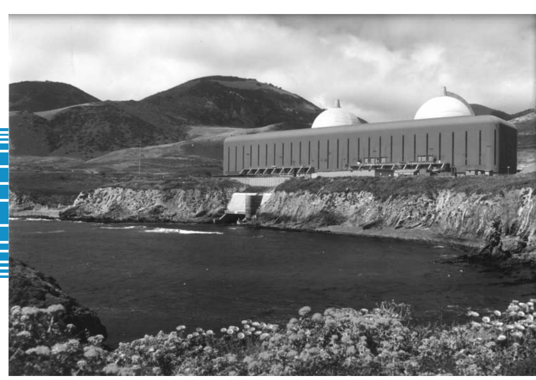
EHC Tubing/Fittings and Air Piping Application and Maintenance Guide

Technical Report

Plant Maintenance Support

Reduced Cost

Equipment Reliability



NMAC

EHC Tubing/Fittings and Air Piping Application and Maintenance Guide

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Final Report, October 2000

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REPORT SUMMARY

The tubing and fittings of electrohydraulic controls (EHC) and the air piping in steam turbines have been a cause of plant trips, load reductions, and maintenance problems. This guide provides information and recommendations to improve the reliability of these components in the EHC and compressed air systems.

Background
Problems with cracked tubing, loose or broken fittings, and damaged air piping continue to cause lost generation and high maintenance costs.

Objectives
- To identify system causes of tubing, fitting, and air piping failures
- To recommend maintenance practices that will improve the reliability of tubing, fittings, and air piping

Approach
A literature search in the area of EHC and air piping systems was performed on industry standards, previously written EPRI guidelines, industry guidelines, and general industry experience and compiled for this guide. Recent failure data from the nuclear industry was also gathered and summarized here. The project team consisted of a principal author, EPRI project manager, and six utility engineers/managers.

Results
This guide provides information on tubing and fittings in the EHC and air piping systems. This information can be used by utilities to identify causes of failures and implement maintenance practices that will improve the reliability of the components.

EPRI Perspective
In nuclear steam turbines, problems occur with tubing and fittings in the EHC and air piping systems. The failure of these components results in lost generation. This guide identifies the causes of the failures and gives acceptable industry practices and guidelines for correcting the problems. This information should greatly improve the reliability of tubing, fittings, and air piping components.

Keywords
EHC
DEH
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Air piping

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ABSTRACT

Electrohydraulic control (EHC) and compressed air systems in nuclear steam turbines have tubing, fittings, and air piping associated with their hydraulic and pneumatic components. The tubing, fittings, and air piping may crack, leak, and/or fail over time because of hydraulic fluid/water contamination, vibration on the system, poor maintenance practices with material selection, and incorrect O-ring or coupling installations. This guide documents acceptable industry practices and guidelines, based on the experience of electric utilities and related industries, that will improve the reliability of these components.

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1 INTRODUCTION

1.1 Organization

The tubing and fittings of steam turbine electrohydraulic control (EHC) systems and the air piping in compressed air systems have been a cause of plant trips, load reductions, and maintenance problems. The Nuclear Maintenance Applications Center (NMAC) sponsored the development of this guide to provide information and recommendations to improve reliability of these components.

Research was conducted to assemble existing failure information on the EHC and compressed air systems. Several EPRI guides were reviewed, and parts of the following guides were used in this report:

- *Compressor and Instrument Air System Maintenance Guide*, March 1998, TR-108147
- *General Electric Electrohydraulic Controls (EHC) Electronics Maintenance Guide*, December 1997, TR-108146
- *Introduction to Nuclear Plant Steam Turbine Control Systems*, May 1995, TR-104885
- *Preventive Maintenance Basis, Volume 37*, November 1998, TR-106857-V37
- *Static Seals Maintenance Guide*, December 1994, TR-104749
- *Steam Turbine Hydraulic Control System Maintenance Guide*, December 1996, TR-107069

Information from the Institute of Nuclear Power Operations (INPO) was solicited and evaluated. Industry literature was researched in the area of EHC hydraulic fluid. Vendor literature was reviewed for tubing and fitting applications. Numerous standards were reviewed for material and fabrication guidelines. Original equipment manufacturer (OEM) technical information was reviewed for the turbine EHC system. Literature from other industries, such as airlines and the military, was reviewed for applicable information relative to this guide.

A utility Technical Advisory Group (TAG) was formed to review the drafts of the guide.

The guide is organized into the following sections:

- Section 1, Introduction, covers the guide organization, industry failure data for EHC hydraulic systems, and industry failure data for compressed air systems.
- Section 2, Control System Operation, covers a general EHC system description, EHC system parameters, and the compressed air system.

- Section 3, Material Selection, includes the EHC system and the compressed air system piping. The EHC system covers the tubing material, flexible hoses, fittings, port connections, and elastomers.
- Section 4, Layout and Installation, covers the EHC hydraulic tubing installation factors, EHC fitting installation factors, EHC fitting assembly procedures, EHC port assembly procedures, hydraulic hose installation factors, miscellaneous notes, and compressed air system piping installation factors.
- Section 5, Preventive/Predictive Maintenance, covers EHC failure causes, an EHC PM template, and compressed air system piping inspections.
- Section 6, Troubleshooting Guidelines, covers EHC fittings, EHC port connections, and compressed air system piping.
- Section 7, Safety Guidelines, covers the EHC fluid MSDS and general safety guidelines.
- Section 8, References, includes codes and standards, EPRI literature, General Electric literature, Westinghouse literature, vendor literature, and industry information.
- Section 9, Acronyms and Abbreviations, includes industry terms and acronyms used in the guide.
- Appendix A includes a list of General Electric and Westinghouse hydraulic-related bulletins.
- Appendix B contains responses from nuclear plants concerning their modifications for vibration in EHC systems.
- Appendix C, Pop Out Summary, includes a list of key human performance, O&M cost, and technical points shown in this guide.

1.2 Pop Outs

Throughout this guide, key information is summarized in “Pop Outs.” Pop Outs are bold lettered boxes which succinctly restate information covered in detail in the surrounding text, making the key point easier to locate.

The primary intent of a Pop Out is to emphasize information that will allow individuals to take action for the benefit of their plant. The information included in these Pop Outs was selected by NMAC personnel and the consultants and utility personnel who prepared and reviewed this guide.

The Pop Outs are organized according to three categories: O&M Costs, Technical, and Human Performance. Each category has an identifying icon, as shown below, to draw attention to it when quickly reviewing the guide.

Key O&M Cost Point

Emphasizes information that will result in reduced purchase, operating, or maintenance costs.

Key Technical Point

Targets information that will lead to improved equipment reliability.

Key Human Performance Point

Denotes information that requires personnel action or consideration in order to prevent injury or damage or ease completion of the task.

Appendix C contains a listing of all key points in each category. The listing restates each key point and provides reference to its location in the body of the report. By reviewing this listing, users of this guide can determine if they have taken advantage of key information that the writers of the guide believe would benefit their plants.

1.3 Industry Failure Data for EHC Hydraulic Systems

A search was conducted in the utility databases for the history of EHC problems in nuclear turbines. Data were collected from the Institute of Nuclear Power Operations (INPO) web site and from previous studies from EPRI.

In 1984, INPO found that turbine control and protection system malfunctions were the second leading cause of plant trips. They published Significant Operating Experience Report (SOER) 84-6, “Reactor Trips Caused by Turbine Control and Protection System Failures.” The number of trips attributed to the EHC system in this report are shown in Table 1-1.

Table 1-1
Reactor Trips Resulting from EHC Problems 1978–1983

Year	Number of Trips
1978	33
1979	28
1980	35
1981	31
1982	23
1983	25

Recommendations by INPO to prevent trips included:

- Making the hydraulic portion of the turbine control system part of the station's preventive maintenance program. The PM activities included filter replacement, EHC fluid sampling, and backup pump testing.
- For the EHC system tubing, the tubing supports were recommended for inspection for vibration and for modification to minimize failures due to cyclic fatigue.

These recommendations are significant because these problems still persist in the industry.

A list of events for the General Electric turbine EHC systems from 1985 through 1996 was extracted from the INPO database, the Nuclear Power Reliability Database System (NPRDS) and the Operating Plant Experience Code (OPEC). Additional data were obtained from three sites that gave a total of 570 events for evaluation. When the events were distributed by subsystem, the hydraulic subsystem was responsible for 113 events or 19.8% of the total events. Of these 113 events, 70 events were categorized as "Leaks in Hydraulics." This is 12.3% of the total events analyzed.

In 1997, NMAC sent a survey to the fleet of GE EHC plants and 36 plants responded. From the responses, there was a perception that the dominant problems in EHC systems were with hydraulics. This did not match the number of events from the database studies mentioned above. The database events and questionnaire results can be found in the EPRI report *General Electric Electrohydraulic Controls (EHC) Electronics Maintenance Guide,* TR-108146.

In the EPRI report *Steam Turbine Hydraulic Control System Maintenance Guide,* TR-107069, a review of Licensee Event Reports (LERs) filed with the U.S. Nuclear Regulatory Commission (NRC) was conducted to identify problems related to the hydraulic portion of EHC systems. Approximately 50 automatic or manual reactor trips were found for the period from January 1990 to June 1996. The 50 events were broken down by components and are shown in Figure 1-1.

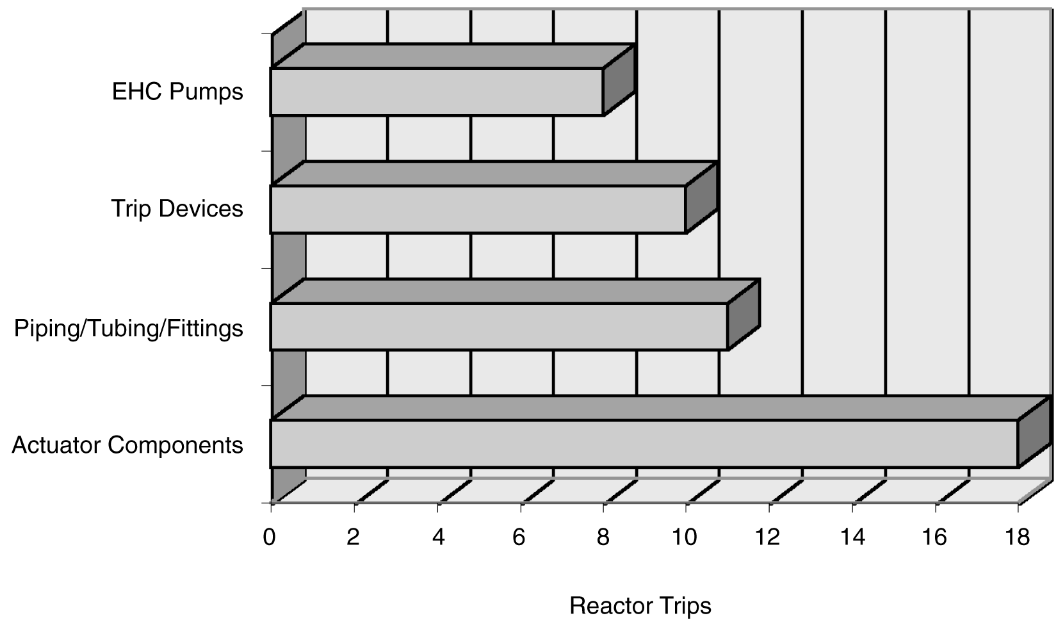


Figure 1-1
EHC Hydraulic-Related Components Involved in Reactor Trips 1990–1996

The causes of these trips are shown in Figure 1-2.

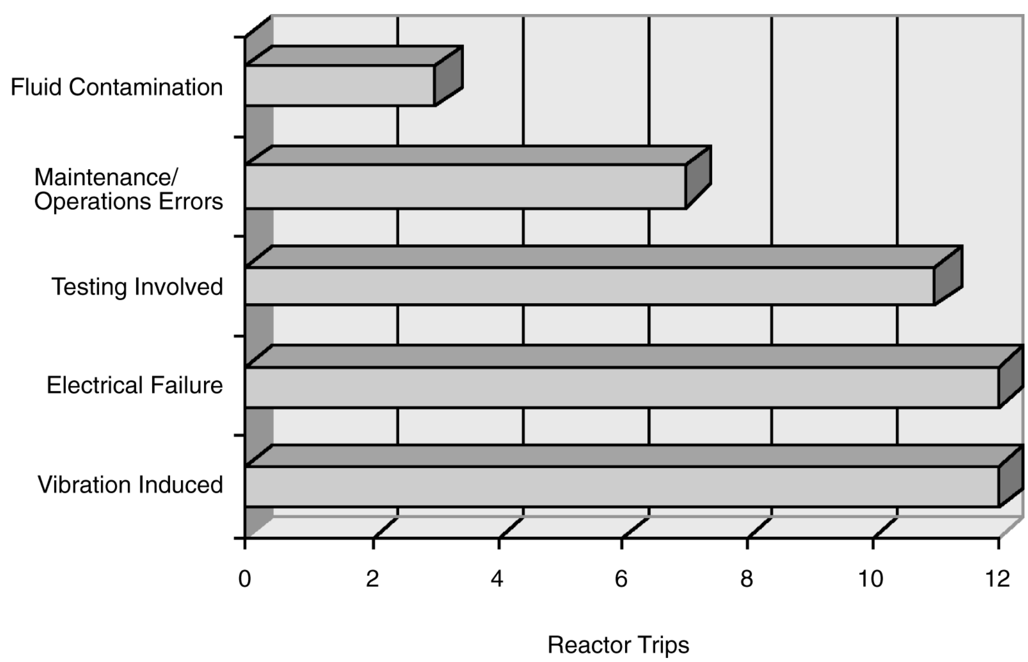


Figure 1-2
EHC Hydraulic-Related Reactor Trip Causes and Contributing Factors 1990–1996 Data

Of the vibration-induced failures, the most commonly occurring were fluid leaks due to cracked or loose piping/tubing, fittings, and plugs. Limit switches were also identified as having vibration-induced failures. When the steam valves were oscillating abnormally, the valve oscillations caused unusual vibration, which induced piping/tubing failures. The maintenance/operations errors included installing the wrong O-rings. The fluid contamination situations included two O-ring problems.

A review of the NPRDS database problem reports is shown in Figure 1-3.

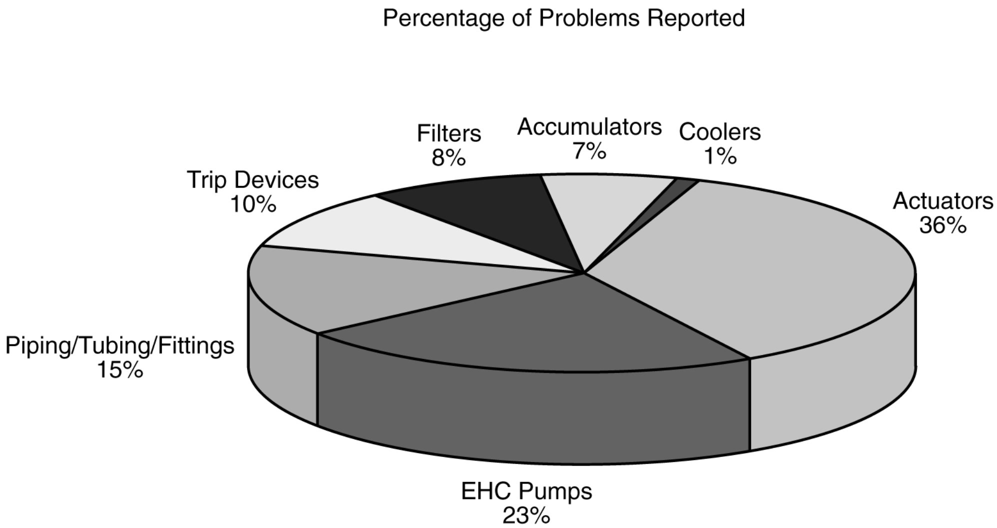


Figure 1-3
NPRDS-Reported EHC Hydraulic-Related Component Problems 1990–1996

The major root causes of the component problems were:

- 20% elastomer failures
- 7% vibration induced
- 6% fluid contamination
- 6% electrical

Several utility report databases on the INPO web site offer recent data on EHC performance. They include the Licensee Event Reports (LERs), Just-In-Time (JIT) Operating Experience, and the Equipment Performance Information Exchange (EPIX) System. The EHC system failures for the 1996–1999 period are shown in Table 1-2. Note that the number of events has decreased significantly from the 1990–1996 data (shown in Figures 1-1 and 1-2). The failed components for these data are shown in Table 1-3.

Table 1-2
EHC System Failures from LERs for 1996–1999

Year	Number of Failures
1996	5
1997	4
1998	3
1999	4
Total	16

Table 1-3
EHC Component Failures from LERs for 1996–1999

Failed Component	Number of Failures
EHC Tubing	3
O-Ring	2
Power Supply, Connector, Fuse	3
Orifice, Seal, Diaphragm, Lever	5
Solenoid, Relay card, Relay	3
Total	16

The JIT Operating Experience database listed four events for inadequate control of EHC maintenance, resulting in-plant transients and leakage of EHC fluid. The events are listed in Table 1-4.

Table 1-4
INPO JIT Events for EHC Maintenance

Date	Failed Component
3/10/94	O-Ring
1/24/97	O-Ring
7/31/98	Tubing
11/24/98	EHC fluid

In the EPIX database, there were three failures for EHC piping, fittings, and rupture discs. These are listed in Table 1-5.

