Plant Support Engineering: Guidance for Replacing Heat Exchangers at Nuclear Power Plants with Plate Heat Exchangers

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Plant Support Engineering: Guidance for Replacing Heat Exchangers at Nuclear Power Plants with Plate Heat Exchangers

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REPORT SUMMARY

Background

Utilities are continuing to pursue license renewal applications and power up-rates, and these initiatives are being undertaken on an aging fleet of nuclear plants. Many plants are facing the necessity of replacing shell and tube heat exchangers to support these initiatives. However, industry expertise to support such activities has diminished since the days of plant construction. There are fewer qualified vendors and equipment manufacturers, materials may have changed, and licensees are typically not staffed for these major undertakings.

This report is the first of a "suite" of guidelines that will enable licensees to be "intelligent customers" when faced with replacing major plant components like heat exchangers to support license renewal and plant life extension.

Objective

- To support nuclear utilities in their efforts to replace heat exchangers by providing a source of knowledge to increase staff awareness and appreciation of the major design, procurement, installation and operation issues that need to be considered

Approach

In cooperation with interested Plant Support Engineering (PSE) members, a task group of utility engineers and industry experts was formed. This group confirmed key issues that a project team could encounter when replacing a heat exchanger at a nuclear power plant and provided input used in the preparation of the guidance set forth in this document. Development of the report was closely coordinated and reviewed to ensure consistency with current industry-wide guidance and lessons learned. Experience-proven practices and techniques were identified during this effort and compiled in this report.

Issues addressed in this document include the following:

- Design information specific to plate heat exchangers, including current materials information, potential instrumentation upgrades, configuration changes, and other opportunities for enhancement while maintaining or increasing design margin
- Development of plate heat exchanger design and procurement specifications
- Supplier selection and management, including vendor oversight issues
- Manufacturing surveillance guidance
- Receipt inspection guidance

- Identification of critical spares and related design information
- Installation issues, enhancements, and lessons learned
- Potential maintenance program enhancements and improvements

Results

The report emphasizes that a project for replacing a heat exchanger should follow a logical sequence of events that affords the project team ample opportunity to evaluate all aspects of the replacement including interface points between the heat exchanger and adjacent equipment and operating systems. The categorization of issues is based upon the typical delegation of activities among the key organizations involved (for example, design engineering, procurement engineering, purchasing, quality assurance, and organizations in the supply chain). The report presents an overall flow of information and the primary purpose of each element of the process. Issues range from initial design considerations, bid evaluation and selection of a supplier, specification and procurement, shipping and storage, installation, disposal of the replaced component, and maintenance planning.

EPRI Perspective

The information contained in this guideline represents a significant collection of human performance information, including techniques and good practices, related to project teams in their support of replacing heat exchangers at a nuclear power plant. Assemblage of this information provides a single point of reference for plant engineering and management personnel, both in the present and in the future. Through the use of this guideline, in close conjunction with the industry guidance, EPRI members should be able to significantly improve and consistently implement the processes associated with replacing a shell and tube heat exchanger with a plate heat exchanger at their plants. This will subsequently help members to achieve increased reliability and availability of the new components and the systems in which they are installed.

Keywords

Bid evaluation
Design modification
Heat transfer
License renewal
Plate heat exchanger
Procurement
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Specification

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1.1 Introduction and Background

Utilities are continuing to pursue license renewal applications and power up-rates, and these initiatives are being undertaken on an aging fleet of nuclear plants. Many plants are facing the necessity of replacing shell and tube heat exchangers to support these initiatives. However, industry expertise to support such activities has diminished since the days of plant construction. There are fewer qualified vendors and equipment manufacturers, materials may have changed, and licensees are typically not staffed for these major undertakings.

1.2 Scope of This Report

1.2.1 Report Structure and Organization

The structure of this report follows the basic process that a project team at a nuclear power plant would follow when a major plant component such as a heat exchanger is replaced. Section 2 introduces the overall process with emphasis on the project management aspects of the entire project. Sections 3 and 4 discuss various design issues associated with a replacement heat exchanger and how those design requirements should be translated into a bid specification for potential heat exchanger suppliers. Section 5 provides guidance on performing the bid evaluation, selecting an appropriate supplier, and resolving purchasing issues normally encountered during a procurement of this magnitude.

Fabrication and shipping and handling issues are discussed in Sections 6 and 7, respectively. Section 8 provides receiving inspection guidance, which is then followed by storage and staging guidance in Section 9. Sections 10 and 11 provide guidance on installing the replacement heat exchanger and recommended preventive maintenance activities, respectively. Section 12 discusses the removal and disposal of the replaced component. An extensive list of references is provided in Section 13.

Appendix A includes an illustrative example of a typical bid specification for a plate heat exchanger. Appendix B includes an example of a typical data sheet for a plate heat exchanger.

1.2.2 Basic Premises of This Report

This report assumes that utility personnel have already performed a replace versus repair or refurbish analysis in accordance with site-specific procedures and that heat exchanger replacement has been determined to be the most cost-beneficial option. As such, the replace vs. repair analysis is not included in the generic process provided in Section 2 and is not discussed further in the remaining sections of this report. This report also assumes that the licensee has selected the plate heat exchanger to be the most suitable design for the plant application. Some of the advantages and disadvantages of plate heat exchangers are provided in Section 3.

Based on the number of current, actual applications of plate heat exchangers in nuclear power plants, the scope of this report focuses primarily on gasketed plate heat exchangers, not welded plate heat exchangers.

Throughout this report, references are included to certain quality assurance implementing standards as a means of establishing a basis for the guidance provided. Although the ANSI N45.2 daughter standards are often referred to, the user of this report should recognize that other quality assurance programmatic and implementing guidance may be equally applicable. Although, from a regulatory standpoint, the ANSI standards are applicable only to safety-related components, the project team may consider these industry standards for certain non-safety component replacements at their discretion. The intent of this report is not to exclude any particular quality assurance guidance, but rather to present in generic terms implementing guidance that is common to most U.S. nuclear power plant licensees.

1.3 Definitions of Key Terms

component – A piece of equipment, such as a vessel, pump, valve, core support structure, relay, or circuit breaker, that is combined with other components to form an assembly. Components are typically designated with an identification number. [1]

equipment designer – The organization in the licensee’s supply chain that is responsible for designing the equipment so that it is suitable for the intended applications.

fabricator – The organization in the licensee’s supply chain that is responsible for fabricating parts, assemblies, and subcomponents that are needed to manufacture the replacement component.

manufacturer – The organization in the licensee’s supply chain that is responsible for manufacturing and assembling the replacement component to the extent required by the licensee.

plate heat exchanger –Synonymous with *plate/frame heat exchanger*.

shell and tube heat exchanger – A heat exchanger consisting of a series of tubes (which are sometimes finned), through which a fluid runs. A second fluid runs over the outside of the tubes to be heated or cooled.

source verification – Activities witnessed by the purchaser or its agent at the supplier's facilities for specific items to verify that a supplier of a commercial grade item controls the critical characteristics of that item. A method for accepting the item. [2]

standard receipt inspection – Activities conducted upon receipt of items including commercial grade items in accordance with ANSI N45.2.2 or ANSI/ASME NQA-1 and NQA-2 to check such elements as the quantity received, part number, general condition of the items, and damage. [2]

supplier – The organization furnishing the replacement component. This could be an original equipment manufacturer, part manufacturer, or distributor. [2]

witness/hold points – A way to ensure that source verification activities are witnessed by utility personnel or their agents.

1.4 Acronyms

ALARA – as low as reasonably achievable

ANSI – American National Standards Institute

API – American Petroleum Institute

ASME – American Society of Mechanical Engineers

ASTM – American Society for Testing and Materials

CFR – Code of Federal Regulations

EPDM – ethylene propylene diene monomer

EPIX – Equipment Performance and Information Exchange

FSD – functional system description

INPO – Institute for Nuclear Power Operations

ISI – in-service inspections

ISO – International Organization for Standardization

IST – in-service test(ing)

LMTD – log mean temperature difference

LOCA – loss of coolant accident

MDMT – minimum design metal temperature

MT – magnetic particle testing

NBR – nitrile butyl rubber

NDE – nondestructive evaluation/examination

NMAC – Nuclear Maintenance Applications Center

NP – nuclear power

NPSH – net positive suction head

NPT – National Pipe Thread

NRC – Nuclear Regulatory Commission

NSSS – nuclear steam supply system

NUPIC – Nuclear Utility Procurement Issues Committee

OSHA – Occupational Safety and Health Administration

PHE – plate heat exchanger

PM – preventive maintenance

PMDB – Preventive Maintenance Database

ppm – parts per million

PSE – Plant Support Engineering

PT – (dye) penetrant testing

QA – quality assurance

RCM – reliability centered maintenance

RT – radiographic testing

RTF – run to failure

SMART – System Monitoring and Reporting Tool

SSC – structure, system, or component

STHE – shell and tube heat exchanger

TIL – Technical Information Letter

TR – technical report

UFSAR – Updated Final Safety Analysis Report

UT – ultrasonic testing

2
PROJECT MANAGEMENT AND PROCESS OVERVIEW

2.1 Generic Process

Figure 2-1 represents a generic process that a project team could follow when replacing a heat exchanger at a nuclear power plant. The process is structured like a typical Gantt chart; each activity is shown in approximate chronological order, and each duration roughly depicts the overlaps of various activities throughout the entire process.

2.2 Key Issues and Report Structure

Figure 2-1 illustrates that a replacement project should follow a logical sequence of events that affords the project team ample opportunity to evaluate all aspects of the replacement including interface points between the component and adjacent equipment and operating systems. The categorization of issues is based upon the typical delegation of activities among the key organizations involved (for example, design engineering, procurement engineering, purchasing, quality assurance, and organizations in the supply chain). Figure 2-1 also depicts the overall flow of information and the primary purpose of each element of the process. Each process element is also cross-referenced to the corresponding section in this report where more detailed implementation guidance is provided.

The user of this report should also keep in mind the following key points when looking at Figure 2-1:

- The design of the replacement component is an iterative process most effectively performed through close collaboration with the equipment designer and manufacturer.
- The design of the replacement component should concurrently consider other aspects of the project to include the maintainability of the equipment and installation issues.

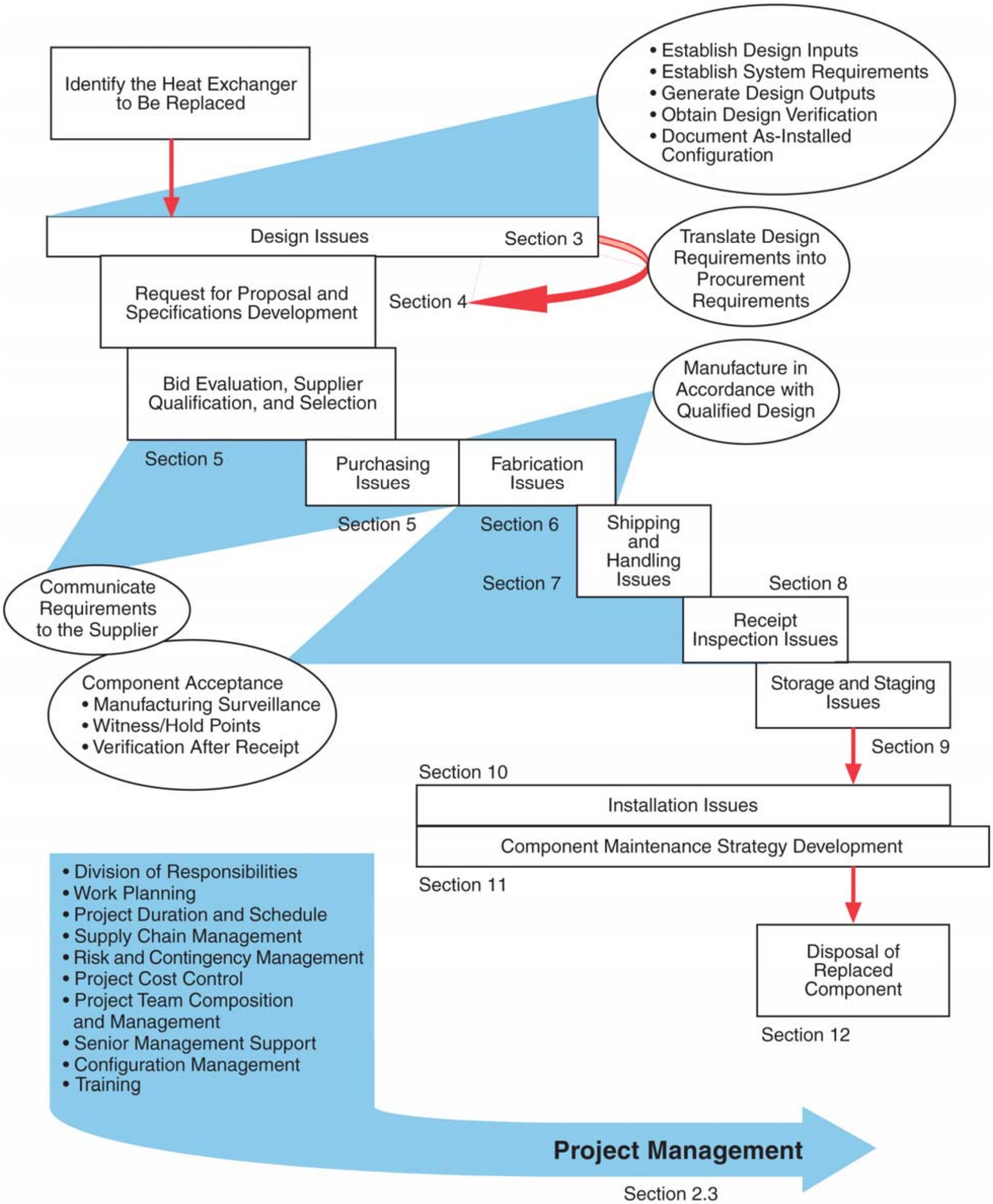

Figure 2-1
Process for Considering Key Issues When Replacing a Heat Exchanger

2.3 Project Management for Replacing Heat Exchangers

2.3.1 General Guidance

One of the keys to success when replacing a heat exchanger is the ability to manage the entire project and to ensure that it remains on schedule and within budget and that the replacement heat exchanger is suitable for its intended application. Although the main focus of this report is with the replacement plate heat exchanger itself, the project manager must have an appreciation for the entire scope of work associated with replacing the existing shell and tube heat exchanger. This most likely involves the modification of various interfacing system components, each controlled with appropriate site-specific design change processes. Figure 2-1 illustrates that project management activities span the entire duration of the project and include many issues that are not necessarily directly related to the replacement heat exchanger nor are they technical in nature. Some of these issues may include any of the following:

- Division of responsibilities – Assigning roles and responsibilities among the various internal and external organizations associated with the design, procurement, manufacture, installation, maintenance, and operation of the replacement heat exchanger.
- Work planning – Coordinating the numerous work activities associated with the replacement heat exchanger and interfacing system components.
- Project duration and schedule – Establishing a project scope, total duration, and milestones so all activities are appropriately planned and scheduled. The project manager should consider the following issues when establishing an overall project schedule for a heat exchanger replacement:
  - Pre-design activities – Walkdowns, inspections of existing heat exchanger, conceptual design studies, review of heat exchanger designs and performance capabilities
  - Pre-award activities – Design engineering activities, specification development, bid evaluation
  - Manufacturing lead time
  - Shipping duration
  - Receiving and staging duration
  - Construction management
  - Demolition schedule
  - Installation schedule
  - Post-installation testing and start-up activities
  - Turn-over activities

  After each of these major elements has been planned, then the licensee’s work planning organization should be used to integrate the overall project schedule and milestones into the site’s overall schedule in accordance with existing utility or site procedures.

- Supply chain management – Interfacing with the various organizations in the supply chain to ensure that each has the necessary capabilities and can implement those controls in a consistent manner with regard to the replacement component and other system components needing replacement or modification.
- Risk and contingency management – Developing plans for addressing unexpected issues arising during the duration of the overall project and ways to estimate the risks associated with implementing various corrective actions.
- Project cost control – Ensuring that the component replacement project remains within the allowable budget.
- Project team composition and management – Ensuring that the appropriate individuals are available to support the component replacement project and possibly including members from the supply chain.
- Senior management support – Ensuring that senior management is aware of the project scope, budget, and progress so as to provide the necessary support throughout the duration of the component replacement work activities.
- Configuration management – Ensuring that the appropriate design change control processes are implemented effectively and that the as-built configuration of the replacement component is accurately represented and conveyed in design output documents.
- Training – Ensuring that personnel associated with the operations and maintenance of the replacement component are provided adequate training if their existing level of training is deemed to be inadequate for the safe and reliable performance of the equipment. Currently, plate heat exchanger manufacturers can provide training if requested by the owner or if the owner does not have prior experience with plate heat exchangers at their unit.

Expectations of the project include ensuring that the replacement heat exchanger satisfies design requirements for its intended application(s), that it subsequently performs reliably, and that adjacent system components are modified as needed to sustain reliable system performance. Successful projects recognize the importance of maintaining close contact with both internal and external organizations.

2.3.2 Project Management Team and Interface Controls

2.3.2.1 Project Management Interface Controls

ANSI N45.2.11 [3] describes implementation guidance for the control of both external and internal interfaces encountered during the design of a component. It suggests that for either type of interface, the project manager should perform the following:

- Identify the interface
- Establish responsibilities
- Establish appropriate lines of communication
- Establish procedures to control the flow of design information

2.3.2.2 Project Management Teams

Since engineering (including the design) occurs sequentially and in an iterative manner, some expertise and awareness of parameters affecting the heat exchanger through all stages of its life should be considered during the design phase. Indeed, it is often the case that many types of expertise are essential at almost every stage of product development and usage. As such, the project manager should solicit and be provided with a variety of expertise concurrently in each stage of the sequential process.

To ensure that the required expertise is available, the project manager should create a multidisciplinary team, where each member has some of the required expertise. This team should guide the component replacement from beginning to end. Table 2-1 lists the typical plant groups that may contribute members to the project team and the estimated extent to which they would be involved.

Table 2-1
Typical Project Team for Heat Exchanger Replacements

Origin of Project Team Members	Anticipated Level of Involvement
Engineering (design, systems, component)	High
Procurement engineering	Medium (unless commercial grade dedication is necessary)
Maintenance	Medium
Installer	High
Project manager	High
QA/QC	Medium
Work control/planner/scheduler	High
Licensing	Low
Operation	Low
Senior management	Medium
Component supplier	High
Plant security	Low
Training	Low (higher for operations and maintenance personnel)
Supply chain	Low (during actual purchasing)
Health physics	Project dependent based on application
Chemistry management	Low (project dependent based on application)

2.3.3 General Project Considerations

Successful project managers recognize the importance of considering various aspects of the replacement as the design of the replacement component and design modifications of adjacent system components progress. This process is often referred to as *concurrent design* because the design evolves throughout the project, and it occurs in concurrent engineering environments. EPRI Report TR-107372, *Guideline for Reverse Engineering at Nuclear Power Plants*, [4] describes concurrent design in the following manner:

> A systematic approach to the integrated, concurrent design of products and their related processes, including manufacturing and support. Causes developers to consider from the outset, all elements of the product life cycle.

In a very general way, design engineering occurs in a sequential manner. Design must occur primarily before manufacturing the replacement heat exchanger; testing and inspection commence after manufacturing has started. Then the replacement heat exchanger is shipped, stored, installed, started, operated, and maintained.

2.3.3.1 Design Considerations

When replacing a heat exchanger, the project manager should factor the following aspects of the component use into its design to the extent feasible:

- Enhancing the ease of installation – During the design of the replacement component, the project team should consider how and where the component will be installed. Layouts, lifting and rigging plans, and space limitations should be communicated to potential component manufacturers so that appropriate features can be designed into the component to facilitate safe handling and installation of the item. Walkdowns should also be considered as a way to share installation concerns with potential manufacturers during the design and bid phases of the replacement project. Examples of design features that can enhance the ease of installation of major plant components may include:
  - Lifting lugs
  - Protective shields, plugs, and caps
  - Internal bracing and padding
  - Modular construction
- Enhancing maintainability – The project team should work with potential suppliers to design any enhancements to the component that will support future maintenance activities. Accessibility, maintenance, repair, and in-service inspection requirements for the plant including the conditions under which they will be performed, should be communicated to potential suppliers. This may result in special instrumentation, physical reconfiguration of the equipment, or allowance for accessibility. Features to consider to facilitate improved maintenance include:
  - Inspection ports – To inspect the condition of the heat exchanger without having to disassemble it.
  - Tightening system (for example, bearing boxes) – On the tightening bolts to facilitate easy disassembly and closing of the heat exchanger. (Typically, no special tools are required.)
  - Mechanical alignment system – To keep the plates easily aligned during opening and closing.
  - Bolted construction – To allow field assembly and future expansion.
  - Shroud – Around the plate pack to keep the heat exchanger clean and protect the personnel in case of leak.

- Bolt covers – To keep the bolts clean and safe from damage. Clean bolts can be easily opened and closed.
- Roof cover – If the heat exchanger is used in an area exposed to sun, rain, and snow, to prevent any undesirable exposure of the plates and gaskets.

- Enhancing equipment performance monitoring and inspection – The project team and potential manufacturers should examine ways in which the performance of the replacement component can be most effectively monitored. Together, the following aspects should be considered:
  - Ability to inspect equipment
  - Enhancements to support equipment performance monitoring
  - Test requirements including in-plant tests and the conditions under which they will be performed
- Determining the need for special tooling – During the design of the component, the project team and potential suppliers should determine if there are any requirements for special tooling—either during the manufacture or operation of the replacement component. In some cases, the design can be modified early in the process to negate the need for special tooling.

2.3.3.2 Other Design Considerations

ANSI N45.2.11 [3] and current industry experience recommend that the project manager consider the following parameters during the design of the replacement heat exchanger. Note that the following list is not intended to be all inclusive, and each project team should use existing plant procedures to ensure that appropriate design aspects are considered during the component replacement:

- Personnel requirements and limitations (including the qualification and number of personnel available for operation, maintenance, testing, and inspection) and permissible personnel radiation exposures for specified areas and conditions
  - ALARA
  - Human factors
- Transportability requirements such as size and shipping weight, limitations, federal regulations, etc.
- Fire protection or fire resistance requirements
- Handling, storage, and shipping requirements
- Requirements to prevent undue risk to the health and safety of the public
  - Radiation releases and dose

- Safety requirements for preventing personnel injury including such items as radiation hazards, restricting the use of dangerous materials, escape provisions from enclosures, and grounding of electrical systems
  - OSHA
  - Industrial safety
  - Hazardous materials
- Special cleanliness requirements

2.3.3.3 Evaluating Industry Experience

The heat exchanger project should consider researching industry experience related to the component being replaced and the performance of potential manufacturers of the replacement component. A wealth of industry experience regarding the replacement of steam generators, steam turbines, and generators already exists. In general, the project team should consider the following sources for researching industry experience:

- INPO Operating Experience
- NRC Bulletins and/or 10CFR21 Notices
- Technical Information Letters (TILs)
- Technical Bulletins
- Other utility experience with similar component replacement
- Nuclear Utility Procurement Issues Committee (NUPIC) Database

3
SYSTEM AND COMPONENT DESIGN ISSUES

3.1 Understanding the Reasons for Heat Exchanger Replacement with a Plate Heat Exchanger

3.1.1 Introduction and General Guidance

As noted in Section 1, many plants are facing the necessity of replacing heat exchangers to support initiatives such as license renewal applications, power up-rates, and degradation of the existing equipment. Before any design activities are undertaken, engineering personnel should fully understand why the heat exchanger is being replaced. Although the reasons may not have a significant effect on implementing the generic process described in this report, it will in most cases affect the scope of the licensee's design and procurement processes.

As also noted previously, one of the basic premises of this report is that utility personnel have already performed a replace vs. repair or refurbish analysis in accordance with site-specific procedures. This report assumes that heat exchanger replacement has been determined to be the most cost-beneficial option. As such, the replace vs. repair analysis is not included in the generic process provided in Section 2 and is not discussed further in this report. This report also assumes that the licensee has selected the plate heat exchanger to be the most suitable design for the given plant application, based on having considered the design factors listed below.

Some of the most common reasons why a shell and tube heat exchanger would be replaced instead of being repaired are presented here. In some cases, replacement may be the best option for a combination of the issues listed below:

- End of life – The shell and tube heat exchanger has reached the end of its design life, can no longer perform design functions, and cannot support plant license renewal.
- Re-tubing – If a significant number of tubes are plugged or degraded, re-tubing may not be practical or economical due to space limitations or other construction constraints.
- Component obsolescence – The shell and tube heat exchanger is obsolete and cannot be maintained properly because:
  - The original manufacturer is no longer in business or does not manufacture an identical component.
  - Newer technologies have replaced those inherent to the original component.
  - Identical spare or replacement parts are no longer available.

- Power up-rate – The original shell and tube heat exchanger design is inadequate to support a power up-rate.
- Degraded performance – The original shell and tube heat exchanger performance has degraded over time, adversely affecting its availability or reliability.
- Improving or enhancing component performance and reliability – In some cases, a heat exchanger will be replaced not only to restore system performance, but also to improve it. Likewise, a heat exchanger may be replaced to improve upon a less reliable design. And in some cases, a component is replaced to enhance system output performance and improve equipment reliability.

  The project team should clearly understand the goals of the heat exchanger replacement and subsequently communicate those objectives to potential suppliers as early in the design phase as possible. Design issues commonly addressed as a way to improve or enhance heat exchanger performance and reliability may include any of the following:

  – Ability to add plates over time to increase capacity
  – The amount of increased capacity anticipated (adequate support of additional load, large enough frame to accommodate additional plates)
  – Plate and connection material considerations and selection (water chemistry and chloride content, thickness of the plate, operating temperature, operating pressure)
  – Gasket material considerations and selection (water chemistry, operating temperature, frequency of disassembly, gasket attachment type, radiation level)
  – Susceptibility to fouling (flow characteristics, wall shear stress, maximum particle size, type of fouling)
  – Component redundancy to facilitate on-line maintenance

3.1.2 Advantages of the Plate Heat Exchanger

The plate heat exchanger offers a number of key advantages over the shell and tube heat exchanger:

- Compactness – As a direct result of its high heat transfer capability, the plate heat exchanger may be installed in one-fourth to one-tenth the floor space required by other types of heat transfer equipment, often performing at a higher heat load. This feature is a primary advantage for nuclear applications. Many of the existing shell and tube heat exchangers could not be replaced with identically sized units because there are often space restrictions, accessibility issues, and interferences preventing the movement or installation of a similar type unit. The plate heat exchanger, which can be assembled to some extent *in situ* due to its modular-type design, has a distinct advantage when replacing the shell and tube heat exchangers that are currently installed at many nuclear power plants.

