) emergency planning, (j) compliance audits, and (k) trade secrets. These sections required immediate implementation. This paper is concerned with section 1910.119(j), mechanical integrity. Specifically, this paper focuses on paragraph (j)(6), which covers quality assurance related to the purchase and installation of fabricated processing equipment.

1910.119 Paragraph J- Mechanical Integrity, Quality Assurance Requirements

This purpose of the mechanical integrity section of the OSHA PSM Standard is to "...ensure that highly hazardous chemicals are contained within the process and are not released in an uncontrolled manner...". Quality assurance associated with new process equipment purchase and installation is included in the mechanical integrity mandate, in addition to the integrity management of existing process equipment.
The scope of the mechanical integrity section includes only that equipment associated with a process that is covered by the standard. Thus, plant process equipment in non-hazardous service, i.e. cooling water, etc. does not have to be included in its provisions. Specific equipment items covered include pressure vessels and storage tanks, piping and piping system components, relief and vent systems, emergency shutdown systems, i.e. controls, alarms and interlocks, and pumps. The above lists pretty well encompasses the major components of a process plant.

The quality assurance paragraph of the rule requires that in the construction of new plants and equipment, the equipment, as it is fabricated, shall be suitable for the process. It includes requirements for appropriate checks and inspections to assure that the equipment is installed properly and is consistent with design specifications and the manufacturers instructions. The QA program has to include maintenance items and spare parts, including such items as bolts and flange gaskets.

**Development of a Quality Assurance Program**

This writer’s interpretation of 1910.119(j)(6) is that complying with the intent of paragraph 6 of the mechanical integrity section of the standard involves considerably more effort than that traditionally performed by the chemical industry, i.e. performing random inspections of equipment during fabrication or just prior to shipping. The program recommended in this paper is based on a holistic approach to quality and begins with equipment design, proceeds through procurement, and concludes with field installation. Its effectiveness depends on top management support and its elements incorporate ISO 9000 concepts. An illustrative example of the top-down approach to quality documents is shown in Exhibit 1. An example of an owner quality program document organization chart, based on the structure in Exhibit 1, is shown in Exhibit 2.

The primary vehicles for achieving quality of purchased equipment are procedures that define quality requirements for capital projects or individual equipment purchases, and a project-specific QA plan that describes those planned activities to assure that the requirements in the procedures are being met. The QA plan should, as a minimum, include the following: (1) A definition of the quality desired and the quality organization with
defined responsibilities, (2) Specification of minimum quality requirements for contractors and vendors, (3) Specification of minimum equipment-inspection requirements based on equipment criticality, and, (4) Verification that the program requirements are being met through systematic audits and/or surveillance activities. Example implementing quality procedures supporting the quality plan are shown in Exhibit 3.

The project QA plan can be tailored to meet the specific contracting strategy at hand, the size of the project, and whether outside E&C contractor(s) are involved or if it is entirely an owner-managed project. The attributes of the project QA plan would not necessarily change from project to project; however, the degree of complexity of the plan will depend on the complexity of the project. Thus, while the equipment purchase quality program being promoted may appear complex, its elements are entirely appropriate for the purchase of an individual maintenance item as well as for a large, multi-contractor capital project. If it is an owner-only project, the responsibilities of the general contractor are transferred to the owner.

**Program Implementation**

**Management Commitment**

Let it be known up front that if management is not committed and supportive of quality it will not work. Quality cannot flow uphill. It is that simple. Too many times when a quality issue conflicts with a project cost or deadline, quality loses.

