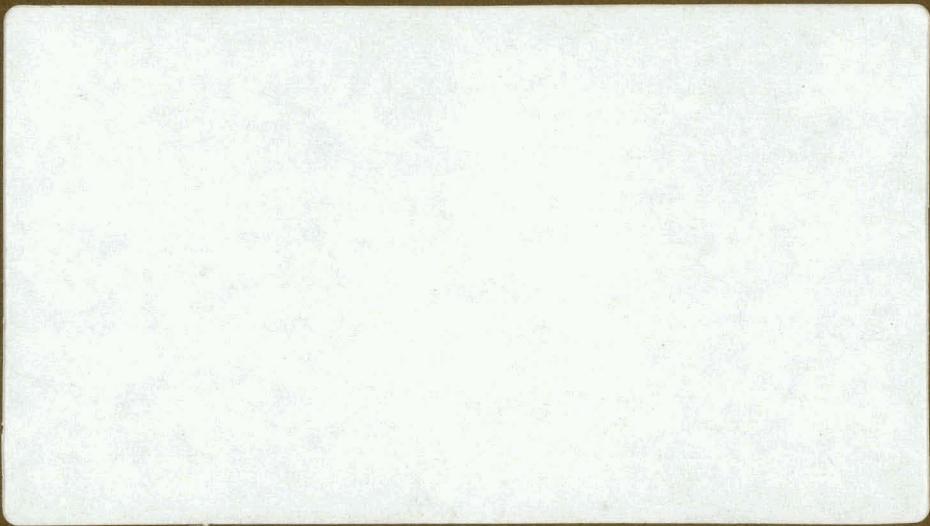


DOE/CS/32199-3

MASTER



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VOLUME 3--APPENDICES (CONT)

FINAL REPORT
FOR **MASTER**
SOLAR PRODUCTION OF INDUSTRIAL PROCESS STEAM
RANGING IN TEMPERATURE FROM 300°F TO 550°F
(PHASE I)

PERIOD OF PERFORMANCE
SEPTEMBER 30, 1978 TO JUNE 30, 1979

DOE CONTRACT NO. ET-78-C-03-2199
FWDC NO. 9-41-4010

JUNE 30, 1979



FOSTER WHEELER DEVELOPMENT CORPORATION

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APPENDIX D.7
INSTRUMENTS

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INSTRUMENTATION

JOB SPECIFICATION 60863-60A1

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I. SCOPE

Instruments and controls are to be furnished in accordance with this standard, and as indicated on the Engineering Flow Diagrams. In case of conflict, this standard supersedes proposal Engineering Flow Diagrams; however, contract Engineering Flow Diagrams supersede this standard.

II. GENERAL

A. Instrument Terminology

Terminology shall conform to ANSI C85.1 and C85.1a, Terminology for Automatic Control.

B. Flow Diagram Symbols and Instrument Identifications (Tag Numbers)

Flow diagram symbols and identification (tag numbers) for instruments and controls shall be in accordance with ENG STD 60A3, (basically ISA Std. S5.1). Additional symbols required for a specific project shall be explained by additions to ENG STD 60A3 as issued for that project.

C. Instrument Index

An Instrument Index listing all instruments for the project and produced by computer shall be furnished.

D. Package Units

1. The instrumentation requirements, when packaged or licensed units are specified, shall conform to this specification wherever possible.
2. Local control panels for package boilers, compressors, process heaters, or other units requiring such panels, shall preferably be furnished by the equipment vendor. The panels with the instrumentation therein and the equipment it is to control shall be tested as a unit wherever possible.

III. DESIGN REQUIREMENTS

A. General

1. Tagging

An identification tag shall be attached to each piece of instrumentation equipment. The tags shall be of sturdy, stainless steel or other equally weather resistant material, permanently fastened to the material with stainless steel screws or pins.

2. Painting

Manufacturer's standard colors shall be used for all project instrumentation, including visible portions of instruments mounted on the control panel, unless otherwise specified.

3. Electrical Equipment and Enclosures

All electrical instrument equipment and enclosures for all field mounted or local panel mounted electrical or electronic instruments (or instruments having electrical connections or power) shall conform to the electrical classification assigned to the area in which they are installed, and shall be suitable for outdoor installation if required.

4. Transmitters

- a. In general, transmitters shall be of the force balance type or other negligible displacement type, except where such devices are not available or another type of device of proven superior performance is available for a specific measurement. All pneumatic transmitters shall be equipped with an air input gauge as a part of the air supply filter regulators.
- b. Process variable indication shall be provided for each transmitter and local controller. This indication shall be either direct reading, or the transmitter output in terms of the process variable.

5. Transmission System

No process fluids of any type shall be piped into the control room. Transmission of the process variable shall be by means of electronic, electric, pneumatic, or thermocouple type instruments.

B. Temperature Instruments

1. Strip chart multipoint temperature recorders shall be thermocouple actuated. Recorder points shall not normally be checked by the multipoint plant temperature indicator. The multipoint plant temperature indicator shall be digital type, thermocouple actuated. Range span shall be suitable for use during plant start-up. A multiplex system with remote multiplexers shall be considered.
2. Board mounted temperature controllers shall use temperature transmitters which are thermocouple actuated. Where required by application, a resistance temperature element may be used.
3. Local temperature controllers having a temperature range span of 400 F (200 C) or less may use filled system transmitters, limited to a maximum operating temperature of 1200 F (650 C), provided the direction the instrument is driven in the event of capillary failure does not create a hazardous situation.
4. Thermocouple instruments shall drive to a safe configuration on thermocouple failure.
5. A separate thermowell with thermocouple connected to the multipoint temperature indicator shall be furnished for checking all resistance bulb type temperature transmitters for main panel mounted control applications.

A single thermowell with dual thermocouples shall be furnished for indicator checking of thermocouple actuated panel mounted controllers, transmitters for main panel mounted control applications, or thermocouple actuated switches for main panel mounted alarms and/or interlock circuits. In intrinsic safe applications, a suitable thermocouple head with mechanical barrier or a separate thermowell shall be furnished for checking purposes.

6. The construction and installation of standard thermocouple, thermometer, and test wells shall be in accordance with ENG STD 65B11. The standard thermowell, except pipe type wells, shall be fabricated of Type 304 or Type 316 stainless steel (contractor option), Where the nature of the fluid is such as to require other material, the thermowell material shall be suitable for the service.
7. Threaded thermowells shall have 2" (50 mm) lagging extention when used with insulation for high temperature. Consideration shall be given for thicker insulation in cold services.

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8. Thermowell lengths shall be as shown on ENG STD 65B11.1 through 65B11.10. Lengths have not been established for filled system thermowells because of variations in the bulb dimensions.
9. Thermowells for dial thermometers and filled system instruments shall be purchased with the instruments to assure proper fit.
10. Thermowell connections into piping or equipment shall be in accordance with Section Q of this standard.
11. Flanged thermowells shall have flanges and weld filler of the same material as specified for the thermowell only when the well and flange form an integral assembly. Where piping specifications permit a carbon steel flange, the well shall be threaded into a blind flange and shall be backwelded if required.
12. With the exception of wells for bulb type elements, protection wells and test wells shall be 0.26" (6.6 mm) bore to receive bimetallic or sheathed thermocouple type primary elements. All thermowells shall be drilled barstock (no built-up type wells) except pipe type wells.
13. Pipe type thermocouple wells with welded ends shall be furnished for gas temperature measurement at fired heaters, boilers, furnaces, flues, stacks, and large vessels. This also includes those wells used for multiple element thermocouple assemblies in reactors, etc. Well material shall be suitable for the process conditions.
14. Velocity and pressure rating calculations of a thermowell will be performed and compared to the service conditions in those services judged to be critical by the Foster Wheeler.
15. Thermocouples shall be furnished with terminal blocks enclosed in a corrosion resistant metallic weatherproof head having a female threaded, gasketed cover. Thermocouple elements shall be in accordance with the ANSI Standard C96.1, "Temperature Measurement Thermocouples." Mineral insulated metal sheathed (normally Type 304 stainless steel) thermocouples shall be used and shall be 1/4" (6.4 mm) O.D. For general service, the nominal thermocouple wire size shall be 18 AWG but within the temperature limits as recommended by the manufacturer.
16. Bi-metallic, fixed stem, dial type gauges furnished with well, shall be used for local temperature indication. Where stem lengths exceeding 24" (610 mm) are required, or where service conditions dictate, thermometers of the filled capillary type may be used.

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C. Flow Instruments

1. Primary Elements

- a. Concentric orifice plates shall generally be used as primary elements for flow instruments. In general, Type 304 or 316 stainless steel (contractor option) orifice plates shall be provided. Where the nature of the fluid is such as to require other material, it shall be suitable for the service.
- b. Orifice plates shall be in accordance with AGA Gas Measurement Committee Report No. 3, "Orifice Metering of Natural Gas", except they shall be 1/8" thick in sizes 14" and smaller, and shall be 1/4" thick in sizes 16" and larger. The minimum orifice flange size shall be 2".
- c. All primary element calculations shall be in accordance with, "Principles and Practice of Flow Meter Engineering" by Spink, AGA Report No. 3 or manufacturer's special formulas for special elements.
- d. Orifices shall be sized so that normal flow rate falls at approximately seven, and minimum flow not less than three, on a 0-10 square root chart. Orifice meter differential range shall be selected for a d/D ratio of 0.75 maximum, and 0.25 minimum. With 2" pipe and 20" (500 mm) or 25" (650 mm) of water column differential range, d/D ratios smaller than 0.25 may be used. In any case, actual orifice diameter shall not be less than 0.25" (6.4 mm). A differential range of 100" (2500 mm) of water, dry calibration, shall normally be used for all liquid flow meters. For compressible fluids differential range in inches of water shall not exceed the normal upstream static pressure in psia, except that for exhaust steam, approximately 15 psig (1.05 kg/square cm.), 50" (1250 mm) range may be used.
- e. Special conditions may dictate the use of devices such as the following:
 - (1) Eccentric or segmental orifice plates shall be used to measure the flow of liquids which contain solids.
 - (2) Venturi tubes or similar types of flow elements may be used to measure the flow of low pressure gases or liquids where loss of pressure is an important consideration.
 - (3) Pitot tubes or averaging Pitot tubes such as Annubar may be used to measure flow in certain applications and shall be so indicated on the Engineering Flow Diagrams.

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(4) Quadrant edge plates or segmental wedges where viscosity conditions dictate.

2. Meter Runs

a. Line Sizes Up to and Including 10"

Weld neck orifice flange unions having flange taps and a minimum rating of 300 lb RF shall be used. Orifice flange taps shall be 1/2" NPT. Flanges shall be in accordance with AGA Report No. 3, except as noted in paragraph III.C.1.b. above.

b. Line Sizes 12" and Larger

Line flanges with radius taps shall be used in place of orifice flanges. Radius taps shall be 1 pipe diameter upstream and 1/2 pipe diameter downstream of inlet face. The installation shall be in accordance with ASME Power Test Code 19.5, Part 5, Chapter 4, Flow Measurement and "Principles and Practice of Flow Meter Engineering" by L.K. Spink. Connections to piping shall be 3/4", with a 1/2" diameter pressure tap hole.

c. Metering orifices shall not normally be installed in lines less than 2". If the line is less than 2", one of the following devices shall be used:

- (1) Swaged (2") meter run
- (2) Certified meter run with corner taps
- (3) Rotameter
- (4) Integral orifice

3. Meter Run Installations

a. Metering orifices shall be in a horizontal line if possible. If not possible, the installation in a vertical line shall always be upward for liquids and preferably downward for gases.

b. Installation shall be in accordance with ENG STD 65B13.1, through 65B13.3, Instrument Piping Standard.

c. Where limited spacing dictates, taps located 45 degrees from the horizontal may be used.

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- d. The minimum length of straight pipe preceding an orifice plate shall be in accordance with AGA Report No. 3, except for those installations not explicitly covered in the installation sketches, in which case minimum runs shall be in accordance with ASME Power Test Code 19.5, Part 5, Chapter 4, or API Recommended Practice RP 550.
- e. All piping upstream and downstream of orifices shall be in accordance with the piping specifications. Specially selected or machined pipe designed to meet AGA Report No. 3, paragraph III.B shall not be furnished.

4. Instruments

- a. Locally mounted flow recorders with pressure pens shall be provided for steam and fuel gas flows to main process units only where shown on Engineering Flow Diagrams. Pressure taps for pressure pens shall be taken from the downstream connection.
- b. The flow of main charge and product streams to and from each process unit shall be recorded as shown on Engineering Flow Diagrams. Locally mounted meters shall be provided for streams which are not flow controlled.
- c. Force-balance or other negligible displacement type flow measuring instruments shall, where possible, be selected for all pneumatic or electronic transmitter services.
- d. Bellows type manometers shall be used for local differential pressure type indicating and recording instruments if an air supply is not readily available in the area. Normally differential pressure force balance transmitters with local receiver instruments shall be used.
- e. Differential pressure instruments shall withstand differential pressures equal to full line pressure without zero or calibration changes. Body materials shall be consistent with the instrument piping material specification.
- f. Rotameter type flow instruments may be used for the following:
 - (1) In pipe sizes 1 1/2" and smaller.
 - (2) For special applications in larger lines where solids are present in the process fluid.

(3) Where an operating flow range exceeds the ratio of 3 to 1 (maximum to minimum). Normal rotameter rangeability is 10 to 1 and the meter shall be selected so that the normal flow falls at 50 to 60% of maximum range.

g. Special conditions may dictate the use of devices such as the following:

- (1) Turbine meter
- (2) Magnetic flow meters
- (3) Target meters
- (4) Positive displacement meters

5. Instrument Installations

- a. All differential pressure type flow meters are to be installed in accordance with ENG STD 65B12.1 through 65B12.65. Normal installation shall utilize a manifold (similar to Anderson Greenwood M4T for close coupling and M1 for remote mounting) and stainless steel tubing.
- b. Force balance or other negligible displacement type flow transmitters shall be mounted at the process line, unless such location makes the transmitters inaccessible.
- c. Rotameters and rotameter transmitters shall be installed in a manner which permits easy meter or float removal for cleaning or repair purposes. Type and rating of end connections shall be in accordance with the piping specifications.
- d. Rotameters (except for purge meters, applications where process conditions dictate otherwise, and in streams that can be temporarily interrupted for service) shall have meter size gate block valves upstream and downstream, and a meter size by-pass with gate valve.
- e. For sealed installations, 4" (100 mm) seal pots shall be used for bellows type instruments. No seal pots shall be used with diaphragm type instruments.

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D. Liquid Level Instruments

1. External displacement type level transmitters and controllers shall normally be furnished for all pressure vessels in level ranges equal to or less than 4 feet (1220 mm). Instrument cases shall be rotatable with respect to vessel connections. Connections on the instruments shall generally be 1 1/2" screwed or 1 1/2" flanged, in accordance with the piping specifications.
2. Internal type displacement or ball float type level instruments shall normally be furnished for open sumps and tanks. They may also be used on pressure vessels under special conditions of extreme temperatures, high viscosity, liquids which could boil in an external cage, corrosion, or where other similar process conditions dictate their use. The design selected shall permit removal of the instrument without the need for entering the vessel for prior dismantling. The minimum mounting flange diameter shall be 4". Stilling wells shall be used where the liquid being measured is subject to turbulence.
3. External differential pressure type level instruments shall be furnished for pressure vessels in level ranges which exceed 4 feet (1220 mm), unless process conditions make such types undesirable, and may be furnished for shorter ranges where accessibility makes them preferable. Flange mounted differential type without block valve, or alternately internal displacer type, may be used where process conditions or accessibility make these preferable regardless of range. Flange mounted differential type shall have manufacturer's standard size flanges; flange ratings shall be in accordance with the vessel specifications.
4. Where process conditions dictate and where shown on the Engineering Flow Diagrams, capacitance, radioactive, ultrasonic, magnetic float, etc., type of instruments may be used.
5. Float and tape negator spring operated indicators may be used where suitable and where high accuracy is required. Gauge boards may be used on storage tanks where accuracy is not critical.
6. External ball float type level switches shall be flanged body type to permit access to the float without removal of the cage from the piping. Connections shall normally be manufacturer's standard size screwed.
7. Displacer, float, and differential pressure type level instruments shall have cages or bodies and trim material suitable for the process fluid, the temperature and pressure conditions. Minimum trim material shall be stainless steel or other alloy.

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8. Gauge glasses shall be used for local level measurement and shall be sized to cover operating level ranges, not abnormal extremes in level. Where the level range exceeds 11 feet (3350 mm), the top and bottom 40" (1020 mm) shall be covered. Where level is to be controlled between the top and bottom 40" (1020 mm), a gauge glass of suitable length shall also be furnished to cover the controllable range.
9. Gauge glasses shall be armored reflex type for all services except the following, where armored transparent type (without illuminators) shall be used:
 - a. Interface between liquids.
 - b. Distillates below 25 degree API Gravity and all crude residuals.
 - c. Liquids containing gum, sediment, or other solid material which may coat the flutes of a reflex glass.
 - d. Liquids requiring protecting shields, such as steam above 300 psig (21.1 kg/square cm) or above 15% caustic solution.
10. Frost shields shall be used if the operating temperature is below 32 F (0 C).
11. Transparent and reflex gauge glass units shall normally be fabricated from standard length sections having 11 7/8" (300 mm) visible length. The maximum unit length shall consist of five glasses. When greater total visibility is required, multiple gauge glass units may be installed either on the vessel or on a pipe column. Chamber connections shall normally be 3/4" screwed.
12. Gauge glasses for low pressure vessels containing low temperature non-flammable fluids, such as water or phosphate solutions, may be tubular glass type in lengths not exceeding 30" (760 mm).
13. Level instruments shall be installed in accordance with ENG STD 65B14.1 through 65B14.40.
- (1) 14. Connections on vessels shall be in accordance with Section III.Q. of this standard below.