  The comparative sizes of shell and tube heat exchangers versus plate heat exchangers are illustrated in Figure 3-1.

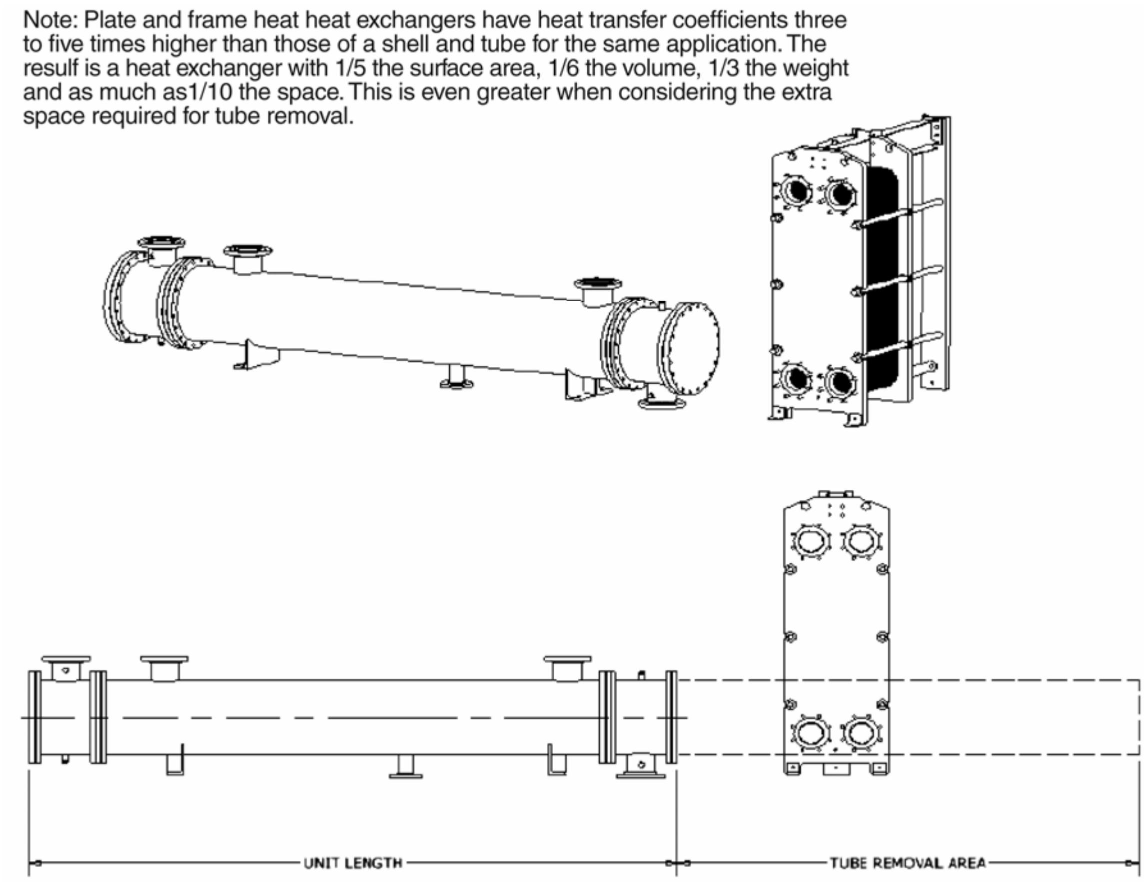

Figure 3-1
Comparative Sizes of Primary Types of Heat Exchangers

- High heat transfer – Film coefficients three to five times higher and lower thermal resistance of the plates (due to thinner material) combine to provide high heat transfer rates compared to tubular or spiral-plate designs. In combination with fully countercurrent arrangement of the plates, this allows heat recovery or regeneration of 90–95% of the heat in many processes.
- Ability to clean the component – The efficient use of heat transfer surface eliminates areas of little or no flow, thus preventing the buildup of dirt or debris. This also allows for effective “cleaning in place” (CIP) to remove chemical film or scaling deposits. On a gasketed plate heat exchanger, the plates are removable for manual cleaning (see “Accessibility” below).
- Accessibility – The gasketed plate heat exchanger provides full access to both sides of the heat transfer surface for inspection, maintenance, and cleaning when the unit has been allowed to foul beyond the capabilities of chemical cleaning. This access is readily accomplished within the installed space of the unit.

- Flexibility – Many processes are not at their optimum as designed and require equipment changes and modification after startup to achieve maximum throughput. This fine tuning is readily achieved with the plate heat exchanger by adding, removing, or rearranging plates as required to meet actual process conditions. Similar adjustments can also be made to accommodate future process or plant expansions or modifications. Welded plate exchangers do not enjoy the same degree of accessibility and flexibility as gasketed plate exchangers. Welded plate pair units can be disassembled and reconfigured only in pairs.
- Economy – The high heat transfer capability reduces the surface area requirements and, thus, the initial cost of the equipment. Additional cost savings carry through as the result of reduced installation space, ease of maintenance, high energy recovery, and reduced service fluid requirements.

3.1.3 Disadvantages of the Plate Heat Exchanger

Plate heat exchangers may be subject to the following issues, particularly in raw water applications:

- System effects:
  - They require the use of a relatively fine strainer (< 0.08 in. [< 2 mm]) because of their narrow passages.
  - Similarly, a highly reliable chemical addition system is essential to maintain the surfaces free of microbiological fouling. An unreliable system could lead to macro fouling of the plenum (distribution header), as well as micro fouling of the plates.
  - A plate heat exchanger must be designed to meet similar pressure drops as the shell and tube heat exchanger it is replacing. A plate heat exchanger with higher pressure drops will subsequently challenge pumps and flow distribution in existing systems. As they foul, this issue can worsen.
- Maintenance:
  - When fouled, a plate heat exchanger is different from a shell and tube heat exchanger to disassemble and clean because each individual plate must be brushed or sprayed clean. If it is the first application of plate heat exchangers at the facility, the initial cleaning evolutions may present a new challenge for some maintenance departments due to a lack of hands-on experience and knowledge.
  - The plates are susceptible to wear and possible damage after numerous disassembly, reassembly cycles.
  - If the maintenance is not carefully performed, leaks can result if debris is caught in the gasket closure area.
  - The gaskets on each plate have a limited service life depending on service conditions. This leads to requirements for periodic refurbishment, which is relatively easy with clip-on gaskets, but expensive and time consuming with glued gaskets. Large plate heat exchangers used in raw water service typically have glued gaskets with service lives lasting approximately 10 years.

- Design:
  - – Nuclear utilities and owners currently have relatively little experience with plate heat exchanger design. As such there is a strong dependence on plate heat exchanger supplier technical information, some of which is proprietary.

3.2 Plate Heat Exchanger Components and Functions

3.2.1 Main Components of the Plate Heat Exchanger and Their Functions

In plate heat exchangers, heat is transferred from one medium to another through thin metal plates, which have been pressed into a special pattern. Figure 3-2 illustrates typical components of a plate heat exchanger.

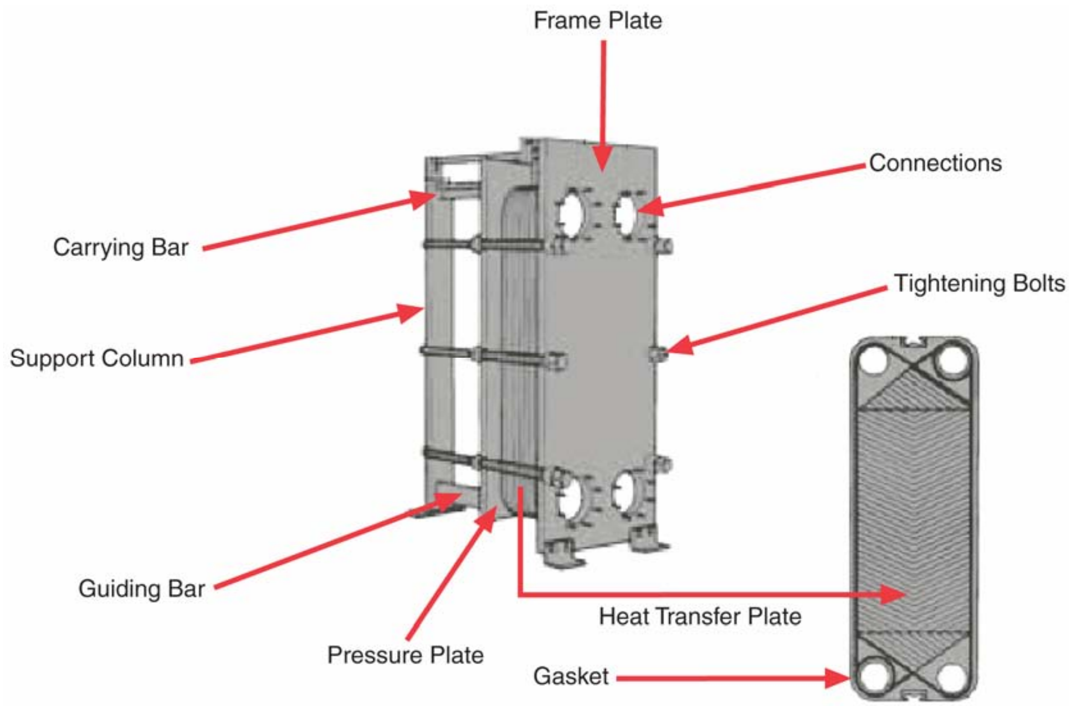

Figure 3-2
Typical Plate Heat Exchanger Components

The plate heat exchanger components shown in Figure 3-2 are:

- Frame plate – The frame plate is the side of the heat exchanger that connects to the inlet and outlet piping of both the hot and cold fluids. It forms the plate against which the pressure plate can squeeze varied numbers of channel plates, to achieve the amount of heat transfer required for the application. This item is often also known as a *fixed cover, stationary cover, fixed head,* or *head*.
- Support column – The support column, along with the frame plate, the carrying bar, and the guiding bar, forms a rigid frame that supports the heat transfer plates and the pressure plate.
- Connections – Connections are holes matching the piping that lead through the frame plate, permitting the media to enter the heat exchanger. Threaded studs around the holes secure the pipes to the equipment. Depending on the application, metallic or rubber-type linings may protect the edges of the holes against corrosion.
- Carrying bar – The carrying bar is what the plates hang from at the top.
- Guiding bar – The guiding bar keeps the plates in line at the bottom.
- Tightening bolts – A number of tightening bolts are used to press together the thin channel plates that are hanging between the frame plate and the pressure plate, bringing them into metallic contact. The bolts are tightened to compress the gaskets enough to seal the narrow passages that have now been formed between the plates.
- Pressure plate – The pressure plate is hung on the carrying bar and is moveable, as are the heat transfer plates. In some rare cases, piping may be connected to the pressure plate. This item is also known as a *follower* or a *movable cover*.
- Heat transfer plates – Heat is transferred through the surface of these plates, except for some small areas near the corners. The number of plates in the heat exchanger is determined by the size of the heat transfer surface required. The plate pack—the heart of a plate heat exchanger—is compressed between the pressure plate and frame plate to form separate flow paths for the process and service fluids. The corrugated plates are usually formed from metal 0.016–0.036 in. (0.4–0.9 mm) thick. Proper plate design and material thickness are determined by the manufacturer so that the plate pack can withstand the full design pressure.

  Plate corrugation can be of many types. One pattern known as *washboard corrugation* consists of troughs that are perpendicular to the direction of the liquid flow. These troughs mate with those of the adjacent plate, but the troughs are kept apart by raised pips that contact corresponding points on adjacent plates, thus forming flow channels. This results in a ribbon flow path. The gap forming the flow channel generally ranges from 0.150 in. to 0.390 in. (3.8 mm to 9.9 mm), depending on the plate design.

  The most commonly used plate pattern is known as the *chevron*. This design is based on corrugations formed at an angle to the liquid flow that, in combination with plates of opposite or different angles, make contact at the corrugation cross-over points to permit flow between them. This pattern forms a flow path broken into many high-turbulence helical streams. Flow channel gaps on chevron plates typically range from 0.080 in. to 0.250 in. (2.0 mm to 6.4 mm).

Most applications with clean fluids use chevron plates with flow channel gaps in the lower half of the range (0.080 in. to 0.160 in. [2.0 mm to 4.1 mm]). At the upper end of the range (near 0.250 in. [6.4 mm]), modern wide-gap chevron plates often replace the traditional washboard-style plates because chevron plates can achieve greater mechanical strength with reduced plate thickness at a lower cost.

- Gasket – Gaskets can be made of various materials, depending on the temperature and corrosiveness of the fluids being handled. For semi-welded plate units, the number of gaskets is reduced by half because sets of two heat transfer plates are welded together on one side. This limits gasket exposure to aggressive chemicals and high temperatures and, where necessary, allows the cost-effective use of elastomers with better chemical resistance.

3.2.2 Functionality of a Plate Heat Exchanger

Figure 3-3 illustrates the flow pattern for a parallel-flow plate heat exchanger.

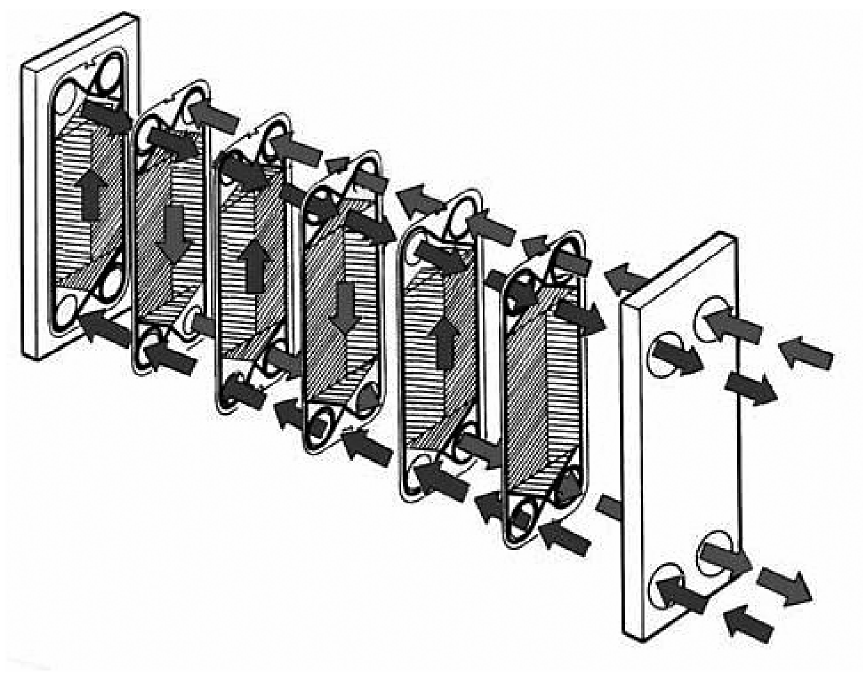

Figure 3-3
Parallel-Flow Plate Heat Exchanger

Figure 3-4 illustrates the flow pattern for a diagonal-flow plate heat exchanger. Note that the difference is that the outlet flow is diagonal to the inlet flow when looking at an end view of the unit. Whereas on the parallel-flow plate heat exchanger, the outlet flow is directly above or below the inlet flow when looking at an end view of the unit.

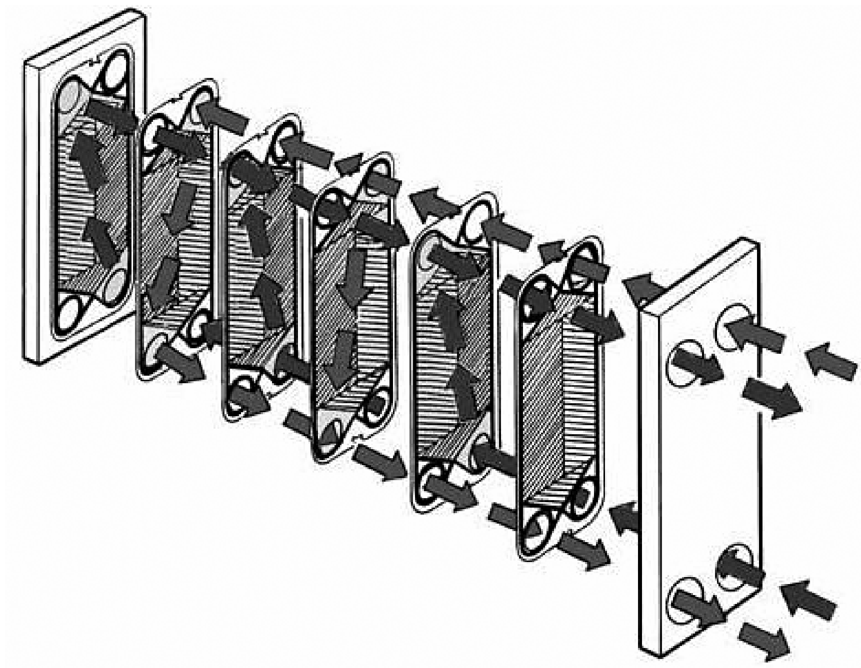

Figure 3-4
Diagonal-Flow Plate Heat Exchanger

When a package of plates is pressed together, the holes at the corners form continuous tunnels or manifolds, leading the media (which participate in the heat transfer process) from the inlets into the plate pack, where they are distributed in the narrow passages between the plates.

Because of the gasket arrangement on the plates, and the placing of “A” and “B” plates alternately, the two liquids enter alternate passages, for example, the warm liquid between even number passages, and cold liquid between odd number passages.

Thus, the media are separated by the heat transfer plate. In most cases, the liquids flow in opposite directions.

During the passage through the equipment, the warmer medium will give some of its heat energy to the heat transfer plate. Heat passes very easily through the heat transfer plate separating the two media. The plate instantly transfers the heat from the warmer medium to the colder medium on the other side. The warmer medium drops in temperature, while the colder one is heated up. Finally, the media are led into a similar outlet manifold at the other end of the plates and discharged from the heat exchanger.

3.2.3 Heat Transfer Losses

The purpose of the equipment is to transfer heat from one medium to another. The novel pattern of the plate material not only gives strength and rigidity, but also greatly increases the rate of heat transfer from the warmer medium to the colder medium. However, the high heat flow through the walls can be severely reduced by the formation of deposits on the wall surfaces.

The corrugations on the heat transfer plates mentioned above induce highly turbulent flow. The induced turbulence generally resists, but does not eliminate, the formation of deposits on the plate surface.

If fouling or deposits occur, they may increase the total "wall thickness" of the plates. The heat exchanger is designed with specific tolerances for the wall thickness. Any increase in wall thickness will reduce the heat transfer capability of the heat exchanger. Also, the fouling or deposits will consist of materials that have a much lower thermal conductivity than the metal plate. Consequently, any fouling or deposits can severely reduce the overall heat transfer rate. Additionally, fouling and deposits are unwanted in heat exchangers because corrosion may occur under the deposits.

3.2.4 Pressure Drop

All heat exchangers offer resistance to media flowing through them. This resistance is a pressure drop, and pressure drops are wasted energy. To maintain adequate flow and heat transfer through the plate heat exchanger, pressure drops should be kept as close as possible to the designed value.

Deposits formed on the heat transfer surfaces lead to reduced flow area between the plates. As flow area decreases, for a given volumetric flow rate, pressure drop (and required pumping power) will increase. To maintain the desired flow through the reduced open area in the heat exchanger, more energy must be expended and will subsequently cause a pressure drop.

An indication that fouling or clogging has occurred include one or both of the following:

- Decreased thermal performance (desired temperatures are not maintained)
- Increased pressure drop in either of the media

Fouling of the surfaces of the heat exchanger may occur when larger particles and fibers are drawn into the heat exchanger. These particles will clog the passageways if strainers or other means of protection have not been provided.

3.2.5 Gaskets

Figure 3-5 illustrates typical configurations for a gasket used in both the parallel flow and diagonal flow type of heat exchangers.

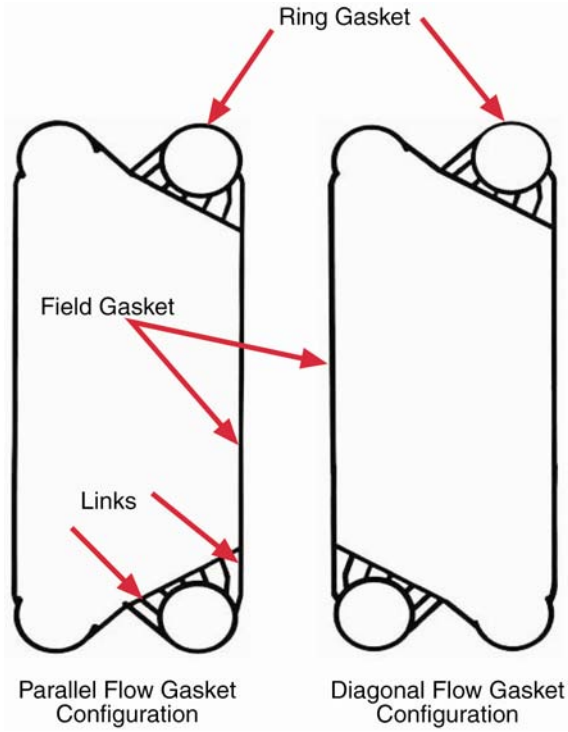

Figure 3-5
Typical Gasket Configurations

The gasket is molded in one piece. The material is normally an elastomer that is selected to suit the actual combination of temperature, chemical environment, external environmental conditions (normal and accident—for example, radiation, temperature, humidity, etc.), and possible other conditions that may be present. The one-piece gasket consists of:

- One field gasket – The field gasket is by far the largest part of the pieces shown, containing the whole heat transfer area and the two corners connected to it.
- Two ring gaskets – The ring gaskets seal off the remaining two corners.
- Links – These three pieces, (one field gasket and two ring gaskets) are held together on larger designs by a few short links. The links have no sealing function at all. These links may also be referred to as *fingers*. Their purpose is simply to tie the pieces together and to add some support in certain areas. On some plate heat exchangers, the gasket is held in place on the plate with a suitable cement or glue.

As already demonstrated, the two media are effectively kept apart by the ring and field gaskets. To prevent intermixing of the media in the corner areas where field and ring gaskets are very close to each other, the link pieces have a number of slots, which opens the area between the field and ring gaskets to the atmosphere. Figure 3-6 illustrates the position of these slots.

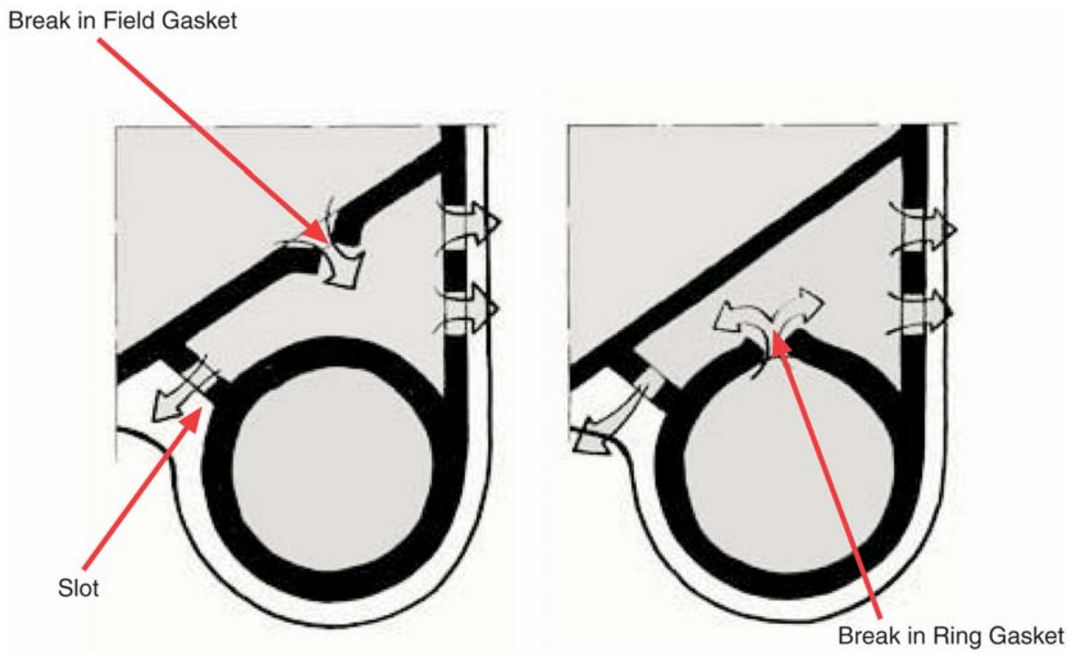

Figure 3-6
Slot Configuration

Any leakage of media across either gasket will escape from the heat exchanger through the slots. It is important for these openings to be kept clear. If they are not, there is a risk that should a leak occur in that region of the plate, there might be a local pressure buildup, which could allow one medium to mix with the other. Care should be taken not to cut or scratch the gaskets while handling the plates.

3.3 System and Component Design Relationship

Figure 3-7 illustrates that the design issues encountered during the replacement of a shell and tube heat exchanger include those directly related to the component as well as those associated with adjacent or interfacing system components. In many cases, adjacent or interfacing system components require some design modification in order to make the replacement heat exchanger suitable. These plant design modifications are just as important to the success of the project as the design of the actual replacement plate heat exchanger.