ANSI/ASQC Standard Q94, Quality Management and Quality System Elements-Guidelines, states that "the responsibility for, and commitment to, a quality policy belongs to the highest level of management". It is management's responsibility to define quality objectives, assign responsibilities, and provide financial resources. Management's commitment is less important to achieving results the smaller the project, as typically the project manager or engineer will have more control over the project execution. However, on large projects, especially those with outside engineering and construction contractors involved, management support is essential.
Contractor/Supplier Evaluation and Selection

The majority of goods and services in industry are purchased on the basis of an approved vendor list. Sometimes these lists have evolved somewhat arbitrarily. If a vendor exhibits blatant incompetence, that vendor is normally removed from the list; however, too little effort is spent on generating an approved list comprised of vendors that have the quality systems in place to prevent problems before they occur, or that have a system in place to correct small problems before they become larger ones. For larger projects involving the support of an engineering and/or construction contractor, partnership with a contractor understanding the need for quality management systems can make the difference between a project that is executed smoothly and one that is constantly plagued with problems which ultimately cost the owner money and result in the type of equipment problems that OSHA is attempting to address. This applies equally to vendors supplying fabricated equipment directly to an owner.

A recommended contractor/supplier evaluation process applicable to both contractors and equipment fabricators includes provisions for initially establishing and maintaining ratings of vendors. The rating process can be graduated, based on the need and the complexity of the project or equipment purchase, and may include ratings based on: (1) past performance, (2) on completion of written quality questionnaires, or (3) on the results of audits. The key to the process is that it be based on owner established quality requirements appropriate to the vendor, and that the requirements be uniformly applied to all potential vendors.

Quality requirements will not necessarily be the same for all categories of suppliers. For a large, complex capital project, involving the extensive design and procurement resources of a engineering/construction contractor, an ISO 9001 based system may be appropriate. For a pressure vessel fabricator, it may be no more than a having a quality manual that meets the requirements of ASME Section VIII, div. 1.

A graduated approach will start with an evaluation of performance history. If a contractor/supplier has successfully worked with an owner company for many years without major incidents, and that successful association can be confirmed, then the supplier might be considered acceptable without any further investigation, if they are otherwise qualified.
for the specific project. However, if there is no documented history with the potential vendor, and the equipment item is considered critical, additional evaluations must be performed.

A contractor/supplier selection/rating procedure, based on evaluating completed questionnaires, usually starts with the request-for-proposal (RFP) stage, with the questionnaire included with the RFP package. The completed and returned questionnaire is evaluated and the contractor assigned a numerical rating, corresponding from excellent to poor. The specific numerical rating is based on the extent to which the completed questionnaire meets the owners written requirements. Sample questionnaires intended for a contractor with management responsibilities, based on ISO 9001 requirements, and one for a vendor supplying fabricated equipment are shown in Exhibits 4 and 5, respectively. A sample evaluation rating form is shown in Exhibit 6.

Most evaluations will result in a vendor/contractor that is: (1) acceptable as is, (2) acceptable with some corrective-action recommendations that require correction prior to acceptance, and (3) vendors who have no realistic hope of meeting the requirements.

Finally, the selection procedure should have provisions for performing a formal audit of the contractor/supplier if the situation warrants it. Audits will be discussed in greater detail later in this paper.

**Equipment Criticality**

As stated earlier, the intent of the OSHA PSM Standard, with respect to mechanical integrity, is to ensure that highly hazardous chemicals are contained within the process and are not released in an uncontrolled manner. As personnel resources and inspection budgets are typically limited, especially on larger projects with hundreds of equipment items, it makes sense to assign those limited resources responsible for project QA/QC to activities based on relative equipment importance, or criticality. Equipment criticality, as it applies here, is a numerical rating that is assigned equipment items based on an evaluation of categories of importance, or risk factors. Categorizing equipment items according to importance allows the inspection and surveillance resources to be allocated where they are most needed, instead of treating the most complex and the most simple equipment items equally.
The risk of an uncontrolled release due to equipment failure will increase with decreasing maturity of the equipment design, with increasing complexity of equipment materials or fabrication, and with increasing safety and environmental consequences of a release. Different equipment classification schemes exist; however, one recommended to meet the concerns of the OSHA PSM standard is based on assigning points to the following categories: (1) safety, (2) fluid characteristics, (3) design maturity, (4) operational significance, and (5) complexity of manufacture, construction, or fabrication. The degree of corrosivity of a fluid would be one example of an input to the fluid characteristics category. Operational significance relates to the importance of the specific equipment item to the continued, safe operation of the unit. Design maturity considers whether an equipment item is an exact duplicate of a previous item with proven performance or is a departure from established design standards and codes.