Table 1-5
INPO EPIX Failure Summary for EHC Piping, Fittings, and Rupture Disc

Date	Failed Component
5/30/97	EHC Tubing Leak
3/2/98	EHC Supply Line
8/27/98	EHC Pump Discharge Weld Leak

Although the numbers of plant trips caused by the EHC system have decreased since the late 1970s and early 1980s, there are still unit trips and load reductions occurring due to EHC malfunctions. Specifically, the tubing, fittings, and elastomers in EHC hydraulic systems continue to cause problems.

1.4 Industry Failure Data for Compressed Air Systems

The number of plant trips related to compressed air system air piping is significantly less than EHC system trips. There were only two failures in the last four years attributed to piping/tubing in compressed air systems.

The LERs for instrument air system piping and tubing are shown in Table 1-6.

Table 1-6
LERs for Instrument Air Systems

Date	Failed Component
8/24/88	Air Line Nipple
1/26/93	O-Ring
1/20/96	Piping
2/13/1996	Pneumatic Valve Positioner
4/18/1996	Air Dryer Exhaust Valve
6/3/1996	Ventilation Damper
6/12/1996	Not Available
3/11/1998	Air Tubing
9/20/1998	Valve Solenoid

In the EPIX database, there were three failures for instrument air supply piping, fittings, and rupture discs. These are listed in Table 1-7.

Table 1-7
INPO EPIX Failure Summary for Instrument Air Supply Piping, Fittings, And Rupture Discs

Date	Failed Component
3/26/97	External Leakage
3/27/97	External Leakage
12/8/99	Piping Erosion

A search was made in the OPEC and NPRDS databases, but no identifiable air piping failures were found.

2 CONTROL SYSTEM OPERATION

2.1 General EHC System Description

Since the 1970s, most nuclear steam turbines use an electrohydraulic control (EHC) system. The EHC system has a dedicated high-pressure, hydraulic fluid system that is controlled with electronic devices. The EHC system provides fast response, precise control, few mechanical components, redundant electronic controls, flexible control schemes, and improved fire safety through the use of fire-resistant hydraulic fluid. In addition, the EHC system requires close attention to hydraulic fluid cleanliness, chemistry, and complex electronic control systems.

Typical components in a General Electric EHC system include:

- Steam valve actuators, which are made up of a cylinder assembly, servovalve, disk dump valve, shutoff valve, fast acting solenoid valve, test solenoid valve, and linear variable displacement transducer (LVDT).
- Emergency trip valves, which include a mechanical trip valve, mechanical lockout valve, and master trip solenoid valve for the Mark I control system. The Mark II control system has an electrical trip valve and electrical lockout valve in addition to the Mark I valves.
- EHC hydraulic fluid skid, which contains a reservoir, hydraulic fluid pumps, filters, coolers, accumulators, heater, air dryer, transfer pump, and filtering pump.
- Tubing, piping, valves
- Instrumentation

A typical layout for a GE EHC skid is shown in Figure 2-1.

Typical components in the Westinghouse electrohydraulic (EH) system include:

- Turbine steam valve actuator, which consists of a hydraulic cylinder, actuator block, servovalve, dump valve, shutoff valve, check valves, LVDT, and filter for the governor and throttle valves. Also, it includes a hydraulic cylinder, actuator block, orifice block, manifold block, dump valve, test solenoid valve, accumulator, and LVDT for the interceptor and reheat stop valves.
- EH reservoir skid assembly, which contains a reservoir, hydraulic fluid pumps, filters, coolers, pump suction strainer, magnetic plugs, and control block.
- Emergency trip system, which includes the overspeed protection controller, emergency trip header and the auto-stop oil system.
- Tubing, piping, valves
- Instrumentation

A typical layout of a Westinghouse turbine EH system is shown in Figure 2-2.

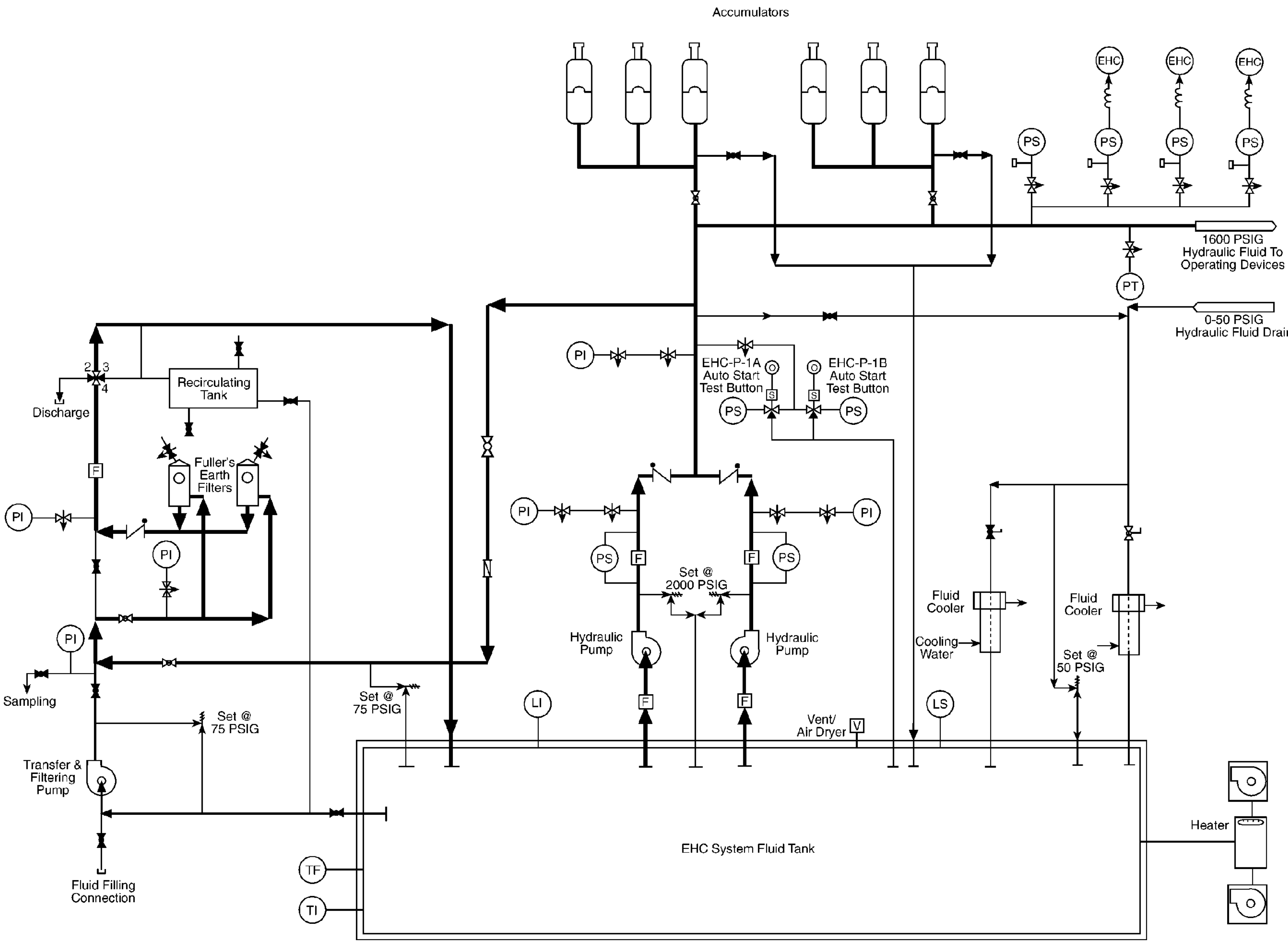


Figure 2-1
Typical GE EHC Skid

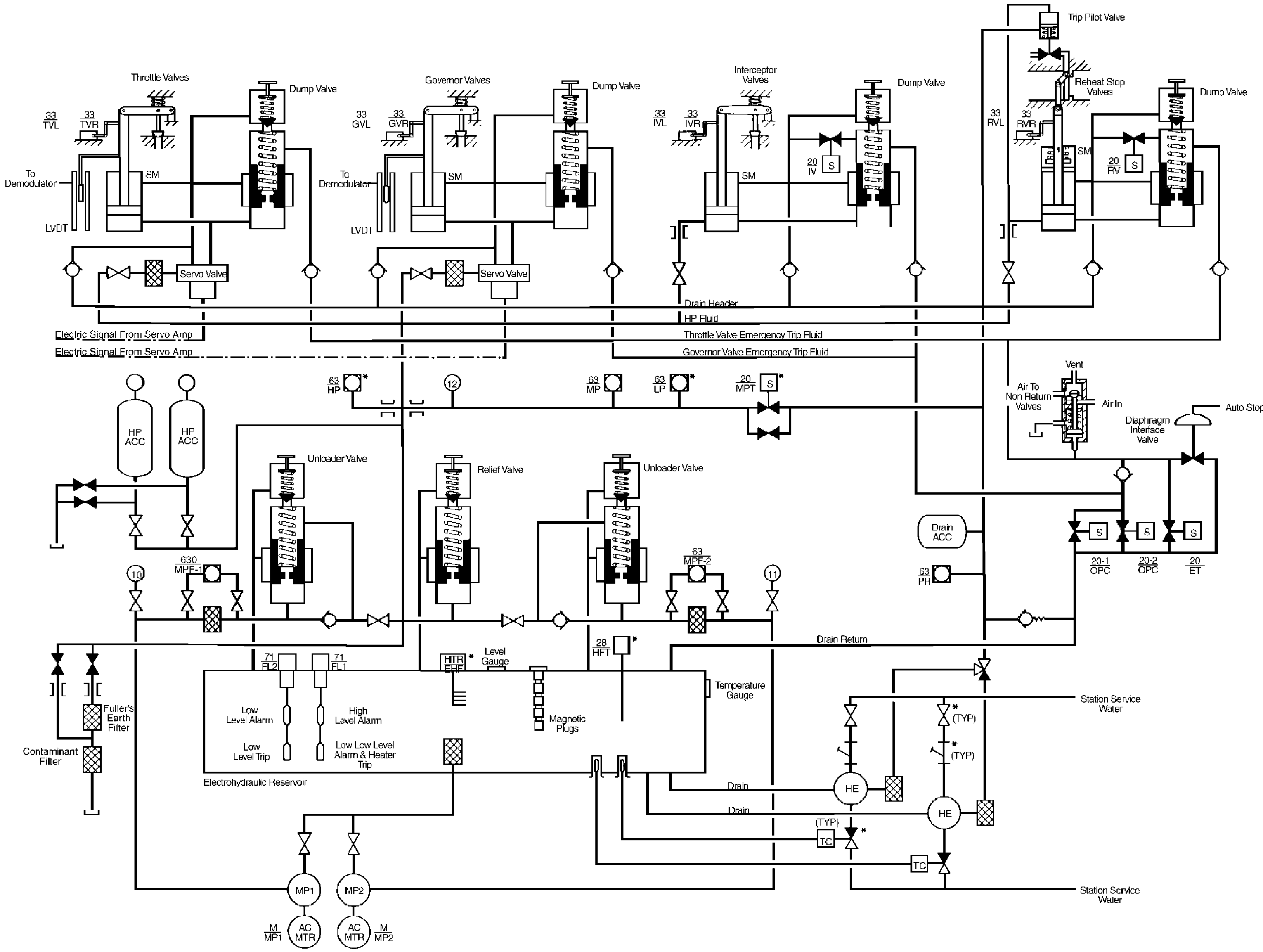


Figure 2-2
Typical Westinghouse EH System

System descriptions and layouts for the Brown Boveri, NEI Parsons, and Siemens systems can be found in the EPRI report *Steam Turbine Hydraulic Control System Maintenance Guide*, TR-107069.

2.2 EHC Hydraulic System Parameters

The EHC hydraulic system parameters include:

- EHC fluid tank

  The typical EHC fluid tank is made from 321 stainless steel plate and holds from 200 to 300 gallons (757 to 1,135 liters) for a Westinghouse design, from 400 to 800 gallons (1,514 to 3,028 liters) for a GE design, and from 4,000 to 6,000 gallons (15,141 to 22,712 liters) for a Siemens design.

- EHC fluid pressures and temperatures

  The EHC fluid pressures are 455 psi (3.14 megapascal or MPa) for Siemens, 1600 psi (11 MPa) for GE, and 2000 psi (13.8 MPa) for Westinghouse. Tubing lines are normally at a temperature of 130°F (54°C) or less. Temperature is a major factor for fluid viscosity and the formation of soaps. To control temperature, a heating system may be supplied to preheat the fluid prior to startup in cold environments. Coolers are used to remove excess heat during operation.

- EHC fluid characteristics

  The type of fluid used in EHC systems is a phosphate ester and can be a natural, synthetic, or a blend. The most widely used EHC fluid is a 50% blend of trixylyl phosphate and t-butylphenyl phosphate. This fire-resistant phosphate ester deteriorates in service by chemical degradation, contamination, and additive depletion.

  The chemical degradation can occur from the ingress of water to the fluid. This is the most damaging form of degradation to the EHC fluid. Contamination can be introduced as particles, metal soaps, mineral oil, or air bubbles. The EHC fluid may have an additive package. (Check with the manufacturer to verify.) If additives are present, depletion will occur over time and can be detected from a sample analysis.

  To extend the fluid life, a permanent filter is used to remove water and particulate. Fuller's earth and Selexsorb are common filtering media. A particulate filter is also present.

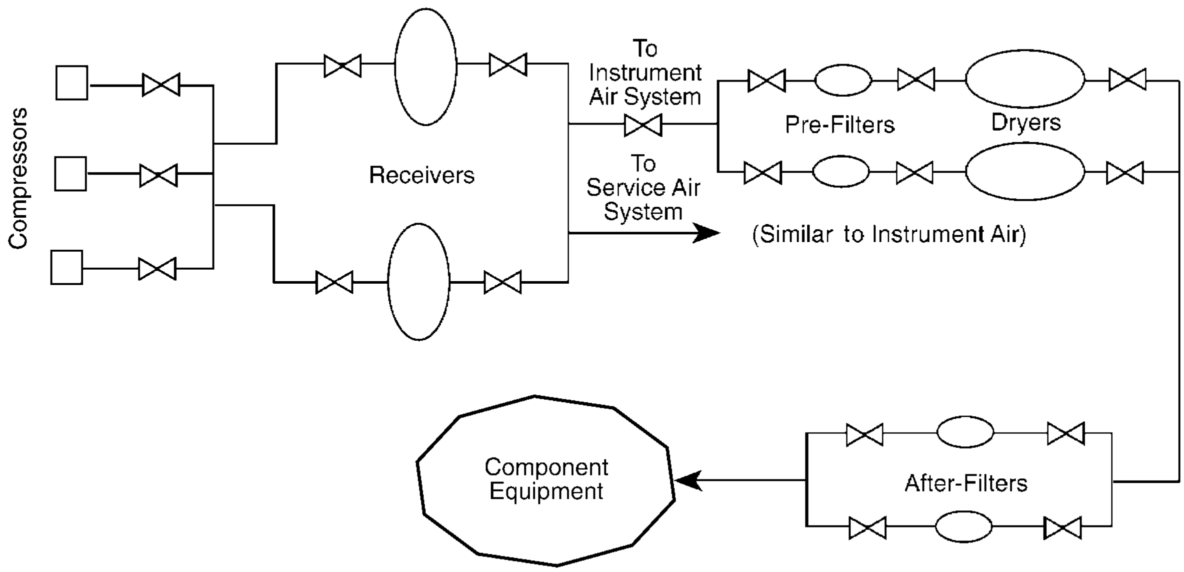
- Tubing requirements

  The EHC fluid is transported to the turbine front standard and turbine valve actuators by tubing. Considering the temperature and pressure requirements, the velocity of the pressure line should be designed for 25 ft/s (27.4 km/h) and the return line for 10 ft/s (10.9 km/h). The typical tubing material used is 304 stainless steel. The fittings used are the 37° flared, flareless, and the newer face seal. Typically, all the fittings are socket welded to the pipe and may have a welded tab to prevent any looseness due to vibration during operation.

2.3 Compressed Air System

Compressed air (100 psig or 689.5 kPa) is needed in the station for service and instrument air functions. The service air is used for pneumatic tools, sand blasters, paint spraying, and general cleaning. Instrument air is used for the operation of valves, instrument and control functions, and breathing. The instrument air system is typically classified as a non-safety-related system; however, many plant systems require the use of instrument air for their operation. The reliability of the system is very important for the functioning of the pneumatic operation of the plant power production systems.

A typical compressed air system layout is shown in Figure 2-3.



Notes:

1. Number, size, and type of compressors vary.
2. Drawing does not contain details such as drains, vents, check valves, etc.

Figure 2-3
Typical Compressed Air System Layout Supplying Service Air and Instrument Air

Typical issues associated with the compressed air system include air quality, lubricant contamination, water in the piping system, particle contamination, and the condition of check valves and air solenoid valves. The piping material used for this system can be carbon steel, galvanized steel, stainless steel, or copper.

3
MATERIAL SELECTION

3.1 EHC System

The tubing, fitting, and piping material used in EHC systems is typically 304 stainless steel for the tubing and piping and 316 stainless steel for the fittings. These materials were selected because of the hydraulic fluid pressure and their suitability for use on high-purity fluid systems.

3.1.1 EHC Tubing Material

Tubing is used to route EHC fluid from the skid to the front standard and valve actuators. Tubing is used, instead of flexible hoses, for added strength in transporting the EHC fluid.