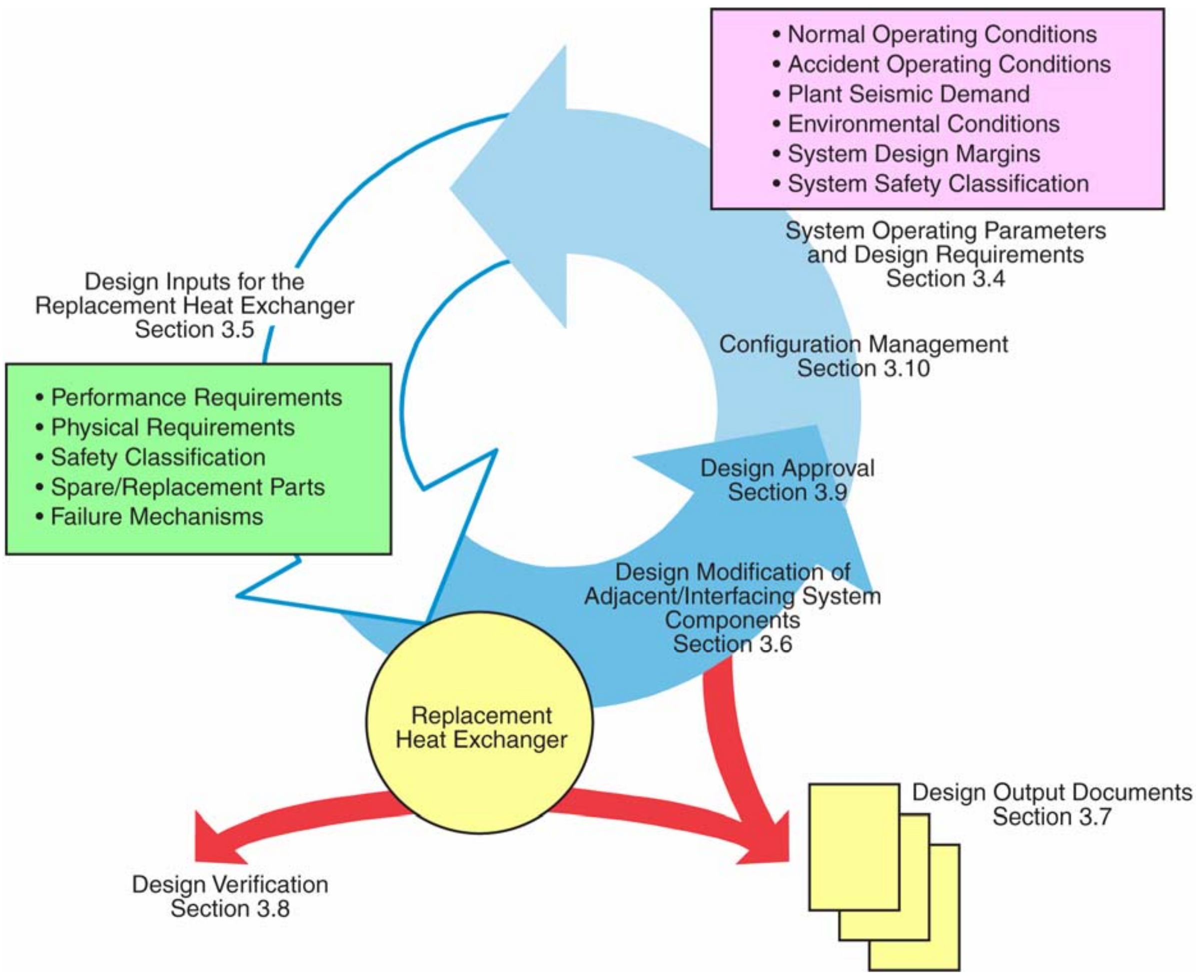

Figure 3-7
System and Component Design

3.4 Establishing System Operating Parameters and Design Requirements

3.4.1 System Normal Operating Conditions

The project team should communicate the following information to potential plate heat exchanger suppliers and designers, as appropriate:

- System fluid flow and heat transfer parameters (for both the hot fluid and the cold fluid)
  - Fluid description and fluid chemistry
  - Flow rate (gal/min [l/min])
  - Minimum/maximum inlet fluid temperature (ºF [ºC])
  - Minimum/maximum outlet fluid temperature (ºF [ºC])
  - Maximum permissible pressure drop (psi [kPa])

- Maximum working pressure (psi [kPa])
- Fluid specific gravity
- Fouling factor
- Specific heat at mean temperature (Btu/lbm-ºF [kJ/kg-K])
- Thermal conductivity at mean temperature
- Mean temperature (ºF [ºC])
- Viscosity at several temperatures in the operating range
- Suspended solids content (%)
- Nature of solids (that is, fibrous, powder, size)
- Flow fluctuations, if any

3.4.2 System Accident Operating Conditions

System operating conditions following a design basis accident should be recognized and provided to potential suppliers. Failure effects requirements of systems, structures, and components (SSCs) including a definition of those events and accidents that the SSCs must be designed to withstand should also be communicated to potential component manufacturers during the design of the item.

3.4.3 Plant Seismic Demands

The project team should ensure that plant- or site-specific seismic loads are communicated to potential suppliers during the design of the replacement heat exchanger. Seismic demands vary from plant to plant, and it is important for potential suppliers to understand the loads that the replacement equipment could be subjected to and to which it should be designed. Because the plate heat exchanger is relatively tall and narrow, additional bracing and supports may be necessary, which could affect the installation and future expansion of the unit if it is subjected to seismic loads.

3.4.4 Environmental Conditions

It is important during the design of the component for the project team to communicate the various environmental conditions to which the replacement plate heat exchanger will be subjected. Consideration should be given to environments during the following scenarios:

- During normal operation – Ambient conditions, wind loads, exposure to the elements
- During and after design basis accidents – Post-LOCA temperature, humidity, radiation, and pressure

Although not a system operating parameter, the plate heat exchanger manufacturer should also be made aware of environmental conditions anticipated during storage (for example, temperature, humidity, atmospheric pressure, and exposure to airborne contaminants).

3.4.5 System Design Margins

The project team should confirm the design margins associated with both the system in which the heat exchanger is installed and the heat exchanger itself. Consideration should be given to means by which the plate heat exchanger may improve design margins. Any changes to design margins should be documented on design outputs such as calculations, drawings, specifications, system descriptions, design basis documents, and the UFSAR. In many cases, the resulting effect on actual design margins may not be determined until after a particular replacement heat exchanger has been selected.

3.4.6 System Safety Classification

The project team should confirm the safety classification of the system in which the plate heat exchanger will be installed and the classification boundaries. This information is typically documented in the UFSAR, functional system descriptions, system design bases documents, technical specifications, and system diagrams and drawings.

3.4.7 Other Considerations

Other considerations that the project team should confirm include:

- Interface requirements including definition of the functional and physical interferences involving structures, systems, and components
- Structural requirements covering such items as equipment foundations and pipe supports
- Access and administrative control requirements for plant security
- Redundancy, diversity, and separation requirements of related structures, systems, and components
- Anticipated in-service testing and inspection requirements
- Anticipated cleaning requirements

3.5 Establishing Design Inputs for the Replacement Component

3.5.1 General Guidance

ANSI N45.2.11 [3] provides the following guidance regarding the establishment of design inputs:

> Applicable design inputs, such as design bases, regulatory requirements, codes and standards, shall be identified, documented and their selection reviewed and approved. Changes from specified design inputs including the reasons for the changes shall be identified, approved, documented and controlled.

First and foremost, the suppliers should be aware of the basic plant location, layout and arrangement requirements for the replacement heat exchanger. When replacing a shell and tube heat exchanger, it is important to understand the current design bases requirements of the system in which the replacement will be installed. This may be different than the requirements originally specified in the original heat exchanger purchase specification because there may have been design modifications performed during the life of the heat exchanger being replaced. Furthermore, the project team should understand the objectives of the heat exchanger replacement and whether one of the objectives is to increase system output performance or improve design margins by virtue of replacing the particular heat exchanger.

3.5.2 Establishing Heat Exchanger Performance Requirements

Plate heat exchanger design functions and operability may vary under various conditions, such as plant start-up, normal plant operation, plant shutdown, plant emergency operation, special or infrequent operation, and system abnormal or emergency operation should be understood by the project team and communicated to potential suppliers. This may include any of the following:

- Instrument and control requirements including indicating instruments, controls and alarms required for operation, testing and maintenance. Other requirements such as the type of instrument, installed spares, range of measurement, and location of indication.
- Heat transfer capacity
- Material requirements including such items as compatibility, protective coating and corrosion resistance
- Mechanical requirements such as vibration, stress, shock and reaction forces
- Component functional mode (heat exchangers are typically categorized as passive components)
- Component failure mechanisms, failure modes and effects (Additional guidance is provided in Appendix A of EPRI report 1008256, *Guidelines for Technical Evaluation of Replacement Items in Nuclear Power Plants*, *Revision 1*. [5]

In some cases, the heat exchanger mechanical and physical interface requirements cannot easily be determined from existing documentation and can be obtained only by inspection or measurement of the actual component. In these cases, the project team may need to gain access to the equipment during an outage to make the necessary inspection or measurement. Depending on plant operating status, the project team may need to plan these outage activities months or perhaps years before the replacement of the heat exchanger.

Given the outputs resulting from modification of adjacent and interfacing system components and the subsequent system operating parameters, the project team should establish the heat exchanger technical requirements to the degree deemed necessary to ensure that all design basis requirements are met. In many cases, the manufacturer is provided latitude to design or offer a heat exchanger that meets the requirements of the design requirements they have been provided. The degree to which the project team is involved in the actual design of the replacement heat exchanger will vary depending on the item, its complexity, and its plant-specific functions.

In most cases, the project team must understand and communicate component-specific performance requirements to potential suppliers in order to ensure that system performance requirements are met. In some cases, it may also be necessary for the project team to determine, select, and specify physical requirements for the component and its parts.

Table 3-1 provides a listing of typical heat exchanger performance requirements that should be considered, as applicable, during the design of the replacement.

Table 3-1
Typical Heat Exchanger Performance Requirements and Characteristics

Heat Exchanger Performance Characteristics:		
• Fluid description and fluid chemistry	• Maximum working pressure (psi [kPa])	• Mean temperature (°F [°C])
• Flow rate (gal/min [l/min])	• Fluid specific gravity	• Viscosity at several temperatures in the operating range
• Minimum/maximum inlet fluid temperature (°F [°C])	• Fouling factor	• Suspended solids content (%)
• Minimum/maximum outlet fluid temperature (°F [°C])	• Specific heat at mean temperature (Btu/lbm-°F [kJ/kg-K])	• Nature of solids (that is, fibrous, powder, size)
• Maximum permissible pressure drop (psi [kPa])	• Thermal conductivity at mean temperature	• Flow fluctuations, if any

3.5.3 Establishing Component Physical Requirements

A list of typical heat exchanger physical requirements that should be considered, as applicable, during the design of the replacement is presented here:

- Coatings
- Gasket material of construction
- Plating
- Dimensions (to within manufacturer's tolerance)
- General configuration or shape
- Surface finish
- Frame material of construction
- Mounting
- Surface hardness
- Gasket durometer hardness
- Permeability
- Tensile strength
- Gasket elasticity
- Plate material of construction
- Thermal conductivity
- Gasket leachable halogen content
- Material thickness
- Weight

3.5.3.1 Available Gasket Materials

The following information is provided to assist project teams in selecting the most appropriate gasket material for the replacement plate heat exchanger.

> Although the plates and gaskets are clearly designed to withstand maximum design pressures and temperatures, certain working fluids or trace constituents of these fluids can attack the gaskets and/or cause swelling. It is important to provide the plate heat exchanger supplier with the fluid constituents to assist in gasket selection. The life of an elastomeric gasket principally depends on operating temperatures, temperature variations and chemical influences. The life expectancy of elastomeric gaskets in the case of continuous operation at the highest recommended maximum temperature is approximately two years. An increase of the temperature by 10ºC will approximately half the life of the gasket. A reduction of the temperature by 10ºC will, on the other hand,

approximately double the life of the gasket. The temperature limits quoted on these sheets are for guidance only as the maximum operating temperatures may be affected by the process stream in either an advantageous or disadvantageous way. Short periods of operation above the specified maximum can usually be tolerated without causing a significant effect on the gasket life.

Gaskets for plate heat exchangers are normally Buna-N (NBR) or EPDM for most applications. Limits on temperature for Buna N are about 250ºF (121ºC). Above that, EPDM can be used to a maximum of about 320ºF (160ºC). It is important to understand that the higher the temperature, the shorter the gasket life. At 320ºF (160ºC), gasket life is about 1–2 years; whereas, at 150ºF (66ºC), it is about 12–15 years. Table 3-2 is a comparison of various gasket materials that the manufacturer should typically consider for a replacement component.

Table 3-2
Gasket Material Characteristics

NBR – Sulfur Cured	
Parameter	**Description**
Typical temperature range	5º F to 239º F (intermittent 275ºF) (-15ºC to +115ºC [intermittent 135ºC]).
Polymer type	Acrylonitrile-Butadine.
Process	Sulfur-cured medium nitrile rubber.
Applications	General-purpose material used for aqueous and fatty duties. Also vegetable and mineral oils. Refrigerant R134a with Alkyl Benzene or Polyalkylene Glycol (PAG) compressor lubricants.
Limitations	Certain restrictions apply when using nitric acid for cleaning.
NBR – Peroxide Cured	
Parameter	**Description**
Typical temperature range	5ºF to 284ºF (intermittent 302ºF) (-15ºC to +140ºC [intermittent 150ºC]).
Polymer type	Special Acrylonitrile-Butadine.
Process	Peroxide-cured nitrile.
Applications	Used for aqueous and fatty duties. Also vegetable and mineral oils. Refrig. R134a with Alkyl Benzene or Polyalkylene Glycol (PAG) compressor lubricants.

Table 3-2 (Continued)
Gasket Material Characteristics

EPDM – Resin Cured	
Parameter	**Description**
Typical temperature range	-31ºF to +320ºF (intermittent 329ºF) (-35ºC to +160ºC [intermittent 165ºC]).
Polymer type	Resin-cured EPDM.
Process	Ethylene Propylene Terpolymer.
Applications	High-temperature general purpose material for chemical environments and steam applications.
Limitations	May not be used with fats, hydrocarbon solvents, or where traces of mineral oil are present, for example, compressor oil in refrigerants.
EPDM - Peroxide Cured	
Parameter	**Description**
Typical temperature range	-31ºF to 302ºF (intermittent 320ºF) (-35ºC to +150ºC [intermittent 160ºC]).
Polymer type	Special Ethylene Propylene Terpolymer.
Process	Industrial peroxide-cured EPDM.
Applications	High-temperature material for hot water and steam. Also for various chemicals.
Limitations	May not be used with fats, hydrocarbon solvents, or where traces of mineral oil are present, for example, compressor oil in refrigerants.

Additional consideration should be given when gasket material is being selected for applications where the gasket could be exposed to ozone.

3.5.3.2 Available Heat Transfer Plate Materials

The following information is provided to assist project teams in selecting the most appropriate heat transfer plate material for the replacement plate heat exchanger.

> Stainless steel resists corrosion due mainly to the high content of chrome, which makes it passivate easily. In addition, grade AISI 316 has a molybdenum content of 2% - 3% which further increases its passivity.
>
> Passivation is a process whereby a protective film of oxide is produced on the surface of the steel. This oxide is produced in atmospheric air, and for example, nitric acid. Liquids such as salt water and hydrochloric acid (HCl), decompose this oxide film and thereby eliminate the resistance to corrosion. If the film is removed by chemical attack or mechanical damage, and conditions prevent the film from being restored, corrosion may occur locally at the point of damage, while other areas remain unaffected.

> The acidity (pH) of the corrosive medium also affects the corrosion resistance of the material. A high pH-value reduces the risk of local corrosion.
>
> In addition to chloride-containing environments, the risk of stress corrosion cracking also increases at relatively high temperatures. Nickel is the alloying element which contributes most to the reduction of stress corrosion and pitting.

Plate material is normally ASTM Type 316 stainless steel for water/glycol/lube oil/steam as long as the chloride levels are low and the pH is above 6. If chlorides are above 200 ppm, other materials, such as 20/18/6 stainless or titanium, should be used because of the risk of stress cracking. The higher the temperature, the lower the level of chlorides is allowed. The following is a comparison of various heat transfer plate materials (listed by commonly used trade names) that the owner and the manufacturer may consider for a replacement component:

- ASTM Type 304 stainless steel – The cheapest grade of the austenitic stainless steels. Although offering a general all-around corrosion resistance to a range of organic and inorganic products, it exhibits a poor resistance to sulfuric and hydrochloric acids. It is particularly susceptible to crevice corrosion induced by chloride-containing cooling waters.
- ASTM Type 316 stainless steel – A general purpose stainless steel suitable for use in a wide range of environments but with limited applications in sulfuric acid. The presence of molybdenum in the alloy confers a level of resistance to chloride-induced crevice corrosion, which will permit its successful application in most cooling waters.
- AISI 317 stainless steel – An alloy suitable for environments where AISI 316 will give a reasonable but generally unsatisfactory life due to crevice, pitting, or stress corrosion cracking. The slightly increased level of molybdenum improves its resistance to crevice and pitting corrosion, while the slightly increased nickel level imparts a slightly greater resistance to stress corrosion cracking.
- Allegheny AL-904L stainless steel – An alloy of particular value for duties involving sulfuric acid and especially phosphoric acid where there is contamination with chloride or fluoride ions. The high nickel content imparts a good degree of resistance to stress corrosion cracking, a failure mode frequently associated with pitting or crevice attack in AISI 316 stainless steels. This is an alloy that offers an excellent compromise between price and corrosion resistance for a wide range of acidic- and chloride-containing environments.
- Avesta 254 SMO stainless steel – An improved grade of AISI 316 resulting from the increased level of molybdenum, which imparts increased resistance to chloride-induced pitting and crevice corrosion and, therefore, is for use in brackish waters where the corrosion resistance of AISI 316 is inadequate. The performance in mineral acids is significantly better than AISI 316. In general terms, the corrosion resistance improves with an increasing molybdenum content.
- Allegheny AL-6XN stainless steel – An alloy exhibiting similar corrosion-resistant properties to alloy 254 SMO.

- Avesta 654 SMO stainless steel – An alloy with superior resistance to chlorides when compared with alloy 254 SMO. This alloy could be used in cold seawater applications. However, any requirement to dose the machine with chlorine to kill bio-growth must be verified.
- ASTM B-160 nickel 200 alloy –Material that tends to be confined to high-strength (over 50%) caustic soda at high temperatures (up to the boiling point), although it is susceptible to chloride-induced crevice corrosion by brackish waters.
- Hastelloy alloy B-2 – An expensive alloy with a useful resistance to hydrochloric acid and a wide range of sulfuric acid concentrations. Its disadvantage lies in its inability to withstand oxidizing environments and contamination of acid streams with ions such as ferric, cupric, etc. If the acid is aerated, it can have a catastrophic effect on corrosion resistance. It is particularly good for handling the products of a Friedel-Craft reaction.
- Hastelloy alloy C-276 – An expensive alloy that is almost immune to attack by chloride ions at low pH values. It has an extremely good resistance to a wide range of sulphuric acid concentrations and can be employed with certain strengths of hydrochloric acid. It is particularly resistant to wet process phosphoric acid and is one of the few alloys that is suitable for use in hot, concentrated sulfuric acid.
- Hastelloy alloy C-22 – An alloy similar in performance to alloy C-276. However, C-22 shows a reduced corrosion rate in low and medium concentrations of sulfuric acid.
- Hastelloy alloy G-30 – Possessing a high nickel and molybdenum content, an alloy suitable for dilute and middle ranges of sulfuric acid concentrations. It is very good where contamination with chloride and fluoride ions occur (for example, gas scrubbing duties) and exhibits an improved resistance in such environments over alloy 825, although at an increased price.
- Monel alloy 400 – Particularly good for acid chloride environments and, under certain circumstances, brackish and saline waters. It has excellent resistance to high temperatures, but it is susceptible to attack by mercury, which is occasionally present as a contaminant.
- Hastelloy alloy C-2000 – Priced similarly to C-276, this nickel alloy is far superior to C-276 and C-22 in dilute- to medium-strength sulfuric acid and in dilute hydrochloric acid. Resistant to boiling 50% phosphoric acid, it also performs better than C-276 and C-22 in hot chloride environments. However, it is inferior to C-276 for sulfuric acids above 70% strength.
- ASTM B265 Grade 1 titanium –Characterized by a high price, low weight (specific gravity 4.5 against approximately 8 for steel), and much greater resistance to corrosion than stainless steel, especially in chloride-containing liquids. It is, in fact, the best material for chloride solutions and is virtually immune to attack by seawater up to 248ºF (120ºC) and other chloride solutions such as calcium chloride. Heat exchangers with titanium plates can normally be used for seawater up to 275ºF (135ºC). However, titanium is not immune to attack by some other concentrated chloride solutions at temperatures over 212ºF (100ºC) and, therefore, in duties where this condition prevails, titanium-palladium is preferred.

The resistance to corrosion of titanium is due to its passivity, (that is, the natural build-up of a protective oxide film) just as for stainless steel. This passive film consists of almost pure titanium dioxide (TiO_2).

- ASTM B265 Grade11 titanium/palladium alloy – An alloy that has an additional 0.15% palladium to titanium, which has a pronounced effect in increasing corrosion resistance. It offers excellent resistance to concentrations of nitric acid up to 70%, although its resistance to dilute sulfuric acid is similar to that of AISI 316. Ti/Pd offers useful performance in hydrochloric acid, especially if the acid is contaminated with oxidizing ions such as ferric, cupric, etc. In general terms, it produces an all-around improvement in resistance to mineral acids (sulfuric/hydrochloric).

3.5.3.3 Available Materials for Wetted Parts

All wetted metal, including connections, should be an alloy. However, with plate heat exchangers, the connection, usually a studded port, is often lined with alloy sheet metal. The alloy used should be compatible with the fluids and is normally the same as the plates.

3.5.4 Determining Heat Exchanger Safety Classification

The project team should confirm the safety classification of the heat exchanger being replaced in order to determine the extent to which 10CFR50, Appendix B requirements apply. If the component is not classified as safety-related, the project team should still determine whether other quality controls and requirements are applicable and whether those requirements are relevant during the design process. Safety classification of components varies from plant to plant, depending on original licensing commitments and subsequent implementation of component categorization programs. The project team should determine which of the following categorization methodologies have been used to determine the current classification of the component being replaced:

- Deterministic/functional safety classification (Safety-related or Non-safety-related)
- Categorization per 10CFR50.65 (Maintenance Rule)
- Categorization per INPO AP-913 (Critical Components)
- Risk-Based Categorization per 10CFR50.69 (High safety significant or Low safety significant)

3.5.5 Heat Exchanger Failure Mechanisms

The project team should have an understanding of typical failure mechanisms associated with the replacement heat exchanger and how those failures can be mitigated or prevented through the application of various design parameters. The most common failure mechanisms associated with plate heat exchangers are fouling and leakage. Table 3-3 describes the various forms of fouling that are most common with plate heat exchangers, their causes, and locations.

Table 3-3
Types of Fouling and their Causes

Type of Fouling	Causes of Fouling	Area Affected by Fouling
Incrustation and scaling	Calcium carbonate Calcium sulfate Silicates	Heat transfer plates
Sediment	Corrosion products Metal oxides Silt Alumina Diatomic organisms	Manifold or plates
Gross fouling	Seaweeds Wood chips/fibers Mussels Barnacles	Manifold
Biological growth - slime	Bacteria Nematodes Protozoa	Heat transfer plates
Hydrocarbon-based deposits	Oil residues Asphalt Fats	Manifold or heat transfer plates

Leakage can be caused in a plate heat exchanger by any of the following circumstances:

- Gaskets that have become damaged, torn, brittle, hard, or dried out
- Excessive corrosion of the plates
- Physical damage to the plates that prevents a tight seal between plates
- An object or debris inadvertently trapped on the gasket
- Water hammer (spikes in operating pressure)
- Other transient operating conditions

3.5.6 Spare and Replacement Parts

As noted earlier in this report, it is often beneficial to consider a maintenance strategy during the design of the replacement component. Subsequently, the project team should consider establishing with potential suppliers the scope of spare and replacement parts necessary to execute the anticipated maintenance, as well as the frequency with which those items should be made available.

During the design and prior to procurement of the replacement component, the project team should consider ways to proactively obtaining certain design information such as materials, dimensions, tolerances, etc., of certain spare or replacements parts from potential suppliers. Having this part-level information provided during the procurement of the component makes acceptance of these items easier in the future and with less engineering involvement.

3.6 Adjacent and Interfacing System Components and Plant Design Modification

3.6.1 Component Interface Points

A key consideration when replacing a major plant component is the identification of all interface points between the new component with the existing system and auxiliary systems associated with the existing component. Identification of interfaces should begin as early in the design as possible to ensure that the new component will not interfere with existing equipment and that operating parameters of interfacing systems are adequate to enable the new component to perform as designed. Interfaces should be categorized into the following areas as summarized in Table 3-4.

Table 3-4
Types and Examples of Key Interfaces

Type of Interface	Examples for Consideration	
Structural	Strength of foundation and structural adequacy	Concrete/masonry
	Physical interferences with existing structures	Footprint configuration
	Maintaining existing accessibility	Equipment anchorage
	Seismic II/I hazard	Physical separation
Mechanical	Piping size, location and method of connection	Material compatibility
	Adequacy of flow, pressure, fluid temperature to or from new component	Freeze protection
	Adequacy and alignment of bearings, gearboxes, and couplings	Containment heat sinks
	Compatibility of fluids with the new component	Direction of rotation of mating rotating elements
	Penetration seals	Paint and coatings
	High-energy line break	Flow-accelerated corrosion
	Flooding	Wind (including tornado)
	Hydrogen generation	Jet impingement
	Pipe breaks and pipe whip	Internal or external missiles

Table 3-4 (Continued)
Types and Examples of Key Interfaces

Type of Interface	Examples for Consideration	
Electrical	Physical location of power cable and wiring mechanisms	Adequacy of existing drive
	Adequacy of power supply and current inputs	Compatibility with existing voltage
	Compatibility with existing circuit inputs and circuit breaking capability	Panels and enclosures
	Protective relaying	Emergency lighting
	Plant computer systems	Circuits and raceways
Instrumentation and Control	Compatibility with existing performance monitoring equipment	
	Physical location of instrumentation tubing, wiring, and cables	
	Adequacy of input signals	
	Accessibility of existing instrumentation and indicators	

3.6.2 Anticipated Effects of Component Replacement

When replacing a heat exchanger and after identifying all of the interface points with existing SSCs, the project team should then postulate any adverse effects that the replacement heat exchanger could have on interfacing equipment performance and design margins. This analysis should be a logical followup to determining interface points and should be categorized by discipline as noted in the preceding table.