Two optional categories that can be included in the rating system, if desired, are economics, which addresses the consequences of a failure on plant shutdown, and availability, which addresses how quickly an item can be replaced.

A point system based on a numerical scale is assigned to each category, according to the degree of risk, lack of knowledge, complexity, etc. The numbers assigned to the different categories can be weighted, based on relative importance. For example, the multiplier assigned to the design maturity category may be greater than that assigned to the equipment complexity category. For each equipment item, a value is assigned to each category and the numbers totaled. The absolute rating then determines the level of attention that the equipment item receives during the project. An example of the assignment of an equipment item to a risk category based on a numerical rating is shown in Exhibit 7. As we shall see, equipment classification forms the basis for all of the owner, contractor, and vendor OA/OC activities planned for the project.

**Quality Requirements for Contractor/Suppliers**

After a qualified contractor/supplier has been selected, based on evidence of possession and proper maintenance of a quality program, the owner project-quality requirements are transmitted with a request for the contractor/vendor to develop a written
project quality plan that addresses the requirements. For a contractor with project management responsibilities, the plan should require that the contractor address the following as a minimum:

Scope
Organization and Responsibilities
Project controls
Quality Improvement
Safety
Document Control
Engineering and Design
Procurement
Construction
Personnel Qualification and Training
Quality Assurance/Quality Control

For a less complex project only those attributes that apply need be addressed. For example, for an individual pressure vessel purchase project, the fabricator should be requested to develop a written document that addresses the fabricator's QA manual contents for that specific equipment item, one which includes specific inspection activities, etc.

The quality assurance (QA) section of the procedure should request a description of the methods, procedures, and checklists that will be employed to assure compliance with the quality plan. The methods commonly used include inspections, surveillances, and audits. The surveillances and audits should account for all those activities that the contractor/supplier is responsible for during the engineering, procurement, fabrication, and construction phases of the project. The surveillance activity plans should provide specific details and address vendors, equipment items, checklists of attributes to be monitored, frequency of monitoring, and the acceptance criteria for those attributes. The plan should also address the quality requirements the contractor's vendors and subcontractors will be obligated to follow during the execution of their responsibilities. It should also describe the system(s) that will be used to evaluate internal, vendor, or subcontractor nonconformances and what procedures will be included to prevent reoccurrences.

All QA activities should be based on equipment criticality ratings. An example of procurement monitoring activities for a generic capital project, based on equipment
criticality, is shown in Exhibit 8. A checklist to execute the general requirements in Exhibit 8 for a category 1 pressure vessel is shown in Exhibit 9. Exhibit 10 shows an example of an inspection checklist that a fabricator might be required to submit for review to fulfill their quality obligations. This checklist is in turn used to develop the contractor's inspection surveillance checklists defined in Exhibit 9.

**Project QA Plan**

The philosophy of the equipment purchase QA program discussed in this paper is based on written procedures that: (1) assure the selection of quality contractors, (2) contractually obligate contractors/vendors to develop written, systematic plans for meeting owner quality requirements, and (3) auditing the process to ascertain that the requirements are being met. The project quality plan is the project-specific document that defines the systematic owner QA/QC activities planned for that project to assure that the contractors and vendors are properly executing their written plans.

The quality plan should define: (a) the quality objectives to be obtained, (b) the allocation of responsibilities and authority during the project, (c) the specific procedures, methods, and work instructions to be applied, and (d) a description of the testing, inspection, examination, and audit programs planned for different stages of the project, i.e. design, procurement, construction. Again, these planned inspections, surveillances, and audits are based on equipment criticality. An example of planned QA functions that might be included in a quality plan based on equipment criticality is shown in Exhibit 11.