Three common tubing types are:

- Welded flash controlled (SAE J356)

  This is the lowest cost tubing, but it is not recommended for 37° flared fittings.

- Welded and drawn (SAE J525)

  This is the most commonly used tubing, and it has a medium cost. This type can be used by all style fittings.

- Seamless tubing (SAE J524)

  This is the highest cost tubing, and it can be used for the flareless and face seal fittings. It is not recommended for the 37° flared fitting.

Key O&M Cost Point

The welded and drawn (SAE J525) tubing is the most commonly used; it can be used by all style fittings and has a medium cost.

General Electric Technical Information Letter (TIL) 1089-2, dated 11/7/90 and titled "Hydraulic Power Unit Pump Discharge Piping Modifications," discusses failure of the discharge piping due to hydraulic pump vibration. This piping is made from 1.5-inch (3.81-cm) diameter schedule 80 pipe and is recommended to be changed to 2.0-inch (5.08-cm) diameter schedule 80 piping. The increased diameter piping changes the stiffness and increases the weld area.

3.1.2 EHC Flexible Hoses

Flexible hose has been used by several utilities to connect to the front standard and valve actuators. The flexible hose is more tolerant of vibration and easier to line up on assembly and reassembly.

The correct hose is chosen based on the pressure (internal EHC fluid) and the temperature (external ambient) required for the application. The metal braid hose material is typically 304 stainless steel, and the hose fittings are 316 stainless steel. Metal braid hoses up to 1 inch (2.54 cm) in diameter can be used for medium-pressure applications, and the 1- to 2-inch (2.54- to 5.08-cm) diameter hoses can be used for high-pressure applications.

It is important for the hose liner to be a compatible material with the phosphate ester EHC fluid. (See Section 3.1.5 for more on compatible materials.) Compatible materials are the same ones used for elastomers with the EHC fluid:

- Viton
- Teflon
- Silicon rubber
- Butyl rubber
- Ethylene propylene (EPDM)

Outside covers that protect the metal braid can be used on flexible hose. The outside cover material should be rated for the temperature environment.

Hose of the metal bellows design should not be used. Generally, a metal bellows-type hose cannot withstand compressive or tensile forces being applied.

Several utilities have changed from using tubing near the valve actuators to using flexible hoses. See Appendix B for more information.

3.1.3 EHC Fittings

A detailed list of fittings for hydraulic tubes can be found in SAE standard J514 JUN98, which includes elbows, tees, connectors, unions, and other fittings. The three types of standard fittings are:

- 37° flared (SAE J514)
- Flareless (SAE J514)
- Face seal (SAE J1453)

The 37° flared fitting is the most widely used fitting (Figure 3-1). This fitting is readily available and has the lowest cost. The correct flaring of the tube is critical for leakage concerns. Overflaring or underflaring prevents the correct assembly of the fitting and causes leakage. Conical seals can be added to ensure that the connection does not leak.

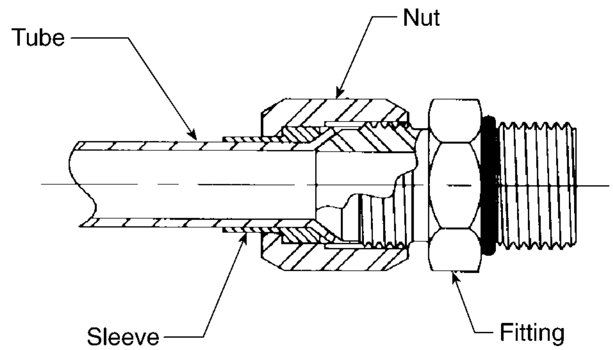


Figure 3-1
37° Flared Fitting

Key O&M Cost Point
The 37° flared fitting is the most commonly used and has the lowest cost.

In addition to the three standard fittings, GE issued a TIL to change this fitting (37° flared) to one designed by GE. In General Electric TIL 841-3A, dated August 1977 and titled "EHC Hydraulic Piping System Improvement," it was recommended that the units convert the 37° flared fittings to a fitting with a different design. It was also recommended that the flared tubing be removed and a new "swivel-nut connector" and O-ring be added. (These connectors can be ordered from GE.) This fitting (see Figure 3-2) is welded to the pipe to prevent leakage. In addition, a tab is welded from the connector to the nut to prevent any rotation of the fitting pieces (see Figure 3-3).

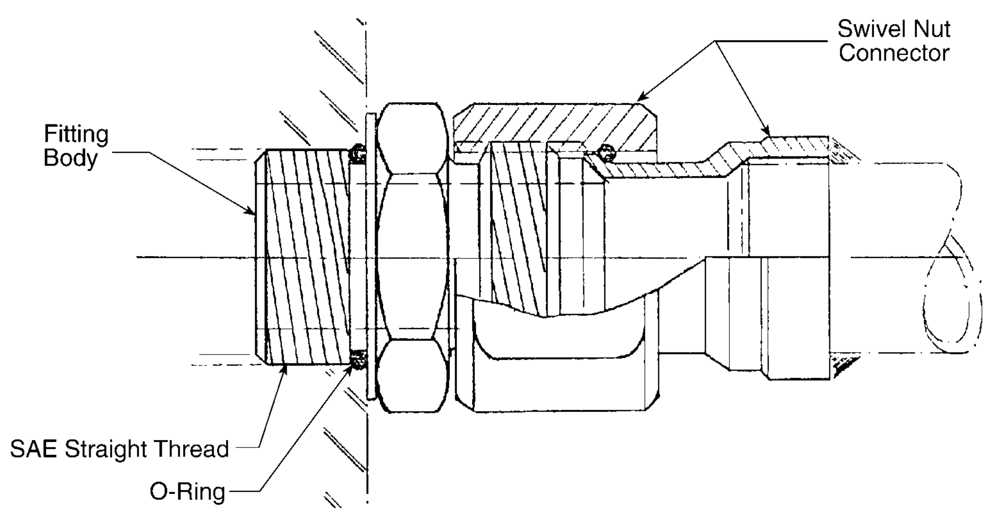


Figure 3-2
GE TIL 841-3a New Design Fitting

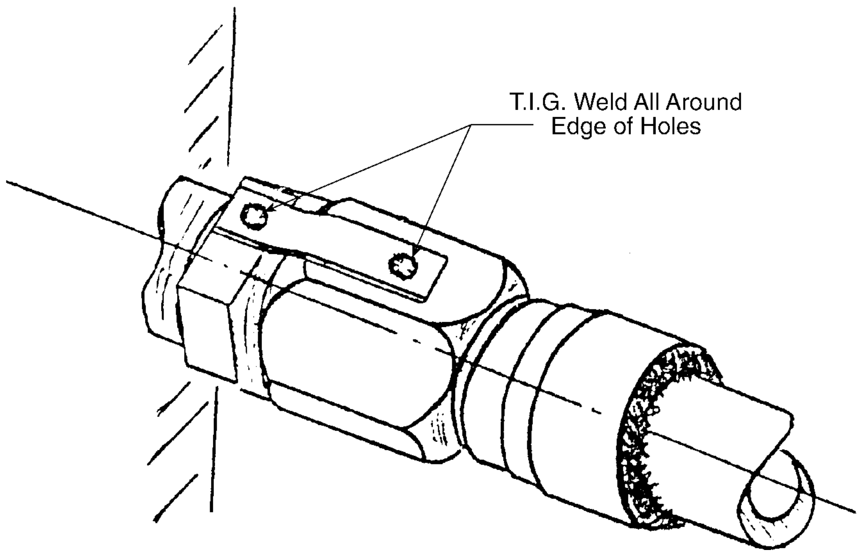


Figure 3-3
GE TIL 841-3a Fitting with Lock Tab

The flareless fitting, as shown in Figure 3-4, is an improvement in sealing from the 37° fitting. It is better suited for environments where vibration is a factor, and it requires minimal tube preparation.

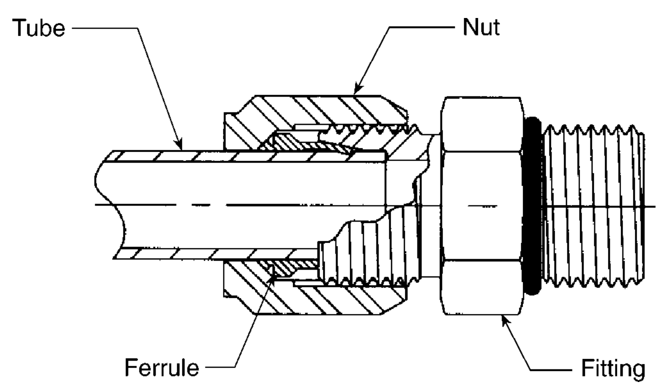


Figure 3-4
Flareless Fitting

Key Technical Point

The flareless fitting is more tolerant of vibration than the flared fitting and requires minimal tube preparation.

The newest fitting is the face seal fitting, which includes an O-ring between the sleeve and body. This fitting, shown in Figure 3-5, is tolerant of high-frequency vibration and is the easiest to assemble.

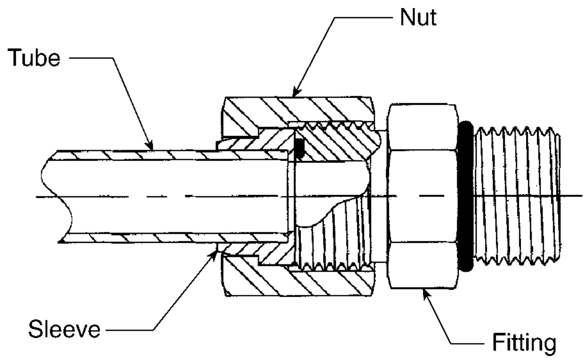


Figure 3-5
Face Seal Fitting

Key Technical Point
The face seal fitting is the most tolerant of the fittings for vibration and is the easiest fitting to assemble.

3.1.4 EHC Port Connections

The fittings are connected into the component housing when the male threaded portion of the fitting is screwed into the female threaded port of the component. The female threaded portion of the housing is called the port. Three common types of ports are:

- Pipe thread ports

This tapered-thread port, shown in Figure 3-6, is the most commonly used. The sealing is metal-to-metal, accomplished by the wedging action of tapered pipe threads. Experience has shown that this type of port works well with a 1/4-inch and smaller National Pipe Thread (NPT) port connections.

Some disadvantages of this port design are:

- Highly torque sensitive
- Susceptible to loosening with vibration and temperature cycling
- Requires thread sealant (that can contaminate the system)
- Prone to galling
- Difficult to seal at high pressure

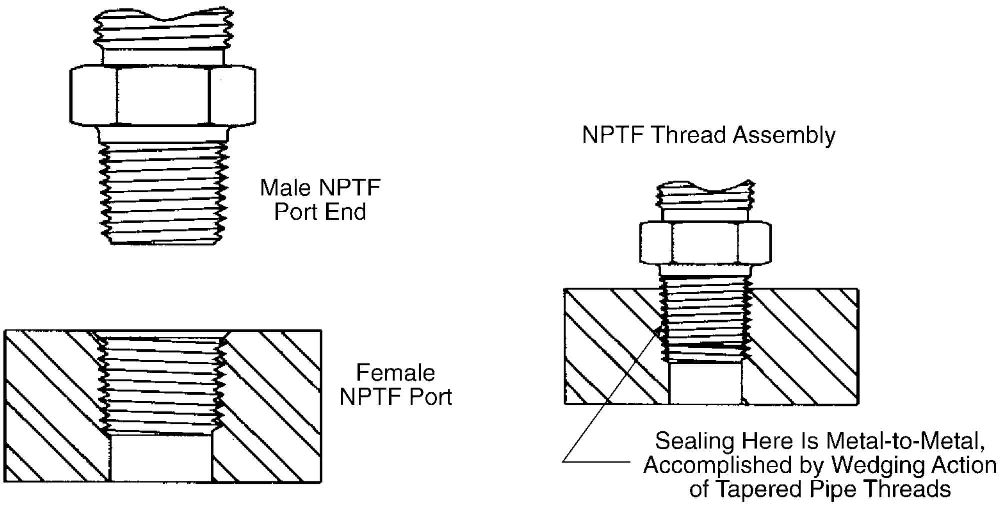


Figure 3-6
Pipe Thread Port

> **Key Technical Point**
>
> **The pipe thread port is used for smaller line sizes.**

- Straight thread ports

  This style of port, shown in Figure 3-7, has straight (parallel) rather than tapered threads. Also, there is an O-ring seal that is more forgiving of surface imperfections. The straight thread port has a longer service life, requires no thread sealant, and is not prone to loosening. Elbows and tees can be positioned easily, and the port has a replaceable seal.

> **Key Technical Point**
>
> **The straight thread port is not prone to loosening and has an O-ring seal.**

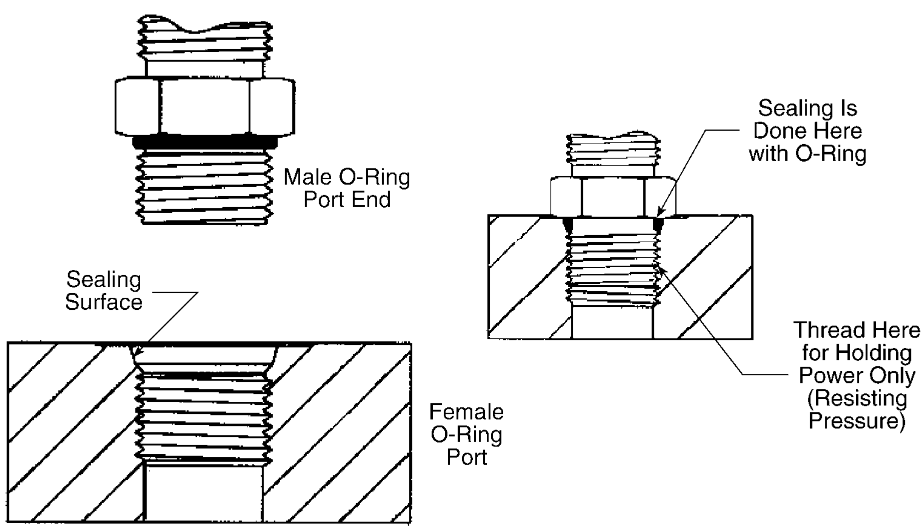


Figure 3-7
Straight Thread Port

- Four-bolt split-flange ports

  This style of port, shown in Figure 3-8, consists of the body, O-ring, two flange clamps, and four bolts. The four-bolt split-flange port style joins tubing or hose directly to the component. The four-bolt port is a flow passage surrounded by a pattern of four tapped holes for accepting the clamping bolts. The flat surface of the port compresses the O-ring contained in a groove in the flange head when the clamp bolts are torqued down. The hydraulic pressure is sealed by the compressed O-ring.

  The four-bolt split-flange port has a long service life with a replaceable seal. It is tolerant of surface imperfections, is not prone to loosening with vibration, is good for hard-to-reach places, and is designed for large line sizes and high pressures. This style requires more time and space to assemble.

Key Technical Point

The four-bolt split-flange port is used for larger line sizes and high pressures.

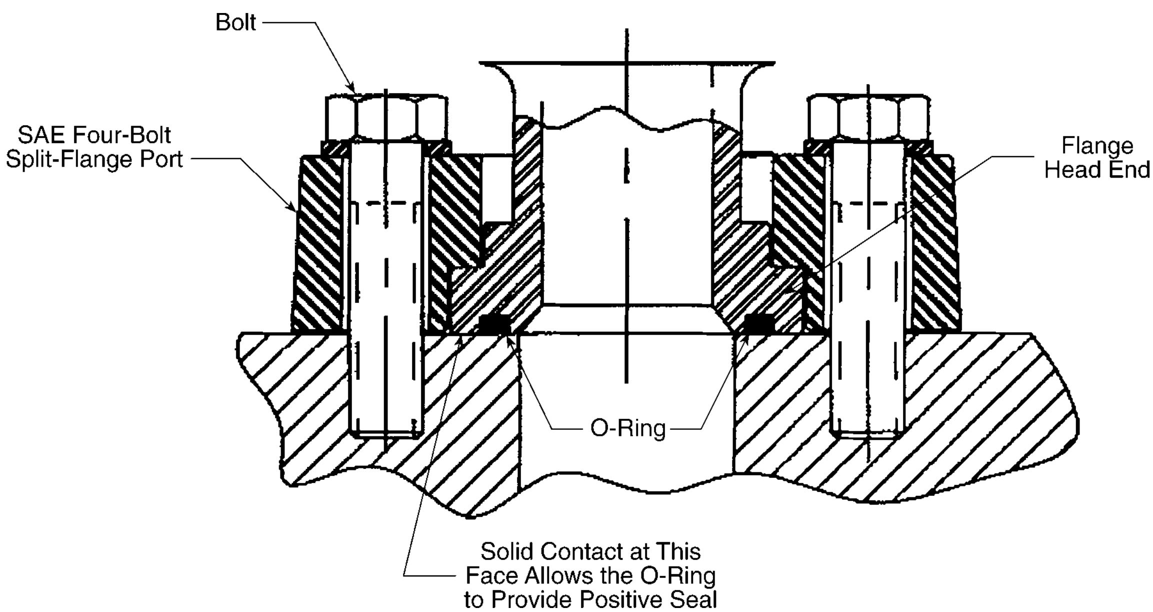


Figure 3-8
Four-Bolt Split-Flange Port

3.1.5 EHC Elastomers

An O-ring seal is used to prevent the loss of EHC fluid outside the tubing, fitting, or port. The seal assembly consists of an elastomer O-ring and a gland. An O-ring is a circular cross-section ring molded from rubber. The gland is usually cut into metal and contains and supports the O-ring. The combination of the O-ring and gland make up the basic O-ring seal assembly.