3.7 Generating and Revising Design Output Documents

3.7.1 System Design Output Documents

In the majority of cases when replacing a shell and tube heat exchanger, design modifications to adjacent and auxiliary SSCs to accommodate the new heat exchanger are necessary. Typically, the project team will revise or update the following design outputs associated with affected system components, depending on the extent to which those system components have been modified:

- Calculations supporting the design of the replacement heat exchanger
  - Civil, electrical, I&C, mechanical
  - Plant computer scaling and alarm setpoints
  - Pipe stress

- System drawings
- Functional system descriptions (FSDs)
- Technical specifications and UFSAR
- Environmental qualifications
- Safe shutdown analyses
- Fire hazard analyses
- Instrument index, setpoint index
- ISI and IST plans
- Flow-accelerated corrosion models

In addition to the system design output documents listed above, installation of a plate heat exchanger may require revisions to licensing documents and regulatory commitments (for example, Generic Letter 89-13 response).

3.7.2 Heat Exchanger Design Output Documents

The design of the replacement heat exchanger should be a collaborative effort between the project team and the equipment designer. As noted in the preceding sections, the project team should establish certain physical and performance design requirements for the replacement heat exchanger and communicate those to the equipment designer or manufacturer in a bid specification. Given these inputs, the equipment designer or manufacturer should be provided latitude to design or offer a heat exchanger that meets the requirements of the design inputs they have been provided or to take documented exceptions. Section 4 provides guidance on developing the bid specification and then refining it when a qualified supplier has been selected. Generally, after the replacement heat exchanger has been designed and manufactured, the equipment supplier will provide the following design output documents:

- Heat exchanger assembly drawings
- Heat exchanger maintenance guidance
- Recommended spare parts lists
- Heat exchanger operating guidance
- Vendor technical manuals
- Testing, NDE, and qualification results
- Performance data sheets and curves

3.8 Design Verification

Section 6 of ANSI N45.2.11 [3] provides implementation guidance for performing design verification. Unless the design of the replacement component is identical to the original, then design verification of the replacement will be required to ensure that the new design is suitable for its intended application(s). The ANSI standard describes three methods for accomplishing design verification – design reviews, alternative calculations, and qualification testing. Special care should be taken when the replacement component is to be installed in a seismically or environmentally qualified system. In those cases, design verification may entail qualification testing that simulates design-basis accident conditions or analysis.

3.9 Design Approval

Design approval may be required from numerous organizations associated with the heat exchanger replacement. Also, separate design approvals may be warranted at both the system and component levels. For example, the project team may need design approval from certain organizations for the entire heat exchanger replacement and its effects on the system in which it is installed. The project team will subsequently approve the design of the actual heat exchanger selected for the replacement project.

It is important that the project manager understand the level of approvals necessary and the roles and responsibilities of the various organizations involved in the design and installation of the replacement component. Potential different types of design approvals that may be relevant when replacing a key plant component such as a heat exchanger are listed below:

- Internal approval of design modifications
- Internal approval of the heat exchanger manufacturer’s design according to existing plant procedures (Typically, this should precede fabrication, but it may not be completed until after the supplier selection and the completion of their design.)
- External approvals from federal, state, and local agencies
- Regulatory approvals and permits
- ASME Code certification

3.10 Configuration Management

Section 7 of ANSI N45.2.11 [3] provides implementation guidance for document controls. When a heat exchanger is replaced, it is important for all related design output documents and maintenance and operations procedures to be updated to reflect the as-installed configuration.

4
DEVELOPING BID SPECIFICATIONS AND REQUESTS FOR PROPOSALS

When replacing a shell and tube heat exchanger, the project team is usually responsible for preparing the specification used to procure the item. This specification is initially communicated to potential suppliers in a request for proposal (that is, a bid request). After a particular manufacturer has been selected to furnish the replacement component, the specification may be revised to reiterate manufacturer- or component-specific design information and will typically be communicated to the selected supplier with a purchase order.

The project team may be responsible for preparing an installation specification, which is provided to the organization leading the construction or replacement effort. This may in some circumstances be the heat exchanger manufacturer. Often the size and complexity of the replacement component and when the component will be installed dictates the degree to which the licensee's own maintenance organization is involved in the actual installation.

In some cases, (often dependent upon the licensee's commitment to the ASME Code), the licensee may be responsible for preparing a design specification to meet Code requirements.

4.1 Developing the Bid Specification for the Replacement Heat Exchanger

A typical bid specification for a replacement plate heat exchanger is provided in Appendix A. The bid specification may convey certain types of technical information in the form of data sheets. In most cases when data sheets are used, one is provided for each mode of operation anticipated for the replacement plate heat exchanger. Appendix B provides an example of a data sheet that is typical for a plate heat exchanger.

The guidance provided in this section should be considered when developing a bid specification to ensure that appropriate issues have been considered. The level of specificity in the bid specification will be dependent upon the complexity of the replacement component and the system in which it will be installed. Care should be taken not to develop the bid specification with a preconceived notion of one particular solution; the specification should adequately communicate all necessary system design requirements and anticipated component-specific needs while remaining broad enough to allow multiple suppliers to bid.

It is important for the project team to correctly specify appropriate technical requirements of the replacement component, to fully understand each supplier's capabilities, and to ensure that the bidders understand the team's expectations down to and including the quality of the workmanship that is expected.

4.1.1 Specifying Technical Requirements

Because the technical requirements specified are a translation of the design requirements, they may be grouped into the same categories as described in Section 3—design basis requirements and component-specific design attributes.

4.1.1.1 Specifying System Design Basis Requirements

System design basis requirements should include, as applicable to the actual component being replaced, any of the following:

- System normal operating conditions
- System accident operating conditions
- Plant seismic demands
- Environmental conditions
- System and component safety classifications
- System parameters exceeding industry or Code requirements
- Description of all interface points and work associated with connecting interfaces

In general, it is not recommended to impose standard fouling factors on a plate heat exchanger. With its inherent high efficiency, those factors will grossly over-surface the unit and lead to degraded performance. Instead, the project team should consider specifying a percentage of over-surface, which would normally be about 10–15% on power plant applications.

4.1.1.2 Specifying Component-Specific Requirements

Component-specific design attributes should also be specified, and could include any of the following:

- Heat exchanger performance requirements, including those that may exceed applicable industry standards or Codes. Typically for a heat exchanger these inter-related parameters include the following:
  - Flow rate (gal/min [l/min]) – **Note:** If there are large seasonal differences in cooling water temperatures, consider the use of multiple smaller exchangers that can be individually shut down during colder temperatures. This eliminates low-flow conditions that can plug a unit if sediment is present.
  - Minimum/maximum inlet fluid temperature (ºF [ºC])

- – Minimum/maximum outlet fluid temperature (ºF [ºC])
- – Maximum permissible pressure drop (psi [kPa])
- – Maximum working pressure (psi [kPa])
- – Fluid specific gravity
- – Specific heat at mean temperature (Btu/lbm-ºF [kJ/kg-K])
- – Thermal conductivity at mean temperature

- Component technical requirements
  - – Noun description of the items with sufficient modifiers to distinguish the item from other similar items.
  - – Industry codes and standards including the applicable revision level. The specific applicable sections of codes and standards should be cited wherever possible. For heat exchangers, the applicable codes and standards generally include the following:
    - – ASME Section II – Material specification
    - – ASME Section III – (Refer to Section 4.1.1.3 of this report)
    - – ASME Section V – Nondestructive testing
    - – ASME Section VIII – Pressure vessel code
    - – ASME Section IX – Welding qualifications
    - – ANSI Section B16.5 – Flanged fittings
  - – Material specifications for plates, frames, and gaskets
  - – Coating specifications

Other technical procurement requirements that may be specified include the following:

- Special manufacturing and fabrication processes
- Nondestructive examination/evaluation (NDE)
- Storage and staging requirements to prevent degradation
- Request for spare and replacement part information
- Means of design verification
- Plant-specific drawings, supplier drawings, and revision level
- Qualification parameters to maintain compliance to a qualification report or environmental and seismic conditions.
- Shelf life requirements
- In-storage maintenance requirements
- Accommodations for special lifting and handling of the plate heat exchanger (for example, lifting lugs or holes)

The level of detail specified in the technical description is dictated by the following parameters:

- The role of the supplier in the equipment design
- The complexity of the replacement heat exchanger
- The heat exchanger's role in performing safety functions
- Manufacturing processes used in the heat exchanger's production
- The bounding conditions that the heat exchanger is required to satisfy
- The history of performance of the supplier and the utility's experience with the supplier

4.1.1.3 Specifying ASME III Code Requirements

For many safety-related heat exchanger replacements at a nuclear power plant, an ASME III design specification is required. An ASME III design specification is a document prepared by the project team or licensee's designee that provides a complete basis for construction in accordance with the requirements of the applicable section of the ASME III Code. The following information should be included in the design specification:

- The Code classification and the licensee's construction code of record
- Design limits, such as stress and stress intensity limits applicable to design loads
- Design loads, such as temperatures, pressures, mechanical loads, and other loading conditions
- Defined functions of components and piping systems
- ASME III Code boundaries
- Anticipated need for Code reconciliation

Usually, the design specification is prepared, stamped by a Professional Engineer (certified PE), and provided to the heat exchanger manufacturer as part of the purchase specifications. In practice, many ASME III heat exchanger manufacturers have a "standard" certified design specification for their "off the shelf" N-stamped heat exchangers, which can be provided to the project team for use in preparing their (the Owner's) design specification.

When determining the technical requirements, the project team should ensure that the heat exchanger specified has not been excluded from nuclear use due to inherent design or performance flaws. Excluded items are generally identified from U.S. NRC Bulletins and Information Notices, 10CFR21 reports, supplier information letters, INPO EPIX, or other sources.

4.1.2 Specifying Quality Requirements

The quality requirements for a replacement heat exchanger should be developed and specified in the procurement document to invoke the necessary supplier controls over manufacturing, design, and purchasing activities that ensure the specified technical requirements are met. The specification should also delineate anticipated quality assurance program responsibilities of the project team and various organizations in the supply chain.

Quality requirements do not take the place or substitute for technical requirements. Heat exchangers that are technically inadequate can be produced under an acceptable quality program, but they will remain technically inadequate for the application.

The quality requirements specified for a replacement heat exchanger should be commensurate with the heat exchanger’s role in performing safety functions, complexity in design and manufacturing processes, production qualification requirements, and special processes. Specific quality requirements may be imposed to focus resources on controlling or imparting certain component-specific design attributes that are critical to its performance and reliability.

When specifying a replacement heat exchanger’s quality requirements, it is necessary to understand the supplier’s use of sub-suppliers and material sources to ensure that appropriate quality requirements are passed on and specified correctly through the supply chain. The licensee’s specific quality commitments from its quality assurance program and UFSAR should be included, as necessary, to ensure compliance to regulatory requirements.

The quality requirements for commercial grade components used in nuclear safety application require special consideration. Commercial grade purchases should not have nuclear unique standards imposed in the purchase documents (that is, 10CFR50 Appendix B and 10CFR21). However, special acceptance requirements may be required. (See EPRI report NP-5652, *Guidelines for the Utilization of Commercial Grade Items in Nuclear Safety Related Applications*. [2])

The quality requirements specified on the procurement document will normally include the following:

- QA program requirements – For a safety-related heat exchanger, this would typically be the specification of a nuclear QA program. Supplier quality assurance programs such as ANSI N45.2, 10CFR50 Appendix B, ASME Section III, NCA 3800; and ASME/ANSI NQA-1 are recognized as nuclear QA programs capable of providing the licensee a basic component. Evidence of the supplier’s quality assurance program commitments is often requested so the project team can review approved quality program manuals or procedures.
- Frequency and types of supplier audits – This should be specified to inform potential heat exchanger suppliers of the need for any performance-based audits in addition to those they have already undergone.

- Source verifications (including witness and hold points) – Source inspections and the witnessing of in-process tests should be specified for manufacturing processes that affect design or performance attributes where the quality cannot be confirmed by other available methods. (For guidance on the other methods available, see ANSI N45.2.13, "Quality Assurance Requirements for the Control of Items and Services for Nuclear Power Plants," [3] and EPRI report NP-5652, *Guidelines for the Utilization of Commercial Grade Items in Nuclear Safety Related Applications*. [2])

  Potential suppliers should also be made aware of the frequency of anticipated source inspections and the degree to which resident inspectors will be present during the manufacturing process (that is, the level of intrusiveness anticipated by the project team). The project team should consider the use of industry experience as a way to determine the scope and frequency of source verification activities.

- Receiving inspections – These should be communicated to the supplier so they are aware of the scope of verification activities that the project team will perform after the heat exchanger is shipped. The primary value in communicating this type of information is to allow the supplier the opportunity to coordinate any special logistical support and resources needed to facilitate the receiving inspections.
- Other special quality requirements may include any of the following:
  - Qualification testing, including mockups
  - Access requirements for inspections, audits, and surveillance
  - Personnel qualification and certification
  - Defect reporting per 10CFR21 for nuclear suppliers
  - Performance of subsupplier's inspection, audit, surveillance, and sampling per established procedures or recognized standards
  - Special processes and cleanliness requirements

The project team should recognize that the following dynamics could have an adverse effect on the quality capabilities of an organization and their ability to provide a replacement component in full compliance with the procurement specification:

- Recent changes in senior management
- Changes within the quality assurance organization
- Designation of a new quality assurance manager
- Recent acquisition of the supplier by a larger organization
- Industry operating experience

4.1.3 Specifying Supplier Documentation Requirements

The amount of supplier documentation necessary will vary, depending on how the replacement component has been classified (that is, safety-related or non-safety-related). In general, supplier documentation is required to furnish the project team with objective evidence that the technical and quality requirements of items have been met. Documentation should be considered a tool in the verification of an item's technical adequacy and quality compliance, but it should not be used without confirmation of its validity. [2, 3]

Supplier documentation requirements should correlate with the specified technical and quality requirements and be specific as to the content. Care should be taken not to request excessive or meaningless documents or test reports that are not applicable to the item. Certificates of Conformance should not rely solely on generalized statements such as, "This item meets the requirements of the purchase document." Instead, the documentation should be validated by the project team and should contain specific statements enabling the supplier to verify specified requirements. In any case, the project team should be involved in the acceptance process.

The range of supplier documentation includes, as applicable, the following (including consideration of quantity and type of media):

- Supplier drawings, procedures, and specifications
- Supplier instruction manuals (including maintenance recommendations)
- Qualification reports
- Certified material test reports
- Nondestructive test reports
- Personnel certifications and qualifications
- Inspection reports
- QA manuals
- Performance test reports
- Certificates of Conformance or Compliance
- Recommended spare and replacement parts lists
- ASME Code data report

A submittal schedule should be specified to inform the supplier when each required document needs to be made available to the project for review. Retention time of records should also be specified as well as the quality and legibility of the records, where necessary to ensure future reproduction capability.

4.1.4 Special Procurement Requirements

Other special requirements that may be specified in the bid specification can include any of the following:

- Qualification testing, including mockups
- Access requirements for inspections, audits, and surveillance
- Personnel qualification and certification
- Defect reporting per 10CFR21 for nuclear suppliers, and how those requirements are passed on to subtier organizations in the supply chain
- Dedication methodology used by a nuclear supplier (Care should be taken to examine this process to ensure that it is adequate and implemented properly.)
- Ways to address ASME Code requirements
- Performance of subsupplier’s inspection, audit, surveillance, and sampling per established procedures or recognized standards
- Special processes and cleanliness requirements

4.2 Developing the Request for Proposal

At this stage of the project, the project team should have completed a conceptual design study and should have a basic understanding of the type of replacement heat exchanger to be installed and the resulting system performance parameters to be achieved by replacing the existing heat exchanger. As such, the project team should compile known design basis and system operating parameters and communicate them to potential heat exchanger suppliers in a request for proposal, or what is commonly referred to as a *bid spec*.

It is not uncommon at this point for a supplier and a particular heat exchanger, demonstrated to be suitable for the plant application, to have been selected.

The project team should communicate the following information to potential bidders:

- The scope of work (equipment only, equipment and installation, etc.)
- The heat exchanger being replaced, including all known design and performance parameters about the existing shell and tube heat exchanger:
  - Ensure that only relevant information about the existing component is provided.
  - Identify any component design information that currently exceeds design basis requirements so that these requirements do not inadvertently or unnecessarily be interpreted as requirements for the replacement.

- The bid specification for the replacement component (Refer to Appendix A) including any of the following:
  - Technical requirements (system design basis requirements, component-specific requirements, ASME Code requirements, system performance requirements that the project team wants to enhance by virtue of replacing the component, etc.)
  - Quality requirements
  - Supplier documentation requirements
- Anticipated supplier interface including walk-down planning, pre-bid meetings, and bid submittal schedule
- Schedule for replacement
- Whether the project team wants to replace the component on-line or during an outage
- Commercial terms and conditions, including type of bid (that is, fixed price, lump sum, time and material, etc.)

Appendix A provides an example of a typical procurement specification for a replacement plate heat exchanger.

4.3 Developing the Installation and Construction Specification

The level of detail and scope of the installation and construction specification will vary, depending upon who is responsible for installing the replacement heat exchanger. In some cases, the project team will install the heat exchanger and, as such, should develop work packages necessary in accordance with existing site-specific procedures.

In some cases, the manufacturer of the heat exchanger will be the installer. When this is the case, then the specification provided to the manufacturer may include both refined procurement and installation requirements. Work done in this manner is often referred to as a design/procure/install contract or a *turn-key* contract. In other cases, the installation and construction may be competitively bid as a separate contract when performed by someone other than the plate heat exchanger manufacturer or the project team.

When replacing a heat exchanger, the project team should consider the following issues for inclusion in the installation and construction specification:

- Scope of components to be demolished
- Limits of demolition (usually communicated on a drawing)
- Sequence of demolition and installation steps
- Description of all interface points and work associated with connecting interfaces
- Description of design modifications necessary on adjacent and ancillary systems
- Scope of work considered low safety significance that could be handled in the field

- Appropriate plan, section drawings, schematics, and flow diagrams depicting the removal of the old heat exchanger and the installation of the replacement heat exchanger
- Lifting and rigging plans for both the old and new heat exchanger
- Quality controls required during the installation of the replacement heat exchanger
  - Nondestructive examination
  - Witness and hold points for inspection and testing during the installation process
  - In-process testing required as the replacement heat exchanger is being installed
- Scope of supporting and ancillary equipment needed for the replacement heat exchanger (that is, procurement responsibilities for items such as weld wire, insulation, etc.)
- Post-installation testing requirements for verification of design performance parameters
- Personnel qualification requirements for craft labor, inspectors, and riggers employed during the installation of the replacement heat exchanger
- Special tools or scaffolding required to install the new component
- Codes and standards applicable to the work associated with installing the replacement component
- Personnel safety issues and ALARA concerns
- Requirements for the submittal of an installation plan and schedule
- Description of organizational interfaces and roles and responsibilities among members and organizations making up the installation team
- Performance acceptance criteria for the new heat exchanger
- Access routing and special considerations for moving the heat exchanger into its designated position
- Special lifting/handling requirements
- Storage/staging requirements (power, air, lighting, etc.)
- Reference to applicable procedures of the installation contractor

Many of the installation issues listed above are discussed in more detail in Section 11. They are listed here so that as the issue is resolved between the project team and the heat exchanger manufacturer, they can be appropriately communicated in the appropriate specification document.

4.4 Developing Service Specifications and Contracts

In some cases, the project team will need to develop specifications to procure various services in support of the component replacement and system design modifications. Service specifications should include the following general requirements:

- Scope of work
  - Type of service needed
  - Applicable industry codes and standards
- Quality requirements
  - Personnel certifications and qualifications
  - Inspection reports
  - QA manuals
  - Performance test reports
- Supplier documentation requirements
  - Certificates of Conformance or Compliance
  - Personnel qualification certificates
- Commercial terms and conditions (Refer to Section 5 for additional guidance.)

5
SUPPLIER QUALIFICATION AND SELECTION, BID EVALUATION, AND PURCHASING

5.1 Supplier Selection and Qualification

In general, the selection of a supplier should be based on an evaluation of their capability to provide items in accordance with the requirements of the procurement documents. In most cases that involve the replacement of a key component such as a heat exchanger, engineering should perform sufficient research on potential suppliers to assess their current technical and manufacturing capabilities, and on industry experience with each potential supplier's products as well. This research should result in a manageable number of potential bidders and should help optimize to the bid evaluation process.

It is important for the project team to correctly specify appropriate technical requirements of the replacement component, to fully understand each supplier's capabilities, and then to ensure that the bidders understand the team's expectations down to and including the quality of the workmanship that is expected.

The project team should also initially consider the quality assurance capabilities of suppliers of safety-related replacement components. In most cases (and when one or more are available), it is beneficial to use suppliers having a nuclear quality assurance program instead of attempting to dedicate a commercial grade component.

5.1.1 Selection of Procurement Sources

Section 4 of ANSI N45.2.13 [3] recommends that the selection of a supplier should be based on evaluation of their capability to provide items in accordance with the requirements of the procurement documents. The standard also requires that procurement source evaluation and selection measures include integrated actions involving one or more organizations (for example, engineering, construction, manufacturing, operations, purchasing, or quality assurance), based upon the item being procured.

Methods to be used in the evaluation of supplier sources and the results should be documented and should include one or more of the following:

- An evaluation of the supplier's history of providing a product that performs satisfactorily in actual use
- The supplier's current quality records supported by documented qualitative and quantitative information, which can be objectively evaluated
- The supplier's technical and quality capability as determined by a direct evaluation of their facilities and personnel and the implementation of their quality assurance program

5.1.2 Supplier Qualification Status

ANSI N45.2.13 [3] states in part that the licensee is responsible for the:

> Evaluation of Supplier's quality assurance program to assure that it is appropriate and satisfies the requirements for the items or services being purchased.

If the replacement heat exchanger is being procured from a supplier from whom the licensee has already procured other items, the project team should verify the supplier's qualification status by reviewing the approved supplier's list (typically maintained by the QA organization). If the replacement heat exchanger is being procured from a new supplier, the QA organization should be advised so that an initial qualification evaluation (that is, a performance-based audit) can be performed.

5.1.3 Supplier Quality Program Capabilities

The project team should ensure that the supplier has the technical capabilities to meet the specification requirements and quality assurance programs to ensure that those capabilities are implemented consistently. Project teams should recognize that supplier quality assurance program capabilities vary significantly among suppliers. Furthermore, a supplier's commitment to a given quality assurance program does not in itself ensure reliable performance of the manufactured component. Ideally, the supplier's program is capable of meeting the licensee's requirements. If it is not, the project team is responsible for addressing those shortcomings in order to achieve the necessary level of quality assurance.

The results of a supplier evaluation should be documented in a report that is made available to engineering personnel for assessment of the supplier's capabilities. The supplier evaluation is important because it serves to confirm that the supplier has the necessary technical capabilities and quality controls and that those capabilities and controls are being implemented properly.

In most cases when procuring a safety-related heat exchanger for a nuclear power plant, the supplier should maintain a quality assurance program that meets the intent of 10CFR50, Appendix B, and should be required to hold certain industry-recognized certifications, as required by each particular project team. The supplier evaluation will also confirm that those certifications are current and adequate for the component being procured.

Section 2 of ANSI N45.2.13 [3] recommends that measures for the control of the procurement of a replacement component are established and include appropriate planning. The ANSI standard, which looks at many key elements of the process used when replacing a major plant component, states in part:

> Planning shall result in the documented identification of methods to be used in procurement activities, sequence of action and milestones indicating the completion of these activities, and the preparation of applicable procedures prior to the initiation of each individual activity listed below. Planning shall provide for the integration of the following:
>
> 1. Procurement document preparation, review and change control
> 2. Selection of procurement resources
> 3. Bid evaluation and award
> 4. Purchaser control of supplier performance
> 5. Verification (surveillance, inspection, or audit) activities by the purchaser
> 6. Control of nonconformances
> 7. Corrective action
> 8. Acceptance of item or service
> 9. Quality assurance records
> 10. Audit of procurement program

Another factor, not explicitly described in ANSI N45.2.13, that should also be considered is the division of QA programmatic responsibilities between the project team and various organizations in the supply chain. These factors are discussed in more detail in the following section.

5.1.4 Potential Plate Heat Exchanger Suppliers

The heat exchanger replacement project team should consider issuing requests for proposals for plate heat exchangers to the manufacturers listed in Table 5-1. The following table should not be interpreted as an endorsement of any manufacturer’s product or quality, and the user of this report may consider suppliers other than those listed below. The information provided was current at the time of publication, but may no longer be applicable.

Table 5-1
Potential Heat Exchanger Suppliers

Manufacturer's Name	Location and Telephone	
Alfa Laval, Inc.	5400 International Trade Dr. Richmond, VA 23231 USA Phone: 804.222.5300	101 Milner Avenue Scarborough, ONT M1S456 Phone: 416.299.6101
APV North America – Heat Transfer Products	105 CrossPoint Parkway Getzville, NY 14068 USA Phone: 716.692.3000	3280 Langstaff Road Concord, ONT L4K428 Phone: 905.760.1852
Graham Corporation	20 Florence Ave. Batavia, NY 14020 USA Phone: 585.343.2216	
Tranter PHE, Inc.	1900 Old Burk Hwy. Wichita Falls, TX 76306 USA Phone: 940.723.7125	

5.2 Bid Evaluation and Award

5.2.1 General Guidance

Section 5 of ANSI N45.2.13 [3] states in general that each licensee should establish a documented system for reviewing and evaluating the bids and awarding the contracts. This established process should be used for the evaluation of bids for a replacement heat exchanger. Figure 5-1 illustrates the general process for supplier selection and bid evaluation that is implemented by many utilities.