**Surveillances and Audits**

Surveillances and audits are at the heart of the owner project QA plan. Surveillances and audits are those activities that permit an owner to verify if the quality requirements planned for the project are being properly implemented.

A surveillance is the act of monitoring or observing to determine if an equipment item conforms to specified requirements. A owner surveillance activity might be planned to observe a critical test or inspection along with the contractor's inspector. These are usually established through witness or hold points.
An audit is a systematic and planned examination to determine whether quality activities or quality programs comply with pre-determined requirements. Audits normally are performed by reviewing in a formal manner program activities, documents, or records to determine that an entire program or system is properly functioning. They can be performed to verify that a contractor or vendor is acceptable for a project prior to contract award or to verify that their written programs are being properly executed during the course of a project. Audits should normally be performed to identify potential trouble spots and to prevent problems before they occur, although they are frequently performed after problems develop to determine if they are indicative of systematic deficiencies that would result in future, similar problems. A audit, planned and performed properly, requires specialized personnel training if the desired results are to be achieved. A flow chart showing recommended steps for performing a formal audit is shown in Exhibit 12. An example of a checklist developed to audit a equipment design process is shown in Exhibit 13.

Small Project Execution

From the above discussion, it may appear that the recommended process for developing and implementing a purchased equipment QA program is intimidating. For a large capital project it can indeed be a complex undertaking. However, for large capital projects involving numerous equipment items, the above procedures and functions are considered minimum requirements if the intent of the OSHA PSM standard is to be met. Otherwise, receiving process equipment designed, constructed, and erected as specified is left to chance.

Once developed, the recommended program and procedures discussed in this paper are easily applied to smaller projects, down to a single equipment maintenance purchase. For an owner project involving the purchase of one or a few equipment items where a E&C contractor is not involved, the primary tool for assuring quality reduces down to the project quality plan. This plan is still based on equipment criticality, and for category 4 equipment items, might include only a surveillance checklist and the assignment of a surveillance inspector to the item. However, the critical attribute of a quality plan is that it be written and contain sufficient instructions to assure that the codes and equipment specifications have
been met. Meeting OSHA PSM requirements is largely based on a linked paper trail and change-of-custody approach.

Conclusions

The OSHA 1910.119 mechanical integrity section has mandated, based on safety, what owners should have been doing all along, based on cost. A properly designed and implemented quality program should cost approximately 1-2% of total project costs, and may even pay for itself. The cost of quality rises based on when errors are discovered. Exhibit 14 shows a chart illustrating the cost of problems depending on when they are detected. As one can see, the point at which a regulatory agency such as OSHA gets involved in a problem, represented on the chart by the letters G and H, represents a high cost multiple compared to detecting those problems earlier.
Quality System Structure

Policy

Manuals

Procedures/Instructions

Documentation/Data

Management  Purchasing  Commission  QA

Engineering  Construction

Quality Plan
(Project Specific)
Title: Exhibit 2- Quality System Document Organization Chart

- Owner Quality Policy Statement
  - Owner Corporate QA Manual
    - Specialized QA Manuals
      - Manuf. QA Manual (ISO)
      - Capital Project QA Manual
        - OSHA PSM QA Manual
        - Equipment Purchase QA Plan
          - Owner Selection Procedure
            - Contractor QA Plan Requirements Procedure
              - Owner Only Project
                - E&C Contractor Project QA Plan
                  - QA
                    - Procedures Checklists
                  - Engineering
                    - Procedures Checklists
                  - Construction
                    - Procedures Checklists
                  - Procurement
                    - Procedures Checklists
**Engineering/Construction Quality Requirements**

<table>
<thead>
<tr>
<th>QA</th>
<th>Eng. Design</th>
<th>Procurement</th>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3. Purchasing QA</td>
<td>3. Constructor Inspection Requirements QC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Vendor Inspection Requirements</td>
<td></td>
</tr>
</tbody>
</table>
Title: Exhibit 4- Contractor Quality System Questionnaire

REFERENCES


PROCEDURE

General

As a minimum, the Contractor completes the questions of the Quality System Evaluation Questionnaire that correspond to the elements of the Quality System applicable to the scope of work.