During installation, the O-ring is mechanically squeezed out of round between the outer and inner members of the gland to close the fluid passage. The seal material under mechanical pressure extrudes into the microfine grooves of the gland. See Figure 3-9 for an installed O-ring. When the EHC fluid pressure is applied, the O-ring is forced to flow up to—but not into—the narrow gap between the mating surfaces and in so doing has gained greater area and force of sealing contact. See Figure 3-10 for the O-ring under pressure.

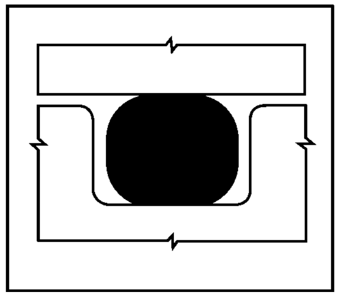


Figure 3-9
O-Ring Installed

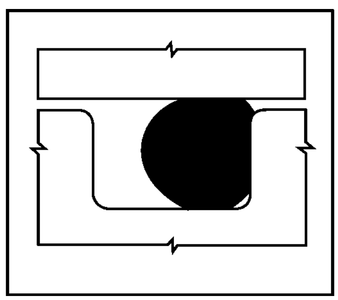


Figure 3-10
O-Ring Under Pressure

Figure 3-11 shows the O-ring at its pressure limit with a small portion of the seal material entering the narrow gap between the inner and outer members of the gland. Figure 3-12 shows the result of further increasing pressure and the resulting extrusion failure. The surface tension of the elastomer is no longer sufficient to resist the flow, and the material extrudes (flows) into the open passage or clearance gap.[1]

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[1] Parker Seals, *O-Ring Handbook*, ORD5700A.

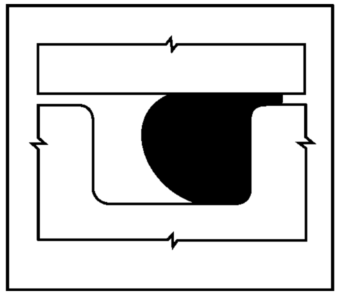


Figure 3-11
O-Ring Extruding

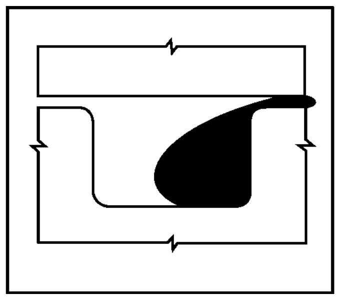


Figure 3-12
O-Ring Failure

Selecting O-rings, gaskets, and seal materials that are compatible with the EHC fluid is very important. The following materials are compatible with this fluid:

- Ethylene-propylene (EPDM).
- Fluorocarbon (FKM) – Viton.
- Butyl rubber.
- Silicone rubber.
- Teflon for pressurized water reactors (PWRs). (Teflon is not used in boiling water reactors (BWRs) because of degradation from radiation.)

Key Technical Point

Material selection for elastomers that are compatible with the phosphate-ester EHC fluid is very important. Acceptable materials are EPDM, Viton, butyl rubber, silicone rubber, and Teflon (PWRs only).

There are several types of Viton seals:

- Viton A seals are general-purpose types that are suited for O-rings, gaskets, and other shapes.
- Viton B seals offer better fluid resistance than the A type.
- Viton F seals offer the best fluid resistance of all Viton types.
- Viton GBL, GLT, and GFLT seals are considered a high-performance family of the fluoroelastomers.
- Viton GBL seals are highly resistant to steam, acid, and engine oils.
- Viton GLT seals are designed to retain the high heat and chemical resistance of general-use grades of Viton fluoroelastomers and improve the low-temperature flexibility of the material.
- Viton GFLT seals are designed to retain the high heat and chemical resistance of the GF high-performance types and improve the low-temperature performance of the material.

3.2 Compressed Air System Piping

The compressed air system can use piping made of:

- Copper
- Carbon steel (ASTM-A106)
- Galvanized steel piping
- Stainless steel piping (ASTM-A213) and tubing (ASTM-A269)

As expected, stainless steel piping experiences the fewest failures due to corrosion or physical damage; however, a stainless steel distribution system is quite expensive. A carbon steel piping system provides satisfactory service as long as the dew point of air is maintained at or below that required by the ISA (Instrument Society of America) standard S7.0.01-1996. Corrosion and leaks in carbon steel piping are quite common where the moisture content of air remains consistently high. It is recommended that all distribution systems be provided with blowdown points to eliminate corrosion products that can accumulate due to occasional moisture intrusion.

Stainless steel obviously has its advantages, but it can be very costly to install. Galvanized steel pipe is a common compromise. Copper tubing has been used, but joints may have pressure limitations, and the maximum possible pressure and temperature conditions must be taken into consideration. Copper also has a relatively high rate of thermal expansion.

Key Technical Point

The material used for the compressed air system piping can be copper, carbon steel, galvanized steel, or stainless steel. Stainless steel piping has the fewest problems but is the most expensive. The use of galvanized steel for piping is a common material choice.

While corrosion-resistant piping is very desirable to prevent corrosion particles in the air stream, plastic piping is not recommended for compressed air systems. This type of piping generally is rated at 80°F (26.7°C), and its pressure rating may fall off rapidly as temperature increases. Plastic piping and its joint and sealing compounds may not be compatible with synthetic lubricants. Acrylic filter bowls have been found to crack when exposed to diesters and similar lubricants.

4
LAYOUT AND INSTALLATION

4.1 EHC Hydraulic Tubing Installation

4.1.1 Routing Factors

Installation of hydraulic tubing must include adequate supports and flexibility for the expansion of turbine components. Several factors to consider in routing are:

- Joint accessibility. Inaccessible joints are difficult and time consuming to service.
- Tubing configuration. Straight tubing runs between fittings do not allow for expansion and contraction. Bends or loops in the tubing allow for movement and relieve stresses at the joints. Some examples of correct and incorrect routing are shown in Figure 4-1.

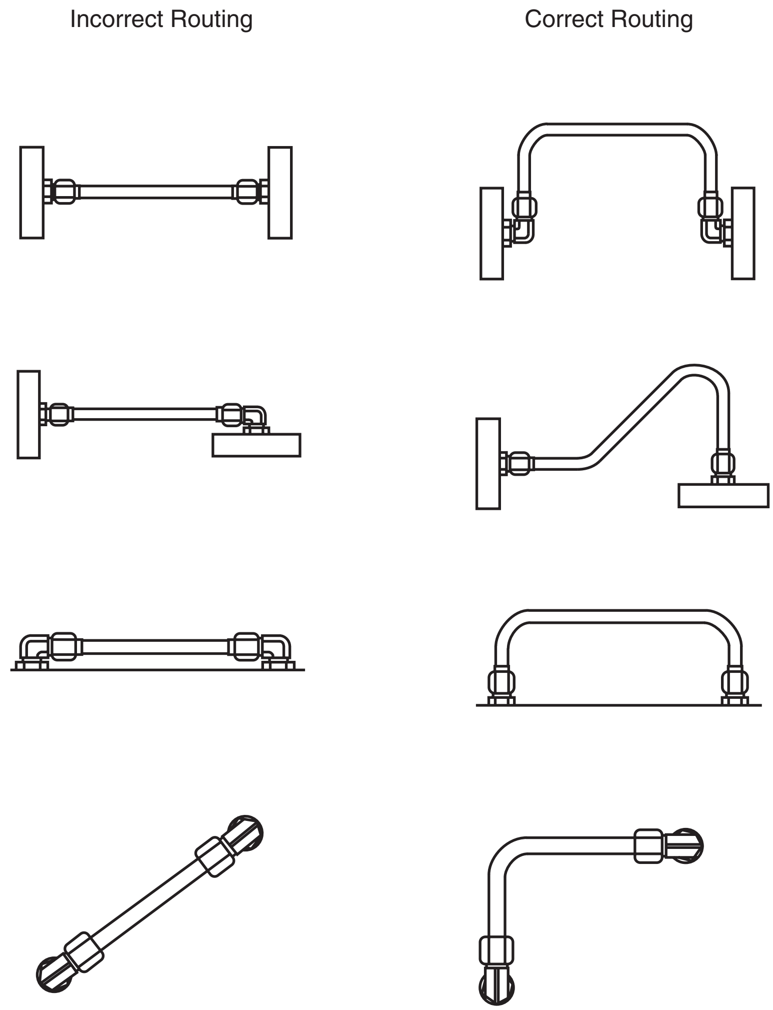


Figure 4-1
Tube Routing Examples

A U-bend and support clamp are used in the routing of long lines for expansion and contraction. See Figure 4-2 for an example of a U-bend.

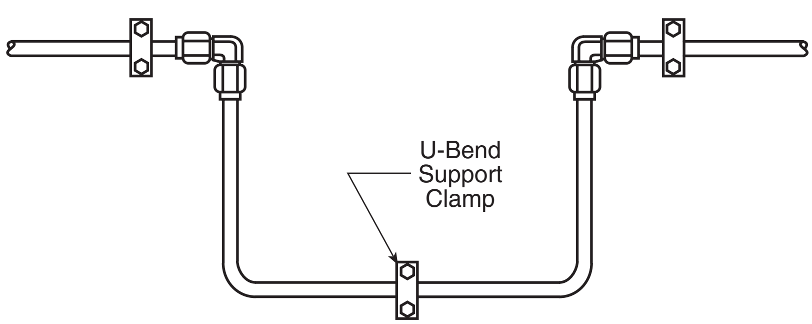


Figure 4-2
U-Bend Tube Routing and Clamp

Even some apparently rigid systems move under load. Tubing can be bent to allow for this motion. See Figure 4-3 for an example of this routing.

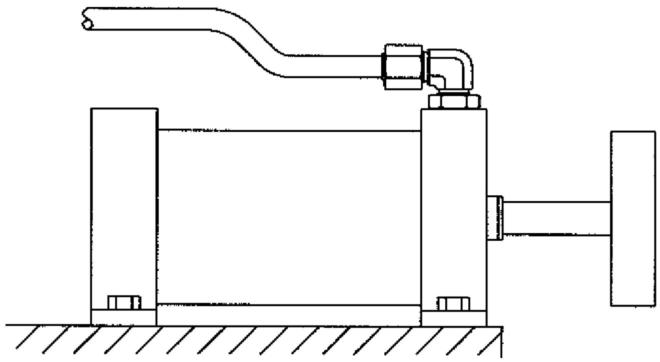


Figure 4-3
Bent Tube

Getting around obstructions using 45° bends is preferable to using 90° bends. The pressure drop in one 90º bend is greater than in two 45° bends. See Figure 4-4 for an example.

Key Technical Point
Using 45º bends is preferable to using 90º bends. The pressure drop in one 90º bend is greater than in two 45º bends.

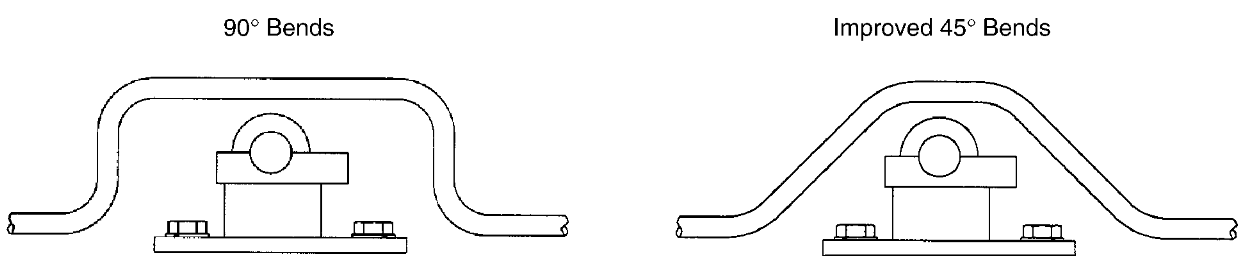


Figure 4-4
45° and 90° Bends

It is important to keep tube lines away from components that require regular maintenance. See Figure 4-5 for an example.

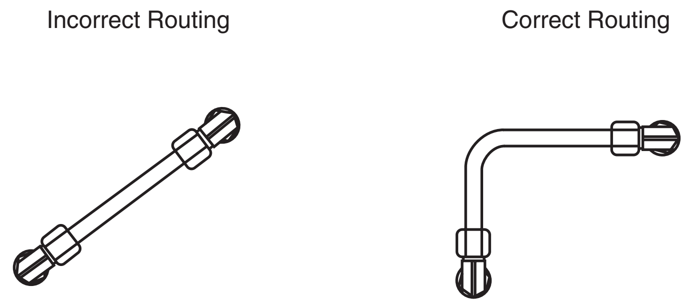


Figure 4-5
Routing Around Components

Keeping the tubes aligned allows for easy troubleshooting and repairs. An example of this is shown in Figure 4-6.

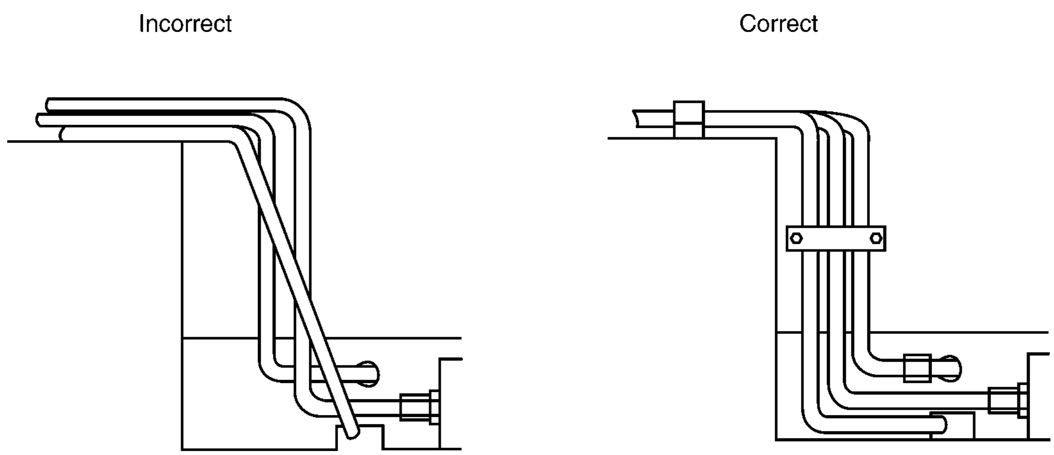


Figure 4-6
Tubes Aligned

- Slope of tube lines. All lines should pitch downward a minimum of 1/4 inch per foot (0.021 mm/cm) from the connection on the front standard and hot position of the steam valves to the point of connection on the hydraulic power unit with no low point in the lines.
- Tube line supports. Tube line supports are used mainly for dampening vibration. Fatigue failure from mechanical vibration accounts for the majority of tube leaks.

  Recommended clamping is shown in Figure 4-7, and recommended spacing is shown in Table 4-1.

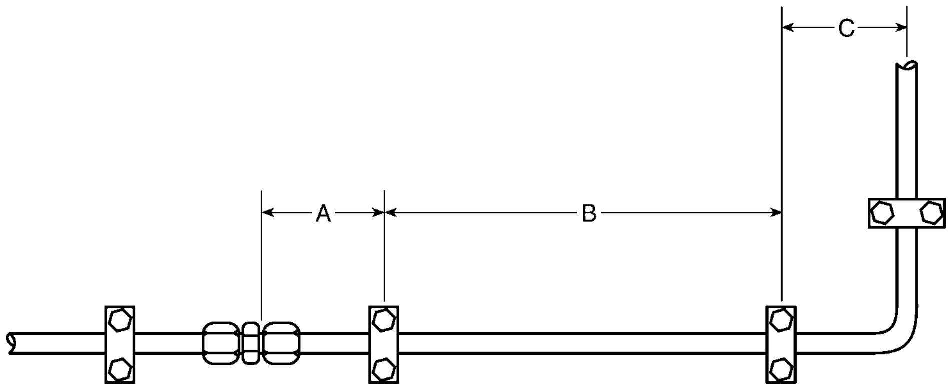


Figure 4-7
Tube Clamping for Vibration

Table 4-1
Recommended Tube Clamp Spacing

TUBE OD	A (in.)	B (ft.)	C (in.)
(in.)			
1/4–3/8	2	3	4
1/2–1	4	5	8
1-1/4–2	6	7	12

Key Technical Point

Tubing supports should be installed so that vibration caused by a unit trip is dampened immediately or within a maximum of three oscillations.

There should be no excessive vibration in the tubing at full load operation. Checks should be made when the unit is fully loaded for any interference between the tubing system and any stationary members. Tubing supports should be installed so that vibration caused by a unit trip is dampened immediately or within a maximum of three oscillations. Special attention should be given to the tubing and support in the vicinity of steam valves. These areas will experience the maximum expansion and vibration.

Key O&M Cost Point

Failure of the tubing and supports in the vicinity of steam valves frequently results in lost generation.