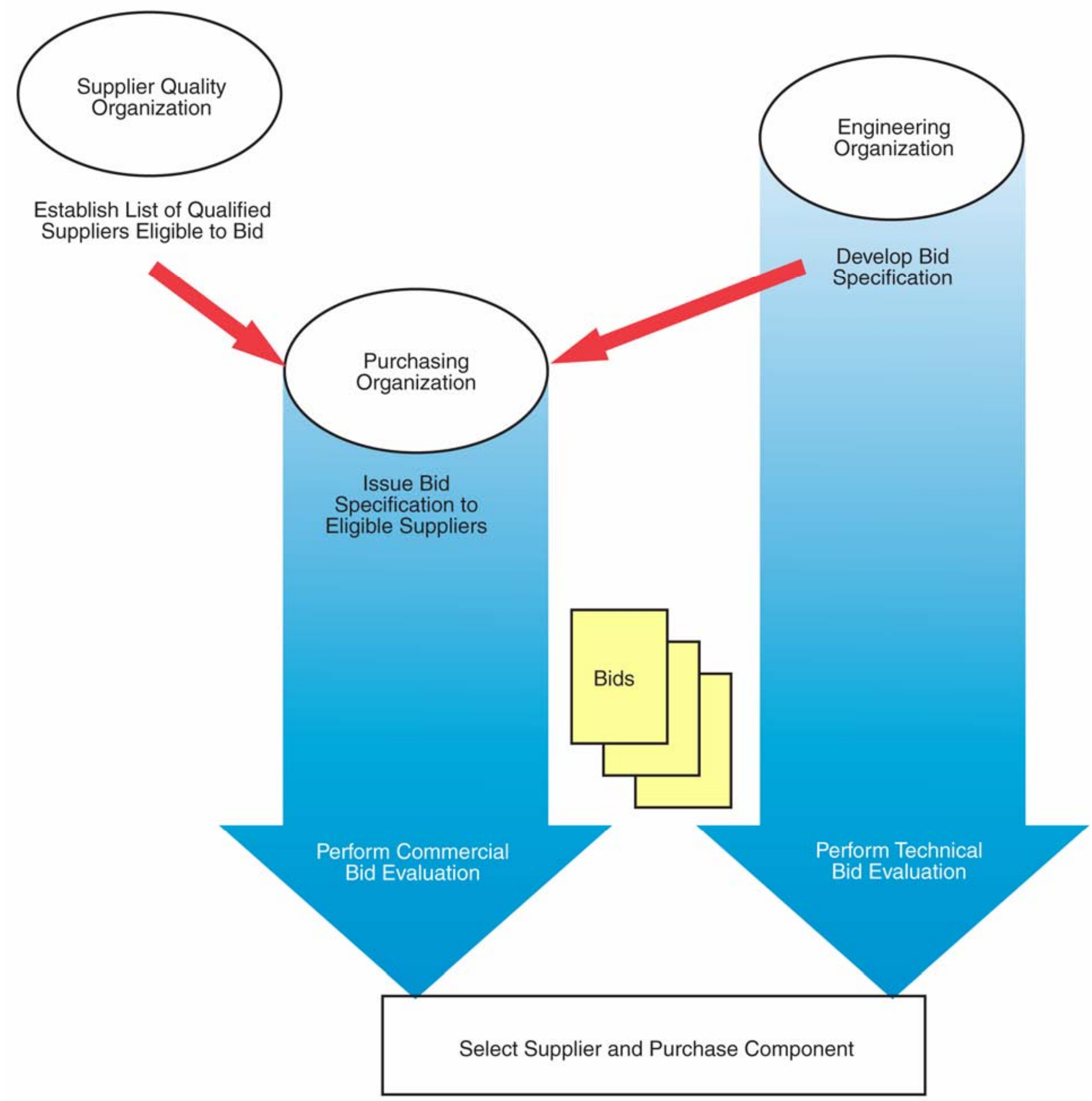

Figure 5-1
Supplier Selection and Bid Evaluation

The figure illustrates that the licensee's QA organization is typically responsible for the initial qualification and screening of potential suppliers. After requests for proposals are issued, the bid evaluation is performed jointly by the licensee's purchasing organization and engineering organization. In most cases, the engineering organization evaluates the technical aspects of each bid, and the purchasing organization evaluates the commercial terms and price of each bid.

Bid evaluations should be made by individuals or organizations designated to evaluate the following subjects, as applicable to the type of procurement and replacement component:

- Technical considerations
- Quality assurance requirements (for example, supplier quality program capabilities, establishment of witness-hold points, manufacturing surveillance, etc.)
- Supplier’s personnel
- Supplier’s production capability
- Supplier’s past performance
- Alternative designs for consideration
- Evaluations of exceptions to the bid
- Schedule adherence
- Operating experience

Other factors, though not quality related, that may be considered include:

- Equipment purchase price and price adjustments
- Supplier experience, reputation, and recognition in the nuclear industry
- Manufacturing facility location
- Ease of doing business
- Commercial terms and conditions
- Warranties

5.2.2 Obsolescence of the Replacement Component

Another issue that the project team should consider during the supplier selection and bid evaluation phase of the project (and an issue not specifically addressed in ANSI standards) is the potential for obsolescence of the replacement plate heat exchanger and future availability of spare parts. The project team should evaluate the supplier and the technologies associated with the replacement with an awareness of any technical issues or concerns with the heat exchanger that may have caused performance degradation in the past. Care should be taken to select technologies and materials that are suitable for the licensee’s application but are not necessarily excessive for the sake of being “state of the art.”

5.2.3 Procurement of ASME N-Stamped Components

Another issue the project team may encounter is the need to procure ASME N-stamped components. This type of procurement is often made more onerous when the supplier of the component no longer maintains the capability to apply the ASME N-stamp. In these cases, the project team should coordinate closely with the procurement engineering organization and determine the applicability of guidance provided in Generic Letter 89-09, "ASME Section III Component Replacements." [6]

5.3 Purchasing Issues and Considerations

The project team should recognize that not all issues will be presented and resolved during the bid evaluation phase; some may arise after the contract has been awarded. Ideally, the project team should attempt to resolve issues as early in the process as possible. The issues noted below are included in Section 2 with respect to the overall project management responsibilities of the project team, but they are reiterated below to emphasize the importance of resolving them prior to the start of fabrication.

5.3.1 Licensee Schedule Demands

One of the first nontechnical issues that should be addressed as soon in the procurement process as possible is the schedule for design, manufacturing, shipping, receiving, and installing the replacement heat exchanger. All licensees have a process for planning and scheduling work activities in the plant, but for a heat exchanger replacement, the process is often much more involved and extensive than when planning and scheduling routine maintenance activities.

5.3.2 Manufacturing Lead Times

Another major issue affecting the selection of a supplier and, subsequently, the procurement of the replacement heat exchanger is the manufacturing lead time. It is most often the case that the manufacturer does not have the heat exchanger readily available in stock and must manufacture the component so that it is suitable for the licensee's particular application and will meet all of the requirements in the design and procurement specification(s).

A primary consideration affecting manufacturing lead time is the safety classification of the component and the resulting level of quality controls that the project team deems necessary. In some cases, the lead time of manufacturing can be reduced significantly if the item can be procured as non-safety-related.

Manufacturing lead times on Type 316 stainless steel plate heat exchangers are as short as 4 weeks for small units and up to about 16 weeks for large units built to ASME Section VIII standards. Historically, a comparable unit constructed of titanium was generally about the same. However, at the time of publication, the delivery of titanium for small units is about six months and up to two years for large units. Heat exchangers designed and manufactured to ASME

Section III standards add considerable lead time due to the need for additional documentation and verification activities.

The project team should consider investigating the supplier’s ability to manufacturer and deliver the replacement heat exchanger prior to the bid phase and during the initial qualification of the primary supplier (and possibly subsuppliers). Guaranteed lead times should be negotiated as part of the commercial terms. By the time a supplier has been selected and a purchase order is being placed, the project team should need only to confirm lead times with the supplier to ensure that the heat exchanger can be delivered to meet the demands of the site.

Manufacturing lead times may vary due to influences beyond either the manufacturer’s or owner’s control. The user of this report should be aware that premiums may have to be paid in order to expedite the delivery of the replacement plate heat exchanger.

5.3.3 Commercial Terms and Conditions

Negotiating commercial terms and conditions is not typically within the scope of engineering organizations. As such, the purchasing organization should take the lead role in resolving these types of issues. Special commercial considerations may include:

- Delivery, title, and risk of loss
- Performance incentives
- Warranty limitations
- Limitations of liability
- Indemnity
- Resolution of nonconformances and arbitration process
- Nuclear financial protection
- Transfer, shipping, routing of the heat exchanger
- Transfer of responsibility during shipment, receipt, storage or staging, and installation
- Type, schedule, and frequency of document reviews
- Quantified level of oversight by the project team
- State laws
- Type of contract, payment terms, and invoicing
- Thermal performance warranty

5.3.4 Procurement Document Preparation, Review, and Change Control

The development of the procurement specification should be a continuation and refinement of the bid specification. The procurement specification should be finalized upon the completion of the bid evaluation and the qualification and selection of the supplier of the replacement heat exchanger. (See Section 5 for detailed guidance.) After a supplier has been selected and the supplier has offered a suitable replacement heat exchanger, the detailed procurement specification can be completed.

Criterion IV of 10CFR50, Appendix B [7] states in part:

> Measures shall be established to assure that applicable regulatory requirements, design bases, and other requirements which are necessary to assure adequate quality are suitably included or referenced in the documents for procurement of material, equipment, and services, whether purchased by the applicant or by its contractors or subcontractors.

In essence, the regulation requires that the procurement specification translate the design requirements established by the project team into procurement requirements.

After the supplier has been selected by virtue of bid evaluation, the licensee’s engineering organization should refine the bid specification as needed so as to clearly communicate necessary technical and quality requirements commensurate with system and heat exchanger design requirements and the supplier’s capabilities to meet them. In most cases, the licensee’s existing processes and procedures should be used to prepare, review, and control changes of the procurement documents needed for the replacement component. Additional guidance is provided in Section 3 of ANSI N45.2.13. [3]

5.4 Handling Exceptions to the Purchase Order

In those cases when the purchase order was awarded to a manufacturer through competitive bids, it is less likely that the manufacturer will take exceptions to the requirements of the purchase order. This is because the supplier will have already had an opportunity to evaluate the licensee requirements during the bid process and any issues regarding their ability to meet those requirements should have already been communicated to the project team and resolved. Technical and commercial exceptions to purchase order requirements tend to be more of a problem when the purchase order is awarded on a sole-source basis without competitive bidding. In these cases, the heat exchanger manufacturer may be seeing the licensee requirements for the first time when the purchase order is awarded. Ideally, there will not be exceptions; but in reality, the project team should be prepared to address them in a timely manner.

5.4.1 Technical Exceptions

The licensee's engineering organizations should take the lead in resolving technical exceptions to the purchase order. In some cases, input from maintenance and operations may be helpful in resolving a technical exception and reaching a feasible solution to the issue. In no circumstances should a purchasing agent or nontechnical personnel attempt to resolve a technical exception to the purchase order. Instead, the issue should be directed to the appropriate engineering organization.

Although the project team should strive to prevent exceptions to purchase order requirements through good planning and supplier selection techniques, in most cases the licensee's existing process for resolving purchasing issues should be used as needed. Technical exceptions that may arise during the specification and procurement of a major plant component could include the manufacturer's inability to meet the following requirements:

- Heat exchanger performance requirements
- Heat exchanger technical requirements
  - Requirements described in industry codes and standards
  - Physical and chemical material properties, in accordance with ASTM and/or ASME
  - Dimensional requirements including tolerances
- Special manufacturing or fabrication processes
- Shipping, packaging, and storage requirements
- Request for spare and replacement part information
- Means of design verification
- Shelf life requirements
- In-storage maintenance requirements

5.4.2 Commercial Exceptions

The licensee's supply chain organization should take the lead in resolving commercial exceptions to the purchase order. In some cases, input from engineering, QA, maintenance, and operations may be helpful in resolving a commercial exception and reaching a feasible solution to the issue.

As noted in the preceding section, the project team should strive to prevent exceptions to purchase order requirements through good planning and supplier selection techniques, and in most cases, the licensee's existing process for resolving purchasing issues should be used as needed. Commercial exceptions that may arise during the specification and procurement of a major plant component could include the manufacturer's inability to meet any of the requirements listed in Section 5.3.3.

5.5 Acceptance Planning

Ideally, acceptance planning should begin during the specification and procurement of the replacement heat exchanger. This affords the project team an opportunity to plan the types of verifications and their schedule with the selected manufacturer (and third-party organizations, if needed) in advance of final design and fabrication. After the supplier and final heat exchanger design have been selected, however, the project team should finalize the scope and frequency of acceptance activities, including any of the following:

- Additional or on-going audits of organizations in the supply chain
- Source verification activities (hold and witness points)
- Receipt test or inspection activities
- Post-installation tests/inspections

Section 10 of ANSI N45.2.13 [3] states, in part, that the licensee shall:

> Establish the method of acceptance of an item or service being furnished by the supplier. Prior to offering the item or service for acceptance, the supplier shall verify that the item or service being furnished complies with the procurement requirements. Where required by code, regulation or contract requirement, documentary evidence that items conform to procurement documents shall be available at the nuclear power plant site prior to installation or use of such items regardless of acceptance methods.

When replacing a major plant component such as a heat exchanger, it is recommended that all of the acceptance activities listed above be used to some extent due to the typical complexity and safety significance of the item. Of these methods, any of which may be chosen by the project team, source verification involves acceptance during the fabrication of the replacement item and is discussed in more detail later in this section of the report.

Section 6 of ANSI N45.2.13 [3] states in general that a licensee should retain the responsibility of monitoring and evaluating supplier performance to the specified requirements of the procurement document. The methods provided may include the following:

- Establishing an understanding between the project team and the supplier of the provisions and specifications of the procurement documents
- Requiring the supplier to identify planning techniques and processes to be used in fulfilling procurement document requirements
- Reviewing documents that are generated or processed during activities fulfilling procurement requirements
- Identifying and processing necessary change information
- Establishing a method for exchanging information contained in the procurement document between the project team and the supplier

Depending on the complexity or scope of the replacement plate heat exchanger, the project team should initiate pre- and post-award activities. These activities may take the form of meetings or other forms of communication to establish the following:

- An understanding between the project team and the supplier of the procurement requirements
- The intent of the project team in monitoring and evaluating the supplier's performance
- The planning, manufacturing techniques, tests, inspections, and processes to be used by the supplier in meeting procurement requirements

Project team notification points, including hold and witness points, should be identified and documented based upon mutual agreement between the supplier and the project team. These activities should be implemented as early as practicable in the procurement process. The depth and necessity of pre- and post-award activity depends on the uniqueness, complexity, procurement frequency with the same supplier, and past supplier performance for the specific component covered by the procurement document.

5.6 Validity of Supplier Certificates and Documentation

5.6.1 Supplier Certification

After a supplier's QA program capabilities and implementation have been evaluated and found to be acceptable and contractual terms have been established, the project team may request certification from that supplier as objective evidence that the specified quality controls were implemented and that purchase requirements have been met.

Section 4 discusses the types of quality requirements that may be specified for a replacement component and the types of documentation that are usually furnished by the manufacturer/supplier.

ANSI N45.2.13 Section 10 [3] provides the following guidance regarding the receipt of a supplier's certificate of conformance:

> Where not precluded by other requirements, documentary evidence may take the form of written certificates of conformance which identify the requirements met by the items. Where certificates of conformance are used, the following minimum criteria shall be met:
>
> a. The certificate should identify the purchased material or equipment, such as by the purchase order number.
>
> b. The certificate should identify the specific procurement requirements met by the purchased material or equipment, such as codes, standards, and other specifications. This may be accomplished by including a list of the specific requirements or by providing, on-site, a copy of the purchase order and the procurement specifications or drawings, together with a suitable certificate. The procurement requirements identified should include any approved changes, waivers, or deviations applicable to the subject material or equipment.

c. The certificate should identify any procurement requirements that have not been met, together with an explanation and the means for resolving the nonconformances.

d. The certificate should be attested to by a person who is responsible for this quality assurance function and position are described in the purchaser's or supplier's quality assurance program.

e. The certification system, including the procedures to be followed in filling out a certificate and the administrative procedures for review and approval of the certificates, should be described in the purchaser's or supplier's quality assurance program.

f. Means should be provided to verify the validity of supplier certificates and the effectiveness of the certification system, such as during the performance of audits of the supplier or independent inspection or test of the items. Such verifications should be conducted by the purchaser at intervals commensurate with the supplier's past quality performance.

Receipt of supplier documentation in general and a certificate of conformance in particular should be an integral part of the acceptance plan for the replacement plate heat exchanger. However, acceptance of a major plant component such as a heat exchanger based solely on the receipt of supplier documentation is not recommended. Instead, the project team should consider using all of the means available to ensure that the plate heat exchanger is conforming to its design requirements and that it will perform all of its design and safety functions. These acceptance methods, as detailed in ANSI N45.2.13 [3], should be considered initially during the development of the specification, during the bid evaluation, and continuing throughout fabrication, receipt, and installation.

5.6.2 Supplier Documentation

The project team's engineering personnel should interface closely with the supplier to ensure that the design is suitable for the plate heat exchanger's intended application. The design interface should result in a qualified and suitable final plate heat exchanger design, and the supplier should be required to furnish the documents necessary to demonstrate the suitability of the design as well as supporting information regarding its installation, operation, and maintenance. These documents, which constitute design outputs from the supplier and inputs to the design modification process, are usually requested by the project team in the final procurement specification, may include any of the following:

- Supplier drawings, procedures, and specifications
- Supplier instruction manuals (including maintenance recommendations)
- Qualification reports
- Certified material test reports
- Nondestructive test reports

- Inspection reports
- Performance test reports
- Recommended spare and replacement parts lists

6
FABRICATION ISSUES

6.1 Establishing Witness and Hold Points

As noted in Sections 4 and 5, witness and hold points should be established to ensure that the project team has an opportunity to witness and verify the conformity of the replacement component to its design requirements as the component is being manufactured, fabricated, and assembled. Although they may have been included in the bid specification and considered during the bid evaluation, witness and hold points should be revisited after the supplier has been selected but prior to the start of fabrication. The project team should finalize the scope of oversight activities and ensure that appropriate individuals are designated and authorized to approve the activities witnessed during the hold points in the fabrication process.

Witness and hold points should be established to ensure that the project team has an opportunity to witness and verify the conformity of the replacement plate heat exchanger to its design requirements as the heat exchanger is being manufactured, fabricated, and assembled. Witness and hold points communicate the following to the manufacturer:

- The attributes of the plate heat exchanger that need to be verified before fabrication resumes
- The point in the manufacturing process where those critical attributes can most effectively be verified

After the witness and hold points are determined and the critical attributes to be verified are identified, the project team and the supplier should determine how best to verify the conformity of the product. This may involve witnessing a test, an inspection, or a special manufacturing process or examining selected programmatic quality controls.

6.2 Manufacturing Surveillance

Manufacturing surveillance is typically a vital step in ensuring the quality of the replacement component, and as such, appropriate resources should be allocated as necessary. When acceptance planning requires licensee source verification, it should be implemented to monitor, witness, or observe manufacturing at the organization in the supply chain most appropriate to evaluate the activities. Source surveillance may require the assignment of personnel to a supplier’s facility.

Manufacturing surveillance is a type of source verification that affords the project team an opportunity to observe a special process that renders or imparts a critical attribute to the replacement plate heat exchanger. Processes that are typically observed may include any of the following:

- Welding
- Assembly
- Finishing
- Coating/plating
- Heat treatment
- Machining
- Testing

The level of manufacturing surveillance should be based on the following factors:

- Uniqueness of the component – Unique and highly specialized components will usually require more surveillance to ensure that the unique design features conform to the established, qualified design.
- Supplier capabilities/certification – Adequate supplier capabilities/certification can negate the need for additional surveillance by the project team. Conversely, if the supplier's capabilities are lacking, then the project team should consider increased surveillance activities to ensure that the component conforms to its design requirements.
- Utility's participation – The project team has the option of using contract employees to perform this activity if it is cost beneficial.
- Safety significance, functions, and reliability of the replacement component

6.3 Potential Component-Specific Issues

The project team should coordinate with the supplier to identify any component-specific design features that would warrant special or frequent manufacturing surveillance. These design features may not be identified in industry codes or standards, so it is important for the project team to require the supplier to provide access so that verifications can occur during manufacturing surveillance.

For example, on a plate heat exchanger, the design of the plates may be an issue worthy of oversight. Some manufacturers recommend that a one-step, single-die process be used to press the plates, instead of attempting to stamp sections of large plates, a half plate at a time, or insert sections (much as one would a leaf on a dining table). Both alternative methods increase the opportunity for a discontinuity at those junctions, especially when the amount of wear varies from one section to another, which is always the case. Discontinuities tend to become a source point for leaks or non-contact between the plates.

Another issue that may be addressed for security reasons is the need to ensure that no foreign materials or substances have been placed inside the heat exchanger piping that may not be detected after the component is fully assembled and tested as a unit on-site.

6.4 Witnessing Tests and Inspections

Similar to manufacturing surveillance, source inspection should be implemented in accordance with plans to perform inspections, examinations, or tests at predetermined points. Source inspection may require the assignment of personnel to a supplier's facility. The following types of tests and inspections should be considered when replacing a major plant component such as a heat exchanger and may be required by codes, standards, or the owner's procedures:

- Material hardness (See the note below.)
- Hydrostatic test
- Durometer hardness for gaskets (See the note below.)
- Material chemical content verification for plates and gaskets (See the note below.)
- Calibration of test equipment

Note: Independent verification of material hardness via testing is normally performed only if the hydrostatic test fails. Material hardness is usually verified by the manufacturer by reviewing certified documentation from the subsupplier during the receiving inspection.

Typical customer oversight activities during the fabrication, assembly, and testing of a plate heat exchanger may include any of the following:

- Hold a pre-inspection meeting.
- Review and approve the documentation that is necessary for fabrication activities (drawings, calculations, inspection and test plan, procedures, etc.).
- Witness hydrostatic pressure test.
- Witness painting of the plate heat exchangers.
- Witness special packing requirements (usually for international shipments).
- Review inspection documents (ASME U1 data report, material test certificates, NDE reports, etc.)

Two tests that are typically performed on-site after installation of the heat exchanger—but may in certain circumstances be performed at the manufacturer's facility—are the following:

- Leak test
- Operability (heat transfer rate and flow)

See Section 10.9 regarding the scope of post-installation testing.

6.4.1 Establishing Acceptance Criteria

Prior to witnessing or, in some cases, actually conducting the test or inspection, the project team should coordinate with the plate heat exchanger manufacturer to establish the acceptance criteria for the activity, which should be mutually agreed upon by the owner. In essence, the acceptance criteria for a given inspection or test are the manufacturer's design criteria with some allowable tolerance range. The test or inspection should verify that the manufactured plate heat exchanger or part thereof is, in fact, conforming to its required design values.

Acceptance criteria for the following attributes are typically established by the documents noted in parentheses next to each attribute:

- Material hardness (per ASTM or ASME material specification)
- Hydrostatic test (per ASTM or ASME specification)
- Durometer hardness for gaskets (per ASTM material specification)
- Material chemical content verification for plates and gaskets (per ASTM or ASME material specification)
- Calibration of test equipment (per NIST guidelines)
- Painting of the plate heat exchangers (per manufacturer's design requirements)
- Special packing requirements (per ANSI requirements)

6.4.2 Nondestructive Examination

The project team should be aware of nondestructive examinations/evaluations (NDE) required either by ASTM material standards or the ASME Code for the materials and parts used to fabricate the replacement component. Additionally, the project team should determine which, if any, of these examinations/evaluations should be witnessed during the source inspection. The scope of nondestructive examination will vary among components, and requirements should be specified in the procurement specification as discussed in Section 4. Typical nondestructive examinations witnessed by the project team during the replacement of a heat exchanger may include any of the following:

- Radiography of welds (RT)
- Fluorescent dye penetrant check of plates (for splits, cracks)
- Liquid penetrant testing (PT) of welds
- Ultrasonic testing (UT) – usually of slabs to determine if laminations occur, but can also be used on welds
- Magnetic particle testing (MT) – testing of slabs and / or welds
- Positive material identification (PMI) of alloy materials to confirm chemical properties
- Impact testing to verify low-temperature properties

- Visual inspection
- Dimensional inspection

Unless extended nozzles are ordered, little in the way of testing for vessels is typically required. The units should be assembled without any pressure-retaining welds, and thus all the welding and NDE requirements are eliminated. If extended nozzles are required, then radiography, magnetic particle, or ultrasonic testing may be appropriate.

Additional guidance regarding nondestructive examination and evaluation is provided in numerous EPRI technical reports and source documents, which are developed and published by the EPRI NDE Center.

6.4.3 Shop Testing/In-Process Testing and Inspection

In many cases with the design and fabrication of a large, complex component such as a heat exchanger, the manufacturer performs numerous in-process tests as the plate heat exchanger is being assembled. In most cases, these tests and inspections are performed at the manufacturer's facility; thus, the term *shop testing* is often used to refer to these types of verification activities. The in-process test or inspection is a way for the manufacturer to verify the acceptability of certain attributes of the plate heat exchanger that might otherwise be difficult or costly to verify after the entire component is assembled. They may also be performed to verify the acceptability and/or operability of a discreet assembly or subcomponent prior to its being installed in the plate heat exchanger. Depending on the function of the discreet assembly or subcomponent and its significance to the overall performance of the plate heat exchanger, the project team should establish a way to verify some or all of these verification activities as the sub-component is being installed. Examples of in-process testing and inspections that may be performed on a replacement plate heat exchanger include verification of the following:

- As-built dimensions, tolerances, and fits between mating parts (for example, plate pack pitch, nozzle location)
- Material verification (for example, heat transfer plates and gaskets)
- Configuration (for example, plate geometry, plate pack arrangement)
- Testing of attributes resulting from special manufacturing processes (for example, plating, painting, heat treatment)

In some cases, the plate heat exchanger is partially assembled on-site. In these cases, some of the above listed verification activities may be performed at that time. Care should be taken to ensure that the personnel selected to perform these oversight activities have the necessary technical skills and familiarity with the plate heat exchanger function and design.

6.4.4 Final Product Testing

Final product testing may be required by either the project team or an industry code or standard as a way to ensure that the plate heat exchanger performance meets established design requirements prior to being released for shipment. When final product testing is deemed necessary, the project team should clearly specify the type of test and applicable codes or standards by which the test will be conducted in the final procurement specification.

However, it may difficult to verify all of the specified performance requirements at the manufacturer's facility. Thus, instead of final product testing prior to shipment, the project team may opt for testing when the plate heat exchanger is installed in its intended application (but this can limit the owner's ability to resolve certain types of nonconformances that may arise). If this testing option is chosen, care should be taken to make accommodations on the heat exchanger for instrumentation needed to record temperature, pressure drop, and flow rate.