Questionnaire

Contractor Identification

Name ____________________________

Division ________________________

Address _________________________

Description of Services to be Supplied ____________________________

______________________________
Management Responsibility

Is your Quality Policy defined, documented and communicated to all employees?

Who will be your Management Representative with the Authority to ensure that the Quality requirements are met?

Do you have a documented description of your Organization, including the responsibilities of personnel who do work affecting Quality of the Supplies?

Quality System

Do you implement a documented Quality System?

Is your Quality System registered by a national or international organization?

Do you implement the applicable elements of your Quality System in accordance with a documented quality plan for the scope of work?

Contract Review

Do you document the review of Contracts?

Design and Design Change Control

Do you implement design control procedures that address the following activities:

- Design Input
- Design Output
- Design Verification
- Design Change

Documentation and Change Control

Do you implement procedures for the control of documents and changes to documents that affect meeting the contractual requirements?

Purchasing

Do you maintain records of acceptable Subcontractors and Vendors?
Please respond to the following questions as they relate to your company's operation. Areas which do not apply to your company's activities should be marked NA (not applicable).

1. **Range of Offerings**
   1.1 Describe the main services, equipment, systems, etc. offered by your company.
   1.2 List what types of work you are qualified to perform.
   1.3 Do you have a standard product line and are you capable of custom design? Which is most common?
   1.4 Which of the above contributes the most towards your annual sales and which do you consider your specialty?

2. **Experience / Client List**
   2.1 How long has your company provided each main type of equipment/systems that you now offer?
   2.2 Provide a list of clients to whom you have supplied equipment/systems. (Emphasis should be on, but not limited to, the petrochemical industry.) Have you provided equipment to any ABCO companies?
   2.3 Describe examples of the most technically challenging equipment/systems which you have provided.
   2.4 What new products have you introduced in the last five years?

3. **Staffing / Expertise**
   3.1 Provide resumes for the key technical, manufacturing and project people within your organization, including professional registrations, associations and experience.
   3.2 What technical expertise does your company possess in terms of personnel which would be relevant to the equipment/systems listed on the cover letter?
   3.3 List the technical disciplines covered in your organization.
   3.4 Furnish organization charts of engineering and manufacturing groups in your company.
   3.5 How many people do you have in each of the following functional areas: design/rating, start-up/commissioning, troubleshooting, controls/instruments, QC/QA?

4. **Methods / Design Techniques / Analytical Tools**
   4.1 Describe the methods used for design and rating of your equipment/systems. (Supply examples of typical design drawings if appropriate.)
   4.2 List all industry codes/standards/practices used by your company.
   4.3 Describe any proprietary methods/design data/technology which positions your companies offerings above those of your competitors.
# VENDOR TECHNICAL RATING

**Vendor Name:** ___________________________  **Date of Rating:** ___________________________

**Vendor Address:** ___________________________  **Rating By:** ___________________________

<table>
<thead>
<tr>
<th>LINE ITEM</th>
<th>PERFORMANCE RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) EXCEL</td>
</tr>
<tr>
<td>RANGE OF OFFERINGS</td>
<td></td>
</tr>
<tr>
<td>EXPERIENCE/CLIENT LIST</td>
<td></td>
</tr>
<tr>
<td>STAFFING EXPERTISE</td>
<td></td>
</tr>
<tr>
<td>METHODS/DESIGN/TECHNIQUES AND TOOLS</td>
<td></td>
</tr>
<tr>
<td>FABRICATION CAPABILITIES SHOP</td>
<td></td>
</tr>
<tr>
<td>PROJECT/JOB EXECUTION</td>
<td></td>
</tr>
<tr>
<td>SUPPLIERS/MATERIALS</td>
<td></td>
</tr>
<tr>
<td>SERVICE/PARTS</td>
<td></td>
</tr>
<tr>
<td>OVERALL TECHNICAL RATING</td>
<td></td>
</tr>
<tr>
<td>Total Points</td>
<td>Criticality Category</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>31-40</td>
<td>I</td>
</tr>
<tr>
<td>21-30</td>
<td>II</td>
</tr>
<tr>
<td>11-20</td>
<td>III</td>
</tr>
<tr>
<td>1 - 10</td>
<td>IV</td>
</tr>
</tbody>
</table>