E. Pressure Instruments (Including Non-Flow Differential Pressure)

1. Main control room board mounted receiver pressure indicators shall normally be furnished for main headers on live and exhaust steam, fuel oil, fuel gas, cooling water, plant air, and instrument air as shown on the Engineering Flow Diagrams.
2. Local pressure gauges shall be Bourdon tube type. Where range requirements cannot be satisfied by Bourdon tube gauges, other standard applicable elements shall be used.
3. Pressure measuring elements shall, in general, be Type 316 stainless steel except:
 - a. Where the nature of the fluid is such as to require other metal, the primary element material shall be suitable for the service.
 - b. On receiver gauges and diaphragm sealed gauges, where bronze elements may be substituted.
 - c. On very low pressure ranges, such as for draft gauges or barometrically compensated elements for absolute pressure where alloy steel elements are not available.
4. Sockets shall be of the same material as the primary element and shall be welded to the element using the same filler material. Brass or bronze elements or sockets may be silver soldered.
5. In general, standard pressure instruments and gauges shall be furnished with full scale pressure ranges having the lower limit of the range equal to zero gauge pressure. Suppressed range pressure instruments may be furnished where required for measurement sensitivity.
6. Locally mounted pressure gauges (except receiver gauges) shall be 4 1/2" (115 mm) size. Locally mounted pneumatic receiver gauges shall be 3 1/2" (90 mm). Local electronic receiver gauge scales shall be 2 1/2" (65 mm) minimum. Panel mounted pneumatic receiver gauges shall be 4 1/2" (115 mm), except those mounted within the graphic section which may be smaller.
7. Direct connected pressure gauges shall be provided with blowout backs or discs. Solid front gauges shall be used on all services.
8. Where seal elements are used, they shall be of the continuous duty type, shall be directly connected to the pressure element, and furnished as an integral part. The process connection on the seal shall normally be 3/4" NPT.

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9. Standard gauge stem size shall be 1/2" NPT, except receiver gauges shall be 1/4" NPT.
10. A 1/2" pipe siphon shall be installed adjacent to pressure instruments on steam and other high temperature services when the instrument is close coupled and/or mounted above the tapping point.
11. Pulsation dampers shall be furnished for all pressure instruments and gauges on the discharge of reciprocating pumps, and on the suction and discharge of reciprocating compressors and other pulsating services.
12. Consideration shall be given to the use of Sprague (or equal) gauge savers on pressure instruments when the operating pressure of the service to which the instrument is attached can rise above the maximum working pressure of the instrument.
13. Pressure instruments shall be located so that the head of liquid between the instruments and the point of measurement does not exceed the manufacturer's limit of impressed static head.
14. Connections in piping or equipment for pressure and differential pressure instruments shall be in accordance with Section III. Q of this standard.
15. Pressure instruments shall be installed in accordance with ENG STD 65B15.1 through 65B15.51.

F. Automatic Controllers

1. Control modes for other than self-acting regulator type local controllers shall normally be on the following basis:
 - a. Single Mode (Proportional Band)
 - (1) Local level controllers
 - (2) Local pressure controllers
 - b. Two Mode (Proportional Band Plus Reset)
 - (1) All panel mounted controllers except temperature
 - (2) Local flow controllers
 - (3) Local temperature controllers
 - c. Three Mode (Proportional Band Plus Reset Plus Derivative)
 - (1) All panel mounted temperature controllers
2. Controllers used for intermittent services such as anti-surge or minimum flow by-passes shall be furnished with anti-reset windup where necessary.
3. Where 4 pipe systems are supplied, the control modes shall be the same as for a panel mounted controller for the same variable.
4. Bumpless transfer switching shall be provided between automatic and manual on all controllers. Controllers shall have provision for adjusting the manual output.
5. Controllers that receive a setpoint signal from an external source shall come equipped with a local/remote setpoint switch, and permit bumpless transfer between setpoint sources.
6. Control function settings, such as setpoint and manual output, manual-automatic transfer switch, etc., shall be located on the front of all panel mounted controllers.
7. Setpoint, process variable, deviation, and continuous controller output indications shall be from the front panel of all panel mounted controllers.
8. Receiver controllers shall be either the indicating process type with a separate or integral recorder, where a recorder controller is specified, or shall be the indicating deviation type.
9. Panel mounted controllers shall preferably be of the self-contained type with removable chassis.

10. Panel mounted instruments shall be provided with tag number identification on both front and rear.

G. Recorders, Chart Drivers, Scales and Charts

1. Local recorders shall, in general, be of the large case type.
2. Chart drives for main board mounted instruments shall be electric motors. Chart drives for locally mounted instruments and local panel mounted instruments shall be electric motors conforming to the electrical area classification assigned to the area in which they are installed; or where electricity is not adequate to permit use of synchronous motors, 7-day spring wound type may be used.
3. A 30-day supply of charts shall be furnished with each recording instrument.

4. Scales and Charts

See following page.

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All charts and scales for direct reading instruments shall use the units shown below. Charts and scales for other instruments shall have factors to convert to the units shown below:

VARIABLE	ENGLISH UNITS	METRIC UNITS	SCALES	CHARTS
Temperature	Degrees F	Degrees C	DR	0-100 un.
Pressure				
Near Atmos.	In. of water	mm of water	DR	0-100 un.
Above Atmos.	psia	kg/sq. cm. G	DR	0-100 un.
Below Atmos.	In. of Hg	mm Hg	DR	0-100 un.
Absolute	psia or in. Hg absolute	kg/sq. cm. A or mm Hg absolute	DR	0-100 un.
Level	% of range for Process; feet and inches of actual height for storage tanks where precise inventory is required.	% of range for Process; millimeters of actual height for storage tanks where precise inventory is required.	0-100 un. or ft. and in. (mm)	0-100 un.
Flow				
Steam and Boiler Feed Water	lbs/hr	kg/hr	0-10 s.r. ***	0-10 s.r. ***
Liquids	U.S. GPM	liter/min.	0-10 s.r. ***	0-10 s.r. ***
Water	U.S. GPM	liter/min.	0-10 s.r. ***	0-10 s.r. ***
Gas or Vapor	SCFH*	N cu.m./hr*	0-10 s.r. ***	0-10 s.r. ***
Air and Nitrogen	SCFH*	N cu.m./hr*	0-10 s.r. ***	0-10 s.r. ***
Rotameters	Unit as above	Unit as above	0-100 un. **	0-100 un.
Analyzers	pH, % oxygen, etc.	pH, % oxygen, etc.	DR	0-100 un.

NOTE:

* Defined as at 60 F and 14.7 psia or 0 C and 760 mm Hg.

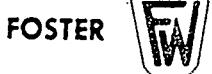
** Direct Reading on transmitter.

*** 0-100 uniform if transmission system includes a square root extractor.

DR - Direct Reading

s.r. - Square root

un. - uniform



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H. Transmission Systems

1. General

- a. Local field mounted control loops shall be pneumatic. Transmitters used with local field mounted control loops shall be pneumatic.
- b. With electronic control room instrumentation, pneumatic-to-current transducers shall be used where signals from local pneumatic loops are transmitted to the control room.
- c. Each field mounted transmitter, controller, control valve positioner, and other air consuming device, shall be provided with its own filter regulator air set.

2. Pneumatic Transmission

- a. Output signal from all transmitters shall normally be 3 to 15 psig (or 0.20 to 1.00 kg/square cm), unless manufacturer's standard or other considerations require otherwise. Instrument air connections shall be 1/4".
- b. All pneumatic receiver instruments and gauges shall normally have receiver elements designed for 3 to 15 psig (or 0.20 to 1.00 kg/square cm) input air signal, unless manufacturer's standard or other considerations require otherwise.
- c. For flow or liquid pressure control where tubing length between control room and field transmitter and/or valve exceeds 350 feet (106,680 mm), and only if specified by Foster Wheeler, the control mechanism may be located at the transmitter or control valve.
- d. Individual pneumatic transmission tubing shall be 1/4" O.D. x 0.030" wall (4 x 6 mm) copper in accordance with the piping specifications. PVC coated copper shall normally be used if the atmosphere is corrosive to copper. Aluminum or polyethylene may be used as an alternative.
- e. Individual tubes may be brought to field junction boxes and bundled fire resistant polyethylene tube assemblies, Dekoron Type B or equal, (with 10% spares) used between the junction boxes and the control panel bulkhead fittings.

- f. Instrument tubing supports shall be fabricated in accordance with ENG STD 68B11.1 through 68B11.14. Supports shall be fabricated from standard structural members. Special shapes, such as "Unistrut", shall be used only for clamp supports. This standard does not provide for special tubing troughs such as "Instrof". Messenger cable may be used for support of bundled tubing where pipe racks are not readily available.
- g. Small groups of tubes shall be supported either from the air supply piping with messenger clips, plastic or metal strips, or in tube race channels suitably braced to structural supports.

3. Electronic Transmission

a. Regulatory Codes

- (1) Unless otherwise specified, all electrical instrument facilities shall comply with the applicable requirements of the latest edition of the National Electrical Code and applicable local codes.
- (2) Where applicable, the design and installation of the materials shall be guided by recommended practices of the ISA and API RP 550, Part I.

b. General

- (1) Electronic panel instruments shall generally be compatible with each other, with field instruments and other devices used on the project, without the use of signal converters. It is desirable that electronic panel instruments, signal converters, function modules, etc. be supplied by the same vendor.
- (2) Signal ranges for electronic process control instruments shall be 4-20 ma DC with common negative.
- (3) Where possible, all field mounted electronic instruments shall employ a true two-wire transmission system.
- (4) Instruments that are mounted in NEC, Class I, Division 1 locations shall be explosion-proof or intrinsically safe. However, instruments that are not readily available in explosion-proof construction, such as some analyzers, will be considered acceptable for Division 1 locations when totally enclosed and purged with instrument air. With loss of purge, the instrument will be de-energized and an alarm circuit actuated per ISA S12.4 Type X.

- (5) Instruments for Division 2 areas shall be treated in a similar way except that loss of purge shall only actuate an alarm per ISA S12.4 Type Z.
- (6) Purging system design shall meet the requirements of ISA STD 12.4 and NFPA 496.
- (7) Where specified as an intrinsically safe installation, all control room instrumentation and associated field transmitters shall be solid state, intrinsically safe, electronic type. All equipment, material, and installation procedures shall be certified as complying with the requirements of NFPA 493, and of the particular vendor's approved design. Approval and/or certification of intrinsically safe process control equipment must come from a nationally recognized laboratory, such as UL, FM, American Gas Association Laboratories, UL of Canada, CSA Testing Laboratories, etc. The primary instrument vendor shall review and provide written certification that loop schematics and wiring diagrams meet the vendor's system design requirements. All instrument installations shall satisfy any existing local codes. Intrinsic safety through the use of barrier devices is desirable.
- (8) Electropneumatic transducers or positioners shall be furnished for control valves which are operated by electronic signals.
- (9) Instruments shall be suitable for operation from a central power supply, either AC or DC as required.
- (10) Thermocouple and voltage signal receivers shall have an input impedance of more than 100 times the impedance in the rest of the circuit. This includes the wiring and the output impedance of the signal source.
- (11) Controllers, recorders, indicators, computer inputs, alarm relays, etc., shall operate on voltage signal measured across vendor-specified calibrated resistors or other electronic devices.

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c. Power Supply for Panel Mounted Instruments

- (1) Panel mounted electronic instruments may be provided with or without integral power supply. Power supply for panel mounted instruments and field mounted transmitters shall be located in the control house.
- (2) Instrument power transforming and stabilization system shall be provided, as required.
- (3) Power supply back-up system will not be provided except where specifically defined in the Proposal or Job Specifications.
- (4) Instrument power supply systems shall be designed in accordance with the instrument vendor's recommendations.
- (5) In general, DC power is derived from AC power by rectifying and filtering. The output of this power supply shall be regulated for AC line variations in accordance with instrument vendor's specifications.

d. Electronic Transmission Wiring

- (1) Installation of thermocouple lead and electronic transmission wiring shall be in accordance with ENG STD 60A2.

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J. Alarms and Signals

1. Alarm and signal systems shall be considered those audible and visual requirements for alerting operating personnel of the need to take corrective process action or to be advised of an operating condition which is deviating from preset limits.
2. Alarm and signal elements shall be actuated from pneumatic or electronic receiver switches located in the control room where there is a receiver instrument on the instrument panel. Where the loop is local only with remote alarm, the switch shall be located in the field. Where there is no transmitted signal, alarm and signal elements shall be actuated from a separate primary instrument.
3. The alarm and signal system shall be solid state and shall include back-lighted window annunciators, horn or buzzer, signal acknowledgement, test and reset (where required) buttons for indication of an abnormal operation condition on the main panel, and back-lighted window annunciators or bull's-eyes on local panels. 20% spare unequipped alarm windows shall be provided.
4. All trouble contacts actuating alarms shall be initiated by the opening of contacts which are closed during normal operation.
5. Enclosures for field mounted electrical instruments shall be rated in accordance with the electrical classification assigned to the area in which they will be installed and shall be suitable for outdoor installation, if required.
6. Alarms shall operate under the same condition as the equipment they protect, such as through power failure; i.e., if equipment continues to operate through power failure, its associated alarms must also operate through power failure.
7. Where one abnormal condition may cause a sequence of events resulting in several alarm signals at almost the same time, a "first-out" system shall be furnished. As an example, the initiating abnormal conditions are indicated by a flashing light and subsequent abnormal conditions are indicated by flashing at a different rate until the upset is acknowledged. When the alarm is acknowledged, the audible device will be silenced, but the alarm light shall still be distinguished from the subsequent alarm lights, acknowledged or not acknowledged.
8. All devices which shut down major items of equipment shall alarm at the time of shutdown, on a first-out sequence annunciator system as described in Paragraph III.J.7 above. This must be in addition to any pre-shutdown alarm.

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9. Installation of intrinsically safe alarm and signal wiring shall be in accordance with ENG STD 60A2. Installation of nonintrinsically safe alarm and signal wiring shall be in accordance with ENG STD 70A1.

K. Emergency Systems

1. Emergency systems shall be considered those requirements for initiating automatically an action to prevent a hazardous condition or situation from developing, or to prevent or reduce further operating upset.
2. The emergency system shall be of the normally energized type, i.e., actuation of emergency action shall be initiated by the opening of contacts which are closed during normal operation.
3. Emergency system (trip) elements shall be actuated from separate primary instruments, except in flow measurement, differential pressure measurement, and analyzer applications, in which case associated primary instruments may be used. Emergency system (trip) elements shall be furnished with SPDT switches. Where an alarm and a trip function are actuated from a common primary instrument, the common element shall actuate a DPDT isolating relay. Trip element contact ratings shall be suitable for the devices they are actuating, e.g., electrical switch gear.
4. Enclosures for field mounted electrical instruments shall be rated in accordance with the electrical classification assigned to the area in which they will be installed and shall be suitable for outdoor installation, if required.
5. Protective devices shall be independent of all other instrumentation. Shutdown interlock (protective) systems shall have a separate, isolated power source.

L. Control Valves

1. Wherever practical, all control valves shall be of the spring and diaphragm pneumatically actuated type. Consideration of piston type actuators, with or without helper springs and/or fail-safe capacity tanks, shall be given for special applications if their failure cannot jeopardize plant safety. Control valve trim and body style shall be determined by the application.
2. Control valves shall usually be sized for a normal flow at no more than 70% of the capacity of the valve, with no less than one quarter of the total system friction pressure drop or 10% of operating pressures to 1000 psig (70.3 kg/square cm), whichever is greater, allotted to the valve. Above 1000 psig (70.3 kg/square cm) a lower percentage of the operating pressure may be used for valve differential pressure depending on process and control considerations. Butterfly valves shall be sized for a maximum flow at 60 degree angular opening, except for a characterized vane valve (such as the "fishtail") which may be sized at 90 degree angular opening. Three-way valves shall be sized to pass maximum flow through either port with minimum available pressure drop through the same port.
3. A noise prediction calculation shall be performed for all control valves. A mechanical or piping modification, or both, shall be made to conform to O.S.H.A. regulations in Sound Pressure Level (SPL) so as not to exceed 90dBA at 3 feet, the plant noise level or more restrictive regulatory rules which apply. Where the noise level exceeds this limit, noise abatement procedures or mechanical valve modification, or both, or special valves, shall be used.
4. Diaphragm motors normally shall be the fully enclosed spring type. Springs shall have linear characteristics permitting full stem travel under operating conditions for signal air pressure range of 3 to 15 psig (0.2 to 1.0 kg/square cm) or 6 to 30 psig (0.4 to 2.0 kg/square cm). Springs shall be corrosion resistant and shall have a readily accessible adjusting nut. Stem position indicators shall be provided.



5. The valve actuator shall be sized to fully stroke the valve against the unbalanced forces acting on the valve plug and stem when the differential pressure across the valve is equal to 110% of the normal operating upstream pressure or the maximum differential pressure that can be experienced in the field (e.g., maximum torque requirement of a butterfly valve; shutoff pressure of a pump during start-up with the receiver at atmospheric pressure or vacuum), whichever is greater. In addition to these forces, allowance shall be made for hysteresis in the movement of the valve components and weight of the moving parts. Loading relays shall not be used to increase stem force in lieu of larger size topwork. Any combination of loading relay and topwork requires Foster Wheeler approval. The valve vendor's standard method of actuator sizing may be used. The cold bench set of the valve spring shall not vary by more than 10% from the spring range requirements for operating pressure.
6. The minimum size for control valves shall normally be 1" in line sizes 1" and larger. In lines smaller than 1", a line size control valve shall normally be furnished. Valves 1 1/4", 2 1/2", and 5" shall not be used. Reduced trim shall be specified when the required valve capacity is below these sizes.
7. Normally, all control valves shall be flanged, except valves such as butterfly, rotary, or ball may be wafer type designed to fit between companion flanges. All flanged control valves shall have face-to-face dimensions in accordance with ISA RP 4.1 wherever practicable.
8. Control valves in process services shall have steel bodies unless the piping specifications require alloy. In water, air or low pressure steam lines where the piping specifications permit, control valve bodies may be cast iron.
9. The minimum flange rating for valves 4" size and smaller shall be 300 lb RF in accordance with ANSI B16.5 for steel or alloy valves, and 250 lb RF in accordance with ANSI B16.1 for iron body valves. For larger sizes the pressure rating shall conform to the piping specifications. The rating for butterfly valves shall conform to the piping specifications, regardless of size.
10. Control valve trim shall be stainless steel as a minimum. Hardened stainless steel or stellite facing shall be furnished for valve plugs, seat rings, guide posts and bushings for pressure drop which exceed 150 psi (10.5 kg/square cm), flashing liquid services, and for fluids which contain solid particles.