6.5 Handling Manufacturing Nonconformances

ANSI N45.2.13 Section 8 [3] states in general that the project team and the supplier should establish and document measures for the identification, control, and disposition of items that do not meet procurement document requirements. The requirements for handling nonconformances are not limited to nonconformances discovered after receipt of the item, and as such the requirements would apply for any nonconformances discovered during the manufacture of the plate heat exchanger as well.

The project team should establish the most appropriate process or procedure for handling nonconformances discovered with the replacement plate heat exchanger as part of the commercial terms and conditions of the procurement specification. Nonconforming items should usually not be released for shipment with expectations that the item will be corrected after its receipt on site.

Nonconformances should be handled using a graded approach where the project team is involved in resolving only those nonconformances that reach the threshold as determined in the final procurement specification. However, the project team should be made aware of and monitor all nonconformances arising during fabrication. Manufacturing nonconformances should normally be addressed in accordance with the following sequence of actions:

- Review the type and extent of the nonconformance.
- Notify the project team of the nonconformance (if it occurs without the licensee present).
- Accept (by the licensee) the disposition of the nonconformance.
- Verify that the nonconformance was dispositioned properly.
- Maintain records, as appropriate.

6.6 Obtaining Required Documentation

As noted in Section 4, the project team should specify the types of documentation needed to ensure that technical and quality requirements have been met by the manufacturer and other organizations in the supply chain, as applicable. Documentation should be considered a tool in the verification of an item's technical adequacy and quality compliance, but it should not be used without confirmation of its validity.

The types of supplier documentation usually specified should include, as applicable, the following:

- Supplier drawings, procedures, and specifications
- Supplier instruction manuals
- Qualification reports
- Certified material test reports
- Nondestructive test reports
- Personnel certifications and qualifications
- Inspection reports
- QA manuals
- Performance test reports
- Certificates of Conformance/Compliance
- Recommended spare and replacement parts lists

Receipt may take place during fabrication, during final product testing, or during receipt of the complete replacement plate heat exchanger. In some cases, documentation specific to a particular assembly or subcomponent may be received separately, based on requirements specified in the design or procurement specification.

6.7 Cleanliness Requirements and Special Controls

The project team should determine if there are any cleanliness requirements exceeding those customary for fabrication of the replacement plate heat exchanger or those requirements already included in related industry codes and standards or the owner's documents.

Criterion IX of 10CFR50, Appendix B [7] states in full:

> Measures shall be established to assure that special processes, including welding, heat treating, and nondestructive testing, are controlled and accomplished by qualified personnel using qualified procedures in accordance with applicable codes, standards, specifications, criteria, and other special requirements.

As such, the project team should ensure that if special processes have been specified and are necessary to impart, render, or control critical attributes of the replacement plate heat exchanger, the appropriate and correlating special quality controls are in place to ensure that those processes have been implemented properly. Again, if there are special quality controls, the licensee's QA organization should be responsible for ensuring that those activities are implemented by the component manufacturer or other organization in the supply chain, as applicable.

Typically, no special coatings are needed for plate heat exchangers while they are in storage because exposed surfaces are either stainless steel, zinc plated, or painted. Similarly, there is usually no special cleaning needed of the plates prior to their installation unless they have been stored improperly and have become dirty or corroded.

7
SHIPPING AND HANDLING ISSUES

ANSI N45.2.2 Section 4 [3] covers the requirements for loading and shipment of items that would be applicable for a replacement component such as a heat exchanger. The standard describes environmental protection during transit, procedures to minimize damage in transit, precautions required when handling items during loading and transit, and identification and inspection on overseas shipment.

7.1 Determining the Optimum Shipping Method

When a heat exchanger is replaced, the method or methods of shipping the plate heat exchanger from the point of manufacture to the site should be evaluated and determined prior to or during the manufacture of the item. The following key issues should be considered:

- The extent to which the plate heat exchanger is assembled prior to arrival on site. In many cases, the plate heat exchanger can be shipped in sections or modules to facilitate easier routing through the plant.
- Cost and schedule constraints.
- Physical size, weight, and overall configuration of the replacement plate heat exchanger (large size may prohibit the use of some transportation means)
- Types of shipping method (truck, rail, ship, aircraft, barge).
- Plate heat exchanger's susceptibility to damage during shipment. Special care should be taken to ensure that the frame is not bent or twisted and that the heat exchange plates are not deformed, pressed, or bent.
- Manufacturer's packaging of the plate heat exchanger. The supplier should take special care to ensure that all subcomponents and heat exchange plates are braced so as not to incur any sort of physical deformation while in transit.

In general, the mode of transportation used should be consistent with the protection classification of the item and with the packaging methods employed. Section 4.2 of ANSI N45.2.2 [3] provides additional guidance when selecting and using open carriers, closed carriers, and special shipments. For plate heat exchangers, the most common mode of transport is a truck. For large components (for example, > 7 ft [> 2.1 m] height), a tarp-covered flatbed truck is used. For smaller units, an enclosed carrier is more appropriate.

7.2 Transportation Routing

ANSI N45.2.2, Section 4.2.2 [3] states in general that the conveyance used for transport should be certified to be structurally adequate to take the loads imposed during loading, while en route, and during unloading. Prior to shipment to ensure safe transit, the project team should have investigated the route. The following issues should be considered when transporting a replacement component:

- The extent to which the plate heat exchanger is assembled prior to arrival on site.
- Cost and schedule constraints
- Physical size, weight, and overall configuration of the replacement plate heat exchanger (large size may preclude the use of certain routes)
- Types of shipping method (truck, rail, ship, aircraft, barge)
- State or local transportation routing requirements
- Plate heat exchanger’s susceptibility to damage during shipment
- Modifications or upgrades that may be needed:
  - Replacing railroad ties or rails
  - Improving the load-bearing capacity of roadbeds or bridges
- Need for escorts (The use of escorts may be specified to accompany shipments when additional surveillance is required during transit of certain items.)

7.3 Packaging for Shipping

The need for physical protection of items due to movement or contact with other items is much more of a concern when the item is in transit than when the item is in storage or after it has been installed in the plant. Therefore, a reduced level of packaging may be adequate after the plate heat exchanger is staged on site. Consideration should be given to how much of the packing materials should be discarded after the replacement component is staged for installation and protection from physical damage is no longer a concern. In most cases, the packaging used during shipping has to be removed to move the plate heat exchanger into place and maneuver it through the access route established in the plant.

The following issues should be considered when determining the type and extent of packaging for a replacement plate heat exchanger during shipping:

- The manufacturer’s recommended means for packaging the plate heat exchanger to provide adequate protection during shipment
- Physical size, weight, and overall configuration of the replacement plate heat exchanger
- Types of shipping method (truck, rail, ship, aircraft, barge)
- Plate heat exchanger’s susceptibility to damage during shipment

- Security requirements and inspections at points of shipment, entry, and receipt
- Minimizing the possibility of theft and vandalism during shipment

Typically, for domestic transport, a plate heat exchanger is skid mounted, with connection openings adequately protected or covered, and is shrink wrapped. For overseas shipments, the plate heat exchanger may be containerized with bracing or export-crated (that is, completely boxed).

No special coatings are needed for plate heat exchangers during shipment because exposed surfaces are either stainless steel, zinc plated, or painted.

7.4 Need for Sensing/Monitoring Devices during Shipment

There are no requirements for sensing or monitoring devices during the shipment of a plate heat exchanger.

7.5 Customs Requirements and Homeland Security Issues

Section 4.5 of ANSI N45.2.2 [3] provides guidance regarding shipments from countries outside the United States. Care should be taken to ensure that current Homeland Security requirements are also met. The following issues should be considered when transporting a replacement plate heat exchanger from overseas:

- Special requirements for overseas shipment required by either the U.S. or the country of origin
- Inspections required at the point of shipment
- Inspections required at the point of entry
- Special packaging needed to accommodate inspections during transport
- Requirements for special identification and markings
- The modes of transportation being used and the requirements specific to those modes
- Requirements for special permits or documentation
- Point of transfer of ownership
- Insurance

7.6 Lifting and Handling Issues

When lifting and handling a plate heat exchanger, the following issues should be considered:

- Loading – The weight, lifting points, or center of gravity indicated on the crate, skid, or package by the shipper should be used to ensure proper handling during loading, transfer between carriers, and unloading.
- Rigging – Rigging requirements should be established by the project team prior to transport and handling of the manufactured plate heat exchanger. Care should also be taken to ensure that carbon steel rigging equipment does not come in direct contact with stainless steel except when attached to lifting lugs, eyes, or pads in order to avoid surface damage.
- Handling precautions – Austenitic stainless steel and nickel base alloy materials should be handled in such a manner that they are not in contact with lead, zinc, copper, mercury, or other low melting elements, alloys, or halogenated material.
- Package and preservation coating – Packages and preservative coatings should be visually inspected after loading, and damaged areas repaired prior to shipment. Items shipped with desiccants should be inspected after loading to ensure that sealed areas are intact.
- Sealed openings – Sealed openings should be visually inspected after loading to ensure that closures are intact. Materials used for resealing should be in accordance with ANSI standards or licensee procedures.
- Stacking – Where special care is deemed necessary to avoid damage, written instruction covering the location and stacking limits of the crates or boxes on the transport vehicle should be specified. These instructions should be marked on the container.
- Bracing – The type of bracing and tie-down methods to be used with the mode of transportation selected for special shipments of replacement components should be specified by the project team.

If lifting lugs or lifting eyes are provided, chains or lifting cables rated above the published weight of the plate heat exchanger should always be used. The heat exchanger should never be lifted by the tightening bolts, connections or the studs around them.

EPRI report1007914, *Lifting, Rigging, and Small Hoist Usage Program Guide*, [8] should be considered as a reference for establishing and applying appropriate lifting and handling requirements.

8
RECEIVING INSPECTION ISSUES

As noted in Section 5, the receiving inspection should be an integral part of the acceptance plan when a major plant component such as a heat exchanger is replaced. The project team should use care when developing a receiving inspection plan to ensure that appropriate physical and performance attributes are adequately verified and that the replacement plate heat exchanger has not been damaged in any way during shipment or during receiving activities. ANSI N45.2.13 Section 7 [3] states in part:

> When planning requires (licensee) receipt inspection, it shall be implemented and coordinated with source verifications performed. During receiving inspection, emphasis shall be placed on assuring that items have not sustained damage in shipment that would influence subsequent fabrication, construction, installation or end use. Sampling may be utilized during receiving inspection when conducted in accordance with established procedures or recognized standards. These measures shall also include provisions for dispositioning (i.e., accept, reject or hold) and handling of items received and services performed.

Receiving inspection should be used to supplement the QA and verification activities that have taken place prior to and during the manufacturing of the plate heat exchanger and should be performed to verify that the supplier has met all of the requirements of the purchase order.

8.1 Developing Appropriate Inspection Attributes

The inspection attributes may be instructions to verify the receipt of certain supplier documentation, which typically should have been described in the final procurement specification. In most cases, the supplier documentation furnished provides objective evidence that certain physical or performance attributes of the replacement plate heat exchanger have been verified as conforming to the manufacturer’s design. When certain component attributes have not been verified prior to receipt, or in cases where additional assurance is needed to verify the conformity of a particular component attribute, the project team may opt to verify a particular physical or performance attribute of the plate heat exchanger via a test or inspection.

8.1.1 Reviewing Documentation Received

ANSI N45.2.13 Section 7 [3] states in part:

> Receiving inspection measures shall include provisions for receiving documentation (such as drawings, certifications, test results and other materials) offered as objective evidence in satisfaction of requirements.

In those cases where the plate heat exchanger has been specified to meet 10CFR50 Appendix B requirements, the supplier's nuclear quality assurance program should have been audited and approved by the licensee's QA organization (or other industry auditing organization). As such, much of the acceptance activities should have already taken place through the implementation of the performance-based audits and source verification activities. Additional acceptance activities occurring during receipt of the plate heat exchanger should primarily ensure that appropriate and accurate documentation has been received in accordance with the requirements of the final procurement specification. These documents include the following:

- Supplier drawings, procedures, and specifications
- Supplier instruction manuals (including maintenance recommendations)
- Qualification reports
- Certified material test reports
- Nondestructive test reports
- Personnel certifications and qualifications
- Inspection reports
- QA manuals
- Performance test reports
- Certificates of Conformance/Compliance
- Recommended spare and replacement parts lists

8.1.2 Testing/Inspecting Component Attributes

When receiving activities are used to verify either physical or performance attributes of the plate heat exchanger that have not already been verified by the supplier via audit or source verification, the project team must establish the appropriate acceptance criteria prior to verifying the attributes. These acceptance criteria should represent the manufacturer's design criteria for the item and should include tolerances as allowed by the item's design.

8.1.3 Testing/Inspecting Supporting/Auxiliary Items

In some cases, the project team may be responsible for testing, inspecting, and supporting auxiliary items, which may include any of the following:

- Spare and replacement items for the plate heat exchanger
- Tools needed to install the replacement plate heat exchanger
- Installation materials (bar stock, shims, blocks, etc.)
- Consumables used during installation (weld rods, lubricants, rags, etc.)

Similar to testing or inspecting the plate heat exchanger itself, if receiving activities are used to verify either physical or performance attributes of supporting or auxiliary items, the project team should establish the appropriate acceptance criteria prior to verifying the attributes. These acceptance criteria should represent the supplier’s/manufacturer’s design criteria for the item and should also include tolerances.

8.2 Site-Specific Testing and Inspection Requirements

Depending on site-specific procedures and requirements, there may be cases where special testing and inspection requirements must be met when a replacement major plant component such as a heat exchanger is procured. Typically, these special requirements should be established through close coordination between the engineering and QA organizations. The special testing and inspection requirements should be determined as early in the procurement process as possible.

9
STORAGE AND STAGING ISSUES

9.1 Storage Level Determination and Requirements

Nuclear licensees have used ANSI N45.2.2 guidance for many years in establishing the necessary controls to package, ship, receive, store, and handle incoming components and replacement parts. Section 2.7 of the ANSI standard provides detailed guidance on how to classify a procured item with respect to protective measures to prevent damage, deterioration, or contamination of the item. Specifically for plate heat exchangers, the storage level most commonly used is ANSI Level C. For replacement gaskets, the most commonly used storage level is ANSI Level B.

To assist the user of this report, the following excerpt is provided regarding categorization of components that may be replaced at a nuclear power plant. ANSI N45.2.2 Section 2.7 [3] states in part:

> Level A. Items classified to Level A are those that are exceptionally sensitive to environmental condition and require special measure for protection from one or more of the following effects: temperatures outside required limits, sudden temperature changes, humidity and vapors, gravitational (g) forces, physical damage, and airborne contamination (for example, rain, snow dust, dirt, salt spray, fumes).
>
> The following shall be used as a guide for classifying items intended for this level classification:
>
> (1) Special electronic equipment and instrumentation
>
> (2) Special materials, such as chemical, that are sensitive to environment.
>
> (3) Special nuclear material (fuel) and sources. The requirements of the NRC fuel license and conditions and other governmental agencies shall be met.
>
> Level B. Items classified to Level B are those that are sensitive to environmental conditions and require measures for protection from the effects of temperature extremes, humidity and vapors, acceleration forces, physical damage, and airborne contamination and do not require special protection required for Level A items.
>
> The following shall be used as a guide for classifying items intended for this level classification:
>
> (1) Instrumentation
>
> (2) Electrical penetrations

(3) Batteries

(4) Welding electrode and wire

(5) Control rod drives

(6) Motor control centers, switchgear and control panels

(7) Motors and generators

(8) Precision machined parts

(9) Spares, such as gaskets, O-rings

(10) Air handling filters

(11) Computers

Level C. Items classified to Level C are those that require protection from exposure to the environment, airborne contaminants, acceleration forces, and physical damage. Protection from water vapor and condensation is not as important as that for Level B items.

The following shall be used as a guide for classifying items intended for this level classification.

(1) Pumps

(2) Valves

(3) Fluid filters

(4) Reactor materials

(5) Compressors

(6) Auxiliary turbines

(7) Instrument cable

(8) Refueling equipment

(9) Thermal insulation

(10) Fans and blowers

(11) Cement

Level D. Items classified to Level D are those that are less sensitive to the environment that Level C. These items require protection against the weather, acceleration forces, airborne contamination, and physical damage.

The following shall be used as a guide for classifying items intended for this level classification.

(1) Tanks

(2) Heat exchangers and parts

(3) Accumulators

(4) Demineralizers

(5) Reactor vessel

(6) Evaporators

(7) Steam generators

(8) Pressurizer

(9) Piping

(10) Electrical cable

(11) Structural items

(12) Reinforcing steel

(13) Aggregates

EPRI report TR-107101, *Packaging, Shipping, Storage and Handling Guidelines for Nuclear Power Plants*, [9] provides additional (component-specific) guidance that may be helpful when a key plant component is replaced.

9.2 On-Site Storage and Staging Capabilities

As noted in the previous section, nuclear licensees have used ANSI N45.2.2 guidance for many years in establishing the necessary controls for storing incoming components and replacement parts. During this time however, licensees shifted their capabilities more toward the long-term storage of spare and replacement parts, and less toward the short-term storage or staging of large components such as heat exchangers that were originally used to construct the plant. Now, as the need to replace certain major plant components increases, licensees should evaluate ways to once again provide adequate storage and staging facilities for these larger pieces of equipment.

ANSI N45.2.2 Section 6 [3] provides guidance for establishing appropriate storage levels and categorizing them in accordance with the four levels discussed in the previous section. To assist the user of this report, ANSI N45.2.2 [3] states in part:

(1) Level A items shall be stored under special conditions similar to those described for Level B items but with additional requirements such as temperature and humidity control within specified limits, a ventilation system with filters to provide an atmosphere free of dust and harmful vapors, and any other appropriate requirements.

(2) Level B items shall be stored within a fire resistant, tear resistant, weathertight, and well-ventilated building or equivalent enclosure. Precautions shall be taken against vandalism. This area shall be situated and constructed so that it will not be subject to flooding: the floor shall be paved or equal, and well-drained. Items shall be placed on pallets or shoring to permit air circulation. The area shall be provided with uniform heating and temperature control or its equivalent to prevent condensation and corrosion. Minimum temperature shall be 40ºF (4ºC) and maximum temperature shall be 140ºF (60ºC) or less if so stipulated by a manufacturer.

(3) Level C items shall be stored indoors or in an equivalent environment with all provisions and requirements as set forth in Level B items, except that heat and temperature control is not required.

(4) Level D items may be stored outdoors in an area marked and designated for storage, which is well-drained, preferably gravel covered or paved, and reasonably removed from the actual construction area and traffic so that possibility of damage from construction equipment is minimized. Items shall be stored on cribbing or equivalent to allow for air circulation and to avoid trapping water.

The project team should also consider the following issues related to the storage and staging of a plate heat exchanger:

- Structural loading capacity of storage and staging areas
- Division of responsibility among organizations in the supply chain and utility organizations involved in the storage and staging of the replacement plate heat exchanger to address issues such as:
  - Lighting
  - Electrical power
  - Fire protection
  - Compressed air supply

Unless otherwise agreed, most manufacturers will deliver the plate heat exchanger ready to be put in service upon arrival (unless otherwise specified in the procurement documents). This means that the plate package is tightened to its correct measurement. Should it be necessary, however, to store the equipment for a longer period (one month or more) before, the following precautions should be made in order to prevent unnecessary wear of the equipment:

- Preferably, the plate heat exchanger should be stored inside in a room with a temperature around 60–70ºF (15–20ºC) and humidity around 70%.
- There should be no ozone-producing equipment in the room, like electric motors or arc-welding equipment, since ozone destroys many rubber materials (cracking).
- No organic solvents or acids should be stored in the room.
- Heat or ultraviolet radiation should be avoided.
- If the plate heat exchanger must be stored outdoors, the precautions mentioned above should be taken as far as practical. The need for protection against the climate, etc., is, of course, even more important in this case.
- If, for any reason, the plate heat exchanger is removed from service or remains in storage for a longer period (that is, greater than six months), it is advantageous to follow the advice above, even if the equipment is not moved from the location. Consideration should also be given to draining the unit and relaxing the plate pack pitch in these cases.

9.3 In-Storage Maintenance Activities

Depending on the length of time the replacement plate heat exchanger will be in storage or staged prior to installation, the project team should determine if there are any in-storage maintenance activities that are needed. The project team should coordinate with the manufacturer to determine what requirements may apply and how often these activities should be performed. EPRI report TR-107101, *Packaging, Shipping, Storage and Handling Guidelines for Nuclear Power Plants*, [9] stresses the need to consider in-storage maintenance requirements as a factor when determining the most appropriate packaging, shipping, storage, and handling of items.

Typical in-storage maintenance concerns for plate heat exchangers may include the following:

- The plate heat exchanger should be vented and drained, and depending on the media processed, it is recommended to rinse and dry it, before and while it is stored. Also, the plate pack pitch should be relaxed.
- Wrapping the plate heat exchanger with a nontransparent plastic film is a good precaution. Use of transparent film can alter paint color if the unit is stored in direct sunlight.
- The tightening bolts should be well covered with a good (and approved for use) rust-preventing coating; and if the piping is not connected to the connections provided, the connections should be covered.

9.4 Licensee Lifting/Handling Capabilities

One of the major considerations when a major plant component is replaced such as a plate heat exchanger is how the heat exchanger will be physically moved from its mode of transportation to its storage or staging area. In many cases, special lifting and rigging is necessary to safely conduct the move. Detailed guidance is provided in EPRI report 1007914, *Lifting, Rigging, and Small Hoist Usage Program Guide*, [8] which should be used as a basis for determining the most appropriate lifting and handling methods, developing a lift plan, and safely moving the equipment into its storage or staging area.

The primary source of lifting guidance should be the manufacturer. When specific guidance has not been provided, the following guidance should be considered. If lifting lugs or holes are provided, always use chains or lifting cables rated above the published weight of the plate heat exchanger. For larger units, never lift by the tightening bolts, connections, or the studs around them.

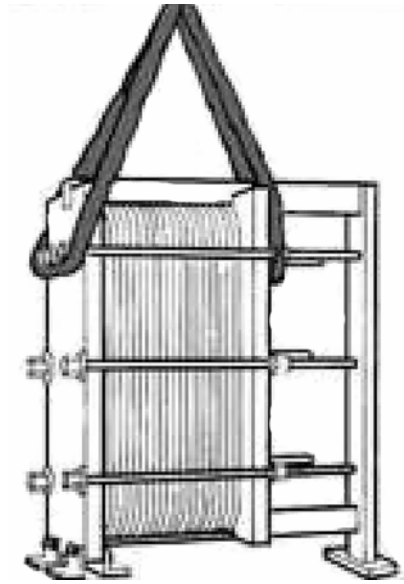

Figure 9-1
Rigging a Plate Heat Exchanger

Whenever a smaller plate heat exchanger (typically, a 2 in. (5.1 cm) connection size or smaller) is lifted, straps may be placed around tightening bolts on both sides of the unit, as shown in Figure 9-1, if lifting lugs or holes have not been provided

If lifting lugs are provided, they should be placed as shown on Figure 9-2. Straps or wire rope should be used to lift the plate heat exchanger itself.

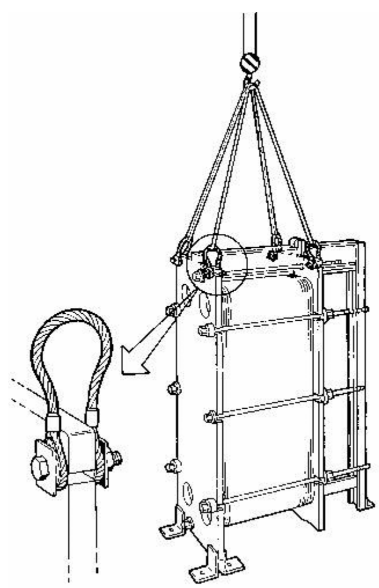

Figure 9-2
Lifting Lugs for a Plate Heat Exchanger

On smaller units (2 in. [5.1 cm] connector size or smaller), only two lifting lugs are required instead of four. Care should be taken to never lift by the tightening bolts, connections, or the studs around them. Figure 9-3 illustrates a three-point lift using two lifting holes in the frame plate and one lifting hole in the carry bar or support column. Lifting at the pressure plate is not recommended because this may cause misalignment of the plate pack.

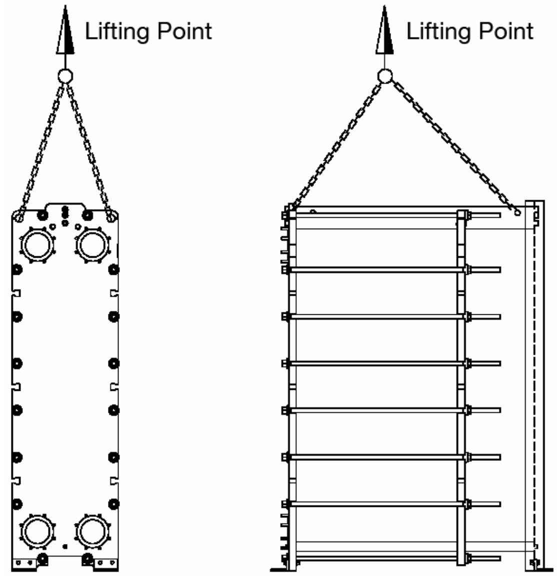

Figure 9-3
Lifting Lugs for a Plate Heat Exchanger

9.5 Materials Management

A primary issue that should be addressed by the project team is ensuring that the replacement plate heat exchanger and its spare and replacement items are controlled and tracked in accordance with existing site-specific processes. In most cases, this entails ensuring that the plate heat exchanger has been assigned the correct equipment identifier and that the spare and replacement items have been assigned appropriate unique stock codes or identifiers.

Care should also be taken to ensure that inventory items unique to the replaced shell and tube heat exchanger are purged from the system and disposed of in an acceptable manner if they cannot be used on other identical components or elsewhere in the plant.