- Fabricating tools. Special tools are needed for the cutting, bending, and tube end preparation of hydraulic tubing:
  - Cutting – For making smooth, square cuts in metal tubing, you can use an electric circular saw, hardened tube cutters, or a sawing vise and hacksaw.
  - Bending – For making smooth, wrinkle-free bends, you can use manual lever- type benders; manual crank, table mount, or vise-mount benders; or hydraulically powered benders.
  - Tube end preparation – The tube end preparation depends on the style of fitting being used. For flared fittings, a vise block and flaring pin, combination flaring tool, rotating cone, and hydraulically operated axial piston are examples of tools needed to prepare the tube. For flareless fittings, a hand tool with fitted body contour or a hydraulically operated tool with preset sizes can be used. For brazing, an acetylene and air torch is used. For flanging, electrical high-speed flanging machines are used.

4.1.2 General Tube Preparations

To prepare the tube to receive a fitting, follow these guidelines:

1. Determine the size of the tube and the length of line that is needed. For flared tubing, take a minor loss of length due to the flare into consideration; for flareless tubing, make provisions for additional tube insertion in the fitting.

2. Use a cut-off saw or other appropriate tool to cut the tube squarely to within 2°.

   A. Cut with a hacksaw and saw guide, a power cutter with a toothed wheel blade, or a tube cutter on soft metal tubing.

   B. Deburr both the inside and outside diameters of the tube end.

   C. Blow off the shavings with low-pressure compressed air.

3. Make any bends prior to flaring, presetting, or brazing:

   A. Measure exactly using a sharp pencil and sleeve as a marking guide.

   B. Bend accurately.

   C. Bend from the same direction whenever possible. If the direction of the bend is reversed, you must adjust for tube stretch.

   D. Measure the spring back and compensate for it.

   E. Do not overbend.

4.2 EHC Fitting Installation Factors

Key Technical Point

The use of swivel fittings, bent tube assemblies, and elbows can greatly improve assembly and disassembly of fittings in close spaces.

4.2.1 Connections in Tight Places

Swivel end fittings can be used with a straight connector when space limitations will not permit full rotation of an elbow or tee fitting. An example is shown in Figure 4-8.

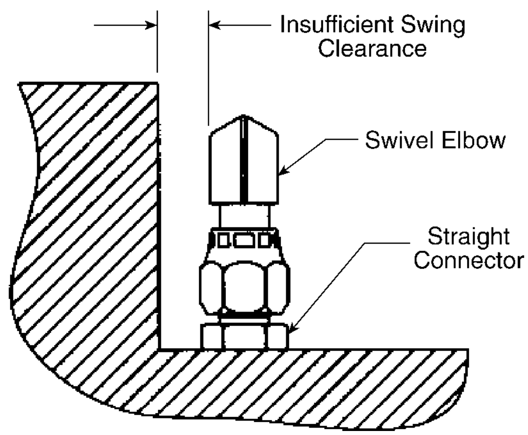


Figure 4-8
Swivel End Fitting with a Straight Connector

The arrangement shown in Figure 4-9 can be used to stack tube lines or provide clearance for ports that are relatively close and within the same plane.

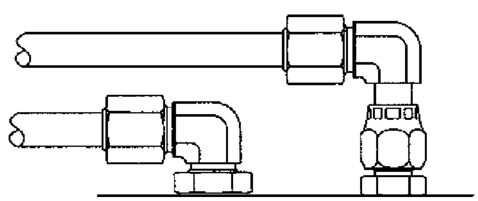


Figure 4-9
Connection Arrangement Providing Clearance

Figure 4-10 requires a minimum swing clearance, a simple adapter, and a more expensive tube or hose assembly.

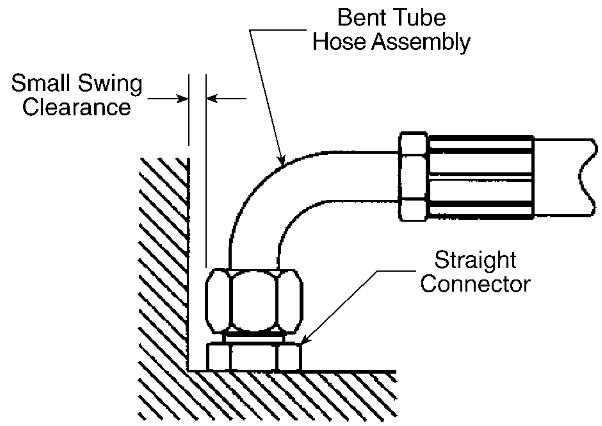


Figure 4-10
Bent Tube Hose Assembly with a Straight Connector

Figure 4-11 requires a larger swing clearance, a more expensive adapter, and a less expensive tube or hose assembly. This results in a more compact assembly and is good for tight places.

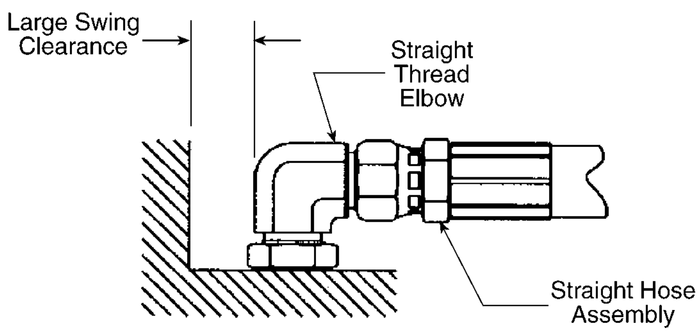


Figure 4-11
Straight Thread Elbow with a Straight Hose Assembly

4.3 EHC Fitting Assembly Procedures

Assembly instructions for the 37° flared fitting, flareless fitting, and face seal fitting are given in this section.

4.3.1 37° Flared Fittings

Follow these assembly instructions for the 37° flared fittings:

1. Before flaring, determine the proper fittings needed for installation; choose the flaring method and the appropriate dies; and lubricate the flaring dies and flaring cone if necessary.

2. For flaring, slip the nut and sleeve on the tube, and flare the tubing in accordance with the recommended procedure. Inspect the flare for the correct diameter, angle, and quality.

   Overflaring or underflaring results in improper assembly and leakage. The tube should be flared at a 37° ± 1/2° angle. The flare surface should be free of embedded burrs, grit, scratches, nicks, pits, cracks, or splits. Any of these can cause leakage.

3. For tightening the fitting, align the tube end and fitting, and tighten the nut to the appropriate torque shown in Table 4-2. When working with different platings, use the flats method given here.
4. Align the tube or hose to the mating fitting, and check to see that the flare seats properly on the nose of the fitting.
5. Bring the tube nut to the finger-tight position. If there is unexpected difficulty or for larger sizes, use a wrench to sit the nut down snugly.
6. Mark the nut and body, and then turn the appropriate number of flats from finger tight (FFFT) from Table 4-2.
7. After tightening, extend the line from the nut to the body.

Table 4-2
37° Fitting Torque and Flat Values

SAE Dash Size	Thread Size	Assembly Torque		Tube Connection FFFT	Swivel Nut or Hose Connection FFFT
		In. Lbs.	Ft. Lbs.		
-2	5/16 - 24	40±5	3±1	-	-
-3	3/8 - 24	70±5	6±1	-	-
-4	7/16 - 20	140±10	12±1	2	2
-5	1/2 - 20	180±15	15±1	2	2
-6	9/16 - 18	250±15	21±1	1-1/2	1-1/4
-8	3/4 - 16	550±25	45±2	1-1/2	1
-10	7/8 - 14	700±50	60±5	1-1/2	1
-12	1-1/16 - 12	1000±50	85±5	1-1/4	1
-14	1-5/16 - 12	1250±50	105±5	1	1
-16	1-5/16 - 12	1450±50	120±5	1	1
-20	1-5/8 - 12	2000±100	170±10	1	1
-24	1-7/8 - 12	2400±150	200±15	1	1
-32	2-1/2 - 12	3200±200	270±20	1	1

4.3.2 Flareless Fittings

Follow these assembly instructions for presetting the sleeve for a flareless fitting:

1. Slide the nut and ferrule over the end of the tube.
2. Preset the ferrule one of three ways: with a fitting body, a ferrule presetting tool, or a hydraulic tool. The choice of methods to preset the ferrule is based on the tubing size. See the manufacturer's recommendations for size guidelines.
   - **With a fitting body:**
     1. Lubricate the threads of the fitting body and both ends of the ferrule.
     2. Place the tube end into the fitting body, making sure the end is bottomed against the seat.
     3. Turn the nut to the finger-tight position.
     4. Tighten the nut 1-3/4 turns more with a wrench
     5. Disassemble and inspect the preset.
   - **With a ferrule presetting tool:**
     1. Lubricate the threads of the tool and both ends of the ferrule.
     2. Seat the tube in the tool until it sits against the shoulder in the tool.
     3. Turn the nut to the finger-tight position.
     4. Tighten the nut 1-3/4 turns more with a wrench.
     5. Disassemble and inspect the preset.
   - **With a hydraulic tool:**
     1. Place the appropriate die into the hydraulic tool.
     2. Lubricate both ends of the ferrule.
     3. Put the tube end into the tool.
     4. Apply pressure to the hydraulic tool until the body die contacts the nut to preset the ferrule.
     5. Relieve the pressure, remove the tube from the tool, and inspect the preset.

3. Inspect the preset (see Figure 4-12) for the following:
   - The ridge should be raised to at least 50% of the ferrule thickness (A).
   - The leading edge should be coined flat (B).
   - There should be a slight bow to the remaining part of the ferrule (C).
   - The back end should be snug against the tube (D).
   - There should be a slight indent around the end of the tube (E).

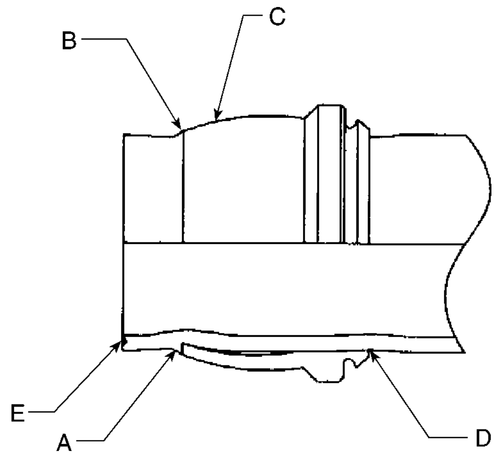
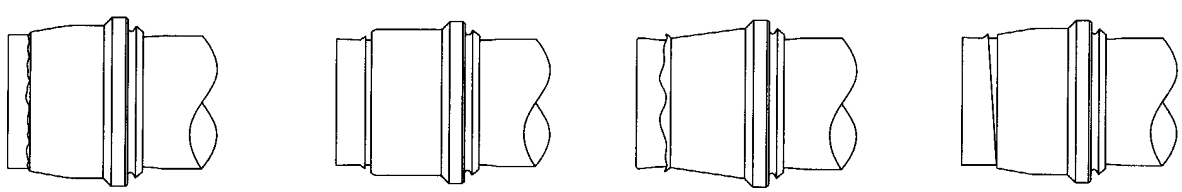


Figure 4-12
Preset Inspection

Figure 4-13 shows incorrect presets and their causes.



Shallow Bite Too Close to End Tube Not Bottomed	Shallow Bite Inadequate Force	Over-Set Ferrule Too Much Force	Uneven Bite Ferrule Cocked on Tube

Figure 4-13
Flareless Fitting Incorrect Presets

For a final assembly or remake, follow these instructions:

1. If a hydraulic tool was used to preset the ferrule, lubricate the fittings.
2. Align the tube and fitting.
3. Tighten the nut to the finger-tight position.

4. Lightly tighten the nut with a wrench until you feel a noticeable wrench resistance.

5. Continue to tighten 1/6–1/4 turn to reload the ferrule.

4.3.3 Face Seal Fittings

Follow these assembly instructions for the sleeve brazing of the face seal fittings:

1. Perform a test fit at the assembly without the braze rings in place. Do not force the assembly into place. If the fit is not correct, make the needed adjustments.
2. Clean the tube end and sleeve with a cleaning solvent.
3. Rough the tube with emery cloth or sand off the surface oxidation and other contaminants. Wipe the tube end clean.
4. Slip the nut on the tubing.
5. Apply some flux on the end of the tubing.
6. Insert the braze ring in the sleeve, and install the braze ring on the end of the tubing.
7. Apply more flux on the sleeve and tubing. The flux may be heated to 150°F (65.5°C) for easier application
8. Thoroughly cover the entire joint area and 1/2 inch (1.27 cm) below it with flux.
9. Light the torch and adjust it to achieve a blue flame.
10. Using a single-tipped or multi-flamed torch, apply the flame to the middle of the sleeve for thin wall tubing; on heavy wall tubing, apply it on the tube just below the sleeve. Use a moderate to high flame for brazing.
11. Heat the braze joint until the flux becomes clear and the sleeve settles on the end of the tubing.
12. Tap the sleeve to ensure that the sleeve is seated properly when the braze ring melts.
13. Let the joint cool for about 10 seconds until the braze has solidified, and then immerse it in braze cleaner.
14. Clean and/or remove any excess braze overflow, discoloration, or oxide build-up from the contact and/or sealing surface of the sleeve with emery cloth or a wire brush (use lightly), being careful not to damage the sealing surface.
15. Inspect the braze joint.

Follow these assembly instructions for the face seal fitting:

1. Lubricate the O-ring slightly with EHC fluid before installation.
2. On installation, ensure that the face seal O-ring is seated and retained properly.
3. Position the tube and nut squarely on the face seal end of the fitting, and tighten the nut to the finger-tight position.
4. Tighten to the appropriate torque according to Table 4-3.
5. Inspect the fitting joint integrity.

Table 4-3
Torque Values for Face Seal Fittings

SAE Dash Size	Tube Side Thread Size	Tube Side Assembly Torque – Upper Bounds for Stainless Steel In. Lbs.	Ft. Lbs.
-4	9/16 - 18	220 + 10	18 + 1
-6	11/16 - 16	320 + 25	27 + 2
-8	13/16 - 16	480 + 25	40 + 2
-10	1 - 14	750 +35	63 + 3
-12	1-3/16 - 12	1080 + 45	90 + 4
-16	17/16 - 12	1440 + 90	120 + 8
-20	1-11/16 - 12	1680 + 90	140 + 8
-24	2 - 12	1980 + 100	165 + 8

4.3.4 Conical Seals

Key Technical Point

The addition of a conical seal can improve the sealing of the flared and flareless fittings.

The use of a conical seal on flared and flareless fittings has improved sealing on minor surface irregularities in the mating surfaces. The conical seals are malleable crush washers designed to yield and flow into imperfections. During installation, the metallic flow at the interface conforms to the imperfections and provides a leak-proof connection.

A conical seal is shown in Figure 4-14.

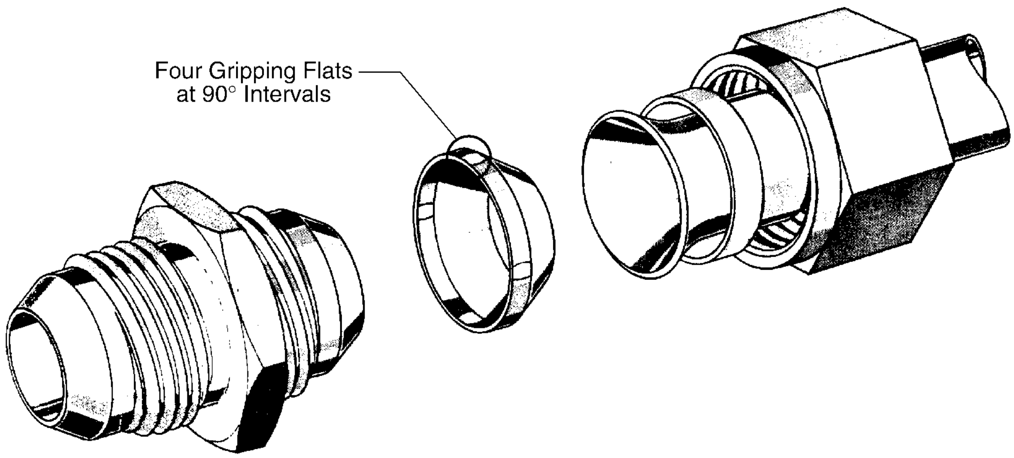


Figure 4-14
Conical Seal

The material selected for the conical seal is based on the type of fluid used, the tubing and fitting material, and the temperature of the fluid. Typical torque values for conical seals are shown in Table 4-4.

Table 4-4
Torque Values for Conical Seals

Tubing OD inches	Seal Dash No.	Copper Seal Inch-Pounds	Stainless Steel or Nickel Seal Inch-Pounds
1/8	-2	80–90	90–100
3/16	-3	100–110	110–125
1/4	-4	150–165	165–190
5/16	-5	200–220	225–250
3/8	-6	300–330	335–375
1/2	-8	500–550	575–625
5/8	-10	710–770	810–875
3/4	-12	990–1100	1125–1250
1	-16	1300–1550	1500–1750
1-1/4	-20	1650–1950	1875–2250
1-1/2	-24	2200–2500	2500–2850
1-3/4	-28	2800–3150	3250–3600
2	-32	3500–3950	4000–4500

4.4 EHC Port Assembly Procedures

The assembly procedures for pipe thread ports, straight-thread O-ring ports, and four-bolt split-flange ports are given in this section.

4.4.1 Pipe Thread Ports

Follow these assembly instructions for the pipe thread ports:

1. Inspect the port and connectors to ensure that threads are free of dirt, burrs, and excessive nicks.

2. Apply sealant/lubricant to the male pipe threads. The first one to two threads should be left uncovered to avoid system contamination. If using tape, wrap 1-1/2 turns in the same direction as the thread. Thread sealants are recommended over Teflon tape.