11. Control valves shall be furnished with packing glands and teflon or teflon-asbestos packing for operating temperatures below 450 F (232 C). For 450 F (232 C) and above, asbestos packing with grease seal lubricator, and isolating valve shall be furnished. Selected vendor's recommended packing for this service may supersede this Paragraph.
12. Radiation extension bonnets shall be provided for operating temperatures of 450 F (232 C) or higher and for operating temperatures of 32 F (0 C) or lower. Selected vendor's recommendations may supersede this Paragraph.

Double-seated globe type control valves shall be top and bottom guided. Single-seated globe type control valves shall be top, top and bottom, or cage guided.

13. Pneumatic valve positioners shall have 3 pressure gauges (2 for electropneumatic). Bypass valves shall be provided except on split range positioners or where the operator is other than 3-15 psig (0.2 to 1.0 kg/square cm). Valve positioners shall be furnished for throttling automatic control valves only under the following conditions:
 - a. Slow response service, such as temperature or averaging liquid level control.
 - b. Venturi throat, three-way, and butterfly valves.
 - c. Unbalanced single-seated valves larger than 1".
 - d. Valves in split range services.
 - e. Coking, crystallizing, gumming, or slurry service.

NOTE: For fast response services where valve positioners cannot be used, but where the operator is other than 3-15 psig (0.2 to 1.0 kg/square cm) and/or where an increased volume of air to the operator is required to increase valve stroking speed, an instrument air relay or a volume booster may be required.

(1) 14. All control valve bodies 1 1/2" size and smaller shall be furnished with block and bypass valves in accordance with Paragraph III.L.17 below.

15. Control valves in corrosive, erosive, or other services shall be furnished with block and bypass valves only where shown on Engineering Flow Diagrams. A corrosive service shall be defined as one in which the process fluid is more corrosive to the wetted parts of the valve than to the piping. Erosive service shall be defined as one where the line fluid contains solids or where the normal operating pressure drop across the control valve exceeds 150 psi (10.5 kg/square cm).
16. Normally, when the control valve is 2" or larger and except when the above Paragraph III.L.15 applies, block and bypass valves shall be omitted. The control valve shall be furnished with a continuously connected handwheel operator except for rotary-motion type valves and electrical motor-operated valves which may use declutchable handwheels if necessary.
17. Size of block and bypass valves shall be determined by the size of the control valve body and line size per the following table:

RECOMMENDED MINIMUM BLOCK AND BYPASS VALVE SIZING

FLEXIBLE DESIGN

LINE SIZE:	1/2		3/4		1	
	CONTROL VALVE SIZE	VALVE BLOCK	VALVE BYPASS	VALVE BLOCK	VALVE BYPASS	VALVE BLOCK
1/2	1/2	1/2	3/4	3/4	1	1
3/4	-	-	3/4	3/4	1	1
1	-	-	-	-	1	1
1 1/2	-	-	-	-	-	-

LINE SIZE: 1 1/2 2 3 4

CONTROL VALVE SIZE	VALVE		VALVE		VALVE		VALVE	
	BLOCK	BYPASS	BLOCK	BYPASS	BLOCK	BYPASS	BLOCK	BYPASS
1/2	1 1/2	1 1/2	-	-	-	-	-	-
3/4	1 1/2	1 1/2	2	2	-	-	-	-
1	1 1/2	1 1/2	2	2	2	2	-	-
1 1/2	1 1/2	1 1/2	2	2	2	2	3	3
2	-	-	2	2	3	2	3	3
3	-	-	-	-	3	3	4	3
4	-	-	-	-	-	-	4	4
6	-	-	-	-	-	-	-	-

LINE SIZE: 6 8 10 12

CONTROL VALVE SIZE	VALVE		VALVE		VALVE		VALVE	
	BLOCK	BYPASS	BLOCK	BYPASS	BLOCK	BYPASS	BLOCK	BYPASS
1 1/2	-	-	-	-	-	-	-	-
2	4	4	-	-	-	-	-	-
3	4	4	6	6	-	-	-	-
4	6	4	6	6	8	8	-	-
6	6	6	8	6	8	8	10	10
8	-	-	8	8	10	8	10	10
0	-	-	-	-	10	10	12	10
12	-	-	-	-	-	-	12	12

NOTE: All sizes in inches

- a. Bypass valves shall be globe type in sizes up to and including 4" bypass valve size, and gate type in sizes larger than 4".
- b. Block and bypass valves and manifolds shall not be larger than main line size.
- c. Increase bypass valve body size one size where control valve body is butterfly design (only when globe valves are used as bypass).
- d. On flashing service or where the control valve outlet main line size is greater than the control valve inlet main line size, the outlet piping from both the control valve and bypass valve, and the downstream block valve itself, shall be no smaller than one size less than outlet main line size.

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18. Screwed or socket weld control valves, if used, shall have flanges or unions immediately adjacent to the valve for removal purposes.
19. A 3/4" drain consisting of pipe nipple and gate valve shall be provided immediately upstream for each control valve.
20. Hand control valves shall have the same characteristics as motor-actuated valves except for the handwheel and fine-threaded stem. Valve position indicators mounted on the actuator yoke shall be furnished.
21. Self-actuated regulators may be used for services where a variation of 10% above or below the set point is not objectionable. Special sizing is required to maintain these allowances.
 - (1) 22. Use of self-actuated regulators may require exceptions to Paragraphs III.L.8 and III.L.9 above.
 23. All control valve arrangements and details shall be in accordance with ENG STD 50B16.1, 50B16.2, 50B16.3 and in accordance with the Engineering Flow Diagrams.



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M. Pressure Relieving Devices

1. The selection, sizing, design, and installation of relief valves, rupture discs, and relieving systems shall be generally in accordance with API RP 520; Sections I and VIII of the ASME Boiler and Pressure Vessel Code, or any other applicable piping or vessel code. In general, valves shall have metal-to-metal seating surfaces. Soft seats, linings, etc. may be required for special services such as slurries.
2. All relief valves except those on water, steam, and air shall, as a minimum, be steel with stainless steel disc and guides.
3. Relief valves on water, steam, and air may be furnished with iron, brass, or bronze bodies as allowed by the piping specification for the service conditions.
4. Thermal expansion valves will be provided only when shown on the Engineering Flow Diagrams.
5. Refer to ENG STD 50A1 for relief valves on turbine exhaust piping.
6. Tank venting shall be provided in accordance with the API Std. 2000, "Venting Atmospheric and Low-Pressure Storage Tanks."
7. All relief valves shall be manufacturer's standard types as recommended for the specified services. These valves shall conform to the following:
 - a. API Std. 526 - "Flanged Steel Safety Relief Valves" for materials and sizes on flanged valves
 - b. API Std. 527 - "Commercial Seat Tightness of Safety Relief Valves with Metal-to-Metal Seats" for permissible leakage
8. Relief valves which discharge to the atmosphere through discharge piping shall have the pipe extend at least 10 feet (3050 mm) above any platform or working area within a 25 feet (7600 mm) radius of the point of discharge. Relief valves shall have a minimum of piping between the protected line or equipment and the valve inlet. The low point of the outlet piping shall be provided with a 3/8" (10 mm) minimum weephole when discharging to atmosphere. The end of atmospheric vents shall be square across the end. The inlet to each relief valve and all vents connected to closed systems shall drain away from the valve.

N. Control Panels

1. The control room shall house the main control panel.
2. The control room shall have a "General Purpose" classification.
3. The general arrangement and dimensions of the main instrument panel shall be in accordance with Type "A" as illustrated hereafter in this standard.
4. All other auxiliary instrument panel boards, such as those furnished for local location near equipment items, shall be Type "A" or "B".
5. Fabrication and finishing of all instrument panels shall be equal to that specified in ENG STD 64A1. Except on panel Types "C" and "D", the instrument bezels shall be finished with manufacturer's standard color.
6. Instruments shall be located on all panels for convenient observation and operation. As far as possible, the horizontal instrument arrangement shall follow the process flow path from left to right.
7. Instrument density on panels allows for at least 5% spare panel instrument space for future instruments.
8. Process lines and symbols for panel Types "C" and "D" shall be removable adhesive-backed plastic. Alternatively, other raised lines and symbols made from aluminum or formica may be used.
9. Engraved identification plates shall be provided for all instruments except where provided as part of the instrument.
10. Instruments shall be provided with tag number identification on both front and rear.
11. One twelve-hour electric motor clock shall be furnished for each control room.
12. Refer to ENG STD 47A2 and 47A3 for front and rear panel clearance dimensions.

P. Analyzers

1. Analyzers shall be furnished in accordance with the Engineering Flow Diagrams.
2. Analyzers with their sampling systems shall be normally purchased as installed systems, with provision for start-up and operating responsibility by the analyzer vendor or subcontractor. Necessary calibrating gases and/or liquids shall be part of this purchased package.
3. Analyzer installations shall generally be in accordance with API RP 550, Part II.
4. Where required, analyzers shall have a dedicated recorder suitable for calibration and display.
5. The sampling system shall generally conform with API RP 550, Part II. The system shall preferably be obtained from the analyzer vendor. If this is impractical, the system design shall be supplied or approved by the analyzer vendor. Each proposed sample system shall be described in detail, in writing, for final Foster Wheeler approval prior to purchase.
6. Provision shall be made for manual injection of a standard sample for calibration and check purposes.
7. Refer to API RP 550, Part II, for a description of sample probes. An ASTM type nozzle shall be used for liquids and the typical gas sample probe for gases. If threaded joints are not applicable, use 1 1/2" flanged connections.
8. The analyzer operation shall not be affected by:
 - a. Ambient or sample temperature fluctuations.
 - b. Barometric or sample pressure changes.
9. All materials shall be suitable for the sample stream and the surrounding atmosphere.
10. Where specified, analytical detector systems shall be installed in noncombustible, weatherproof, heated, well ventilated and/or air conditioned walk-in type houses provided with all necessary utilities and with sufficient space for adequate access to all parts of the analyzer. Analyzer installation shall be located to minimize obstruction to other equipment.

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11. The minimum specifications for the above analyzer buildings shall be as follows:
 - a. Steel frame, galvanized (16 gauge) siding and roof, sheet steel door. Heat (25 psig or 1.76 kg/square cm steam) is required to maintain 60 F (16 C) when the ambient temperature is 33 F (0 C). Provide gravity ventilation for air circulation. Provide adequate lighting. Provide a floor drain.
12. A power isolating switch shall be included at the local analyzer installation in the field and also in the control room.
13. Where applicable, analyzer buildings may be furnished by the analyzer vendor as subcontractor.

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Q. Connections for Instruments on Vessels and Piping**Temperature Wells (see Note 9)****Piping and Vessels**

600 lb and 800 F or lower carbon steel	1" scrd. (1) (6)
Alloy for hydrogen service	1 1/2" flgd.
Above 600 lb and 800 F	1 1/2" flgd.
All lined piping or vessels	1 1/2" flgd. (except where minimum size is 2")
Stainless steel piping or vessels	1 1/2" flgd.
Duct or stack	1 1/2" scrd.

Orifice Piping

Flange Taps (below 900 lb)	1/2" scrd. (3)
Flange Taps (900 lb and above)	3/4" scrd. (3)
Pipe Taps	3/4" scrd. or S.W. (3) (8)

Pressure Taps (including diff. press.)

Piping	3/4" scrd. or S.W. (4)
Vessels	3/4" scrd. or S.W. (10)
Duct, Stack, or Heater Wall	1 1/2" scrd. (with sleeve thru refractory if required)

Level Instruments

External Displacer	1 1/2" scrd. or S.W. (1)
Internal Displacer	4" flgd.
Diff. Pressure Taps	3/4" scrd. or S.W. (10)
Diff. Pressure with Dip Tube	4" flgd.
Diff. Pressure, Flange Mounted	Mfr. Std.
Flush Diaphragm	
Diff. Pressure, Flange Mounted	Mfr. Std.
Extended Diaphragm	
Internal Ball Float	
3 1/2" O.D. Ball	4" flgd.
5" O.D. Ball	6" flgd.
Level Switches, Internal Float	4" flgd.
Level Switches, External Float	1" Scrd. or S.W. (10)
Dielectric Probe and Conductivity	Mfr. Std.

Gauge Glasses

Gauge Glass only	3/4" scrd. or S.W. (10)
Single Gauge Glass, where piping projection exceeds 15"	1 1/2" scrd. or S.W. (10)
Gauge Glass and Displacer	2" flgd.
Gauge Glass Standpipe	2" flgd.

NOTES:

1. If screwed or socket weld connections are not permitted, 1 1/2" flanged connections shall be furnished.
2. If screwed or socket weld connections are not permitted, 2" flanged connections shall be furnished.
3. For horizontal meter runs, orifice taps shall preferably be located on the horizontal centerline for liquid steam services, and on the top vertical centerline for gas services. Where piping clearances are a factor, taps may be located 45 degrees from the horizontal centerline, above or below as indicated by the location of the differential pressure measuring device.
4. The type of connections for pressure taps shall conform to the appropriate piping specifications.
5. Materials of construction shall be as per the piping specification.
6. No back-welding of threaded connections shall be permitted.
7. Ratings of all flanged connections shall conform to the appropriate piping or vessel specification.
8. 1/2" hole drilled in pipe wall.
9. Connections for multipoint thermowells, retractable, purged and skin temperature thermowells shall be selected to suit manufacturer's standard equipment.
10. If screwed or socket weld connections are not permitted, 1" flanged connections shall be used.

R. Instrument Air Supply

1. The main instrument air supply shall be furnished without interruption from other general air user requirements. The instrument air supply shall be distributed at nominally 100 psig (7.03 kg/ square cm). An instrument air supply drier system designed to deliver 110% of maximum system requirements shall be supplied.
2. Instrument air shall be dehydrated to a dew point of approximately 40 F (4.44 C) below area average cold season temperature.
3. For ten or more pilot users the dry air supply to a control panel shall be from a single pressure reducing station, with filter, upstream and downstream block valves. A spare reducing valve, filter and block valves shall be piped in parallel. All piping downstream of these filters shall be brass. The headers back of each board shall be brass pipe with 1/4" fitting brazed to the pipe for individual instrument air supply.
4. Air supply piping to locally mounted instruments, small auxiliary panels, and panels with less than ten air pilot users shall conform to the piping specification, and each shall be fitted with an individual combination air supply regulator and filter.

S. Accessibility

1. Connections shall be located for maximum convenience in operating and servicing the instruments. The following general rules shall be adhered to, unless limited by other requirements in the design of the unit:
 - a. Connections shall be oriented so that instruments or piping will not obstruct aisles or platforms.
 - b. Control valves shall be accessible from the ground, platforms, or permanent ladders. Clearance shall be allowed between the top of the diaphragm and the underside of the nearest obstruction above it for the removal of the diaphragm. Special clearance shall not be provided for removal of valve trim. Clearances for handwheel operators and valve positioners shall be considered in accordance with the valve vendor's drawing (see ENG STD 50A1).
 - c. Primary measuring elements for instruments operating in conjunction with control valves shall be located so that the instrument can be mounted close to the control valve without excessive length of meter leads. Local instruments operating in conjunction with control valves shall be located, when feasible, so that they are visible from the control valves. When not feasible, a receiver gauge shall be mounted visible from the control valve.
 - d. Connections for local pressure gauges, dial thermometers, and test wells shall be located so that gauges will be at a visible level and test points will be readily accessible.
 - e. Orifice for pedestal mounted flow meters (except in air or gas service or underground lines) shall be located at a minimum elevation of 7 feet (2135 mm) above grade or platform to allow the meter leads to slope to the instruments.
 - f. Orifices and line mounted flow transmitters, as well as thermocouples, which are located less than 22 feet (6705 mm) above grade shall be accessible from portable ladders. Above 22 feet (6705 mm) they shall be accessible from walkways, ladders, platforms, and/or portable platforms.
 - g. Clearance shall be provided at orifices for valves, pots, or instruments which may be located at the line.
 - h. Connections on vessels for gauge glasses and level instruments shall be oriented to minimize the effect of inlet and outlet streams on the instruments.

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- j. Gauge glasses and level instruments shall be adjacently located and, if possible, the gauge glass shall be visible from any valve which controls the level in the vessel.
- k. All instruments requiring adjustment shall be accessible for servicing from grade, walkways, ladders, or platforms. Accessibility from the ground shall be from a portable ladder. In addition, transmitters may also be accessible from portable platforms.

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T. Winterization

See ENG STD 85A1, 85A2.

U. Inspection

For shop inspection requirements, refer to the Purchase Order.