10
INSTALLATION ISSUES

10.1 Pre-Installation Requirements

10.1.1 Determining the Optimum Access Route

Prior to installing a major component replacement such as a plate heat exchanger, the project team should evaluate the possible access routes that are available to move the heat exchanger from its storage or staging area to its final plant location. The evaluation should consider the following factors:

- Need for any special lifting or handling equipment
- Impact of routing on plant operations, if applicable
- Impact of routing on existing plant equipment and the extent to which plant modifications may be required to physically move the replacement plate heat exchanger into place
- Personnel safety and ALARA considerations
- Physical space limitations and known interferences
- Ability to change the physical orientation of the replacement plate heat exchanger during the routing
- Susceptibility of damage to the plate heat exchanger during the routing

The need to specify an access route is most critical when the plate heat exchanger is delivered fully assembled. When this is not the case, the need is dictated by the size of the largest subcomponent, which is usually the frame plate or the carrying bar.

10.1.2 Establishing Lifting and Rigging Requirements

The primary source of lifting guidance should be the manufacturer, and this guidance should be implemented in accordance with the site's lifting and rigging requirements. When specific guidance has not been provided, the guidance in EPRI report 1007914, *Lifting, Rigging, and Small Hoist Usage Program Guide*, [8] should be considered.

This report provides a generic process for establishing lifting and rigging requirements that would be very appropriate for moving a replacement plate heat exchanger. The guideline states that the first step in the generic process is to ensure that a technical person or group of technical personnel have adequately planned and evaluated the lift. Under no circumstances should a lift be conducted relying solely on one individual's "skill of the craft" knowledge or experience. As such, the verification of personnel qualification and certification, when appropriate, is necessary for effectively implementing the process described in this section.

The report stresses that to ensure safety and effective lifting, each lift should be planned and evaluated as needed. The evaluation should minimally include the following elements:

- Analyze the load.
- Determine the weight of the load.
- Determine the load center of gravity.
- Establish the means to stabilize the load.
- Consider clearances available and the load path.
- Consider past history of similar lifts and lessons learned.

Each step of the process is detailed in the report, and should be used when a major plant component such as a heat exchanger is replaced.

10.1.3 Developing a Lift Plan

The lift plan may vary depending on the complexity of the lift, the weight of the load, the criticality of the equipment being lifted, and the schedule. Lift plans can vary in the level of detail contained in the plan, and the degree to which the utility's engineering organization is involved in its development, and the degree to which the plan can be used generically. Some lift plans are applicable to only one lift, whereas some are generic for a particular type of lifting or rigging equipment. Lift plans can be grouped into the following types:

- Pre-engineered lift plans with significant engineering involvement
- Pre-planned lifts that are primarily driven by the scope of the work order
- Field-planned lift plans that are developed in the field by craft personnel
- At-the-job lift plans developed solely for one particular lift

The lift plan may contain a checklist and may include sketches or drawings as a way to convey how the lift should be conducted.

10.2 Interferences

Ideally, physical interferences should have been identified during the design phase of the project when all interface points were identified and evaluated. The project team should consider the use of optical scanning technology and three-dimensional (3D) modeling as tools to assist in identifying and addressing physical interferences.

However, cases may arise where the physical layout of the plant does not match drawings; consequently, interferences may result. In these cases, the project team should implement existing procedures for resolving nonconformances and, depending on the severity of the interference, coordinate resolution with various engineering disciplines and organizations as necessary.

10.3 Plant Conditions Facilitating Installation (On-line vs. Outage)

The project team should clearly establish, as early in the design and specification process as possible, whether the heat exchanger replacement will occur when the plant is on-line or if it must be replaced during an outage. EPRI report 1009708, *Guidance for Developing and Implementing an On-Line Maintenance Strategy*, [10] may be used when making this key decision. Unless the plate heat exchanger is small or skid mounted, the replacement would usually be performed during an outage and not while the unit remained on-line.

10.4 Expertise Needed to Install the Equipment

As noted in Section 4, during the design and specification phase of the project, the project team should determine who is best suited to install the replacement plate heat exchanger. In some cases, the manufacturer of the equipment will also be the installer. When this is the case, the specification provided to the manufacturer may include both procurement and installation requirements. Work done in this manner is often referred to as a design, procure, and install contract or a *turn-key* contract. In these cases, the project team normally can delegate the authority to the plate heat exchanger manufacturer to provide the craft labor and technical skills needed to complete the entire installation. Any shortfalls in personnel availability, expertise, or certification should be addressed by the project team and met using alternative sources.

In most cases, it is recommended that the manufacturer's technical representatives be present during installation activities.

10.5 Sequence of Installation Steps

10.5.1 General Guidance

The sequence of installation steps should be closely coordinated between the project team, the component manufacturer, and the installer (if different than the manufacturer). If the plate heat exchanger is to be replaced during a system outage, the sequencing should begin with the safe shutdown of the system. The sequencing should also include the following:

- All necessary demolition work of existing equipment
- Mechanical, electrical, I&C interface disconnects, protection, and rerouting, as needed
- Design modification of existing SSCs to accommodate the new plate heat exchanger
- Handling of the new component as it is moved through its access route

- Plate heat exchanger placement
- Interface reconnections
- In-process testing and inspection
- Integration of activities into the overall outage or work schedule (A readiness review is recommended to ensure that the sequence is feasible.)

10.5.2 Key Installation Issues Related to Plate Heat Exchangers

- Foundations – Information necessary for the preparation of the foundation usually appears on the data sheet provided by the manufacturer. In some cases, it may be practical to place the plate heat exchanger in a drainage box (with capacity for the total volume of the plate heat exchanger). The outlet of the drainage box should be generously dimensioned, not less than 2 in. (5.1 cm) in diameter.
- Foreign materials – Care should be taken before connecting any piping to the plate heat exchanger, to ensure that that all foreign objects have been flushed out of the system. The user should ensure that fluids are clean from debris because debris will most likely plug a plate heat exchanger. A strainer should be installed if necessary (for example, for river, lake, or seawater service). Temporary strainers should be considered during startup to keep construction debris, slag, etc., from plugging the exchanger. There are models available from a limited number of vendors that can handle debris, but as discussed in Section 3, the amount of debris and equipment limitations should be discussed with the vendor during the development of the bid specification.
- Working space – It is necessary to leave an adequate amount of free space around the equipment (normally 1.5 x the width of the unit), as shown in Figure 10-1, to provide access and make future service possible. Except for a place to put the plates, if removed from the plate heat exchanger, no additional space is typically required for servicing the plate heat exchanger.

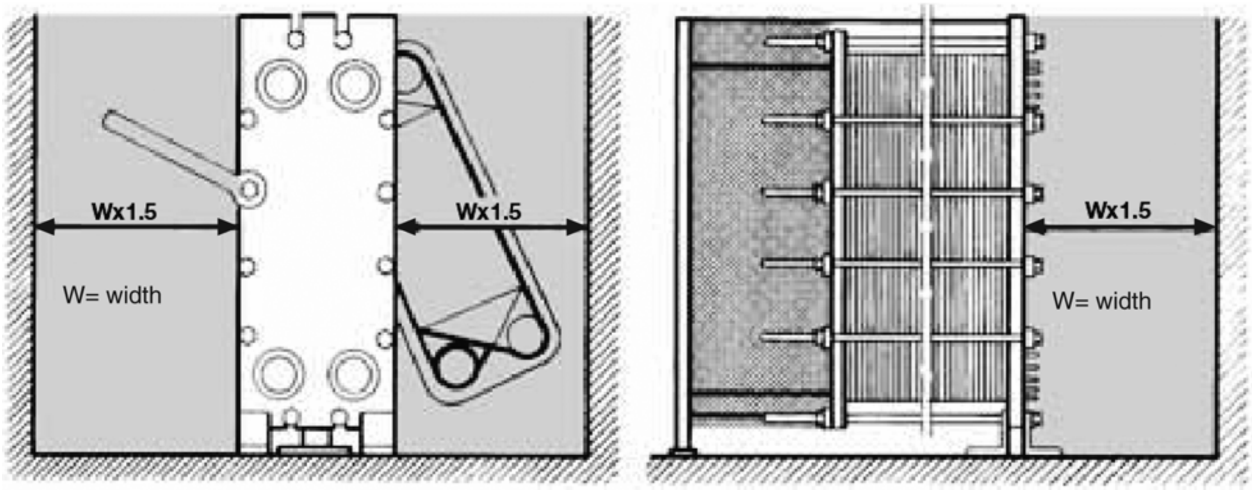

Figure 10-1
Required Working Space for a Plate Heat Exchanger

The measurements shown in Figure 10-1 are recommended by Alfa Laval to provide reasonably good working conditions during installation of the plate heat exchanger as well as for future maintenance and service. If floor space is restricted, the dimensions suggested can be reduced.

- Pipes – The licensee should ensure that no measurable stress is placed on the plate heat exchanger by the piping system.
- Shut-off valves – In order to enable the plate heat exchanger to be opened when necessary, shut-off valves should be provided on all connections. These may be referred to as *isolation valves*.
- Pressure relief devices – The licensee should ensure that the required pressure relief devices are properly installed prior to initial operation. Applicable codes and corresponding standards for proper size requirements of these pressure relief devices should be consulted.
- Connections on the pressure plate – Some plate heat exchangers may also have connections on the pressure plate. In such cases, it is important to check against the drawing or the nameplate that the plate pack has been tightened to the right measurement before the piping is connected. When piping is connected to the pressure plate, a short 90º spool piece should be installed between the plate heat exchanger and the piping. These spools should be directed upward or sideways, as shown in Figure 10-2, which will simplify pressure plate removal during servicing. Provisions for expansion joints may be considered to facilitate tightening of the heat exchanger heat transfer plate pack.

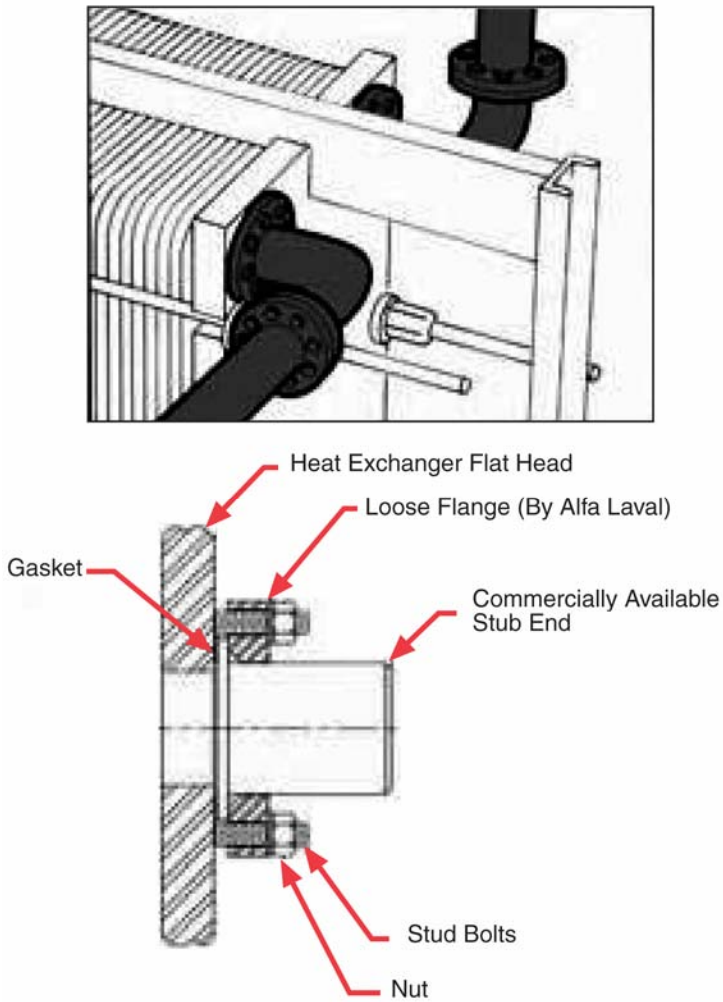

Figure 10-2
Proper Installation of Spool Pieces

- Venting – Venting of both sides of the plate heat exchanger must be provided. This is important and enables air to be drawn from the system during startup. It also allows air or gas to be removed during operation, and it permits faster drainage.
- Spray deflectors – If the owner is planning to clean the plate heat exchanger on-site, special provisions may be considered during initial installation to protect adjacent equipment from being sprayed when the cleaning begins. These deflectors may be simple curtains hung from appropriate supports as a way to contain the spray during future washing.
- Plate Alignment – The owner should ensure that the manufacturer has provided a proper metal-metal alignment system for the plates. In many cases, the frame can be used for a fixed reference point on alignment.

10.6 Special Tools Required and Accessories

When the heat exchanger manufacturers were initially being reviewed and selected, the project team should have identified any needs for special tools during the installation of the replacement plate heat exchanger. During installation, the project team should ensure that the appropriate tools are available, have been inspected, being used properly, are calibrated, and are being used by qualified and/or certified personnel. The following special tools and consumables should be made available during the installation of the plate heat exchanger:

- Hydraulic equipment for disassembly
- Large wrenches
- Drip trays for the collection of drained fluids
- Provisions for a spray screen
- Availability of air and water for cleaning and maintenance activities
- High-pressure sprayer (4000 psi [27.6 MPa]), usually for on-site cleaning

The project team should also ensure that adequate drainage is available.

10.7 Special Quality Control Requirements

Another issue related to the replacement of a heat exchanger is the need for special quality controls during the installation phase. In most cases, the project team should coordinate quality control activities with the QA organization during the design and specification phase of the project. In some cases, industry codes and standards will dictate that certain quality controls be applied during the installation. The equipment manufacturer and the installation contractor may also prescribe certain quality controls.

As noted in Section 5, the project team should address the need for quality controls during the development of the installation specification. Typical activities that may require quality controls and documented evidence of satisfactory completion include the following:

- Nondestructive examination
- Witness and hold points for inspection and testing during the installation process
- In-process testing required as the replacement plate heat exchanger is being installed, which may necessitate special provisions to enable the inspections to occur

10.8 Personnel Safety/ALARA Issues

The project team should ensure that personnel safety and ALARA issues addressed in the installation specification are mitigated during the installation of the replacement plate heat exchanger. Typical concerns that may be applicable when replacing a major plant component include the following:

- ALARA – Minimizing radiation exposure and dose rate.
- Special shielding.
- Working in proximity to equipment being lifted.
- High temperature or humidity environment.
- Protective shrouds – It is the responsibility of each person operating or repairing equipment to take the necessary precautions to comply with all applicable safety regulations. Most manufacturers provide protective shrouds for plate heat exchangers. These shrouds will prevent possible injuries and/or damage as a result of sudden leakage from the plate package.
- Hand gloves – To avoid hand injuries, protective gloves should always be worn when handling plates, as illustrated in Figure 10-3.

Figure 10-3
Handling Plates

The project team should ensure that personnel involved in the installation of the replacement component meet all applicable OSHA requirements.

10.9 Post-Installation Testing

The project team should ensure that post-installation testing is conducted in accordance with the requirements specified in the installation specification and/or the manufacturer's recommendations. The project team and manufacturer should work closely to establish the following:

- Baseline performance criteria for the replacement plate heat exchanger
- System operating conditions under which the plate heat exchanger will be tested
- Acceptance criteria for meeting established performance standards
- The type of post-installation test most appropriate for measuring performance data
- Procedures and instructions for conducting the post-installation tests
- Qualification requirements for personnel conducting the prescribed tests
- Ways to measure the results of the post-installation tests
- Benefits of pre-service inspections and/or in-service inspections
- Instrumentation and calibration requirements

Post-installation tests and inspections usually conducted on plate heat exchangers may include any of the following:

- Leak test to ensure pressure boundary and no evidence of leaks at normal operating pressure
- Thermal performance test at rated flow, pressure, and temperature
- Test of new system features (for example, strainer alarms, system flushing, automatic valve actuation, etc.)

11
DEVELOPING THE PLATE HEAT EXCHANGER MAINTENANCE STRATEGY

11.1 Inputs Regarding Preventive Maintenance

11.1.1 Plate Heat Exchanger Manufacturer

The project team should coordinate with the component manufacturer beginning during the design and procurement phases of the replacement plate heat exchanger to begin developing the preventive maintenance program for the new component. The plate heat exchanger manufacturer should be required to furnish recommendations regarding the types of preventive maintenance activities and their frequency.

11.1.2 EPRI NMAC

The project team should research the EPRI Preventive Maintenance Database (PMDB) to determine if specific guidance has been developed by EPRI for the replacement plate heat exchanger. As part of EPRI's EPRI PM Basis Database program, there is an ongoing effort to develop technical guides and documentation of industry experience on PM optimization. Additional information can be found at www.epri.com by searching on the keyword PMDB.

11.1.3 Industry Experience

As another source of input, the project team should consider the preventive maintenance experience with models similar to the new plate heat exchanger. Care should be taken to consider differences in the type of component and technologies associated with the new plate heat exchanger when drawing on past maintenance experience.

11.2 Preventive Maintenance Guidance for Plate Heat Exchangers

11.2.1 Introduction to Plate Heat Exchanger Maintenance

A plate heat exchanger, like any other machinery is subject to degradation and will eventually require some form of maintenance to ensure continued performance and also to extend its operating life. The common problems are performance failures, for example, due to fouling and clogging, and mechanical failures, for example, internal and external leakage.

The main parts that generally require maintenance or replacement are the plates and gaskets. It is important to have clean plates to ensure peak thermal performance. Plates can be chemically cleaned to remove scale buildup and other deposits. Damaged plates can be replaced. Gasket lifetime depends on process variables such as operating temperature, temperature variations, differential pressure, compatibility with the fluids involved, and the environment in which the plate heat exchanger is installed. Irrespective of the time the plate heat exchanger is actually used or in operation, the gaskets are subject to physical aging and chemical deterioration—swelling or shrinkage, hardening, loss of sealing force, cracking, and blowout of the gasket. The best indication of gasket failure is external leaks.

Preventive maintenance for a new plate heat exchanger generally consists of two primary activities: cleaning different types of fouling and regasketing. Each maintenance activity is discussed in more detail in the following sections.

11.2.2 Cleaning Different Types of Fouling

Section 3 discussed various types of fouling and their causes that are typical for plate heat exchangers. Based on these types of fouling, care should be taken to ensure that the appropriate cleaning methods and solutions are used. The following methods of mechanical cleaning after opening may be considered:

1. Soft brush and running water – Minor fouling may be safely removed with a soft brush and running water, as shown in Figure 11-1. Special care should be taken to avoid gasket damage. Surfaces should be dried with a cloth or rinsed with clean water.

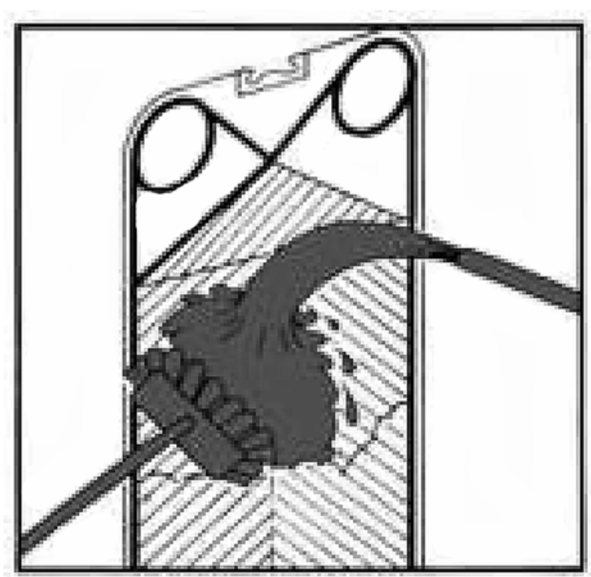

Figure 11-1
Cleaning with a Soft Brush and Running Water

2. High-pressure sprayer – Figure 11-2 illustrates the use of a high-pressure sprayer (typically less than 4000 psi [27.6 MPa]) to remove significant or gross amounts of fouling.

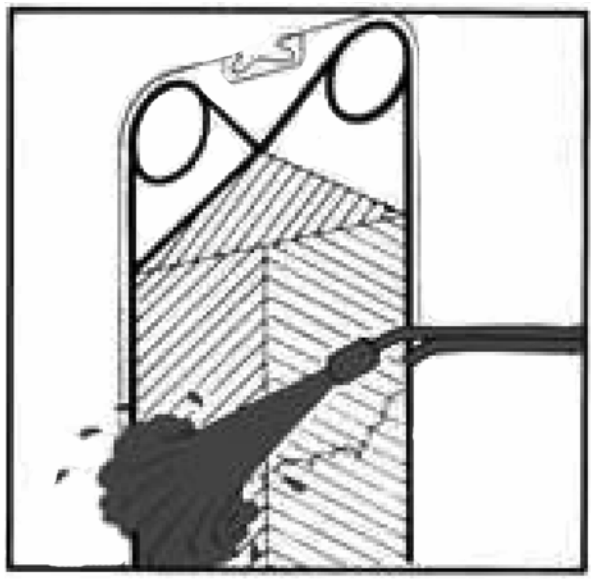

Figure 11-2
Cleaning with a High-Pressure Hose

Care should be taken to ensure that gaskets are not damaged when a high-pressure sprayer is used by not spraying directly on the gaskets.

3. Chemical cleaning – Chemical cleaning by utility personnel is not recommended and should be performed only by experienced personnel. Table 11-1 describes the types of chemicals suitable for cleaning various types of fouling if this option is taken by the owner.

Table 11-1
Chemical Cleaning of Plate Heat Exchangers

	Type of Fouling			
Chemical Cleaning Compound	Incrustation and Scaling	Sediment	Gross Fouling	Biological Growth - Slime
Nitric Acid	X	X		X
Sulfamic Acid	X	X		X
Citric Acid	X	X		X
Phosphoric Acid	X	X		X
Complexing Agents (EDTA, NTA)	X	X		X
Sodium Polyphosphates	X	X		X

Under no circumstances should hydrochloric acid be used with stainless steel plates, and under no circumstances should hydrofluoric acid be used with titanium plates. Water of more than 300 ppm chlorine may not be used for the preparation of cleaning solutions. It is very important for carrying bars and support columns made of aluminum to be protected against chemicals. The addition of surfactants can improve the cleaning effect on the sedimentary type of fouling. Maximum concentrations should not exceed 4% by weight, and maximum temperatures should not exceed 140ºF (60ºC).

11.2.3 Replacing Gaskets

Gaskets can be attached by mechanical means or by glue. Mechanical methods of attachment allow easy on-site replacement of a gasket by the maintenance crew. However, debris can be caught behind the gasket and cause leaks upon reassembly. Mechanical methods of gasket attachment are best used when both fluids are clean, the unit will not be opened for many years, or gaskets are slated for replacement during the time that the unit will be opened.

For most power plant applications, it should not be necessary to replace gaskets often, and certainly not each time the unit is cleaned or opened for inspection. The need to replace gaskets may be based on service life, compression set, loss of physical properties of the gaskets, and allowable leakage, but it should be based primarily on the manufacturer's recommendations.

Service water plate heat exchangers will typically need cleaning, and gaskets normally last a long time; thus, a glued system that does not break down should be used. If the glue breaks down, the gaskets will fall off the plates at random spots, and debris may get underneath. Field repairs of glued gaskets are not recommended; the plates should be replaced, and the failed gasket should be returned to the manufacturer for regasketing.

Regasketing can be performed on either the gluefree design or the glued-gasket configuration. The gluefree design uses a clip-on type of gasket, one example of which is illustrated in its unattached configuration in Figure 11-3.

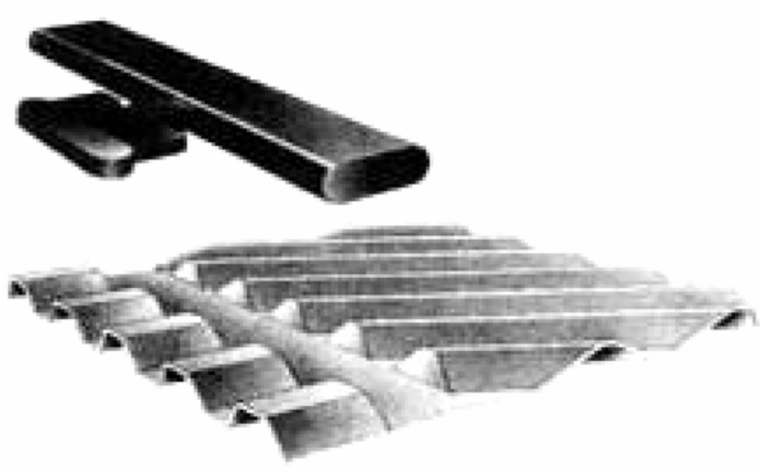

Figure 11-3
Clip-On Gasket in a Gluefree System

The clip-on gasket is attached to the plate by two gasket prongs, which slip under the edge of the plate to hold the gasket securely in alignment in the gasket groove. The prongs are shown on the gasket positioned above the plate on Figure 11-3. The prongs are situated at regular intervals around the periphery of the plate. When the plate heat exchanger is assembled and tightened, the gasket provides a tight seal around the plate, as shown in Figure 11-4.

Figure 11-4
Properly Installed Clip-On Gasket

Regasketing of mechanically attached or gluefree gaskets can also be performed in the field, using the recommended preparatory and installation guidance provided by each plate heat exchanger manufacturer. Figure 11-5 provides another example of how a gluefree-type gasket can be pressed into place to form an appropriate seal between heat transfer plates.

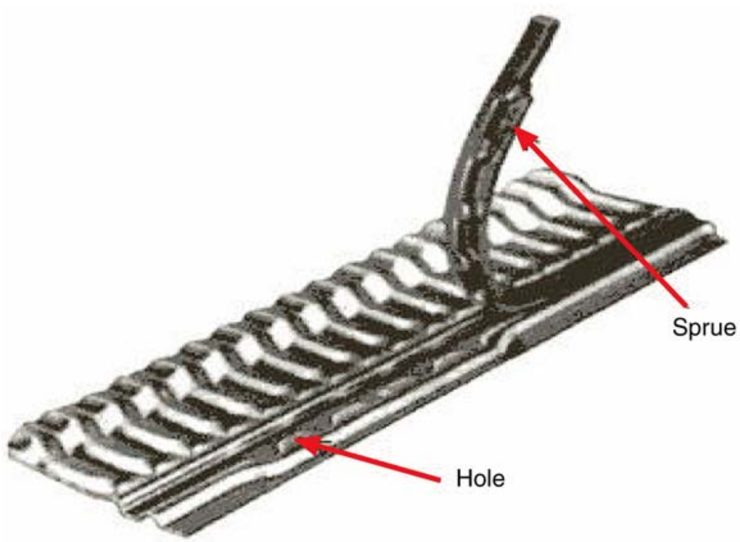

Figure 11-5
Press-In Gluefree Gasket

11.3 Determining Critical Spares

As noted earlier, it is often beneficial to consider a maintenance strategy during the design of the replacement plate heat exchanger. Subsequently, the project team should consider establishing with potential suppliers the scope of spare and replacement parts necessary to execute the anticipated maintenance, as well as the frequency with which those items should be made available.