3. Screw the connector into the port to the finger-tight position.

4. Wrench tighten the connector the number of turns from finger tight (TFFT) values shown in Table 4-5.

Table 4-5
Pipe Thread Port TFFT Values for Steel and Brass Fittings

Pipe Thread Size – NPTF	Turns from Finger Tight (TFFT)
1/8 - 27	2–3
1/4 - 18	2–3
3/8 - 18	2–3
1/2 - 18	2–3
3/4 - 14	2–3
1 - 11-1/2	1.5–2.5
1-1/4 - 11-1/2	1.5–2.5
1-1/2 - 11-1/2	1.5–2.5
2 - 11-1/2	1.5–2.5

5. If leakage occurs, check for damaged threads and the total number of threads engaged. Typically, the total number of threads engaged should be between 3-1/2 and 6. Any number outside this range indicates either under/overtightening of the joint or out of tolerance threads.

4.4.2 Straight-Thread O-Ring Ports (Non-Adjustable)

Follow these assembly instructions for straight-thread O-ring ports (non-adjustable):

1. Inspect and ensure that the parts are free of burrs, nicks, scratches, or any foreign particles.
2. Install the O-ring on the port end of the fitting.
3. Lubricate the threads and O-ring with EHC fluid.
4. Turn the fitting in full length until finger tight.
5. Tighten to the torque given in Table 4-6. Use the upper limits of the torque ranges for stainless steel fittings. Values in the chart are for lubricated assemblies.

Table 4-6
Straight-Thread O-Ring Fitting (Non-Adjustable) Steel

Fitting Size	SAE Port Thread Size	In. Lbs.	Ft. Lbs.
2	5/16 - 24	90 ± 5	7.5 ± .5
3	3/8 - 24	170 ± 10	14 ± 1.0
4	7/16 - 20	220 ± 15	18 ± 1.0
5	1/2 - 20	260 ±15	22 ± 1.0
6	9/16 - 18	320 ± 20	27 ± 2.0
8	3/4 - 16	570 ± 25	48 ± 2.0
10	7/8 - 14	1060 ± 50	90 ± 5.0
12	1-1/16 - 12	1300 ±50	110 ± 5.0
14	1-3/16 - 12	1750 ±75	145 ± 6.0
16	1-5/16 - 12	1920 ±25	160 ± 6.0
20	1-5/8 - 12	2700 ±150	225 ± 12.0
24	1-7/8 - 12	3000 ±150	250 ± 12.0
32	2-1/2 - 12	3900 ±200	325 ± 15

4.4.3 Straight-Thread O-Ring Ports (Adjustable)

Follow these assembly instructions for straight-thread O-ring ports (adjustable):

1. Inspect and ensure that the parts are free of burrs, nicks, scratches, or any foreign particles.
2. Install the O-ring on the port end of the fitting (if it does not have one), taking care not to nick it.
3. Lubricate the threads and O-ring with EHC fluid.
4. Back off the lock nut as far as possible. Make sure that the back-up washer is not loose and is pushed up as far as possible.
5. Screw the fitting into the port. Hand tighten until the back-up washer contacts the face of the port.
6. To position the fitting, unscrew it by the required amount, but not more than one full turn.
7. Using two wrenches, hold the fitting in the desired position, and tighten it to the appropriate torque for the given size according to Table 4-7. Use the upper limits of the torque ranges for stainless steel fittings. Values in the chart are for lubricated assemblies.

Table 4-7
Straight-Thread O-Ring Fitting (Adjustable)

Fitting Size	SAE Port Thread Size	In. Lbs.	Ft. Lbs.
4	7/16 - 20	190 ± 10	16 ±1.0
6	9/16 - 18	420 ± 15	35 ±1.0
8	3/4 - 16	720 ± 25	60 ± 2.0
10	7/8 - 14	1260 ± 50	105 ± 5.0
12	1-1/16 - 12	1680 ± 75	140 ± 6.0
16	1-5/16 - 12	2520 ± 100	210 ± 8.0
20	1-5/8 - 12	3100 ± 150	260 ± 12.0
24	1-7/8 - 12	3800 ± 150	315 ±12.0

4.4.4 Four-Bolt Split-Flange Ports

Follow these assembly instructions for four-bolt split-flange ports:

1. Make sure that sealing surfaces are free of burrs, nicks, scratches, or any foreign particles.
2. Lubricate the O-ring with EHC fluid.

3. Position the flange and clamp the halves.

4. Place the lock washers on the bolt, and bolt through the clamp halves.

5. Hand tighten the bolts.

6. Torque the bolts in a diagonal sequence in small increments to the appropriate torque level listed in Table 4-8 (Code 61) or 4-9 (Code 62).

Table 4-8
Code 61 Bolt Size and Assembly Torques

Dash Size	Flange Size	Bolt Thread	In. Lbs. Torque	Ft. Lbs. Torque
12	3/4	3/8 - 16	300 ± 50	25 ± 4.5
16	1	3/8 - 16	375 ± 50	31 ± 4.5
20	1-1/4	7/16 - 14	488 ± 62	41 ± 5
24	1-1/2	1/2 - 13	625 ± 75	52 ± 6
32	2	1/2 - 13	725 ± 75	60 ±6

Table 4-9
Code 62 Bolt Size and Assembly Torques

Dash Size	Flange Size	Bolt Thread	In. Lbs. Torque	Ft. Lbs. Torque
12	3/4	3/8 - 16	300 ± 50	30 ± 4.5
16	1	7/16 - 14	375 ± 50	46 ± 4.5
20	1-1/4	1/2 - 13	825 ± 50	69 ± 6
24	1-1/2	5/8 - 11	1500 ± 100	125 ±8

4.5 Hydraulic Hose Installation Factors

Key Technical Point

Because of vibration problems, some plants have replaced tubing with flexible hose in the lines to the valve actuators .

Steel braided hose has been used in the EHC system to supply fluid to the valve actuators. According to Section 3.2, the hose should be chosen based on the EHC fluid pressure and ambient temperature. Also, it is important that the hose liner be compatible with the EHC fluid.

In installation, consider the following recommendations:

- Do not use bend radii that are tighter than those recommended.
- Allow slack to compensate for hose contraction under pressure.
- Avoid twisting the hose.
- Route the hose away from hot surfaces and sharp edges, avoid rubbing it against components, and install it with enough slack to allow for movement of the components in operation.

From the SAE J517 “Hydraulic Hose” standard, the factors that will reduce the life of hydraulic hose are:

- Flexing the hose to less than the specified minimum bend radius
- Twisting, pulling, kinking, crushing, or abrading the hose
- Operating above or below the hose operating temperature range
- Exposing the hose to surge pressures above the maximum operating pressure

4.6 Miscellaneous Notes

4.6.1 Sealants/Lubricants

Key Technical Point

Pipe thread sealants are available as dry, pre-applied tape, paste, and anaerobic liquid. The connectors with dry, pre-applied sealant from the manufacturer may be remade a few times without needing additional sealant. Teflon tape does not offer much resistance to loosening from vibration. Paste sealants can be messy to work with. Paste sealants and anaerobic liquids may require a curing period.

Sealants/lubricants assist in sealing and providing lubrication during assembly and reduce the potential for galling. Pipe thread sealants are available in various forms such as dry pre-applied tape, paste, and anaerobic liquid.

Pre-applied sealants, such as Vibraseal and powdered Teflon, are usually applied to connectors by the manufacturer. Connectors with some of these sealants may be remade a few times without needing additional sealant. Vibraseal may also help reduce loosening due to vibration.

Teflon tape, if not applied properly, can contribute to system contamination during assembly and disassembly. In addition, because of Teflon’s high lubricity, fittings can be more easily overtightened, and it does not offer much resistance to loosening due to vibration.

Paste sealants can also contribute to system contamination if not applied properly. They are also messy to work with, and some types require a cure period after component installation, prior to system startup.

Anaerobic liquids are available from several manufacturers and perform sealing as well as thread-locking functions. They are applied to the connectors by the user and require a curing period prior to system startup. Some are soluble in common hydraulic fluid and will not contaminate the system. For proper performance, they need to be applied to clean, dry components. Be sure to carefully follow the manufacturer’s directions when applying these liquids.

4.6.2 Tube and Fitting Damage

Key Technical Point

Abuse of tubes and fittings will cause leaks. Damaging sealing surfaces and threads in handling and storage, overtightening fittings, incorrectly retightening fittings, and using tubing lines as supports are commons forms of abuse.

The following are some common forms of tube and fitting abuse to avoid:

- Damaging sealing surfaces and threads in handling and storage. Do not remove caps and plugs while putting parts in storage. Caps also provide a method of installing O-rings without damage.
- Overtightening fittings. Thinking that “if a fitting leaks, tighten it a little more” is not always correct. Overtightening, more often than not, distorts the part, and causes leakage.
- Retighten fittings. Check to see if the fitting is tight. If not, tighten it to the appropriate torque. If the fitting is tight and the leakage continues, wait until the unit is down, and check for the cause of the leak. Then, retighten it to the recommended make-up procedure.
- Using tube lines as structural supports, ladder rails, etc. This puts a strain on joints, causing leakage.

Key O&M Cost Point

Because of leaks in the lines near steam valve actuators, some plants have installed isolation valves.

Some utilities have installed isolation valves in the branch lines to individual valve actuators. This allows for isolation of leaks that occur at an actuator. The valves are welded in the line, compression valves that are locked open during operation. See Appendix B for more information.

Note: Much of the information in this section was taken from the Parker Fluid Connectors *Industrial Tube Fittings Catalog* and Parker Hannifin Corporation’s Dry Technology Seminar. Their permission to use this material is appreciated.

4.6.3 Fluid Carbonization

Westinghouse Availability Improvement Bulletin (AIB) 8102, dated 6/15/1981 and titled "Electrohydraulic Control System Tubing Inspection," recommends the inspection of tubing runs for possible contact with hot turbine components.

Key Technical Point

EHC fluid is subject to carbonization at temperatures above 225°F (107°C).

EHC fluid is subject to carbonization at temperatures above 225°F (107°C). For tubing installation, it is important to avoid close contact with heat-producing equipment, for example, steam lines, steam valves, or pumps. If the tubing has been exposed to temperatures above 225°F (107°C), the tubing should be checked for fluid carbonization. A functional trip rest of the steam inlet valves can be performed. If the valves are sluggish or have intermittent motion, this may be an indication that the tubing is plugged and should be replaced. On outdoor units that have their tubing runs trace heated and insulated, the temperature of these lines must not exceed 160°F (71°C) to prevent stress corrosion cracking of the stainless steel piping.

4.6.4 Tube Supports

Westinghouse Operation & Maintenance Memo (OMM) 040, dated 10/10/1983 and titled "EH Actuator Tubing Support Bracket Addition," recommends that a bracket be installed on the tubing near the actuator. This addition was the result of operating experience that indicated the potential for tube cracking and loss of EH fluid because of insufficient tube support near the actuator.

4.6.5 Shut-Off Valve

GE TIL 1123 recommends the addition of shut-off valves and accumulators to the control valve actuator assemblies. The accumulators reduce the fluctuations in the EHC system from the electronic pulses to the control valve actuators.

4.6.6 Socket Welds

During 2000, the EPRI Repair and Replacement Applications Center (RRAC) is supporting the development of a Code Case for the weld overlay repair of socket welds. (Socket welds are used in securing the fittings on the tubing.) The configuration is a 2-to-1 fillet weld (the length of the fillet weld is 2 times the leg fillet). See Figure 4-15 for this configuration. This technique may provide significant cost/time savings and, in some cases, maybe performed while the plant is on line. Vogtle Nuclear Station has had successful experience with using a 3-to-1 fillet weld.

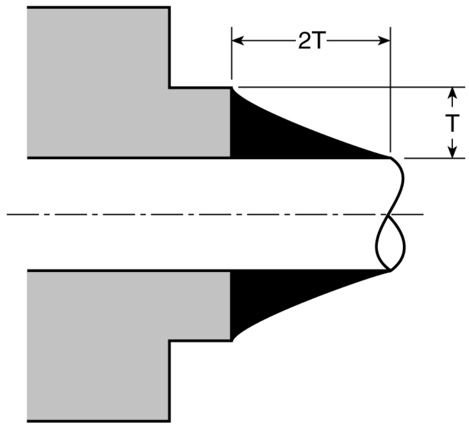


Figure 4-15
Socket Weld Configuration

4.6.7 Bolted Joints

The EPRI *Bolted Joint Maintenance and Application Guide*, TR-104213, can be used for general procedures and assembly guidelines for bolted joints.

4.7 Compressed Air System Piping Installation Factors

Key Technical Point

Properly sizing the piping and valves for the air system reduces pipe friction and pressure drop in the system.

Installation of properly sized distribution piping pays ongoing dividends by reducing pipe friction and pressure drop in the system. In addition, making the distribution piping into a loop provides alternative flow directions for varying demands and reduces pressure drop. Distribution header piping should be arranged with a slight slope away from the compressor and the air receiver to avoid any moisture in the piping.

The header connection from the air receiver should be sufficiently high to be above any potential liquid level in the air receiver, if it was not properly drained. Drop legs from headers should be included with traps for condensate removal. Properly located and maintained compressed air dryers can prevent condensate in headers. Piping from the header to points of use should connect to the top or side of the header to avoid being filled with condensate and should be kept as short as possible.

Key Technical Point

Pressure drop from the header to the point of use should not exceed 1 psi (50 mm Hg) during the duty cycle.

An ample number of tapped connections in the headers and piping also allow evaluation of air pressure at points throughout the system.

Some plants have their air distribution piping near the roof of buildings, which exposes the piping and associated valves to increased heat in summer conditions. On the other hand, distribution piping may run between buildings and be exposed to direct sunlight in the summer and extreme cold in the winter. Piping must be adequately supported and must allow for thermal expansion.

Ideally, piping should be corrosion-free not only to eliminate corrosion particles that can block orifices, instruments, and valves, but also to avoid deterioration of the pipe itself.

5 PREVENTIVE/PREDICTIVE MAINTENANCE

5.1 EHC Failure Causes

Problems with tubing, fittings, and supports can cause leaks in the EHC hydraulic system. Some of the causes and corresponding preventive (PM) and predictive maintenance recommendations are:

Key Technical Point

Many tube and fitting leaks are caused by high cycle fatigue damage from vibration. Some utilities have replaced the rigid tubing with flexible hoses near valve actuators. Clamps can be added to the tubing lines to dampen the vibration.

- Tube and fitting cracks from vibration. Vibration from the valve actuators and EHC pumps cause cracking in the EHC tubing and fittings. Typically, the vibration is high cycle fatigue induced. The PM strategy is to visually inspect for tubing movement during operation. In addition, vibration analysis is used for the EHC pump and motor coupling. Careful attention should be given to the baseline data and trending of data to detect problems.

  An exhaustive search was made in the industry for vibration data and analysis on EHC tubing. No information was found. See Appendix B for EHC modifications for vibration problems.

  The addition of clamps for dampening vibration is recommended. See Figure 4-7 and Table 4-1 for the recommended spacing of the clamps. Hydraulic hoses have been installed at valve actuators by some utilities to eliminate the vibration on the rigid tubing.

  For BWR units, TIL 1123 was issued to install accumulators on control valve assemblies. The accumulators reduce the effect of the pulsations of the control valve actuators. This reduces the vibration on the EHC tubing.

- Improper tube flaring**.** The incorrect flaring of the tube for fitting connections will cause leaks. The tube flaring procedure can be found in Section 4.3.1. Some utilities use a conical seal (see Figure 4-14) to improve any imperfections in the flared tube surface. In addition, the flareless and face seal fittings are improved designs that do not require tube flaring for installation.

Key Technical Point

Visual inspections should be performed on fittings and ports with O-rings for swelling or protrusion of the O-ring.

- O-ring failures. Improper O-ring materials, sizes, and installation will cause leaks. Compatible seal materials are given in Section 3. Procedures for sizing and installing O-rings should be included in the affected work packages. In addition, a visual inspection should be performed for any swollen or protruding O-rings after installation.
- Improper support**.** Westinghouse and GE have issued bulletins for improved support of the EHC pump discharge piping and the tubing to actuator connections. See GE TIL 1123-3, "Hydraulic Leaks in BWR Steam Turbine Electrohydraulic Control Systems;" TIL 1089-2, "Hydraulic Power Unit Pump Discharge Piping Modifications;" TIL 894-4, "EHC Hydraulic Shutoff Valves;" Westinghouse OMM –040, "EH Actuator Tubing Support Bracket Addition;" and AIB-7701, "Inspection of EH Fluid Pump Discharge Tubing." Check with the OEM for any modifications that are recommended. Loose supports can be caused by vibration and can be detected by a visual inspection on a monthly walkdown by a system engineer. Lock-tabs on fittings can be installed for persistent vibration problems. See Section 3 for more details.
- Personnel damage**.** During outages, tubing can be mishandled. Fittings are disassembled for component inspections and repairs. The sealing surfaces and threads can be damaged if not properly protected. On reassembly, the fittings can be overtightened, which will cause leaks. Tubing can be stepped on and damaged. Also tubing can be used improperly used to support ladders and other equipment. Proper handling of the tubing and fittings during outages should be included in the work instructions when working on the EHC system.
- Failed welds**.** Improper seal welds on the fittings can cause cracked tubing and leaks. Welding procedures should be verified for the socket welds on any of the fittings. One utility has had success with a 3-to-1 leg fillet weld on the fitting. EPRI is working on a Code Case for a 2-to-1 leg fillet weld. See Section 4 for more information.
- Stress corrosion**.** Cracks in the tubing and fittings can occur from chemistry problems in the EHC fluid. The addition of cleaning solvents can increase the chlorine content above the acceptable limit. The EHC fluid should be sampled and analyzed on a 1 to 3 month basis, depending on the results.