V. Field Testing and Calibration

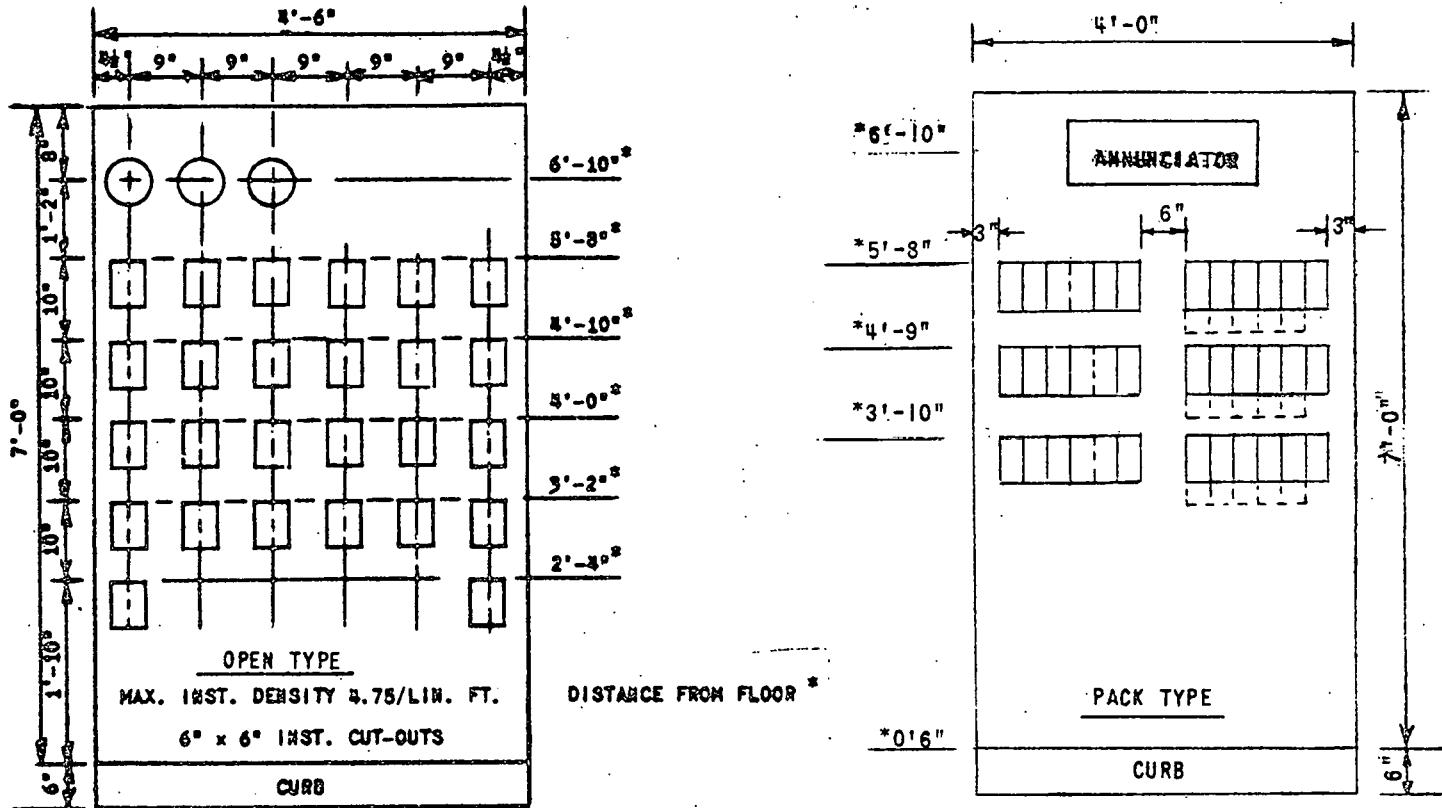
(1) See ENG STD 60D1-Field Evaluation, Testing and Calibration of Instruments.

W. Panel Types

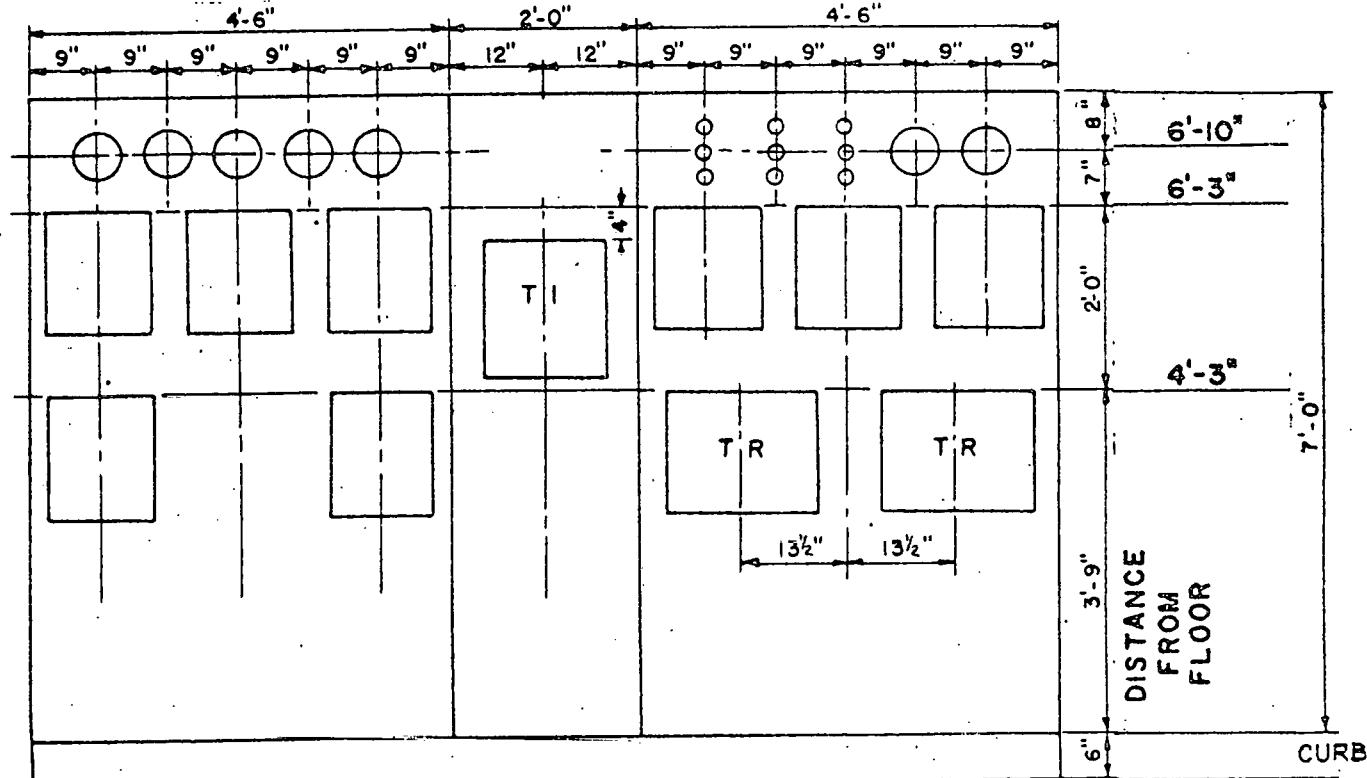
See following pages.

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TYPE "A"-CONVENTIONAL-MINIATURE INSTRUMENTS



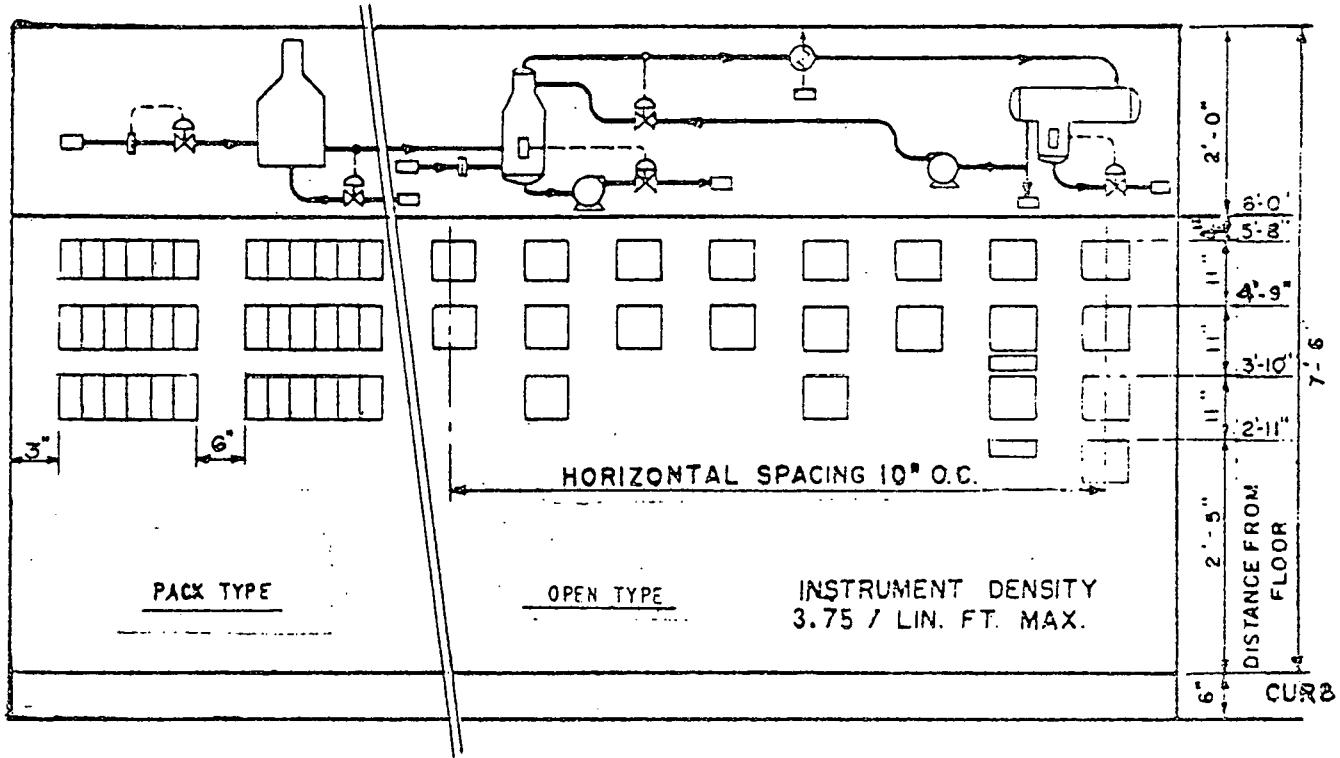
TYPE "B"-CONVENTIONAL - LARGE CASE INSTRUMENTS

**NOTE: LOCATION OF 2'-0" SECTION IN PANEL ARRANGEMENTS IS OPTIONAL
WHEN ADJACENT PANEL IS TYPE "C", ADD 6" TO HEIGHT OF PANEL ON TOP.**

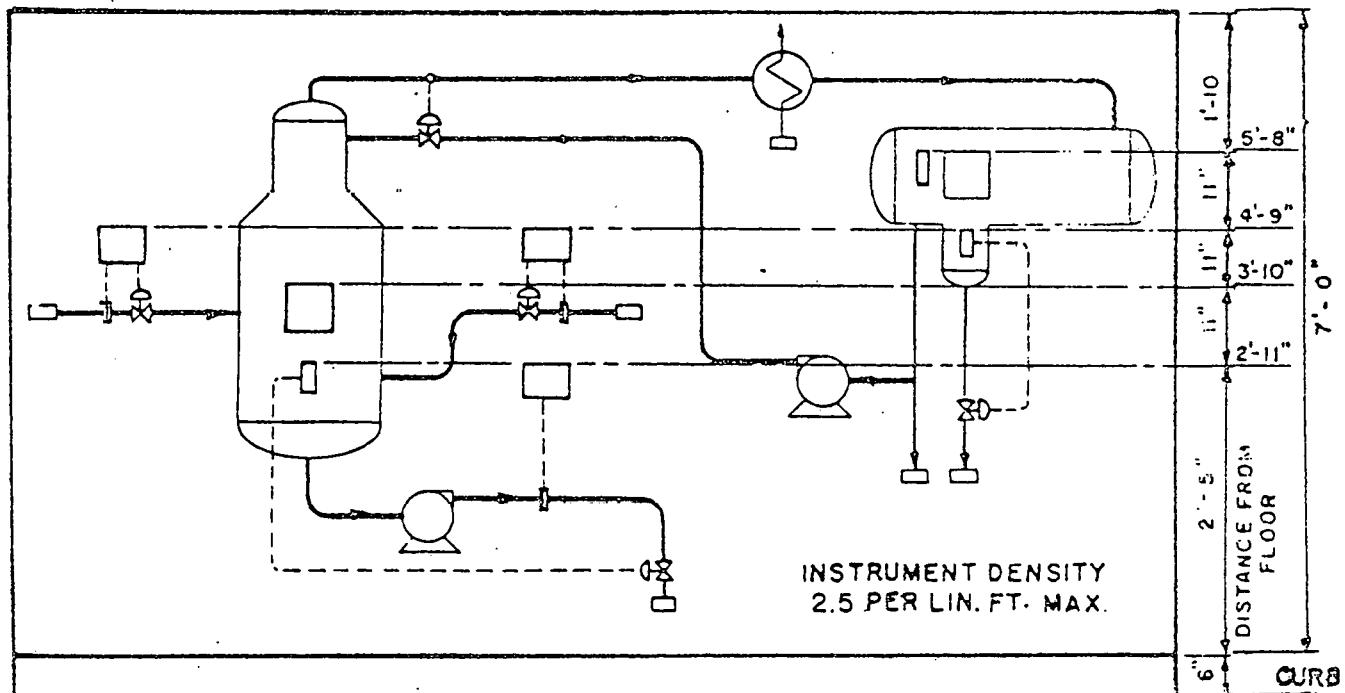
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TYPE "C" - SEMI- GRAPHIC

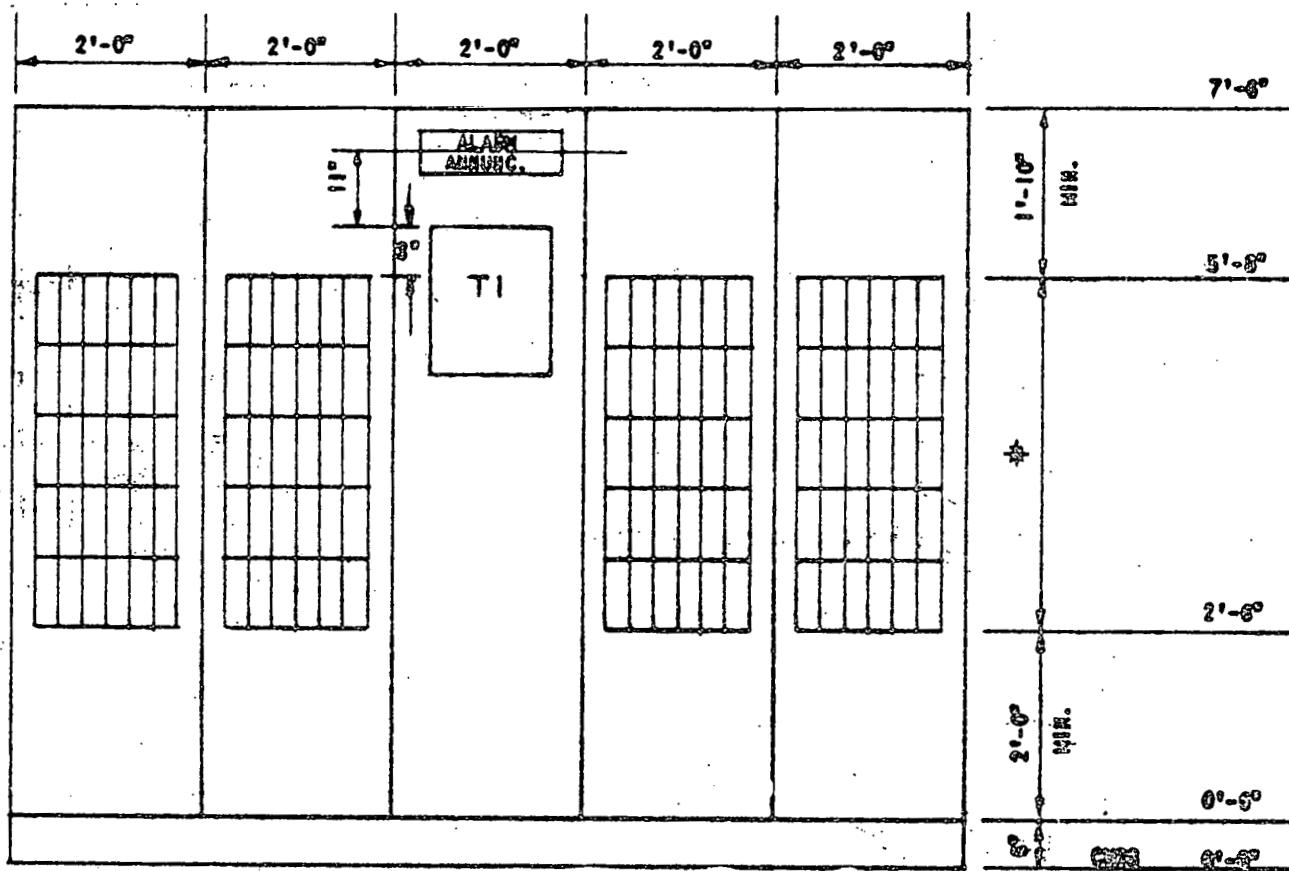


TYPE "D" - FULL GRAPHIC

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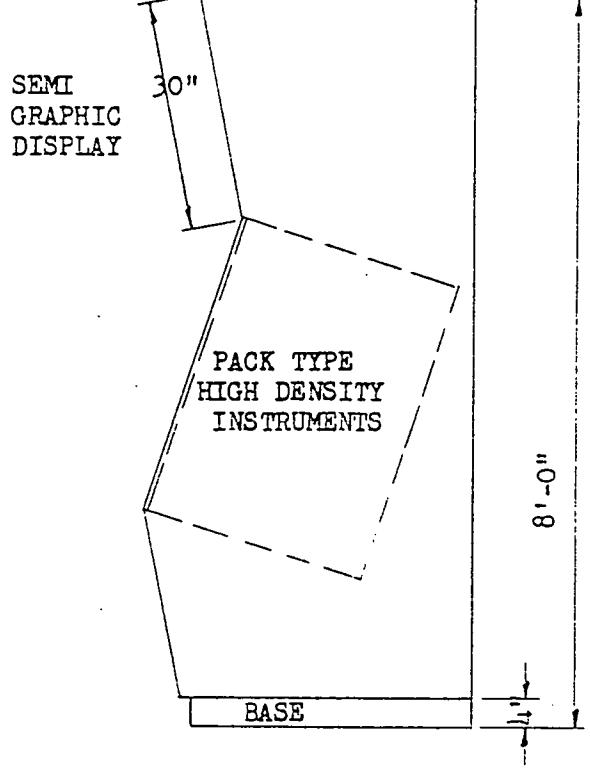
* THIS DIMENSION AS WELL AS THE NUMBER OF VERTICAL AND HORIZONTAL ROWS OF INSTRUMENTS MAY VARY DEPENDING ON INSTRUMENTS FURNISHED. IN NO CASE SHALL THE LOWER PORTION OF THE BOTTOM ROW INSTRUMENT BE LOWER THAN 2'-0" ABOVE THE FLOOR, NOR SHALL THE UPPER PORTION OF THE TOP ROW INSTRUMENT BE HIGHER THAN 5'-8" ABOVE THE FLOOR.