* Assurance of item Quality includes verification that Technical, Quality, and Commercial requirements are met.
**Title: Exhibit 8- Equipment Criticality Rating QA Plan**

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activities:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Bid (for vessels, field-fab only)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Technical Assessment</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Quality Assessment</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Financial Assessment</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Award (after Bid-tab)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Technical Assessment</td>
<td>X</td>
<td>X</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>-- Quality System Assessment or QA Manual Review</td>
<td>X</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Financial Assessment</td>
<td>X</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-Award</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Technical Quality Meeting</td>
<td>X</td>
<td>X</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Pre-fabrication Meeting</td>
<td>X</td>
<td>X</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>-- Inspection Surveillance</td>
<td>X</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>-- Testing Surveillance</td>
<td>X</td>
<td>X</td>
<td>S</td>
<td></td>
</tr>
</tbody>
</table>

X = All
S = Sampling
Category 1 Inspection Plan, Vessels - EXAMPLE

1.0 Pre-Award Meeting

-- Review schedule
-- Review commercial requirements
-- Review projected shop load during fabrication period
-- Establish potential subvendors
-- Review drawing submittal schedule.

2.0 Pre-fabrication/Inspection Meeting

-- Review purchase order
-- Review equipment specifications
-- Review assembly procedure
-- Review project specifications
-- Review drawings
-- Review subvendors
-- Review materials of construction/materials control
-- Review fabrication details
-- Review manufacturing and quality plans to establish witness and hold points. Special emphasis on NDE.

3.0 Inspection Plan - (See Attachment B)

4.0 Publish a meeting agenda for all scheduled prefabrication meetings. The document will be issued approximately ten days in advance of the particular meeting and will include the following information:

-- Date and time of meeting
-- Location where meeting held
-- Vendor representation: Engineering, production, material control, quality control, scheduling, shipping
-- Client Representation
-- Contractor Representation
<table>
<thead>
<tr>
<th>Ref.</th>
<th>Activity Description</th>
<th>Controlling Procedure</th>
<th>Acceptance Criteria</th>
<th>Verifying Document</th>
<th>NDT</th>
<th>Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Weld Procedures</td>
<td>N/A</td>
<td>ASME IX</td>
<td>ASME IX</td>
<td>WPS/FPQR</td>
<td>R</td>
</tr>
<tr>
<td>2.</td>
<td>Welder Qualifications</td>
<td>N/A</td>
<td>ASME IX</td>
<td>ASME IX</td>
<td>WFP</td>
<td>R</td>
</tr>
<tr>
<td>3.</td>
<td>Material Receiving</td>
<td>Vendor QA doc.</td>
<td>ASME II</td>
<td>ASME II</td>
<td>MTR's</td>
<td>I</td>
</tr>
<tr>
<td>4.</td>
<td>Fabrication</td>
<td>ASME VIII</td>
<td>Approv. dwgs.</td>
<td>Shop Traveler</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Leak Check Assembly</td>
<td>Vendor QA</td>
<td>ASME V, A-2</td>
<td>ASME VIII, U-W-21</td>
<td>PT report</td>
<td>PT I</td>
</tr>
<tr>
<td>9.</td>
<td>Weld seal flange</td>
<td>WPS/FPQR</td>
<td>Approv. dwgs.</td>
<td>Shop Traveler</td>
<td>H</td>
<td></td>
</tr>
</tbody>
</table>

Key:  R-Review     I-Imp. Point     H-Hold Point     K-Kommission
### Exhibit 11 - Project Equipment Purchase QA Plan