Typically, there are no spare parts required for a plate heat exchanger. The actual number of spare parts should be based on each owner's experience, the perceived criticality of the item, and the system applications. On a two-year operational cycle, typical spare and replacement items for a plate heat exchanger include the following items:

- Spare heat transfer plate pack – If the plate heat exchanger is to be reconditioned frequently, a spare plate pack (which normally includes glued gaskets) is recommended. The spare plate pack can replace the dirty plates that will be removed from the plate heat exchanger and sent for reconditioning. If there are a number of units of the same model, the spare plate pack should be of the maximum number of plates.
- Spare heat transfer plates and end plates – It is normally recommended to store 10% of the heat transfer plates in a plate pack as spare plates and a few end plates. As noted, the heat transfer plate will normally include the glued gasket.
- Mechanically-attached gaskets and liners – If the gaskets will be used within five years from the date of manufacture, it is recommended that 10% of the complete gasket set be kept as spares. If not, 5% of the total number of flow gaskets is usually sufficient. It is also prudent to maintain one end gasket as a critical spare.
- Bolts, nuts, and washers – If the unit is opened frequently, a few spare bolts, nuts, and washers are recommended

During the design and prior to the procurement of the replacement plate heat exchanger, consideration should be given to establishing ways to proactively obtain from potential suppliers certain design information such as materials, dimensions, tolerances, etc., of certain spare and replacements parts. Having this part-level information provided during the procurement of the component will make acceptance of these items in the future easier and with less engineering involvement.

Care should be taken to ensure that the manufacturer's recommendations for shelf life are considered for replacement gaskets. EPRI report TR-107191, *Packaging, Shipping, Storage and Handling Guidelines for Nuclear Power Plants*, [9] provides additional guidance, which should be considered for long-term storage of the items listed above.

11.4 Establishing Condition Monitoring Requirements

The project team should research the EPRI Preventive Maintenance Database to determine if condition monitoring guidance has been developed by EPRI for the replacement component. As part of EPRI's EPRI PM Basis Database program, there is an ongoing effort to develop templates as an addendum to the Preventive Maintenance Basis. EPRI report 1000621, *Equipment Condition Monitoring Templates: Addendum to the Preventive Maintenance Basis, TR-106857 (Volumes 1-38)*, [11] provides detailed guidance.

Additional sources of information that may be considered when establishing condition monitoring requirements for the replacement component are the following EPRI reports:

- *End-Use Performance Monitoring Handbook*, TR-106960 [12]
- *Equipment Condition Assessment: Application of On-Line Monitoring Technology*, 1003695 [13]
- *Guideline for System Monitoring by System Engineers*, TR-107668 [14]
- *SysMon 2.0 User's Guide: System Monitoring by System Engineers*, *37 System Templates*, 1000260 [15]
- *System Monitoring and Reporting Tool (SMART) Study: Generic Application Evaluation*, 1002964 [16]
- *System Monitoring by System Engineers: 37 System Monitoring Plans*, TR-107434 [17]

Specific to plate heat exchangers, the owner should monitor both the temperature, pressure drop, and flow conditions. Changes in these operating parameters can be used to indicate growth or fouling within the flow path or on the heat transfer plates. Loss of chemical or bio-fouling control may warrant additional monitoring of the plate heat exchanger performance parameters.

11.5 Modifications to the Plate Heat Exchanger

Permanent addition or removal of heat transfer plates should not be performed without having conducted an engineering evaluation to ensure that the resulting configuration continues to perform within system design basis requirements. It may be beneficial during the design modification to install the replacement plate heat exchanger, to also determine the system margin, and subsequently determine if there is any possibility of operating the unit with less than the initial number of plates provided by the manufacturer.

12
DISPOSAL OF THE REPLACED HEAT EXCHANGER

When a major plant component such as a heat exchanger is replaced, much of the technical focus is often on selecting a suitable replacement, procuring the item, and ensuring that it performs in accordance with its design. However, a key phase of any replacement project is the disposal of the old component after it is removed from the plant. In many cases, the old heat exchanger cannot be moved in one piece due to its physical size. In other cases, the aged equipment is contaminated with radiation and must be handled appropriately.

The project team should develop a way to safely and cost-effectively dispose of the replaced heat exchanger. The factors listed below should be considered as early in the design and procurement processes as feasible to ensure that the necessary personnel, tools, permits, and resources are available to properly dispose of the old shell and tube heat exchanger after it is removed from service.

12.1 Disposal Facility Capabilities

In parallel with the specification and design of the replacement heat exchanger, the project team should study feasible ways to dispose of the replaced equipment and determine the capabilities of the disposal facility and organization. During this evaluation, the project team should consider the following:

- Removal from site
- Interface with contracted demolition work
- Transportation capabilities
- Decontamination
- Storage
- Salvaging

12.2 Decontamination vs. Long-Term Storage

The project team should evaluate whether to decontaminate the replaced heat exchanger or place it in long-term storage. To assist in this evaluation, the project team should consider the following EPRI reports:

- *Advanced Volume Reduction and Waste Segregation Strategies for Low-Level Waste Disposal*, 1003436 [18]
- *Decontamination of Reactor Systems and Contaminated Components for Disposal or Refurbishment: Developments and Experience with the EPRI DFD Chemical Decontamination Process*, 1003026 [19]
- *Environmental Settings and Solid-Residues Disposal in the Electric Utility Industry*, EA-3681 [20]
- *Low Level Waste Inventory Management Program for Storage and Disposal: Source Dk 1.0 -- Software Description and User's Manual*, TR-103810 [21]

12.3 General Environmental Concerns

The project team should consider general environmental concerns when planning for the safe disposal of the removed heat exchanger and any auxiliary equipment. These concerns may include the following:

- Hazardous chemicals and materials – Some debris resulting from raw water may be categorized as hazardous waste.
- Radioactivity
- State and local permits
- State and local environmental impact studies and statements

12.4 Opportunity to Refurbish/Salvage Replaced Component

The project team should determine if there are opportunities to refurbish the replaced heat exchanger and use it in another plant application, although this is usually not a feasible option for a piece of equipment as large as a shell and tube heat exchanger. In some cases, the replaced heat exchanger can be salvaged and/or sold to an interested third party. The engineering organization is not normally responsible for making these decisions, but may be solicited for input.

Salvaging and reselling parts of the heat exchange is very important, considering the significant amount of nickel and copper typically contained in a shell and tube heat exchanger.

12.5 Shipping and Handling Issues of Contaminated Equipment

If the replaced heat exchanger will be shipped off-site and it is radioactive, the project team should consider requirements for special shipping and handling. Care should be taken to ensure that all federal, state, and local regulations are studied and met by the project team prior to moving the equipment off-site.

13 REFERENCES

13.1 In-Text References

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2. *Guidelines for the Utilization of Commercial Grade Items in Nuclear Safety Related Applications.* EPRI, Palo Alto, CA: 1988. NP-5652.

3. ANSI N45.2, "Quality Assurance Program Requirements for Nuclear Power Plants."

4. *Guidelines for Reverse Engineering at Nuclear Power Plants.* EPRI, Palo Alto, CA: 1998. TR-107372.

5. *Guidelines for Technical Evaluation of Replacement Items in Nuclear Power Plants, Revision 1.* EPRI, Palo Alto, CA: 2004. 1008256.

6. NRC Generic Letter 89-09, "ASME Section III Component Replacements."

7. 10CFR50 Appendix B, *Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Facilities*, Office of the Federal Register, National Archives and Records Administration, U.S. Government Printing Office, Washington, D.C.

8. *Lifting, Rigging, and Small Hoist Usage Program Guide.* EPRI, Palo Alto, CA: 2003. 1007914.

9. *Packaging, Shipping, Storage and Handling Guidelines for Nuclear Power Plants.* EPRI, Palo Alto, CA: 1997. TR-107101.

10. *Guidance for Developing and Implementing an On-Line Maintenance Strategy*. EPRI, Palo Alto, CA: 2004. 1009708.

11. *Equipment Condition Monitoring Templates: Addendum to the Preventive Maintenance Basis, TR-106857 (Volumes 1-38).* EPRI, Palo Alto, CA: 2000. 1000621.

12. *End-Use Performance Monitoring Handbook.* EPRI, Palo Alto, CA: 1996. TR-106960.

13. *Equipment Condition Assessment: Application of On-Line Monitoring Technology*. EPRI, Palo Alto, CA: 2004. 1003695.

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16. *System Monitoring and Reporting Tool (SMART) Study: Generic Application Evaluation*. EPRI, Palo Alto, CA: 2001. 1002964.

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19. *Decontamination of Reactor Systems and Contaminated Components for Disposal or Refurbishment: Developments and Experience with the EPRI DFD Chemical Decontamination Process*. EPRI, Palo Alto, CA: 2001. 1003026.

20. *Environmental Settings and Solid-Residues Disposal in the Electric Utility Industry*. EPRI, Palo Alto, CA: 1984. EA-3681.

21. *Low Level Waste Inventory Management Program for Storage and Disposal: Source Dk 1.0 -- Software Description and User's Manual*. EPRI, Palo Alto, CA: 1994. TR-103810.

13.2 Other References

10CFR21, Revision 2, *Reporting of Defects and Noncompliances*, 1995, Office of the Federal Register, National Archives and Records Administration, U.S. Government Printing Office, Washington, D.C.

10CFR50.2, *Definitions*, Office of the Federal Register, National Archives and Records Administration, U.S. Government Printing Office, Washington, D.C.

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AP-913, Equipment Reliability Process Description (Revision 1), Institute of Nuclear Power Operations, Atlanta, GA: November 2003.

API 662/ISO 15547, Plate Type Heat Exchangers, American Petroleum Institute, Washington, DC: 2000.

APV Heat Transfer Handbook, APV North America – Heat Transfer Products, Tonawanda, NY.

APV Plate Heat Exchangers for the Power Industry, APV North America – Heat Transfer Products, Getzville, NY.

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IEEE Std 344-1987, Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations, IEEE, Piscataway, NJ.

NRC Generic Letter 89-02, “Actions To Improve the Detection of Counterfeit and Fraudulently Marketed Products,” March 1989.

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NRC Generic Letter 89-13, Service Water System Problems Affecting Safety-Related Equipment.

NRC Generic Letter 91-05, “Licensee Commercial Grade Procurement and Dedication Programs,” April 1991.

NRC Regulatory Guide 1.100, March 1976, Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants.

Plate Heat Exchanger Operational and Maintenance Manual, Alfa Laval, Inc.,

Plate Heat Exchanger Specification, Alfa Laval Thermal, Inc., 1997.

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Specification for Plate and Frame Heat Exchangers, APV North America – Heat Transfer Products, Tonawanda, NY, 2003.

Supplemental Guidance for the Application of EPRI Report NP-5652 on Commercial Grade Items. EPRI, Palo Alto, CA: 1994. TR-102260.

A
EXAMPLE OF A TYPICAL BID SPECIFICATION

This appendix provides an example of a typical bid specification for the type of plate heat exchanger applicable for use in a nuclear power plant. This specification is provided solely for illustrative purposes and should not be used by the licensee without ensuring that each requirement meets the design parameters for their intended plant-specific application.

This example does not include any of the commercial terms and conditions, schedule requirements, and other administrative requirements that may need to be communicated to prospective bidders. Guidance on developing a complete bid specification is provided in Section 4. The term *shall* is used in this example only for illustrative purposes and does not imply that each requirement is applicable in every procurement scenario.

Development of this example was made possible using technical input that was provided courtesy of Alfa Laval, Inc. and APV North America – Heat Transfer Products.

1.0 General

1.1 This specification covers the design, fabrication, and performance of plate heat exchangers.

1.2 Plates shall not be subcontracted or purchased for resale.

1.3 The plate heat exchanger manufacturer shall have an established and on-going Quality Assurance and Quality Control program. Manuals of these programs shall be available for inspection at the plant. (**Note:** The scope and type of quality assurance programs will vary among suppliers and may change over time.)

1.4 Any exceptions to this specification shall be documented by the supplier, as well as their means for meeting the intent or basis of the specification.

2.0 Applicable Codes and Standards

2.1 10CFR21

2.2 10CFR50, Appendix B Quality Assurance requirements

2.3 ASME Section II - Material Specification

2.4 ASME Section III

2.5 ASME Section V - Non-Destructive Testing

2.6 ASME Section VIII - Pressure Vessel Code

2.7 ASME Section IX - Welding Qualifications

2.8 ANSI Section B16.5 - Flanged Fittings

Additional codes and standards may be needed, depending on the system application and whether the plate heat exchanger will be installed in a safety-related application or if it must operate during and after design basis accidents.

3.0 Certification

1.1 The plate heat exchangers shall be designed, fabricated, and tested in accordance with the requirements of Section VIII, Division 1 of ASME Code and shall bear a permanently affixed nameplate with the appropriate code stamp and National Board Registration Number. Canadian Registration Numbers (CRN) are required for all vessels with Canadian destinations.

Depending on each owner's licensing commitments, the plate heat exchanger may be required to meet ASME Section III or other codes and standards as noted above.

4.0 Frame Construction and Requirements

4.1 Preference will be given to a single pass design with all the connections located on the frame plate.

4.2 The frame plate and pressure plate shall be constructed of carbon steel (ASTM Type A516, Grade 70 is typically furnished) in sufficient uniform thickness and strength to operate within the designated design and test pressures. Design strength calculations are to be submitted at the engineer's request. Welded reinforcements or stiffeners are prohibited.

Note: Other frame plate and pressure plate materials are available if required by the owner's specific application.

4.3 The pressure plate shall be provided with a bearing-supported roller assembly for units greater than 36 in. (91 cm) in height, measured from the floor to the top of the unit. The roller assembly allows the follower to slide more easily when opening or closing the unit.

4.4 The top and bottom carrying bars and tightening bolts shall be designed to allow for at least a 20% expansion of the heat transfer plate pack, while still providing maintenance space.

4.5 The heat exchanger frame shall be bolted together to permit easy replacement of top and bottom carrying bars for expansion beyond the original frame size supplied. Welded construction of the carrying bar to the frame assembly is prohibited.

4.6 The top and bottom carrying bars shall have a smooth finished surface where the heat transfer plates come in contact with the bars. The surfaces of the carrying and guide bars that come into contact with the plates shall be stainless steel. All carbon steel frame components (except bolts) shall be painted or zinc plated.

4.7 The design of the plate heat exchanger (plate and carrying bar design) shall permit the removal of any plate in the plate pack without the need to remove any other plates.

4.8 Frame tightening bolts shall be constructed of ASTM A193 B7 carbon steel with ASTM A194 2H carbon steel nuts and shall be mechanically retained to prevent accidental side removal. The design shall be such that there is positive tie bar retention within the frame without having to completely disassemble the tightening bolts to remove the plates. The bolting system shall be designed such that only four tightening bolts are required for 80% of the pressure plate travel during opening and closing of the unit. This is required to minimize maintenance downtime.

4.9 Tightening bolts shall be equipped with a captive nut at the head (fixed cover). Tightening bolts shall be equipped with either keyed working nuts or threaded nuts at the follower (movable cover) to allow for easy opening and closing of the unit. Welding of the nuts to the tightening bolts is prohibited. Tightening bolts shall be coated with a rust-preventive lubricant. Tightening bolts shall be equipped with lock-washers at the moveable cover to facilitate opening and closing of the unit from the fixed cover. In addition, a protective sleeve shall be installed on all exposed threads.

(**Note:** As an option, the owner may consider requesting bearing box washers equipped at the fixed cover on all units greater than 50 in. (1.3 m) in height.)

4.10 The plate pack shall be covered with a shroud.

(**Note:** The shroud is usually constructed of aluminum or stainless steel and is typically required to meet OSHA standards.)

4.11 The plate heat exchanger shall be supplied with lifting holes or devices, as required, to facilitate the safe movement of the unit. Lifting devices shall be supplied on all units with 6 in. (15.2 cm) ports or larger. Together, these shall be designed to support one and a half times the unit’s weight. Instructions for lifting shall be clearly visible on the unit.

4.12 Plate alignment shall be maintained mechanically through the use of the top and bottom carrying bars to minimize horizontal (perpendicular to carrying bar) and vertical movement of the plates. This alignment system shall be built into the carrying and guide bars as well as pressed into the plate pattern.

(**Note:** Other alignment systems are often available. For example, the gasket design may include raised lugs that interlock in a tongue and groove fashion to further prevent plate movement during exchanger tightening and ensure alignment of sealing surfaces.)

4.13 All exposed frame parts shall be surface prepared to an SSPC SP-6 commercial grade finish, and receive a prime coat of a polyurethane primer and a finish coat of polyurethane paint to a total dry film thickness between 3 and 6 mils (0.08 and 0.15 mm).

(**Note**: Coatings standards will most likely vary among manufacturers, and the owner's coating requirements may supersede those of the manufacturer.)

5.0 Connections

5.1 Connections equal to or less than 2 in. (5.1 cm) shall be NPT (threaded) type.

(**Note:** NPT type connections may not be appropriate for some service applications such as service water or corrosive fluids.)

5.2 All plate type heat exchangers with connections greater than 2 in. (5.1 cm) shall be equipped with either studded connections or lap joint flanged nozzle connections.

5.3 For studded units, each connection shall be equipped with a liner that prevents the process fluids from coming in contact with the head and follower. The liner shall be fabricated from materials compatible with the process fluids being handled.

5.4 If flanged connections are required, they shall comply with the following:

- Spool piece designs shall allow for a minimum projection of 1 ft (30.5 cm).
- Flange ratings and facings shall comply with ANSI B16.5 requirements.
- Pad-type built-up nozzles with studs tapped into the flange are not permitted.
- Nozzle necks shall be fabricated from materials that are compatible with the process fluids unless a lined neck is specified.

6.0 Heat Transfer Plates

6.1 Only heat transfer plates pressed from a homogeneous single sheet of metal in one step shall be used. No multistage pressing of one sheet is allowed. Plate inspection shall be performed during production to ensure uniformity of pressing depth and absence of defects.

6.2 All plates and gaskets shall be permanently marked (typically on the outer edge) to identify the material, thickness, raw plate supplier and heat numbers (traceability) and quality associated with its manufacture. In addition, each plate should be identified to ensure its proper location within the plate pack.

6.3 The plates shall be of herringbone (chevron) pattern to provide the highest possible heat transfer.

(**Note:** Manufacturers should be given the latitude to offer variations of the chevron pattern geometry and gaps depending on the plant-specific application.)

6.4 All plates shall have metal-to-metal contact between the plates to permit high-pressure differentials, including contact points around the plate perimeter to prevent plate deformation and gasket blowout and to ensure structural integrity and elimination of vibration.

6.5 Plates shall have an appropriate thickness such that the plate can withstand the maximum operating pressure with no pressure on the adjacent plates (full differential pressure) or result in loss of material strength. Similarly, each plate channel shall be designed to withstand the design pressure with no pressure on the adjacent plate channels (full differential pressure).

(**Note:** As of the publication date of this report, the typical minimum plate thickness was 0.016 inches (0.4 mm).)

6.6 Each plate shall have adequate reinforcement to reduce deformation when plates are slid along the top and bottom carrying bars.

(**Note:** Examples may include a rolled edge integral hanging eye or welded reinforcement.)

6.7 No welded reinforcing strips are allowed on the heat transfer plate in the wetted area.

6.8 Gasket grooves in the plate shall be designed to retain the gaskets, but allow for thermal expansion.

6.9 The gasket groove shall provide 100% support of the gasket periphery. No part of the gasket should be unsupported or exposed to guard against gasket blowout.

6.10 Heat transfer end plates shall be provided and sufficiently gasketed at the fixed and moveable covers to prevent hot and cold medium from coming in contact with these covers.

7.0 Gaskets

7.1 Gaskets shall be of a one-piece molded design. Gaskets shall be fully contained between plate gasket channels to prevent the gasket from being forced out of the channel under operating pressure. Gaskets shall be designed to prevent intermixing of fluids and to prevent any leak from being visually evident at the external surface of the plate pack.

Mixing of gasket materials within fully gasketed units is not permitted.

7.2 Inactive port gasket areas shall be vented to the exterior in such a manner that no mixing can occur between the fluid circuits.

7.3 No special tools shall be required to attach the gasket. All gaskets shall be identical except the end plate gasket between the end plate and the frame.

(**Note:** The owner should indicate whether glued gaskets are needed for their plant-specific application.)

7.4 If glue is used to hold the gasket on the plate, it shall be compatible with the gasket material and the process fluids being handled. Glued gaskets must be heat-cured to ensure that they are properly bonded to the plate.

(**Note:** A common adhesive is a two-component epoxy glue that has been heat-cured.)

8.0 Design Requirements

8.1 Heat exchanger performance and design shall be in accordance with an attached data sheet (Refer to Appendix B for an example). All performance calculations must include an appropriate allowance for fouling. Calculated heat transfer coefficients, with and without the additional fouling surface, must be indicated on the manufacturer's submitted computer performance calculation data sheets.

(**Note:** A typical fouling allowance for a plate heat exchanger is 10% excess surface area. Specification of excessive fouling factors should be avoided.)

8.2 The design of the unit shall not use more than 40% of the allowed pressure drop in the ports and port entry area.

8.3 Pressure drops, in pounds per square inch (or kilopascals), across each circuit of the plate heat exchanger shall not exceed those noted on the attached data sheet.

8.4 The vendor shall indicate on their data sheets the port velocities for each liquid being handled in the plate heat exchanger.

(**Note:** Port velocity limitations are dependent on the fluid composition, port dimensions and configuration, and the materials selected. In most cases, the port velocities should not exceed 22 feet per second (6.7 meters per second).)

9.0 Testing and Certification

9.1 All factory hydrostatic testing of the plate heat exchanger is to be scheduled in conjunction with the engineer to determine if a representative should be present.

(**Note:** The plate heat exchanger shall be tested to a test pressure in accordance with the applicable code. The hydrostatic test shall be in accordance with the design code. The plate heat exchanger shall be stamped in accordance with the code specified.)

9.2 The hydrostatic test water should not have a chloride content that exceeds 50 ppm and should be completely drained prior to shipment.

9.3 The plate heat exchanger manufacturer is required to make factory representation available if field thermal and/or pressure testing is required.

9.4 If field testing of the heat exchanger fails to meet the performance requirements of the contract documents, the manufacturer shall be responsible for whatever additions, modifications, or replacements and re-testing that may be necessary to provide a plate heat exchanger that fully conforms to the specified requirements.

10.0 Preparation for Shipment

10.1 The plate heat exchanger shall be shipped to the site as completely assembled units, if possible, or in modular sections, as deemed necessary by the owner.

10.2 The plate heat exchanger shall be pressure tested and flushed clean at the factory prior to shipment. All nozzle connections shall be factory sealed to prevent the entrance of foreign matter into the heat exchangers during shipment, storage, and installation.

10.3 A nameplate shall be securely attached to the plate heat exchanger in a location that is easily accessible and visible after installation. The vessel identification number along with other pertinent design details shall be on the nameplate.

10.4 Port locations shall be clearly marked and correspond with the certified vendor drawings.

11.0 System Design Requirements

4. Guidance regarding the scope of system design requirements specified is provided in Section 4.1 and Appendix B.

B

EXAMPLE OF A TYPICAL DATA SHEET

This appendix provides an example of a data sheet typical for a plate heat exchanger, which is based on data sheets contained in API 662/ISO 15547, "Plate Type Heat Exchangers." The example below has been modified somewhat to make it more relevant to the user of this report. Information noted with an asterisk (*) indicates data typically furnished by the manufacturer when the project's specification has been confirmed.

Prepared by:		Job No:*	
Customer:		Ref. No:*	
Address:		Proposal No:*	
Plant Location:		Date:	Rev:
System Operating Mode:		Item No:	
Model Number:*		Connected In: Parallel Series	
Area Per Unit:*	(m^2)	Frames/Unit:*	Area/Frame:* m^2

Performance for One Unit

		Hot Side		Cold Side	
Fluid Allocation:					
Fluid Name:					
		Inlet	Outlet	Inlet	Outlet
Total Fluid Flow:	Kg/s				
Noncondensables:	Kg/s				
Temperature:	ºC				
Density:	Kg/m^3				
Specific Heat:	kJ/kg ºC				
Thermal Conductivity:	W/m ºC				
Viscosity:	MPa s				
Overall Fouling Allowance:	% Excess Area				
Wall Shear Stress:*	KPa/Velocity (mps)	/		/	
Inlet Pressure:	kPa	/		/	

Pressure Drop Allowed:	kPa	/	/
Pressure Drop Calculated:*	kPa	/	/
Design/Test Pressure:	kPa	/	/
Design/MDMT Temperature:	ºC	/	/
No. Passes/No. Channels Per Pass:*		/	/
Total No. of Plates:*		Plate Chevron Angle(s):*	
Plate Thickness:*	mm	Nominal Plate Gap:*	mm
Heat Exchanged:	W		
LMTD:*	ºC	Corrected LMTD:*	ºC
Transfer Rate:*	W/m^2 ºC, Clean	Service: (1)	

Materials of Construction				
Fixed and Movable Covers:	Plates:			
Tie Bolts:	Gaskets:			
Shroud:	Connections:			
Gasket Type: Glued Gluefree				
Sizes and Weights				
Connections Size, Rating, & Facing	Hot Side		Cold Side	
Inlet Size:*				
Outlet Size:*				
Code Requirements:				
Frame Size:* (LxWxH) mm	Max. Plate Capacity:*			
Unit Weights*, Dry: Kg	Filled with Water: Kg			
Remarks: (1) Indicate need for seismic and/or environmental qualification (2) State whether studded or flanged Other				
Nozzle Sketch(es), if appropriate:				

Note: SI (metric) units are shown on this data sheet for illustrative purposes only and may be replaced with English units, depending on the convention used by the plate heat exchanger manufacturer.

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