TYPE "E" - DEVIATION CONTROLLERS - TREND RECORDERS

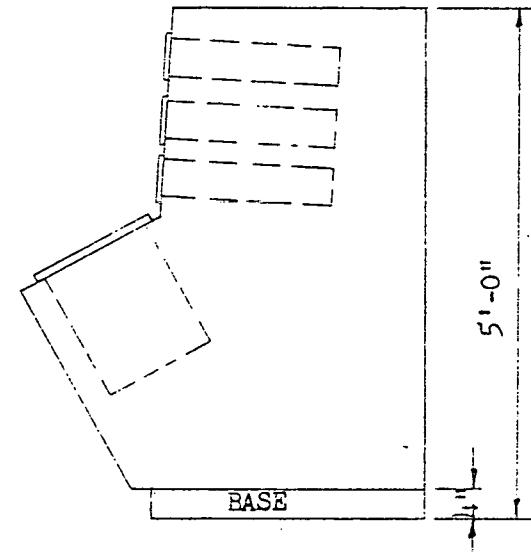
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"K" DESIGN
TYPE F

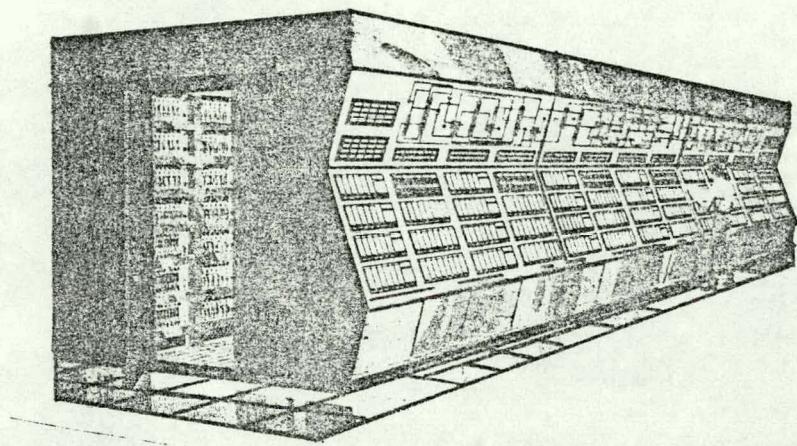


CONSOLE DESIGN
TYPE G

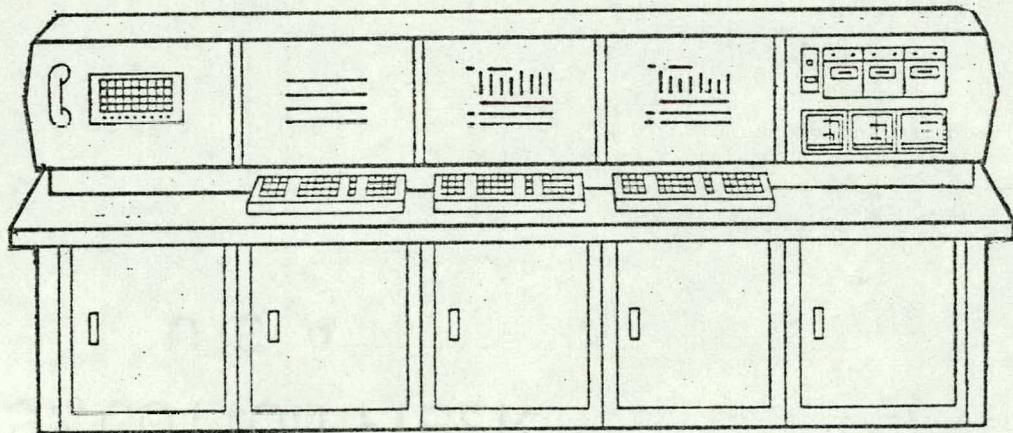
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TYPE H - WALK-IN PANEL



TYPE J - OPERATOR CONSOLE WITH CRT DISPLAYS

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IV. REFERENCES

Latest editions or revisions of the following documents are referred to in this standard:

A. Foster Wheeler Standards

1. ENG STD 47A2, Standard Building Specification, Control House, Concrete Block Wall, Flat Roof
2. ENG STD 47A3, Standard Building Specification, Control House, Concrete Block Walls, Peaked or Sloped Roof
3. ENG STD 50A1, Piping
4. ENG STD 50B16.1 through 50B16.3 Piping Reference Standards, Control Valve Arrangement
5. ENG STD 60A2, Instrumentation, Electronic Wiring Standard
6. ENG STD 60A3, Instrumentation, Symbols and Identification
- (1) 7. ENG STD 60D1, Field Inspection, Testing and Calibration of Instruments.
8. ENG STD 64A1, Standard Specification for Shop Fabricated Piped and Wired Instrument Panel Board
9. ENG STD 65B11.1 through 65B11.10, Instrument Piping Standards, Thermocouple Wells
10. ENG STD 65B12.1 through 65B12.65, Instrument Piping Standards, Flow Meter Installations
11. ENG STD 65B13.1 through 65B13.6, Instrument Piping Standards, Orifice Installation
12. ENG STD 65B14.1 through 65B14.40, Instrument Piping Standards, Piping at Level Instruments
13. ENG STD 65B15.1 through 65B15.51, Instrument Piping Standards, Pressure Instrument Connections
14. ENG STD 68B11.1 through 68B11.14, Support and Rack Standards
15. ENG STD 70A1, Electrical Standard
16. ENG STD 85A1, Winterizing Ambient Temperature above 32 F

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17. ENG STD 85A2, Winterizing, Ambient Design Temperature from 15 F to 32 F

(1) 18. ENG STD 85F1, Winter Design Temperature

B. American National Standards Institute

1. ANSI C85.1 and C85.1a, Terminology for Automatic Control
2. ANSI C96.1 Temperature Measurement Thermocouples
3. ANSI B16.1 Cast Iron Pipe Flanges and Flanged Fittings
4. ANSI B16.5 Steel Pipe Flanges, Flanged Valves and Fittings

C. American Petroleum Institute

1. API RP 520, Part I and Part II, Recommended Practice for the Design and Installation of Pressure-Relieving Systems in Refineries
2. API STD 526, Flanged Steel Safety Relief Valves
3. API STD 527, Commercial Seat Tightness of Safety Relief Valves with Metal-to-Metal Seats
4. API STD 2000, Venting Atmospheric and Low-Pressure Storage Tanks

D. American Gas Association

1. Gas Measurement Committee Report No. 3, Orifice Metering of Natural Gas

E. ASME Boiler and Pressure Vessel Code

1. ASME Power and Boiler Code
 - a. Section I, Power Boilers
 - b. Section VIII, Division 1, Pressure Vessels
2. ASME Power Test Code 19.5

F. Instrument Society of America

1. ISA RP 4.1, Uniform Face to Face Dimensions for Flanged Control Valve Bodies
2. ISA STD S5.1, Instrumentation Symbols and Identification

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3. ISA STD S12.4, Instrument Purging for Reduction of Hazardous Area Classification
- G. National Electrical Code
- H. L. K. Spink: Principles and Practice of Flow Metering Engineering
- J. NFPA National Fire Codes
 1. No. 493 Intrinsically Safe Control Equipment
 2. No. 496 Purged Enclosures for Electrical Equipment



INSTRUMENTATION
SYMBOLS AND IDENTIFICATION

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JOB SPECIFICATION 60863-60A3

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NOTE: The instrument numbering system is based on "Data Acquisition and analysis - Guidelines for 1PH Demonstration Projects" issued by S.E.R.I. March 30, 1979.

I. GENERAL

- A. Instruments shall be identified by a system of letters and numbers generally in accordance with the Instrument Society of America Standard S5.1, extracts from which follow. Minor modifications have been made, e.g., pp. 3, 7, 16 and computer symbols.
- B. Each instrument will be identified first by a system of letters used to classify it functionally. (See Tables 1 and 2 for the system of letters). To establish a loop identity for the instrument, a number will be appended to the letters. This number will, in general, be common to other instruments of the loop of which this instrument is a part. A suffix is sometimes added to complete the loop identification.
- C. Where ISA Standard S5.1 offers alternate methods of presentation, FWEC practice is to use the method requiring the fewest symbols. Symbols will not be shown for the following:
 1. Valve positioners.
 2. Field mounted I/P transducers, when no solenoid valve or other device is in line between I/P and valve.
 3. Balloons identifying control valves (except in the case of split range control valves or where the valve is separated from the rest of the control loop enough to cause confusion).
 4. Balloons identifying flow and temperature primary elements.
 5. Multiplexing, when used for panel mounted temperature indication only.
 6. Local process variable indicators on transmitter outputs, unless it is intended to designate a special location for the indicator, as shown by a note next to the tagging balloon.

II. FUNCTIONAL IDENTIFICATION

- A. The functional identification of an instrument will consist of letters from Table 1, and will include on first-letter, covering the measured or initiating variable, and one or more succeeding letters covering the functions of the individual instrument. Exceptions to this rule are the use of the single letter L to denote a pilot light that is not part of an instrument loop and computer functions which will use modifying-letters only.
- B. The succeeding-letters of the functional identification designate one or more readout or passive functions, or output functions, or both. A modifying-letter may be used, if required, in addition to one or more other succeeding-letters. Modifying letters may modify either a first-letter or other succeeding-letters, as applicable. All letters of the functional identification shall be upper case. For examples of combinations of functional identification letters, see Table 2.

11. FUNCTIONAL IDENTIFICATION (cont'd)

TABLE 1

FIRST LETTER		SUCCEEDING LETTERS		
MEASURING OR INITIATING VARIABLE	MODIFIER	READOUT OR PASSIVE FUNCTION	OUTPUT FUNCTION	MODIFIER
A ANALYSIS (3)		ALARM		
B BURNER FLAME		USER'S CHOICE (1)	USER'S CHOICE (1)	USER'S CHOICE (1)
C CONDUCTIVITY (ELECTRICAL)			CONTROL COMPUTER/AUTO/MAN (6)	
D DENSITY (MASS) OR SPECIFIC GRAVITY	DIFFERENTIAL			
E VOLTAGE (EMF)		PRIMARY ELEMENT		
F FLOW RATE	RATIO (FRACTION)			
G GAGING (DIMENSION)		GLASS		
H HAND (MANUALLY) INITIATED				HIGH
I CURRENT (ELEC.)		INDICATE		
J POWER	SCAN		MULTIPLEX OR TREND	
K TIME OR TIME SCHED.			CONTROL STATION (COMPUTER/MAN (6)	
L LEVEL		LIGHT PILOT (4)		LOW
M MOISTURE OR HUMIDITY				MIDDLE OR INTERMEDIATE
N USER'S CHOICE (1)		USER'S CHOICE	USER'S CHOICE (1)	USER'S CHOICE (1)
O USER'S CHOICE (1)		ORIFICE (RESTRICT')		
P PRESSURE OR VACUUM		POINT (TEST) CONNECTION		
Q QUANTITY OR EVENT	INTEGRATE OR TOTALIZE			
R RADIOACTIVITY		RECORD OR PRINT		
S SPEED OR FREQUENCY	SAFETY		SWITCH	
T TEMPERATURE			TRANSMIT	
U MULTIVARIABLE		MULTIFUNCTION	MULTIFUNCTION	MULTIFUNCTION
V VISCOSITY			VALVE, DAMPER, OR LOUVER	
W WEIGHT OR FORCE		WELL		
X UNCLASSIFIED (2)		UNCLASSIFIED (2)	UNCLASSIFIED (2)	UNCLASSIFIED (2)
Y USER'S CHOICE (1)			RELAY OR COMPUTE	
Z POSITION			DRIVE, ACTUATE OR UNCLASSIFIED FINAL CONTROL ELEMENT	

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II. FUNCTIONAL IDENTIFICATION (contd)

C. Notes For Table 1-- Meanings of Identification Letters

1. A user's choice letter is intended to cover unlisted meanings that will be used repetitively in a particular project. If used, the letter may have one meaning as a first-letter and another meaning as a succeeding-letter. The meanings need be defined only once in a legend, or otherwise, for that project. For example, the letter N may be defined as modulus of elasticity as a first-letter and oscilloscope as a succeeding-letter.
2. The unclassified letter X is intended to cover unlisted meanings that will be used only once or to a limited extent. If used, the letter may have any number of meanings as a first-letter and may have any number of meanings as a succeeding-letter. Except for its use with distinctive symbols, it is expected that the meanings will be defined outside a tagging balloon on a flow diagram. For example, XR-2 may be a stress recorder, XR-3 may be a vibration recorder, and XX-4 may be a stress oscilloscope.
3. First-letter A for analysis covers all analyses that are not listed in Table 1 and are not covered by a user's choice letter. It is expected that the type of analysis in each instance will be defined outside a tagging balloon on a flow diagram.
4. A pilot light that is part of an instrument loop shall be designated by a first-letter followed by succeeding-letter L. For example, a pilot light that indicates an expired time period may be tagged KL. However, if it is desired to tag a pilot light that is not part of a formal instrument loop, the pilot light may be designated in the same way or alternatively by a single letter L. For example, a running light for an electric motor may be tagged either EL, assuming that voltage is the appropriate measured variable, or XL, assuming that the light is actuated by auxiliary electric contacts of the motor starter, or simply L.
5. If a given loop has more than one instrument with the same functional identification, then a suffix shall be appended to the loop number, e.g. FV-2A, FV-2B, etc., or TE-25-1, TE-25-2, etc. However, if a computer or Data Logger is involved, the use of suffixes may not be compatible and unique consecutive numbers shall be used. The main instrument should take the number of the Primary Case, e.g. with High and Low Flow arrangement, the transmitters shall be numbered, say FT-2 and FT-3, whereas the main instrument would be numbered FRC-2.
6. When a digital control system is being used, the type of analog backup used can be distinguished by using output functions C or K.

11. FUNCTIONAL IDENTIFICATION (con't)

TABLE 2

11. FUNCTIONAL IDENTIFICATION (cont'd)

TABLE 3

DESIGNATIONS FOR RELAYS
AND COMPUTER FUNCTIONS

THE FUNCTION DESIGNATIONS ASSOCIATED WITH RELAYS AND COMPUTERS MAY BE USED AS FOLLOWS, INDIVIDUALLY OR IN COMBINATION. THE USE OF A BOX ENCLOSING A SYMBOL IS REQUIRED; THE BOX IS INTENDED TO AVOID CONFUSION BY SETTING OFF THE SYMBOL FROM OTHER MARKINGS ON A DIAGRAM.

SYMBOL	FUNCTION
1 1-0 OR ON-OFF	AUTOMATICALLY CONNECT, DISCONNECT, OR TRANSFER ONE OR MORE CIRCUITS PROVIDED THAT THIS IS NOT THE FIRST SUCH DEVICE IN A LOOP.
2 Σ OR ADD	ADD OR TOTALIZE (ADD AND SUBTRACT)
3 Δ OR DIFF.	SUBTRACT
4 $\begin{array}{c} + \\ - \\ + \\ - \end{array}$	BIAS
5 AVG	AVERAGE
6 % OR 1:3 OR 2:1 (TYPICAL)	GAIN OR ATTENUATE (INPUT:OUTPUT)*
7 X	MULTIPLY
8 \div	DIVIDE
9 $\sqrt{\quad}$ OR SQ.RT.	EXTRACT SQUARE ROOT
10 X^n OR $X^{1/n}$	RAISE TO POWER
11 F (X)	CHARACTERIZE
12 1:1	BOOST
13 > OR HIGHEST MEASURED VARIABLE	HIGH-SELECT. SELECT HIGHEST (HIGHER) MEASURED VARIABLE (NOT SIGNAL, UNLESS SO NOTED).
14 < OR LOWEST (MEASURED VARIABLE)	LOW-SELECT. SELECT LOWEST (LOWER) MEASURED VARIABLE (NOT SIGNAL, UNLESS SO NOTED).
15 REV	REVERSE
16. A.E/P OR P/I (TYPICAL)	CONVERT FOR INPUT/OUTPUT SEQUENCES OF THE FOLLOWING:
	DESIGNATION SIGNAL
	E VOLTAGE
	H HYDRAULIC
	I CURRENT (ELECTRICAL)
	O ELECTROMAGNETIC OR SONIC
	P PNEUMATIC
	R RESISTANCE (ELECTRICAL)
B. A/D OR D/A	FOR INPUT/OUTPUT SEQUENCES OF THE FOLLOWING
	A ANALOG
	D DIGITAL
17. \int	INTEGRATE (TIME INTEGRAL)
18. D OR d/dt	DERIVATIVE OR RATE
19. I/D	INVERSE DERIVATIVE
20. AS REQUIRED	UNCLASSIFIED

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III. LOOP IDENTIFICATION

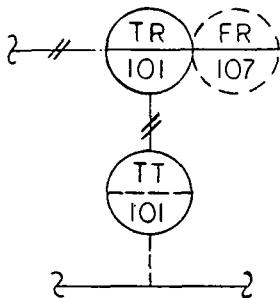
- A. The loop identification of an instrument will generally use a number assigned to the loop of which the instrument is a part. Each instrument loop shall have a unique number. An instrument common to two or more loops may have a separate loop number, if desired.
- B. A single sequence of loop numbers shall be used for all instrument loops of a contract regardless of the first letter of the functional identification of the loops. The loop numbering sequence will begin with the number 1 and run consecutively until all loops in a given contract are identified.
- C. It is Foster Wheeler practice to assign a new contract number to each section of a multi-section job. Therefore, to discriminate between such sections, the functional identification letters may be preceded by the last one or two digits of the contract number. Or, if process area numbers are assigned, they may be used as a prefix to discriminate between loop numbering in different process areas.