<table>
<thead>
<tr>
<th>QA FUNCTIONS (*)</th>
<th>CRITICAL EQUIPMENT CATEGORY (**)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Develop ACC Project QA Plan.</td>
<td>I   II  III  IV</td>
</tr>
<tr>
<td>2. QA Review of Project Specifications.</td>
<td>X   X   X   -</td>
</tr>
<tr>
<td>3. Assessment of Prime Vendor/Contractor Quality System.</td>
<td>X (1) X (1) X (2) -</td>
</tr>
<tr>
<td>4. ACC Participation in Assessment of Sub-tier Vendor/Contractor's Quality System.</td>
<td>X (1) X (1) - -</td>
</tr>
<tr>
<td>5. QA Review of Purchasing Documents to assure that Items 6, 7, 8, 9, 10, and 11 are specified when applicable.</td>
<td>X   X   X   -</td>
</tr>
<tr>
<td>6. Specify Submittal of Vendor/Contractor Quality System Manual.</td>
<td>X   X   X (2) -</td>
</tr>
<tr>
<td>7. Specify ACC rights of access to Vendor/Contractor's facility including Sub-tiers' and right to identify witness &amp; hold points. Include disclaimer that inspection by ACC does not relieve the Vendor/Contractor's obligation to fully meet the Specifications for the work.</td>
<td>X   X   X   X</td>
</tr>
<tr>
<td>8. Specify Resolution of Nonconformities before delivery to ACC.</td>
<td>X   X   X   X</td>
</tr>
<tr>
<td>9. Specify or Develop an Inspection Plan.</td>
<td>X   X   - - (3) - - - (3)</td>
</tr>
<tr>
<td>10. Specify or Develop a Procurement Surveillance Plan.</td>
<td>X (4) X (5) X (6) -</td>
</tr>
<tr>
<td>11. Specify or Develop a Construction Surveillance Plan.</td>
<td>X (7), (9) X (7), (9) X (8), (9) -</td>
</tr>
<tr>
<td>12. QA Review of Vendor or Contractor Inspection, Test, and other Quality Assurance Related Documentation.</td>
<td>X   X   X (10) X (11)</td>
</tr>
</tbody>
</table>
Auditing

Audit Initiation

Client requires audit program: 5.1

Determination of scope, objectives, timing: 5.1.2.3

Selection of audit team leader: 5.1

Audit team leader checks own qualifications: 5.1

Qualified

Yes

Review:
- Long term audit program
- Q System: 5.2.1.2

Acceptable

No

Report

Yes

Report

L
Design Review Elements

1. Were the inputs correctly selected and incorporated into the design?
2. Are assumptions necessary to perform the design activity adequately described and reasonable?
3. Are the appropriate quality and quality assurance requirements specified?
4. Are the appropriate codes, standards, regulatory requirements properly identified and their requirements for design met?
5. Have applicable construction and operating experiences been considered?
6. Have the design interface requirements been satisfied?
7. Was an appropriate design method used?
8. Is the output reasonable when compared to the input?
9. Are the specified parts, equipment, and processes suitable for the required application?
10. Are the specified materials compatible with each other and the design environmental conditions to which the material will be exposed?
11. Have adequate maintenance features and requirements been specified?
12. Are accessibility and other design provisions adequate for performance of needed maintenance and repair?
13. Are the acceptance criteria incorporated in the design documents sufficient to allow verification that design requirements have been satisfactorily accomplished?
14. Have adequate pre-operational and subsequent periodic test requirements been appropriately specified?
15. Are adequate handling, storage, cleaning and shipping requirements specified?
Title: Exhibit 14- Cost of Quality

LOG 10 ($)

COST

STAGE AT WHICH ERROR IS DETECTED

A - ON "DRAWING BOARD"
B - AT CHECKING
C - DURING PRODUCTION
D - DURING CONSTRUCTION
E - AFTER COMMISSIONING
F - FIELD RETROFIT NEEDED
G - LAWSUITS FROM FAILURE
H - NEGATIVE JUDGMENTS FROM LAWSUIT