Key Technical Point

Fluid analysis is critical for the performance of the EHC fluid system. Checking for moisture, particulates, resistivity, chemicals, etc., enables detection of problems that affect the tubing, fittings, ports, and hydraulic components.

Key Technical Point

Deterioration in the EHC fluid from the presence of moisture is relatively rapid, and failures from this presence can be expected after 8–10 months of exposure.

Fluid analysis is used for the EHC fluid to determine the presence of moisture, particulates, and additive depletion. Deterioration from the presence of moisture is relatively rapid. Failures can be expected after 8 to 10 months of exposure. Turbines located outside are more prone to moisture from condensation. Thermal degradation can occur when exposed to heat sources greater than 150°F (65.5°C). Deterioration can be very rapid, depending on the amount of heating and the fluid's moisture content.

Particulates can be introduced by improper filter maintenance, filter failures, or improper fluid transfer and handling. Failure from particulates can take 5 to 10 years to occur. Sampling of the fluid should initially be on a monthly interval and can be increased to 3 months if the results are acceptable.

Low resistivity in the EHC fluid can cause electrochemical erosion to the corners of the servovalves. The fluid analysis should include a check for resistivity. INPO (in Operation & Maintenance Reminder 423, "Maintaining Main Turbine Hydraulic Control System Fluid Quality") has recommended a higher level of resistivity than the OEMs.

Key Technical Point

Fluid analysis should include checks for water, acid, viscosity, particle count, electrical resistivity, and chlorides.

Fluid analysis should include checks for water, acid, viscosity, particle count, electrical resistivity and chlorides. The EPRI *Steam Turbine Hydraulic Control System Maintenance Guide*, TR-107069, lists the areas to be checked and the typical industry limits.

Key Technical Point

Empirical inspections from a system engineer walkdown and an operator round are invaluable in detecting leaks.

A system engineer walkdown is recommended on a monthly basis to detect problems before the equipment breaks down. The walkdown should include inspecting for:

- Damage, fretting, or leaks in tubing
- Excessive pipe vibration and support integrity
- Wetting in actuators
- Leaks
- Looseness of bolting, cable, and conduit condition
- Verification that pressure cycle time is within OEM specifications
- Leaks on the turbine front standard
- Loose fittings
- Clamps and cable damage
- Leaks from pumps and accumulators

- Loose fasteners and supports
- Verification that temperatures, pressures, and flows are in the acceptable range
- Unusual noises

Operator rounds are recommended on a regular basis and should include inspecting for:

- Leaks
- Unusual noises
- Loose, damaged, or missing fasteners and hardware
- Pressure oscillations
- Desiccant color
- Heater fan failure and unusual vibration
- Verification that all system operating parameters and levels (especially hydraulic oil) are within desired ranges

A listing of EHC hydraulic components, the corresponding failure causes, and PM recommendations are shown in Table 5-1.

Table 5-1
EHC Tubing and Fitting PM Recommendations

Hydraulic Component	Failure Causes	PM Recommendations
EHC fluid	Moisture	Fluid analysis Operator rounds Filter and strainer maintenance
	Particulate	Fluid analysis Operator rounds Filter and strainer maintenance Functional tests
	Thermal	Fluid analysis Operator rounds
	Chemical contamination	Fluid analysis Filter and strainer maintenance
	Additive depletion	Fluid analysis
	Resistivity	Fluid analysis

Table 5-1 (cont.)
EHC Tubing and Fitting PM Recommendations

Hydraulic Component	Failure Causes	PM Recommendations
Elastomers, O-rings, gaskets, bladders, and seals	Swelling	Operator rounds Overhaul System engineer walkdown
	Deterioration of material properties	Operator rounds Overhaul System engineer walkdown Fluid analysis
	Wear	Operator rounds Overhaul System engineer walkdown Fluid analysis
	Improper assembly	Work package procedures Operator rounds Overhaul System engineer walkdown
	Improper material	System engineer walkdown Operator rounds Material specified in work packages
Tubing and fittings	High cycle fatigue vibration	Vibration analysis System engineer walkdown Operator rounds Addition of clamps
	Improper flaring	Correct procedures and tools Change to flareless or face seal Conical seal addition
	Stress corrosion	EHC fluid analysis
	Failed welds	Proper weld procedures Visual inspection
	Personnel damage	Proper protection for threads and surfaces during disassembly Precautions in EHC work packages
	Improper support	Vibration analysis OEM review and repairs System engineer walkdown Operator rounds
EHC servovalves	Electrochemical erosion	EHC fluid analysis

5.2 EHC PM Template

While the OEM-recommended intervals are a good starting point, the following are intervals from an EPRI review. The Preventive Maintenance Template from the *Preventive Maintenance Basis, Volume 37: Main Turbine EHC Hydraulics,* TR-106857-V37, is shown in Table 5-2.

Table 5-2
PM Template for EHC Hydraulics from EPRI TR-106857-V37

PM Task	Intervals
Vibration analysis	3 months
Fluid analysis	1 month
System engineer walkdown	1 month
Operator rounds	As required

5.3 Compressed Air System Piping Inspections

Key Technical Point

Performing a visual inspection for leaks of the air piping and header on a regular basis is very important.

The following recommendations come from the EPRI *Compressor and Instrument Air System Maintenance Guide,* TR-108147:

- Walk down and inspect all headers, distribution piping, and joints on a regular basis.
- Take care with piping located close to passageways and other equipment because physical damage can occur from forklift trucks, from movement of equipment, and from being climbed on.
- Where damage is observed, check the piping for leaks.

The following are ways to check for air leaks in the piping joints and connections:

- Apply a soap solution and watch for bubbles of air escaping the piping or joint.
- Use ultrasonic leak detection devices, depending on the location of the leak and the background noise level.
- Use tracer gases to test the distribution system for leaks.
- Use ultrasonic equipment to test for pipe wall thickness and joint insertion.
- Use X-ray testing to check joints. A disadvantage of using X-ray testing can be poor image quality and restriction of personnel access during X-raying.

6
TROUBLESHOOTING GUIDELINES

6.1 EHC Fittings

Key Human Performance Point

In order to troubleshoot an EHC leak with a fitting or port, it is important to find the root cause of the leak.

Troubleshooting hydraulic leaks in the turbine EHC system should include these steps:

1. Determine the true location of the leak.
2. Check to see if the joint has been tightened properly.
3. Use Tables 6-1 through 6-3 to find the cause of the leak and correct it.

Tables 6-1 through 6-6 from the Parker Hannifin Corporation’s Dry Technology Seminar were used with permission.

Table 6-1
Leakage at a 37° Flared Fitting

Condition	Probable Cause
Flare under size	The tube was not inserted far enough in the flaring dies.
Flare over size	The tube was inserted too far in the flaring dies.
Flare out of square	The tube cut-off was out of square or faulty flaring tool was used.
Flare eccentric	A faulty flaring tool was used or the tube quality was poor.
Split flare	The tube is too hard or the tube ID has scratches or draw marks.
Axial ridge on flare ID	Improper tube. The ID has a weld bead on it.
Pock marks on flare ID	The tube end was not deburred or cleaned properly before flaring.
Scratches on flare	The tube ID is not clean or has draw marks. The flaring cone was worn.
Fitting nose deformed (collapsed) excessively	The fitting was over tightened or the fitting is too short.

Table 6-2
Leakage at a Flareless Fitting

Condition	Probable Cause
No identification on the tube end	The tube was not bottomed in the fitting. Compare the length from the end of the tube to the front end of the ferrule of a known good assembly to that of the assembly in question. If it is too short, this assembly should be scrapped.
Shallow bite	Inspect for turned-up ridge of material. A failure to achieve this ridge can be traced to either the nut not being tightened enough or the tube not being bottomed against the stop, which allowed the tube to travel forward with the ferrule. In some instances, this assembly can be reworked.
Over-set ferrule	Too much pressure or more than 1-3/4 turns from finger tight was used to pre-set the ferrule, or the nut was severely overtightened in the final assembly. This assembly should be scrapped.
Ferrule cocked on the tube	The ferrule may become cocked on the tube when the tube end is not properly lined up with the body. Generally, this condition is caused by faulty tube bending. All bent tube assemblies should drop into the fitting body prior to make up. This assembly should be scrapped.
No bite	If all of the prior checks have been made and the ferrule still shows no sign of biting the tube, it may be that the tube is too hard. This assembly should be scrapped.

Table 6-3
Leakage at the Face Seal Fitting

Condition	Probable Cause
Leakage from braze	Poor braze joint. Flux and reheat the joint. Remove and replace the sleeve. Repeat the brazing in accordance with recommended procedures.
Missing or damaged O-ring	Replace the O-ring. Ensure that the O-ring is properly seated in the groove prior to final assembly.
Improper O-ring	Install the proper size O-ring with characteristics that are suitable for the service pressure and temperature.
Damaged components	If sealing surfaces, threads, etc., are nicked or gouged, replace them with good quality components.
Braze overflow	Remove the braze overflow, melted flux, and oxide build-up from the sealing surface without damaging it prior to assembly. Otherwise, flux and reheat the joint, remove the old sleeve, and rebraze a new one.
Misalignment	Ensure that the flat face of the sleeve is brazed perpendicular to the tube. Properly bend the tubing, when necessary, to the desired angle to ensure good alignment during installation.

If the fitting shows signs of high-cycle fatigue and vibration is suspected as the cause, refer to Section 4 for additional clamping and tube positioning information.

If multiple fitting and tubing failures occur, the piping restraint and accumulators installed at the control valves should be checked.

6.2 EHC Port Connections

Use Tables 6-4 through 6-6 to find the cause of the leak in the port connections and correct it.

Table 6-4
Leakage at the Pipe Thread Ports

Condition	Probable Cause
No sealant was used or the sealant has worn thin.	Apply new sealant and retighten to specification.
Threads are galled.	Replace the fitting and/or component.
Fitting screws are too far into the port.	The port opened up or cracked. Replace the component.
Threads are severely nicked.	Replace the fitting.
Seals initially but vibrates loose after some time.	Replace the port with an SAE straight-thread port.

Table 6-5
Leakage at SAE Straight-Thread O-Ring Ports

Condition	Probable Cause
With an adjustable fitting, the washer is too loose (the washer should not move by its own weight or rock too much on the undercut).	Replace the fitting.
The fitting threads are distorted	The fitting is too soft or overtorqued. Replace the fitting or tighten to the proper torque.
There are severe scratches or nicks on the port face.	Replace the port.
The spot face of the port is smaller than the washer diameter.	An improper port tool was used. Reface the port.
The port boss has cracked.	A component is defective or the fitting is overtorqued.
The port threads are distorted (yielded).	The fitting is overtorqued. Replace the port.

If leakage persists after the fitting lock nut has been torqued properly, disconnect the fitting from the port. Make sure that the O-ring is of the correct size and material. Replace the O-ring with a new, good quality O-ring, and reconnect the fitting to specification. If the leakage persists, troubleshoot as described in Table 6-5.

Table 6-6
Leakage at Four-Bolt Split-Flange Ports

Condition	Probable Cause
The port has severe scratches or nicks in the seal area.	Resurface the port
The face of the outer lip of the flange has deep scratches and nicks.	Replace the flange.
The flange is distorted (overpressurization).	Replace the flange.
The clamp halves are distorted.	Replace the clamp halves.
The bolts are bent.	Replace the bolts.

6.3 Compressed Air Piping

Copper piping is easily damaged by physical impact or misuse. Also, the joints in a copper pipe are soldered or brazed. Soldered joints can fail due to poor joint insertion, inadequate solder penetration, or external stress. There are no national codes or specifications for soldering. The American Welding Society (AWS) considers a 70% filled joint to be adequate if the voids are small and discreetly dispersed.

ASME Code B31.1 provides specifications for the brazing of copper piping. Brazing is preferred to soldering, particularly for copper pipes above 1 in. (2.5 cm) in diameter to ensure that a joint has sufficient strength under pressure.

As stated in Section 5, leaks in the air piping and joints can be found by using a soap solution, ultrasonic leak detection devices, tracer gases, ultrasonic thickness testing, or X-ray testing.

7 SAFETY GUIDELINES

7.1 EHC Fluid Material Safety Data Sheet (MSDS)

The most commonly used EHC hydraulic fluid is Fyrquel. It is a clear, colorless, odorless liquid with a permissive exposure level of 3 mg/m^3. According to the Material Safety Data Sheet (MSDS), Fyrquel 220 MLT is a hydraulic fluid that is fire resistant. The control measures include:

- Respiratory protection. If engineering controls do not maintain airborne concentrations to an acceptable level, wear a Niosh-approved organic vapor acid gas respirator with dust, mist, and fume filters.
- Ventilation. Use general or local exhaust ventilation to keep fume or vapor levels as low as possible.
- Protective gloves. Wear vinyl or latex gloves.
- Eye protection. Wear safety glasses or chemical splash goggles.
- Other protective equipment. An eye wash station, a safety shower, and protective clothing (lab coat) should be available.
- Work hygienic practices. Observe good industrial hygiene practices. Wash your hands thoroughly before eating, drinking/smoking, and after handling EHC fluid.

Signs/symptoms of overexposure are:

- Irritation
- Dizziness
- Nervousness
- Tremors
- Headache
- Weakness
- Abdominal cramps
- Diarrhea
- Nausea
- Vomiting

- Sweating
- Tearing
- Blurred vision
- Muscle twitching
- Uncoordination
- Salivation
- Chest discomfort
- Coma
- Death

If the hydraulic fluid spills, follow these steps:

1. Stop the leak.
2. Erect a dike to prevent the fluid from spreading.
3. Absorb the spill with an inert material such as sand, clay, sawdust, or kitty litter.
4. Sweep up the material, and place it in a suitable container for disposal.
5. Wash the spill area with detergent and water. Do **not** flush EHC fluid to the sewer/waterways.

Key Human Performance Point

When testing the EHC system for leaks after maintenance, a precaution is to pump down the turbine building floor drain sump and lock out the pumps. This would prevent any spilled EHC fluid from getting downstream of the floor drains.

After maintenance on the EHC system is performed, the system should be charged and checked for leaks. If leaks are found, the EHC fluid could go to the floor drains, to the turbine building floor drain sumps, and then to the waste system. A precaution when testing the EHC system after maintenance is to pump down the turbine building floor drain sump and lock out the pumps until the system check is complete. In this way, the waste system would be protected from any spilled EHC fluid intrusion into the system.

7.2 General Safety Guidelines

Key Human Performance Point

When working with EHC fluid, wear personal protective equipment, and follow the lock-out/tag-out procedures.

Several general guidelines exist for working around the turbine EHC and compressed air system:

- Wear personal protective equipment. The use of hard hat, safety glasses, and earplugs is standard for a generating unit.
- Follow the lock-out/tag-out (LOTO) procedures. Always follow the guidelines for isolating the equipment electrically, pneumatically, hydraulically, electronically (some control systems have soft tags), and mechanically. When working on the EHC hydraulic system, the EHC pump motor breakers should be isolated, and all steam valves should be in a tripped, closed condition. When working on the compressed air system, the compressors should be isolated electrically and pneumatically before work begins on the piping.
- Wear leather gloves except when operating machinery. Vinyl or latex gloves should be worn when working with EHC fluid.
- Long-sleeved shirts are better when working around EHC fluid but not while operating machinery.
- Chemical splash goggles are preferred over safety glasses when working with EHC fluid.

8 REFERENCES

8.1 Codes and Standards

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ASTM 511-96, "Standard Specification for Seamless Stainless Steel Mechanical Tubing."

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SAE J515a, "Hydraulic 'O' Ring."

SAE J516 JUN84, "Hydraulic Hose Fittings."

SAE J517 JUN82, "Hydraulic Hose."

SAE J533b, "Flares for Tubing."

SAE J1065, "Pressure Ratings for Hydraulic Tubing and Fitting."

SAE J1453, "Fitting O-Ring Face Seal."

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Introduction to Nuclear Plant Steam Turbine Control Systems. EPRI, Palo Alto, CA: May 1995. TR-104885.

Preventive Maintenance Basis, Volume 37: Main Turbine EHC Hydraulics. EPRI, Palo Alto, CA: November 1998. TR-106857-V37.

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8.3 General Electric Literature

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General Electric Technical Information Letter 966-2, “Periodic Operational Tests EHC Mark I Trip System (GEK 17812E),” March 5, 1984.

General Electric Technical Information Letter 1089-2, “Hydraulic Power Unit Pump Discharge Piping Modifications,” November 7, 1990.

General Electric Technical Information Letter 1130-2, “Electrohydraulic Control (EHC) System Filter Element Gasket Material,” March 8, 1994.

8.4 Westinghouse Literature

Westinghouse Availability Improvement Bulletin 7701, “Inspection of E.H. Fluid Pump Discharge Tubing,” February 21, 1977.

Westinghouse Availability Improvement Bulletin 8102, “Electro Hydraulic Control System Tubing Inspection,” June 15, 1981.

Westinghouse Availability Improvement Bulletin 9107, “EH Fluid Supply System Enhancement Constant Pressure Pumps,” December 27, 1991.

Westinghouse Operation & Maintenance Memo 025, “Electro Hydraulic Control System Unloader Valves,” June 29, 1981.