IV. SYMBOLS

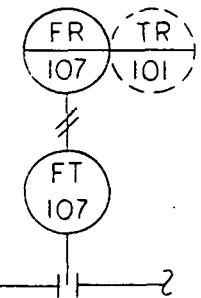
- A. It is not the intention of this standard to list all symbols or combinations. ISA Standard S5.1 lists many more.
- B. Control valve positioners and control valve electric-to-air converters will not be shown. Therefore, with an electrical system, the controller output (electrical) signal will be schematically shown connected to the valve diaphragm, the actual installation will have a converter.
- C. In addition, various expedients may be used on individual contracts. For example, the letter "V" just outside the circle can indicate an item supplied by a package vendor, or the letters "LP" can indicate a local panel mounting.
- D. The actuator action in the event of actuating medium failure shall be shown on control valves (see control valve symbols on page 9).
- E. Also, when dual pen instruments are shown on different flow diagrams, a note can show "To second pen on TR-101" or the tangential circle can be shown in phantom as follows:

IV. SYMBOLS (con't)

E (cont'd)



P/I DIAGRAM NO.1



P/I DIAGRAM NO.2

F COMPUTER FUNCTIONS WILL BE SHOWN AS A HEXAGON. USE MODIFYING LETTERS ONLY SINCE THE MEASURED VARIABLE "UJ" IS IMPLIED BY THE HEXAGON.

G THE SYMBOLS USED TO DEPICT INSTRUMENTATION ON FLOW DIAGRAMS AND OTHER DRAWINGS ARE SHOWN BELOW:

CONNECTION TO PROCESS

/// / / /

PNEUMATIC SIGNAL

~~~~~

ELECTROMAGNETIC (NUCLEAR) OR SONIC SIGNAL

-----

ELECTRICAL SIGNAL

— L — L —

HYDRAULIC SIGNAL

\* — X — \*

CAPILLARY TUBING (FILLED SYSTEM)



7/16 DIA.

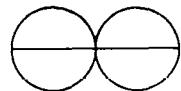
LOCALLY MOUNTED



MOUNTED ON BOARD



MOUNTED BEHIND THE BOARD OR OTHER CONTROL ROOM LOCATION



INSTRUMENT FOR TWO MEASURED VARIABLE  
(BOARD MOUNTED)

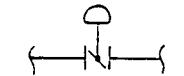


LOCAL PANEL BOARD MOUNTED

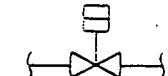


COMPUTER FUNCTION (IN CONTROL ROOM BUT NOT  
NECESSARILY BOARD MOUNTED)

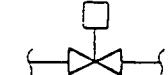
IV. SYMBOLS (con't)



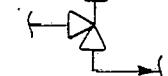
DIAPHRAGM OPERATED BUTTERFLY DAMPER OR LOUVER



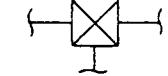
CYLINDER OPERATED VALVE



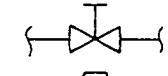
SOLENOID OPERATED VALVE



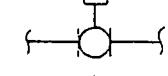
ANGLE VALVE



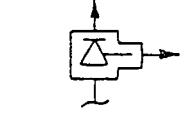
3-WAY VALVE BODY



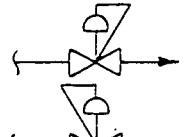
HAND CONTROL VALVE



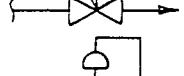
BALL OR ROTARY PLUG VALVE



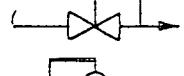
AUTOMATIC RECIRCULATION CONTROL VALVE



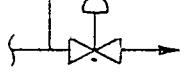
PRESSURE REDUCING VALVE-SELF-CONTAINED (REGULATOR)



BACKPRESSURE VALVE-SELF CONTAINED (REGULATOR)



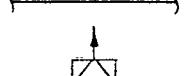
PRESSURE REDUCING VALVE WITH EXTERNAL PRESSURE TAP



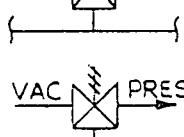
BACKPRESSURE VALVE WITH EXTERNAL PRESSURE TAP



SAFETY VALVE (RELIEF)



RUPTURE DISC.

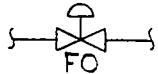


PRESSURE & VACUUM RELIEF VALVE

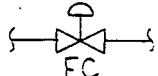


TRAPS

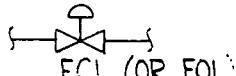
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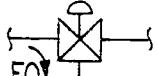
2-WAY VALVE-FAIL OPEN



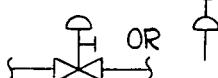
2-WAY VALVE-FAIL CLOSED



2-WAY VALVE-FAIL LOCKED



3-WAY VALVE: SHOWN SPLITTING FLOW AND FAIL POSITION



DIAPHRAGM OPERATED VALVE WITH SIDE MOUNTED  
HANDWHEEL (OR TOP MOUNTED)



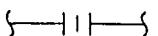
CHEMICAL SEAL



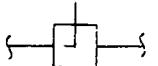
PURGE



RESET FOR LATCH TYPE ACTUATOR



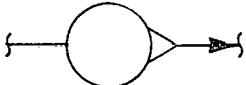
ORIFICE PRIMARY ELEMENT



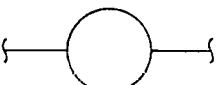
PILOT-TUBE OR ANNUBAR



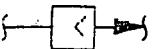
VENTURI TUBE OR FLOW NOZZLE



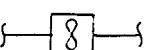
ROTAMETER TYPE FLOW METER



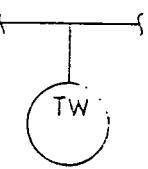
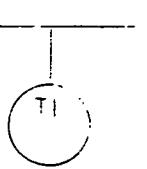
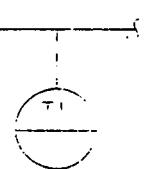
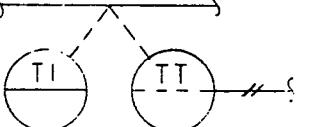
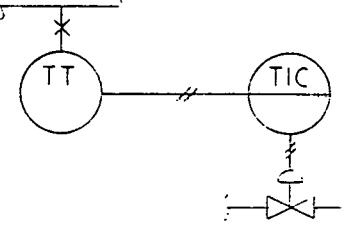
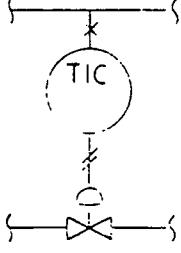
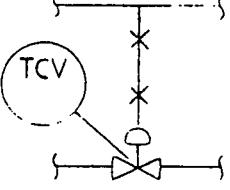
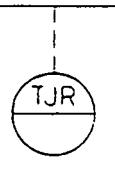
INLINE TYPE FLOW METER OTHER THAN ROTAMETER

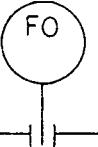
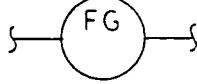
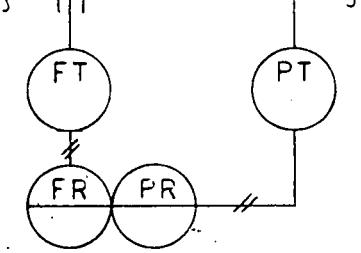
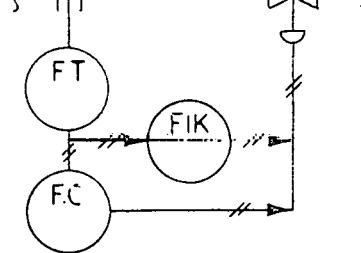
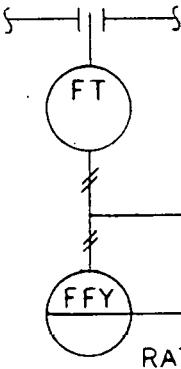


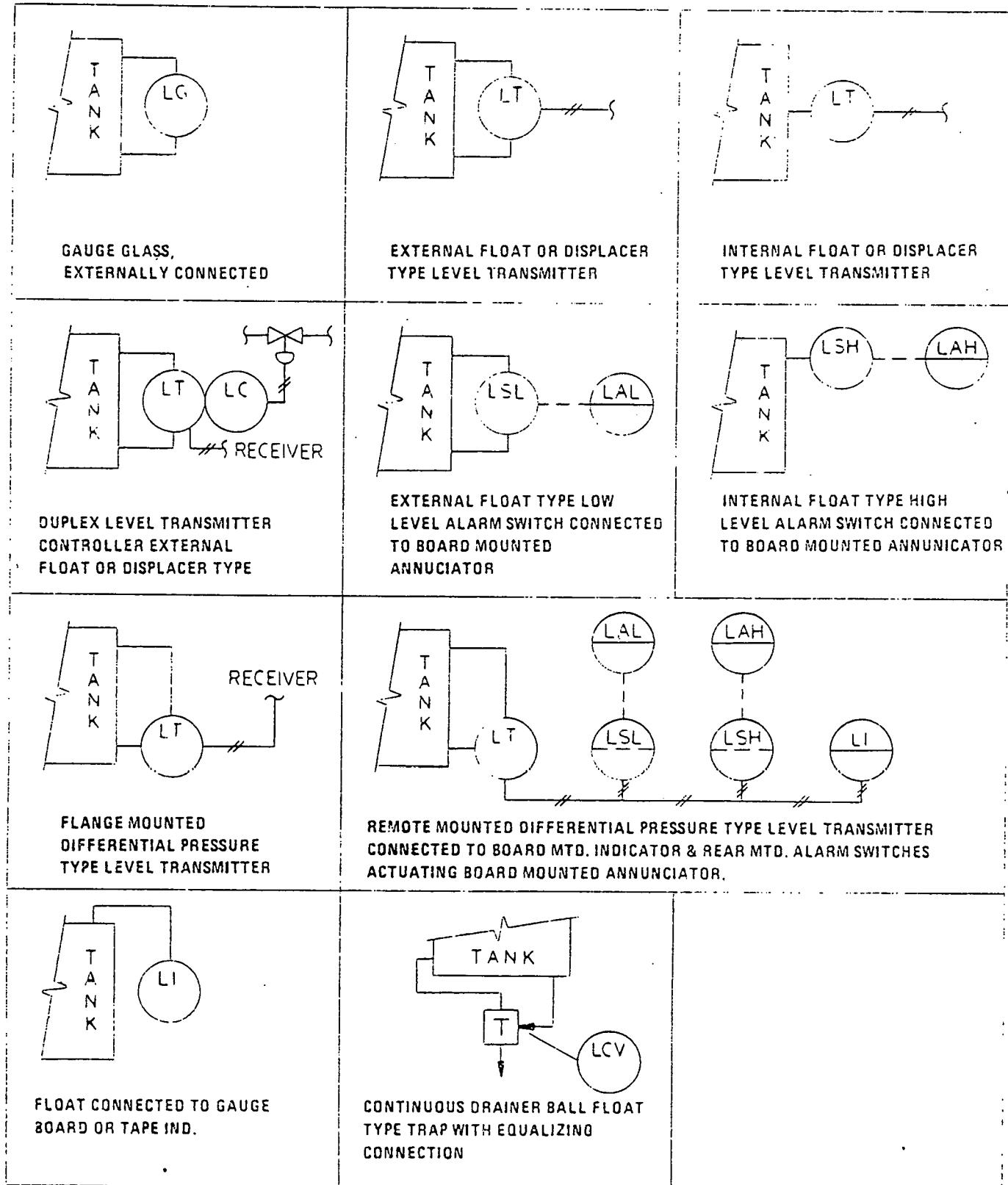
VORTEX FLOW METER

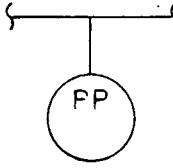
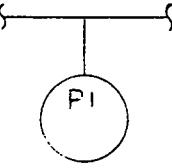
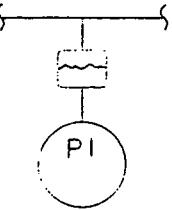
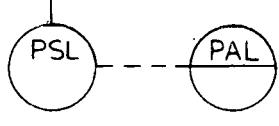
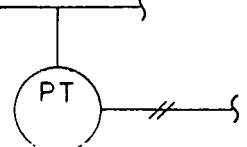
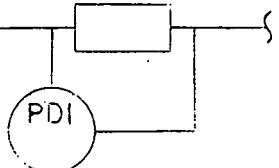
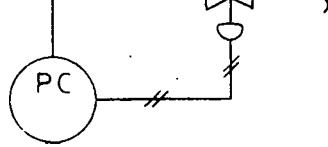
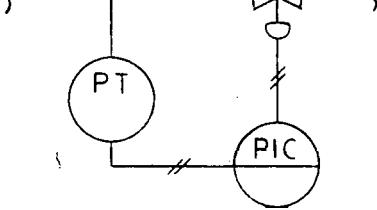
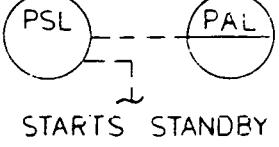


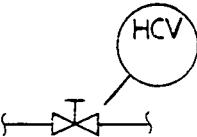
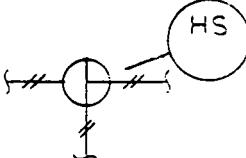
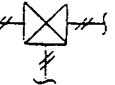
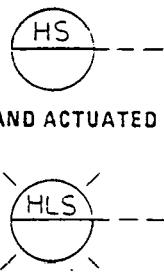
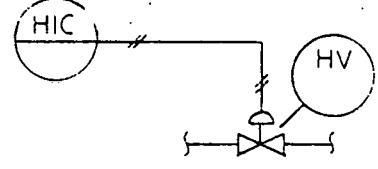
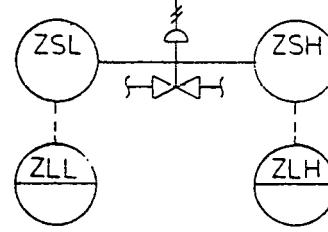
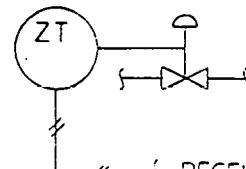
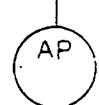
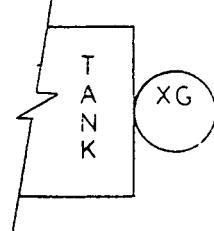
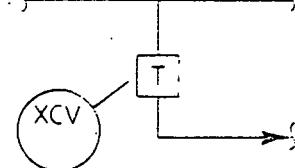
TURBINE METER

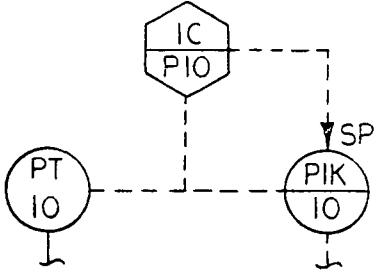
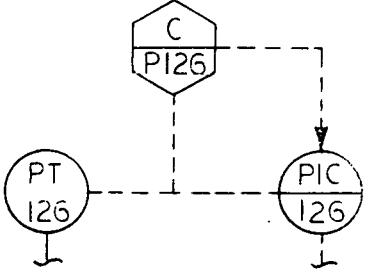
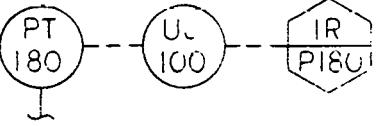
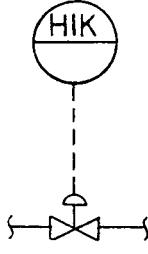
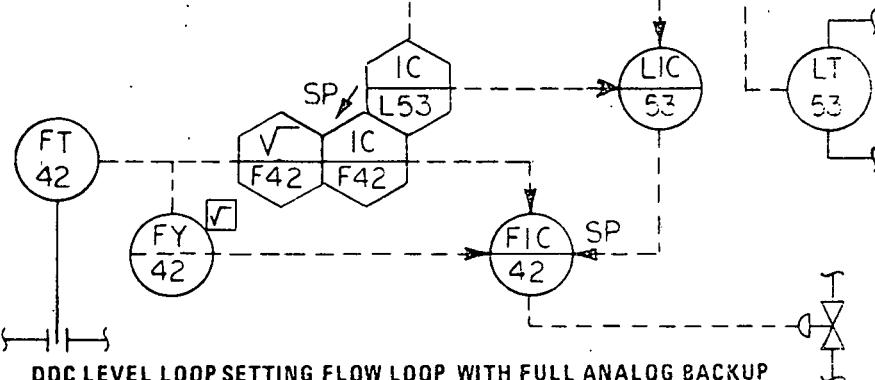
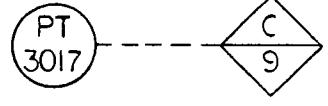
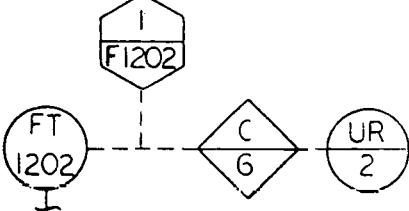
|                                                                                             |                                                                                     |                                                                                                                              |
|---------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|
|            |    |                                           |
| TEMPERATURE TEST CONNECTION<br>WITH WELL                                                    | LOCAL TEMPERATURE INDICATOR                                                         | BOARD MOUNTED TEMPERATURE IN-<br>DICATOR (CAN ALSO BE USED WHEN<br>TEMPERATURES ARE MULTIPLEXED<br>TO BOARD MOUNTED DISPLAY) |
|            |  |                                          |
| DUPLEX THERMOCOUPLE CONNECTED<br>TO REAR BOARD MTD. TRANSMITT-<br>ER AND CHECKING INDICATOR | FILLED SYSTEM TYPE<br>TRANSMITTER AND<br>INDICATING CONTROLLER                      | FILLED SYSTEM TYPE<br>LOCALLY MOUNTED<br>INDICATING CONTROLLER                                                               |
|          |  |                                                                                                                              |
| SELF ACTUATED TEMPERATURE<br>CONTROL VALVE                                                  | THERMOCOUPLE OR RESISTANCE<br>BULB CONNECTED TO MULTIPONT<br>RECORDER               |                                                                                                                              |
|                                                                                             |                                                                                     |                                                                                                                              |

|                                                                                                                                                                                                      |                                                                                                                                                                         |                                                                                                                                                                           |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <p>FLOW ELEMENT<br/>NO MEASURING INSTRUMENT<br/>PROVIDED</p>                                                       |  <p>ORIFICE TYPE LOCAL FLOW<br/>INDICATOR</p>                                          |  <p>RESTRICTION ORIFICE<br/>(NO METER RUN REQUIRED)</p>                                |
|  <p>FLOW SIGHT GLASS</p>                                                                                            |  <p>ROTAMETER TYPE FLOW<br/>INDICATOR</p>                                             |  <p>POSITIVE DISPLACEMENT<br/>TYPICAL FLOW TOTALIZING INDICATOR</p>                    |
|  <p>INLINE TYPE FLOW METER<br/>OTHER THAN ROTAMETER.<br/>IDENTIFY OUTSIDE BALLOON<br/>(E.G. INTEGRAL ORIFICE)</p> |  <p>COMBINED FLOW/PRESSURE<br/>RECORDER WITH LOCAL<br/>TRANSMITTER FOR EACH PEN</p> |  <p>FLOW CONTROL STATION WITH<br/>LOCAL CONTROLLER<br/>(4-TUBE SYSTEM)</p>           |
|  <p>RATIO</p>                                                                                                     |                                                                                                                                                                         | <p>RATIO CONTROL SYSTEM IN WHICH THE<br/>SET POINT OF A FLOW CONTROLLER IS<br/>ADJUSTED (VIA A RATIO RELAY) BY THE<br/>REFERENCE FLOW. BOTH FLOWS BEING<br/>RECORDED.</p> |



|                                                                                                                                                                                                     |                                                                                                                                                                                                         |                                                                                                                                                                                                            |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <p>PRESSURE CONNECTION WITH<br/>PROCESS CONNECTION BLOCK<br/>VALVE AND INSTRUMENT<br/>BLEED ONLY (TEST POINT)</p> |  <p>LOCAL PRESSURE INDICATOR<br/>(INCLUDES PRESSURE VACUUM<br/>AND DRAFT)</p>                                          |  <p>LOCAL PRESSURE INDICATOR<br/>WITH CHEMICAL SEAL</p>                                                                 |
|  <p>LOCALLY MOUNTED LOW<br/>PRESSURE ALARM SWITCH<br/>CONNECTED TO BOARD MTD.<br/>ANNUNCIATOR</p>                  |  <p>PRESSURE TRANSMITTER (INCLUDES<br/>PRESSURE, VACUUM &amp; DRAFT) IF<br/>ABSOLUTE IDENTIFY OUTSIDE<br/>BALLOON</p> |  <p>DIFFERENTIAL PRESSURE INDICATOR</p>                                                                                 |
|  <p>LOCAL PRESSURE CONTROLLER<br/>BLIND TYPE, PILOT OPERATED</p>                                                 |  <p>PRESSURE TRANSMITTER<br/>CONNECTED TO BOARD MTD.<br/>INDICATING CONTROLLER</p>                                  |  <p>STARTS STANDBY<br/>LOW PRESSURE SWITCH WITH TWO<br/>OUTPUTS OPERATING AT SAME<br/>TIME FOR ALARM AND CONTROL.</p> |
|                                                                                                                                                                                                     |                                                                                                                                                                                                         |                                                                                                                                                                                                            |

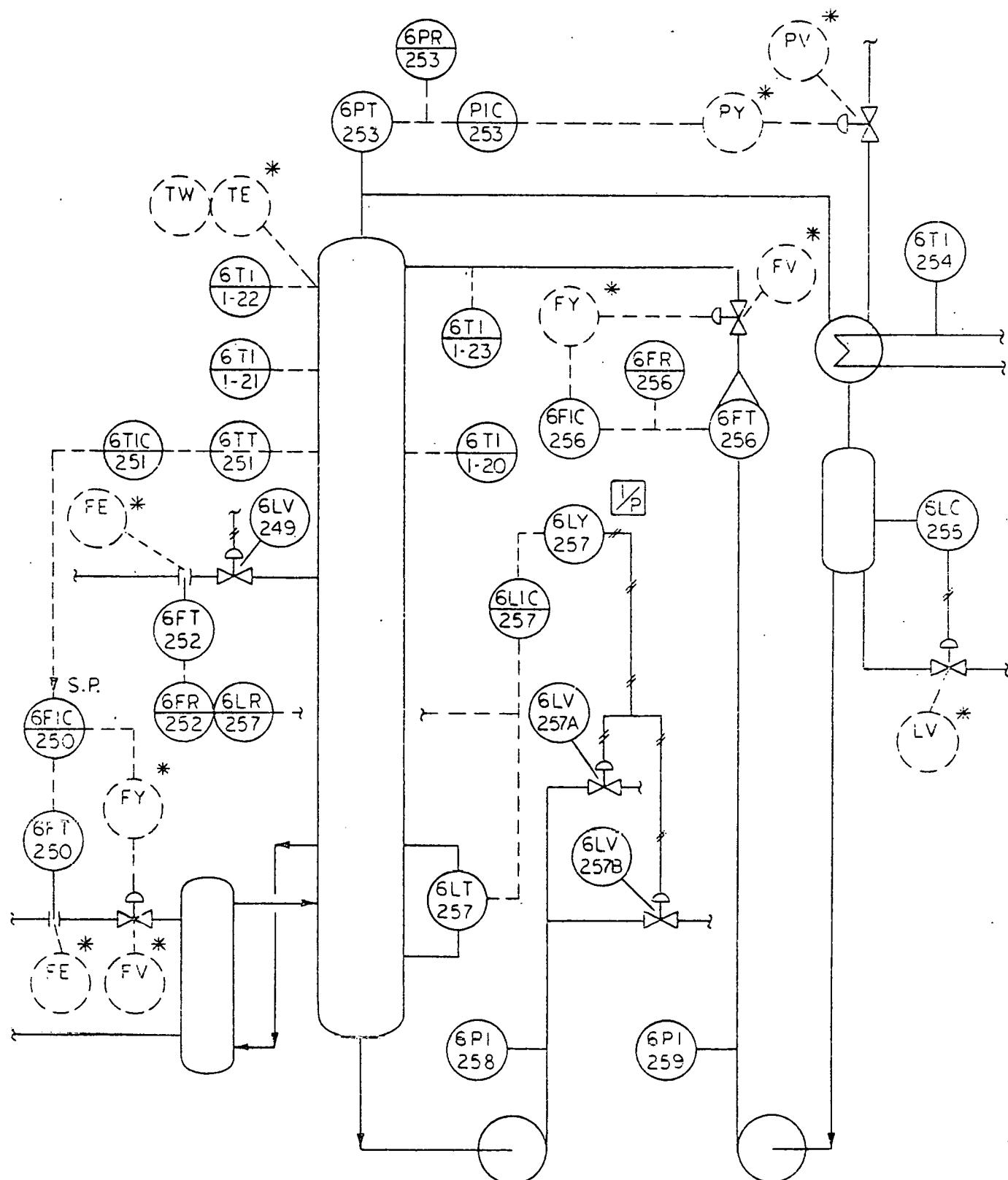
|                                                                                     |                                                                                                                                                                              |                                                                                                                                                                        |
|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    | <br>ALT:  | <br>HAND ACTUATED ELECTRIC SWITCH<br>HAND ACTUATED ELECTRIC SWITCH WITH PILOT LIGHT |
|    |                                                                                           | <br>RECEIVER                                                                        |
|  | <br>VIEW                                                                                  |                                                                                   |
|                                                                                     |                                                                                                                                                                              |                                                                                                                                                                        |

|                                                                                                                                                                                                                  |                                                                                                                                                                                                            |                                                                                                                                                         |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <p>A/M STATION ON COMPUTER SUPERVISORY MODE CONTROL WITH CRT DISPLAY</p>                                                       |  <p>COMPUTER/AUTO/MANUAL STATION ON COMPUTER CONTROL WITHOUT CRT DISPLAY</p>                                             |  <p>PRESSURE MULTIPLEXED TO COMPUTER FOR CRT DISPLAY AND LOGGING</p> |
|  <p>MANUAL CONTROL STATION IN COMPUTER BASE SYSTEM</p>                                                                         |  <p>DDC LEVEL LOOP SETTING FLOW LOOP, WITH FULL ANALOG BACKUP</p>                                                       |                                                                                                                                                         |
|  <p>PRESSURE SIGNAL TO BOARDMOUNTED PATCHBOARD OR MATRIX BOARD CONNECTION (NO.9), CAPABLE OF OUTPUT TO MULTIPLE LOCATIONS</p> |  <p>FLOW LOOP CONNECTED TO DATA DISPLAY AND TREND RECORDER ON PANEL BOARD (POINT NO.6 OF 12 POINT TREND RECORDER).</p> |                                                                                                                                                         |
|                                                                                                                                                                                                                  |                                                                                                                                                                                                            |                                                                                                                                                         |

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INSTRUMENTATION  
SYMBOLS AND IDENTIFICATION

FOSTER  WHEELER  
PROCESS PLANTS DIVISION



\* TYPICAL SYMBOLS NOT SHOWN AS PART OF FWEC NORMAL PRACTICE, SEE PARAGRAPH I.C.

APPENDIX D.8  
ELECTRICAL

REVISION INDEX

| <u>PAGE</u> | <u>REV.</u> | <u>DATE</u> |
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| 4           | 0           | 6/1/79      |
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I. SCOPE

This specification specifies the general requirements for the design, equipment, materials and installation of the electrical facilities for a solar boiler house and solar field, located at Dalton, GA.

The facilities are limited to the electrical services associated with the building and solar field and will include the following systems:

All lighting - normal, emergency and exit signs  
Receptacles - convenience and power  
Electric Instrument Wiring  
Telephone Conduits  
Grounding

A. Work Covered by This Specification

The work covered by this specification shall include furnishing all labor, material, equipment and services to install the complete electrical system as specified herein.

Unless otherwise specified, this includes all electrical design necessary for the following work:

1. Installation of complete internal distribution system for power, including panelboards, disconnects, cable, conduit, and fittings.
2. Installation of complete distribution system for lighting including the necessary transformers, feeders, distribution panelboards, branch circuits, lighting fixtures, control switches, receptacles, cable, conduit and fittings.
3. Installation of empty raceways and cabinets for the telephone system.
4. Connection of permanently installed equipment for heating, ventilation and air conditioning system (supplied by others) or package air conditioning units.
5. Installation of complete ground system including fittings, clamps, conduit and wire.
6. Installation of complete electric instrument wiring system, including connections to field instruments and control panel and necessary cable, conduit, fittings and electrical boxes.
7. Installation of emergency lighting system, including exit signs, when specified.

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ELECTRICAL SPECIFICATION

FOSTER  WHEELER  
PROCESS PLANTS DIVISION

I. SCOPE (Continued)

B. Work Not Covered by This Specification

The following equipment items and work shall be the responsibility of others:

Telephone system wires, cables, equipment and instruments - to be furnished and installed by telephone company

II. GENERAL

A. Codes and Regulations

Except where indicated otherwise in this specification, the design, equipment, materials and their installation shall conform to the minimum requirements of the latest edition of the following applicable standards and codes:

1. US Dept. of Labor: Occupational Safety and Health Act (OSHA)
2. American National Standards Institute (ANSI)
3. National Fire Protection Association (NFPA)
4. National Electrical Safety Code (NBS Handbook H30)
5. National Electrical Code (NFPA #70)
6. National Electrical Manufacturers Association (NEMA)
7. Insulated Power Cable Engineers Association (IPCEA)
8. Underwriters' Laboratories, Inc. (UL)
9. Local Laws and Regulations

B. Equipment and Materials

1. Equipment and materials furnished shall be as specified in this specification and shall satisfy all requirements dictated by the exposure of the area in which the equipment or materials are installed.



PROCESS PLANTS DIVISION

## ELECTRICAL SPECIFICATION

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II. GENERAL (Continued)B. Equipment and Materials (Continued)

2. The equipment and materials furnished shall be labeled, listed, certified, accepted, or otherwise determined to be safe for the use by a nationally recognized testing laboratory such as one of the following:
  - a. Underwriters' Laboratories, Inc. (UL)
  - b. Factory Mutual Engineering Corporation (FM)

C. Classification of Areas

## 1. Natural Nonhazardous

Unless otherwise specified, the buildings and their facilities shall be classified as nonhazardous.

III. ELECTRIC SERVICE

Unless otherwise specified, the electric service characteristics shall be as follows:

|                                                                |                                                                      |
|----------------------------------------------------------------|----------------------------------------------------------------------|
| Power                                                          | 480 volt, 3 phase, 3 wire, 60 hertz,<br>solidly grounded neutral.    |
| Lighting receptacles,<br>instrument power and<br>miscellaneous | 120/208 volt, 3 phase, 4 wire, 60 hertz,<br>solidly grounded neutral |

In general, the building design shall be based upon receiving a power feeder at 480 VAC, as required for all electrical services.

Stepdown transformers shall be used to obtain all other voltages as required, such as 120 VAC for lighting.

IV. CONDUIT, CONDUIT FITTINGS AND THEIR INSTALLATIONA. General

1. Except as noted herein, all wiring shall be run in approved conduit of one of the following types:
  - a. Rigid steel, hot dipped galvanized
  - b. Intermediate metal conduit (IMC), zinc coated
  - c. Electrical metallic tubing (EMT)

IV. CONDUIT, CONDUIT FITTINGS AND THEIR INSTALLATION (Continued)

A. General (Continued)

2. Wiring for fixtures in hung ceiling area may be run in flexible metallic conduit or armored type cable where permitted by local code.
3. Flexible steel conduit (maximum 6 feet long, 3/4" trade size) or armored type (BX) cable shall be permitted only in hung ceilings from recessed lighting units to associated outlet boxes.
4. Flexible liquid tight conduit shall be provided for connections to vibrating or rotating equipment (minimum 18" long), and as otherwise indicated on the drawings. Conduit shall be Anaconda American Brass "Sealtite", type NA flexible conduit, with T & B Series 5331 fittings as required, or approved equals.

B. Conduits shall be manufactured in conformance with the latest published standards of ASTM and UL and shall be as follows:

1. Conduit fittings for IMC shall be steel, threaded, of standard pipe dimensions, galvanized inside and out.
2. Electrical metallic tubing may be used for conduit installations below 2 inches diameter.
3. Electrical metallic tubing connectors and couplings shall be steel, smooth, galvanized, inside and out, with screw type compression fittings, and with nylon insulated bushing such as manufactured by O.Z. or Crouse-Hinds type MW series or approved equal. Tubing shall be seamless or continuously threaded joints.
4. Threading of conduit shall be done using sharp dies and cutting oil to avoid tearing of the threads. Conventional thread lubricants may be used for making threaded joints.
5. All IMC and EMT shall be 3/4" minimum, except as otherwise noted, being true and smooth inside and out, and free of injurious defects.

Rigid Steel conduits shall be 3/4" minimum for power and lighting and 1/2" minimum for control and instrumentation, unless otherwise noted. They shall be true and smooth inside and out and free of injurious defects.

IV. CONDUIT, CONDUIT FITTINGS AND THEIR INSTALLATION (Continued)

B. (Continued)

6. Flexible steel conduit and armored type BX cable shall be used only with terminal fittings approved for the purpose, as manufactured by O.Z. or approved equal.
7. Conduit fittings, Crouse-Hinds form 8 or approved equal, shall be provided where specified or required. A bushing and double locknuts shall be provided at the end of each conduit where it enters an outlet box, cabinet, panel or pull box. Bushings for conduit 2" and above shall be insulated grounded type (O.Z. type BLG). For 3/4" to 1½" conduits use insulated bushings (O.Z. type B). All joints in conduits shall be made with standard couplings unless neither conduit can be turned. In that case, the joint shall be made with O.Z. type "SSP" split coupling or Erickson couplings. Running threads are not permitted.