Westinghouse Operation & Maintenance Memo 040, “EH Actuator Tubing Support Bracket Addition,” October 10, 1983.

8.5 Vendor Literature

Parker Fluid Connectors, *Industrial Tube Fittings*, Catalog 4300, January 1999.

Parker Hannifin Corporation, Dry Technology Seminar, Course #4300TR1-PN.

Parker Seals, *O-Ring Handbook*, ORD5700A.

8.6 Industry Information

INPO Significant Operating Experience Report 84-6, “Reactor Trips Caused by Turbine Control and Protection System Failures,” November, 1984.

INPO Operation & Maintenance Reminder 423, “Maintaining Main Turbine Hydraulic Control System Fluid Quality,” December, 1996.

9 ACRONYMS AND ABBREVIATIONS

AIB	Availability Improvement Bulletin (from Siemens Westinghouse)
ALARA	as low as reasonably achievable (an approach to radiation exposure)
ANSI	American National Standard Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing Materials
AWS	American Welding Society
BWR	boiling water reactor
CAL	Customer Advisory List (from Siemens Westinghouse)
DEH	digital electrohydraulic controls
EH	electrohydraulic
EHC	electrohydraulic controls
EPDM	ethylene propylene seal material
EPIX	Equipment Performance and Information Exchange (an information exchange system for failures of components within the scope of the Maintenance Rule for nuclear power plants.)
EPRI	Electric Power Research Institute
ETSV	electrical trip solenoid valve (used on a General Electric turbine control system)
FAS	fast-acting solenoid
FFFT	flats from finger tight
FKM	fluorocarbon material (Viton)

GE	General Electric
HPU	hydraulic power unit
INPO	Institute of Nuclear Power Operations
ISA	Instrument Society of America
JIT	Just In Time database (JIT operating experience, information used in preparing personnel to perform nuclear plant operations)
LER	Licensee Event Reports (database of reports from nuclear plants for loss of unit load incidents)
LOTO	Lock-Out/Tag-Out
LVDT	linear variable displacement transducer
MSDS	Material Safety Data Sheet (contains health concerns and cautions for hazardous materials)
NMAC	Nuclear Maintenance Applications Center
NPRDS	Nuclear Power Reliability Database System
NPT	National Pipe Thread (ANSI B1.20.1)
NPTF	National Pipe Thread Fine (SAEJ476, ANSI B1.20.3)
NRC	Nuclear Regulatory Commission
OEM	original equipment manufacturer
OMM	Operation and Maintenance Memo (from Siemens Westinghouse)
OPEC	Operating Plant Experience Code
OSHA	Occupation, Safety and Health Administration
PM	preventive maintenance
PUR	Product Upgrade Recommendation (from Siemens Westinghouse)
PWR	pressurized water reactor
QA	Quality Assurance

RCM reliability-centered maintenance

SAE Society of Automotive Engineers

TAG Technical Advisory Group

TAFEFU transfer and fuller’s earth filtering unit

TFFT turns from finger tight

TIL Technical Information Letter (from General Electric)

A HYDRAULIC-RELATED BULLETINS LIST

A.1 General Electric Hydraulic-Related Bulletins List

Table A-1
General Electric Technical Information Letters (TIL) List

TIL #	Date	Subject
1165-3	5/1/91	Periodic Operational Testing (Off-Line) of Mechanical Overspeed Trip Devices on 1500 rpm and 1800 rpm Nuclear Large Steam Turbines
1142-2	12/7/93	Plastic Plugs Used in Auxiliary Parts of Oilgear Trip and Reset Solenoid Valves
1130-2	3/8/94	Electrohydraulic Control (EHC) System-Filter Element Gasket Material
1123-3	10/14/92	Hydraulic Leaks in BWR Steam Turbine Electrohydraulic Control Systems
1115-3R1	5/8/92	Replacement of Large Steam Turbine EHC Hydraulic Power Unit Main Pumps
1089-2	11/7/90	Hydraulic Power Unit Pump Discharge Piping Modifications
1053-4	12/11/89	EHC Hydraulic Power Unit – Hilco Fuller's Earth Cartridge Redesign
1050-3R1	3/9/90	Electrohydraulic Control (EHC); Front Standard Electrical Trip Solenoid Valves (ETSV)
969-3R1	12/27/93	Periodic Turbine Steam Valve Tests-Nuclear Steam Turbines
966-2	3/5/84	Periodic Operational Tests-EHC Mark I Trip Systems, GEK-17812E
957-3	3/11/83	Maintenance Recommendations for Camshaft Operated Control Valves, GEK-72354
949-3	5/19/82	Maintenance of Main Stop Valves for Fossil Turbines, GEK-85280
946-3	3/8/82	EHC Mark II Standby Mechanism
945-2	3/8/82	EHC Hydraulic Power Unit TAFEFU Safety Recommendations
923-3	3/18/81	EHC Disk Dump Valves
895-2	2/1/80	EHC Mark I Mechanical Trip Valve
894-4	12/17/79	EHC Hydraulic Shutoff Valves

Table A-1 (cont.)
General Electric Technical Information Letters (TIL) List

TIL #	Date	Subject
890-39	11/27/79	Recommendations for the Maintenance of Separately Mounted Fossil Control Valves with Individual Actuators on Large Steam Turbines
877-3	10/2/78	EHC Hydraulic Power Unit
848	10/21/77	Solenoid Valves on EHC Control Pass
841-3A	7/27/77	EHC Hydraulic Piping System Improvements
796-2	12/29/75	Water Contamination of EHC Fluid Through the Coolers
785-3	8/4/75	Restricting Flow Through Flushing Valves During EHC Flushing
769-2	3/19/75	EHC Fluid Systems Valve Test
759-1	1/9/75	EHC Hydraulic Power Unit Filters
487		Handling and Storage of EHC Components

A.2 Westinghouse Hydraulic-Related Bulletins List

Table A-2
Westinghouse Availability Improvement Bulletins (AIB), Operation & Maintenance Memos (OMM), Customer Advisory Lists (CAL), and Product Upgrade Recommendations (PUR) List

Date	Document	Subject
08/03/98	PUR 1096	Repack all manual valves and check valves in the control fluid piping system with EHC fluid compatible packing material.
08/03/98	PUR 1042	Upgrade the control fluid tank.
03/15/93	AIB-9301	Steam Turbine Overspeed Protection System. Supercedes CAL 92-02, issued 02/13/92.
12/04/92	AIB-9204	EH Control System Autostop Relief Valve. Supercedes AIB-7717, issued 11/04/77.
02/13/92	CAL-92-02	Operation Maintenance Testing of and System Enhancements to Turbine Overspeed Protection System.
12/27/91	AIB-9107	EH Fluid Supply System Enhancement Constant Pressure Pumps. Supercedes AIB 8901, issued 03/31/89.
12/20/91	AIB-9106	EH Control System Unloader Valve Modification. Supercedes OMM-025, issued 06/29/81.
04/19/91	OMM-126	Removal of EH Actuator Grease Fittings.
09/06/90	OMM-121	BB95 and 96 Control Valve Spring Seat Retainer Bolt.
08/13/90	OMM-120	Maintain EH System Servovalves.
02/09/90	OMM-108	Maintenance of Main Stop Valves and Reheat Stop Valves.
01/30/90	OMM-107	Controlling Biological Growths in Turbine-Generator Lube Oil.
03/31/89	AIB-8901	Replacement of Denison Model T1C EH Fluid Supply Pumps. Canceled 12/27/91. Superceded by AIB-9107.
11/18/88	OMM-092	Steam Turbine Generator Motoring and Overspeed Protection.
11/04/87	AIB-8704	Replacement Diaphragms for Interface Diaphragm Valves.
06/11/86	OMM-063	Inspection Recommendations for Moog Servovalves.
05/23/86	AIB-8602	Emergency Trip System Control Block Modification.
10/10/83	OMM-040	EH Actuator Tubing Support Bracket Addition.
02/25/83	OMM-033	Port Restriction Test of Schutte & Koerting Eight-Inch Duplex Three-Way Valves.
12/16/82	OMM-032	Nuclear Turbine DEH Operational Recommendations.
07/23/82	AIB-8204	Auxiliary Drive Turbine EH Control System Drain Line Modification.
06/29/81	OMM-025	EH Control System Unloader Valves. Canceled 12/20/91. Superceded by AIB-9106.
06/15/81	AIB-8102	EH Control System Tubing Inspection.

Table A-2 (cont.)
Westinghouse Availability Improvement Bulletins (AIB), Operation & Maintenance Memos (OMM), Customer Advisory Lists (CAL), and Product Upgrade Recommendations (PUR) List

Date	Document	Subject
03/23/81	OMM-021	Color Coded O-ring Compounds.
03/23/81	OMM-022 Rev. #1	Emergency Trip System Circuit Protection.
12/19/80	OMM-019	EH Control System Heat Exchanger Inspection.
09/14/79	OMM-009	Steam Turbine EH Fluid Reservoir Pressure Switch Snubber Installation.
07/28/78	OMM-003	Steam Valve/Hydraulic Actuator Alignment.
11/4/77	AIB-7717	Inspection of Steam Turbine EH Control System Auto-Stop Relief Valves.
02/21/77	AIB-7701	Inspection of EH Fluid Pump Discharge Tubing.

B
NUCLEAR PLANTS WITH MODIFICATIONS FOR VIBRATION IN EHC SYSTEMS

Information was solicited from the GE EHC Listbot web site for the following questions:

For the time period since 1996:

1. If you have experienced problems with the hydraulic tubing and fittings in the EHC system, what are the problems? For example, leaks, cracks in tubing and fittings, high-cycle fatigue damage, stress-corrosion cracking, etc.

2. What modifications have been performed to correct these problems? For example, installed flex hose to valve actuators, installed valve isolators to valve actuators, installed tube clamps for vibration, etc.

3. What modifications are planned for future work?

The answers received are found in Table B-1.

Table B-1
Utility Responses on EHC Modifications

Utility/Plant	Problems	Modification	Future Work
Commonwealth Edison/Dresden Units 2 & 3/Quad Cities Units 1 & 2	Leaks in the fittings and low cycle fatigue cracks.	Installed flex hoses on control valves. Added isolation valves to all supply EHC lines to the main turbine valve actuators. Installed accumulators on control valves.	Upgrade the hydraulic power unit for example, new pumps, heat exchangers, etc.
Commonwealth Edison/La Salle Units 1 & 2	Two broken tubing pieces on control valve accumulator assemblies from high cycle fatigue. Also, a leak on a control valve fast-acting solenoid (FAS) line due to O-ring failure at the actuator fitting.	Installed a “beefed-up” tubing piece on an accumulator. Previously installed isolation valves in each supply line at all actuators and flexible hoses in the lines to control valves and bypass valves.	Install a dry air purge line to the EHC reservoir.
Alliant Energy/Duane Arnold Energy Center	IGSCC.	Replaced about 1/2 of system and installed 304 L SS tubing and flareless fittings	N/A
PSE&G/Hope Creek Plant	No problems since 1996.	Installed accumulators on control valves	Install isolation valves at each valve actuator to facilitate maintenance.
Southern Nuclear Operating Co./Vogtle Nuclear Station	Leaks at 37° flare fittings. Tubing breaks at actuators. Vibration-related breaks near skid.	Used copper conical seals. Installed flex hoses and isolation valves. Installed pulsation dampener on pump discharge.	No information.

C
POP OUT SUMMARY

Key Human Performance Point

Page	System	Key Human Performance Point
6-1	Troubleshooting Guidelines EHC Fittings	In order to troubleshoot an EHC leak with a fitting or port, it is important to find the root cause of the leak.
7-2	Safety Guidelines EHC Fluid MSDS	When testing the EHC system for leaks after maintenance, a precaution is to pump down the turbine building floor drain sump and lock out the pumps. This would prevent any spilled EHC fluid from getting downstream of the floor drains.
7-3	Safety Guidelines General Safety Guidelines	When working with EHC fluid, wear personal protective equipment and follow the lock-out/tag-out procedures.

Key O&M Cost Point

Page	System	Key O&M Cost Point
3-1	Material Selection EHC Tubing Material	The welded and drawn (SAE J525) tubing is the most commonly used; it can be used by all style fittings and has a medium cost.
3-3	Material Selection EHC Fittings	The 37° size flared fitting is the most commonly used and has the lowest cost.
4-5	Layout and Installation Routing Factors	Failure of the tubing and supports in the vicinity of steam valves frequently results in lost generation.
4-20	Layout and Installation Tube and Fitting Damage	Because of leaks in the lines near steam valve actuators, some plants have installed isolation valves.

Key Technical Point

Page	System	Key Technical Point
3-4	Material Selection EHC Fittings	The flareless fitting is more tolerant of vibration than the flared fitting and requires minimal tube preparation.
3-5	Material Selection EHC Fittings	The face seal fitting is the most tolerant of the fittings for vibration and is the easiest fitting to assemble.
3-6	Material Selection EHC Port Connections	The pipe thread port is used for smaller line sizes.
3-6	Material Selection EHC Port Connections	The straight thread port is not prone to loosening and has an O-ring seal.
3-7	Material Selection EHC Port Connections	The four-bolt split-flange port is used for larger line sizes and high pressures.
3-9	Material Selection EHC Elastomers	Material selection for elastomers that are compatible with the phosphate-ester EHC fluid is very important. Acceptable materials are EPDM, Viton, butyl rubber, silicone rubber, and Teflon (PWRs only).
3-10	Material Selection Compressed Air System Piping	The material used for the compressed air system piping can be copper, carbon steel, galvanized steel, or stainless steel. Stainless steel piping has the fewest problems but is the most expensive. The use of galvanized steel for piping is a common material choice.
4-3	Layout and Installation Routing Factors	Using 45° bends is preferable to using 90° bends. The pressure drop in one 90° bend is greater than in two 45° bends.
4-5	Layout and Installation Routing Factors	Tubing supports should be installed so that vibration caused by a unit trip is dampened immediately or within a maximum of three oscillations.
4-7	Layout and Installation EHC Fitting Installation Factors	The use of swivel fittings, bent tube assemblies, and elbows can greatly improve assembly and disassembly of fittings in close spaces.

Key Technical Point

Page	System	Key Technical Point
4-13	Layout and Installation Conical Seals	The addition of a conical seal can improve the sealing of the flared and flareless fittings.
4-18	Layout and Installation Hydraulic Hose Installation Factors	Because of vibration problems some plants have replaced tubing with flexible hose in the lines to the valve actuators.
4-19	Layout and Installation Sealants/Lubricants	Pipe thread sealants are available as dry, pre-applied tape, paste, and anaerobic liquid. The connectors with dry, pre-applied sealant from the manufacturer may be remade a few times without needing additional sealant. Teflon tape does not offer much resistance to loosening from vibration. Paste sealants can be messy to work with. Paste sealants and anaerobic liquids may require a curing period.
4-20	Layout and Installation Tube and Fitting Damage	Abuse of tubes and fittings will cause leaks. Damaging sealing surfaces and threads in handling and storage, overtightening fittings, incorrectly retightening fittings, and using tubing lines as supports are common forms of abuse.
4-21	Layout and Installation Fluid Carbonization	EHC fluid is subject to carbonization at temperatures above 225°F (107°C).
4-22	Layout and Installation Compressed Air System Piping Installation Factors	Properly sizing the piping and valves for the air system reduces pipe friction and pressure drop in the system.
4-22	Layout and Installation Compressed Air System Piping Installation Factors	Pressure drop from the header to the point of use should not exceed 1 psi (50 mm Hg) during the duty cycle.

Key Technical Point

Page	System	Key Technical Point
5-1	Preventive/Predictive Maintenance EHC Failure Causes	Many tube and fitting leaks are caused by high cycle fatigue damage from vibration. Some utilities have replaced the rigid tubing with flexible hoses near valve actuators. Clamps can be added to the tubing lines to dampen the vibration.
5-1	Preventive/Predictive Maintenance EHC Failure Causes	Visual inspections should be performed on fittings and ports with O-rings for swelling or protrusion of the O-ring.
5-2	Preventive/Predictive Maintenance EHC Failure Causes	Fluid analysis is critical for the performance of the EHC fluid system. Checking for moisture, particulates, resistivity, chemicals, etc., enables detection of problems that affect the tubing, fittings, ports, and hydraulic components.
5-2	Preventive/Predictive Maintenance EHC Failure Causes	Deterioration in the EHC fluid from the presence of moisture is relatively rapid, and failures from this presence can be expected after 8–10 months of exposure.
5-3	Preventive/Predictive Maintenance EHC Failure Causes	Fluid analysis should include checks for water, acid, viscosity, particle count, electrical resistivity, and chlorides.
5-3	Preventive/Predictive Maintenance EHC Failure Causes	Empirical inspections from a system engineer walkdown and an operator round are invaluable in detecting leaks.
5-6	Preventive/Predictive Maintenance Compressed Air System Piping Inspections	Performing a visual inspection for leaks of the air piping and header on a regular basis is very important.

Target:

Nuclear Power

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EPRI creates science and technology solutions for the global energy and energy services industry. U.S. electric utilities established the Electric Power Research Institute in 1973 as a nonprofit research consortium for the benefit of utility members, their customers, and society. Now known simply as EPRI, the company provides a wide range of innovative products and services to more than 1000 energy-related organizations in 40 countries. EPRI's multidisciplinary team of scientists and engineers draws on a worldwide network of technical and business expertise to help solve today's toughest energy and environmental problems.

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