C. Installation

1. Conduits installed underground shall be 1" minimum, secured to prevent shifting during concrete pour, and shall be a minimum of 18" below grade, 1" below the finished floor slab, and where run below terrazzo or similar finish shall not protrude into the floor finish construction.
2. Exposed conduits shall be installed only after proposed runs have been checked on plans and after site inspection for interference with work of other trades. Exposed conduits shall be installed in parallel rows neatly racked at right angles and parallel to all walls, floors and ceilings and at structural members.
3. Conduits shall be supported from ceilings by means of trapeze hangers and from walls by means of brackets utilizing the Unistrut (or approved equal) channel support system. All hangers, inserts, brackets and fittings shall be galvanized. Beam clamps shall be suitable for structural members and conditions. Hanger rods shall be galvanized steel or cadmium plated, 3/8 in diameter minimum. Each conduit shall be fastened to the channel support (Unistrut No. P-1000 or P-1001 Series) with a suitable clamp (Unistrut P-1111 B through P-1124 for IMC or rigid conduit, or Unistrut No. 1426 B through 1431 B for EMT). All steel bolts, nuts, washers and screws shall be galvanized or cadmium plated.

IV. CONDUIT, CONDUIT FITTINGS AND THEIR INSTALLATION (Continued)

C. Installation (Continued)

4. Conduits shall be supported every 10 feet (maximum), flexible conduits at least every 4½ feet.
5. Joints between aluminum steel components, if unavoidable, shall be made by coating the threads with zinc petroleum jelly compound or zinc chromate.
6. Where conduit is installed concealed with finished block, blazed block or tiled walls it shall be located so as not to cause a visible change in the finished appearance of such walls. Where required, deep boxes and/or equipment shall be used to comply with the above.
7. Conduits shall be protected or shall be plugged with suitable caps to prevent entrance of moisture or foreign material during construction.
8. All field bends shall be made with tools and equipment manufactured especially for this purpose.
9. Fish tape shall be drawn through all conduits installed for future wire to indicate that the conduit is clear of obstructions and ready for installation of wire.
10. In no case will the Seller be permitted to cut a structural member, beam or column to facilitate the installation of conduit, etc., without the approval of Purchaser.
11. Exposed conduits at mechanical equipment shall be rigidly braced to the floors.
12. Where conduits cross expansion joints allowing for building movement, cross joints with approximately 24" flexible conduit with a suitable copper strap bonded to the "rigid" conduit ends.
13. Openings in the outside walls and roof for conduit, duct, tray, bolts, etc., shall be made watertight after installation is completed. For conduit, this shall be done by providing pipe sleeves in concrete with a minimum clearance  $\frac{1}{2}$ " around the conduit, and packing this sleeve with acrylic caulk or other approved sealing material.
14. Parallel conduit runs for instrumentation must be kept at least 12" away from hot surfaces. A minimum clearance of 6" shall be kept where a conduit crosses a hot pipe.

IV. CONDUIT, CONDUIT FITTINGS AND THEIR INSTALLATION (Continued)

D. Pull boxes and junction boxes NEMA Type 12 of proper size and design shall be provided as required to facilitate installation of wire and cable. All boxes shall be sized in accordance with NEC. Covers shall be held in place with corrosion resistant machine screws. Boxes shall be securely mounted to the building structure independent of the conduits entering or leaving the box.

E. Outlet Boxes

1. A NEMA Type 12 enclosure shall be furnished and installed for every outlet and switch. All enclosures shall meet the requirements for galvanized finish specified for steel conduits.
2. Enclosures shall be of dimensions suited and adapted to its specific location and kind of fixture or receptacle to be used and the number and arrangement of wires in conduits. Each enclosure shall be securely fastened to the building structure.

F. Before proceeding with the installation of conduits and enclosures the Seller shall check the location of all outlets and shall make any adjustments required by local condition. Where outlets or fixtures are fixed by specific dimensions on electrical drawings, or are shown on shop or field drawings, the Seller shall adhere to these locations. Switch outlets shall be located on the lock side of doors. Unless otherwise specified outlets shall be installed at the following elevations above the finished floor:

|                                         |        |            |
|-----------------------------------------|--------|------------|
| Convenience Outlets (Mechanical Spaces) | 3'-6"  | Centerline |
| Convenience Outlets (Finished Areas)    | 1'-6"  | Centerline |
| Telephone Outlets                       | 1'-6"  | Centerline |
| Switch Outlets                          | 4'-2"  | Centerline |
| Thermostats                             | 5'-2"  | Centerline |
| Motor Controller                        | 5'-0"  | Centerline |
| Wall Bracket Outlets                    | 7'-10" | Centerline |
| Toilet Room Outlets                     | 5'-0"  | Centerline |

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V. WIRE AND CABLE

A. Basis For Cable Sizing

1. The allowable current carrying capacity of cables shall be as specified in the National Electrical Code and IPCEA.
2. Feeders to distribution centers and transformers shall be sized based upon the maximum demand of initial loads. In general, feeders shall have a current carrying capacity equal to 125% of the maximum demand or nameplate rating, whichever is greater.
3. Sub-feeders from distribution centers to load shall be sized based upon the nameplate rating of the load.
4. Cables shall be sized to limit voltage drops as follows:
  - a. Feeders and Sub-feeders 1% based upon maximum demand or nameplate
  - b. Motor Branch Circuits 3% from the power center to the motor (using motor nameplate), but no smaller than the minimum size permitted by NEC
  - c. Lighting Branch Circuits 2% from the panel to the farthest outlet
5. For lighting and power circuits 600 volts, and below, the smallest wire size shall be #12 AWG, except that #14 AWG shall be used for controls.
6. For instrument cable see Para. XV.

B. Cable Construction

1. Conductors #12 AWG and larger shall be stranded; conductors #14 AWG and smaller shall be solid.
2. In general, for cables installed in conduit, cable insulation types shall be as follows:

V. WIRE AND CABLE (Continued)

B. Cable Construction (Continued)

2. (Continued)

- a. For services 600 volts and below, cables shall be 600 volt, heat and moisture resistant thermoplastic insulated, with nylon jacket, type THWN/THHN.
- b. For fixture stems, #14 AWG, 600 volt, Type SF-2 stranded fixture wire shall be used.
- c. For instrument services PVC insulated wire and cable shall be used (See Para. XV).
3. Multiple conductor cable shall not be used for lighting and power work, except for:
  - a. Appliance cords
  - b. BX type armored cable as outlined in Paragraphs IV.A.2, IV.A.3 and IV.B.6 of this specification.
4. All feeders and risers shall be tagged at both ends and in pull boxes or panel box gutters through which they pass.
5. All cable shall comply with applicable portions of IPCEA Standard S-61-402.

C. Motor Feeders and Control

Cable for power and control leads to motors 600 volts and below shall be installed in the same conduit when the power cable is #2 AWG or smaller. For power cables larger than #2 AWG, power and control cable shall be installed in separate conduits.

D. Color Coding

1. The color coding for single conductor cables shall be as follows:
  - a. Power phase leads shall be black.
  - b. Multiwire lighting circuits and 2-wire branch circuits connected to the same system shall conform to the following:

Single Phase, 3 wire - Black (L1), Red (L2), White (N)

Three Phase, 4 wire - Black (L1), Red (L2), Blue (L3), White (N)

Three Phase, 3 wire ~ Black (L1), Red (L2), Blue (L3)

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V. WIRE AND CABLE (Continued)

D. Color Coding (Continued)

1. (Continued)

- c. All control leads, including those for pushbutton stations, interlock circuits, instrument control circuits; current and potential transformer circuits, etc., shall be red.
- d. Power supplies to/from instruments shall be yellow (live line) and white for the neutral.
- e. All grounding conductors shall be either bare or have a green covering.

VI. LIGHTING DISTRIBUTION SYSTEM

A. Lighting Design

1. The lighting system shall be designed utilizing the minimum number of fixtures consistent with the illumination levels specified below in Paragraph VI.B.
2. Lighting fixtures shall not be located directly over equipment with exposed moving parts.
3. Lighting systems shall be designed to minimize glare.
4. In general, lighting circuits shall be switched from local switches.
5. Branch circuits using a common neutral conductor shall be arranged for minimum current in the neutral conductor. Loads on all phases shall be equally balanced as closely as possible.
6. Exit lights and exterior door lights are to be provided.

B. Lighting Intensities

The lighting system shall be designed for the levels of illumination tabulated below, when calculated on the basis of initial lamp lumens modified by a factor of 70% to allow for deterioration in lamp output in service. (Derived from the following publications: API Recommended Practice for Petroleum Refineries, API RP540, American National Standard Practice for Industrial Lighting, ANSI Std A 11.1, and American National Standard Practice for Office Lighting, ANSI Std A 132.1).

VI. LIGHTING DISTRIBUTION SYSTEM (Continued)B. Lighting Intensities (Continued)

The illumination level is defined as the mean of the maximum and minimum values of illumination calculated at various points throughout the illuminated area.

| <u>LOCATION</u>                               | <u>ILLUMINATION LEVEL<br/>FOOT CANDLES</u> | <u>WORKING<br/>PLANE</u>       |
|-----------------------------------------------|--------------------------------------------|--------------------------------|
| Laboratory                                    | 100                                        | 36"                            |
| Control Rooms:                                |                                            |                                |
| General                                       | 50                                         | Floor                          |
| Vertical Face of Control Board                | 50                                         | Horizontal Centerline of Panel |
| Consoles, Desks (Horizontal Level)            | 50                                         | 30" *                          |
| Rear of Panel                                 | 15                                         | 48" *                          |
| Telephone Equipment Room                      | 20                                         | Floor                          |
| Locker Rooms                                  | 20                                         | Floor                          |
| Machine Shops:                                |                                            |                                |
| Rough Bench & Machine Work                    | 50                                         | 36" *                          |
| Medium Bench & Machine Work<br>Rough Grinding | 100                                        | 36" *                          |
| Stairways, corridors                          | 20                                         | Floor                          |
| Toilets and Washrooms                         | 30                                         | Floor                          |
| Air Conditioning Equipment                    | 10                                         | Floor                          |
| Boilers, Boiler Pumps, Compressors            | 20                                         | Floor                          |
| Solar Field Area                              | 5                                          | Ground                         |
| General Yard Areas                            | 0.5                                        | Ground                         |

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VI. LIGHTING DISTRIBUTION SYSTEM (Continued)

B. Lighting Intensities (Continued)

| <u>LOCATION</u>             | <u>ILLUMINATION LEVEL</u> | <u>WORKING</u> |
|-----------------------------|---------------------------|----------------|
|                             | <u>FOOT CANDLES</u>       | <u>PLANE</u>   |
| <b>Offices</b>              |                           |                |
| General                     | 150                       | 30" *          |
| Private                     | 150                       | 30" *          |
| Washrooms                   | 30                        | Floor          |
| Stairways, corridors        | 20                        | Floor          |
| Computer Operating Consoles | 150                       | 30" *          |

\* Elevations from the floor

C. Emergency Lighting

1. When specified, sufficient emergency lighting shall be provided in all locations where illumination is required during an emergency.
2. The emergency lighting system shall be completely independent of the normal power supply. Emergency circuit wiring shall not enter the same raceway, cable, box, or cabinet with other wiring.
3. Under normal conditions, emergency lighting fixtures shall be operable and energized from the normal power source. Transfer to the emergency source shall take place automatically in the event of a normal source failure.
4. Emergency Battery Units
  - a. Wall mounted emergency light units are to operate when AC power fails. Units shall be dual light, 12 V DC, complete with battery, fully automatic high and low rate charger, indicating pilot light, test switch, and provisions for connection to 115 V AC, 60 Hz, single phase wiring. Each unit shall have enough capacity to provide light for a minimum of 90 minutes, while maintaining 87½% of nominal battery voltage. (Dual Lite No. 12-ED series, or approved equal).



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VII. LIGHTING FIXTURES

A. Fixture Types

Type a. In general, fluorescent lamp fixtures shall be used for indoor areas requiring high illumination levels. Ballasts shall be rapid start Class P thermal protected, high power factor (90 min.), filled with a thermosetting compound (leak-proof), have a rated noise level of 30 dB or less and be listed by UL, and approved by CBM, and ETL. (Westinghouse Ventilated reflector type, # H260 HV or approved equal).

Incandescent fixtures may be used where high illumination levels are not required.

Type b. Emergency lights shall be of the self-contained type with battery, solid state charger, automatic transfer in case of power failure. (Dual Lite # 12-EDN-150-2-KB-A-V-LD-SST or approved equal).

Type c. Outside lights shall be mercury vapor (or high pressure sodium) with integral constant wattage ballast, (Holophane "Wallpack" Cat. 488-000 or approved equal).

Type d. Vertical surface illumination of instrument panels shall be obtained by the use of fixtures specially designed for the purpose, with adjustable lamp setting for beam control and prismatic lens (Holophane No. 6044 series or approved equal).

B. Lamps

1. Fluorescent lamps shall be "cool-white" as manufactured by G.E., Westinghouse, or Sylvania. 2 lamp type F 48T12 HO.
2. Mercury-Vapor lamps shall be "deluxe-white" as manufactured by G.E., Westinghouse or Sylvania.
3. Lamps for exit lights and emergency battery units shall be as recommended by manufacturer.
4. Incandescent lamps shall be inside frosted.
5. High pressure sodium (HPS) lamps shall be diffuse type "Lucalox" as manufactured by G.E. or approved equal.

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VII. LIGHTING FIXTURES (Continued)

F. Locations

1. Fixture rows shall be mounted in straight lines, except where location is dictated by equipment location.
2. Space conditions must be coordinated with other trades to avoid interferences.
3. Each door to outside shall have an interior exit light and exterior door light.
4. In the case of large, office type buildings, exit signs with directional arrows shall be located in corridors, etc., indicating paths of egress.

G. Mounting

Refer to architectural drawings for ceiling finish schedules and to manufacturer's installation details for the required fixture mounting accessories.

In general, fluorescent fixtures in finished areas shall be of the recessed, static type. In unfinished areas, surface or pendant mounted fixtures may be used.

H. Wiring

1. Refer to Paragraph V for fixture wire specifications.
2. Splices within fixture housings or outlet boxes are to be made with wire nuts of the proper size.

VIII. LIGHTING AND RECEPTACLE PANELBOARDS

A. General

Panelboards shall be 3 phase, 4 wire, 120/208 volt with main circuit breaker, bus bars and branch circuit breakers mounted in an enclosed cabinet (NEMA 12) with trim and door. Cabinet trim, door and finish shall be the manufacturer's standard. Main lug size, main breaker size and the number of branch circuit breakers shall be as indicated on contract drawings or material lists. Panel short circuit rating shall be 10,000 amps minimum.

VIII. LIGHTING AND RECEPTACLE PANELBOARDS

- B. Branch and main circuit breakers shall be as specified in Paragraph XI of this specification.
- C. Bus bars and main circuit breakers shall be rated 100 A minimum.
- D. All single pole breakers shall be arranged and connected to the main bus so that on 3 phase, 4 wire panels, any three adjacent breaker poles are connected to phase A, B and C respectively and that the same relationship of phase sequence is maintained.
- E. One spare circuit shall be provided for each 5 active circuits in the initial design. Circuit loading shall not exceed 16 A for a 20 A breaker.
- F. A durable, corrosion resistant lighting directory shall be installed at each panelboard.

G. Installation

- 1. In general, cabinets shall be set at such a height so that the topmost branch breaker shall not be more than 6 feet from the floor.
- 2. Top trim shall line up on all panels mounted adjacent to each other.

IX. LIGHTING TRANSFORMERS (DRY-TYPE)

In general, transformers under this category may be used for the following services:

Lighting  
Receptacles  
Instruments  
Heat Tracing  
Space Heaters

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IX. LIGHTING TRANSFORMERS (DRY-TYPE) (Continued)

A. Basic Arrangement

1. Unless otherwise specified, lighting transformers shall be of a dry type, rated 480V-208Y/120V, and have the following features:
  - a. Sealed Insulation
  - b. 115 C maximum temperature rise
  - c. Noise levels shall not exceed those listed in ANSI Standard C89.1, for the size transformer used
  - d. A minimum of 2-2½% FCAN and 2-2½% FCBN taps

Transformers shall be installed at lighting panel locations on the basis of one for each lighting panel.

2. All lighting transformers shall be protected by an individual overcurrent device in the secondary side set at no more than 125% of rated secondary current and a primary feeder overcurrent device set at no more than 250% of the rated primary current.

B. Accessories

1. Transformers shall be provided with standard accessories for the KVA and voltage ratings.
2. Transformers shall be provided with suitable vibration dampers, as manufactured by Fabreeka Products Co., type Fabcel Vibration Isolation Mounts or approved equal. Dampers shall be designed to suppress transmission of vibrations of 120 Hz and multiple harmonics.

C. Installation

1. Transformers 30 KVA and below shall be wall mounted. Those above 30 KVA shall be floor mounted.
2. All transformer cases and neutrals shall be grounded. Refer to Paragraph XIII.

X. SWITCHES, WIRING DEVICES, WALL PLATES

- A. Each switch and wiring device shall have a suitable back-box sized in accordance with the National Electrical Code requirements. Refer to Paragraph IV.E of this specification.
- B. Convenience receptacles shall be arranged in groups of not more than 6 for each lighting panel branch circuit.
- C. In offices and control rooms, receptacle outlets shall be provided along the walls, spaced no more than 12 feet apart, with a minimum of 2 receptacles per room.
- D. Receptacles
  1. 15A, 125V convenience receptacles for office and control room areas shall be 2 pole, 2 wire grounding type, duplex, Hubbell Cat. No. 5262 or approved equal.
  2. 15A, 125V clock hanger outlet, if required - 2 pole, 3 wire grounding type Hubbell Cat. No. 5235 or approved equal, with stainless steel plate.
  3. 20A, 125V, receptacles for appliance circuits shall be 2 pole, 3 wire grounding type, Hubbell Cat. no. 5362 or approved equal.

E. Switches

1. 20A, 120-277V single pole switch, Hubbell Cat. No. 1221 or equal.
2. 20A, 120-277V three way switch, Hubbell Cat. No. 1223 or equal.

F. Device Plates

1. All switches and receptacle outlets shall be provided with stainless steel plates (Hubbell or equal) suitable for the above receptacles and switches.
2. Where plates are to fit exposed conduit fittings, they shall be consistent with the type of fittings installed.

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XI. CIRCUIT PROTECTIVE DEVICES

- A. All receptacles located in areas susceptible to moisture indoor or outdoor, shall be protected with ground fault interrupter.
- B. All circuit breakers for 120/208 volt panels shall be rated as follows:
  1. Branch circuit breakers shall be 20A at 120/240 volts AC, single pole with noninterchangeable trip elements. UL listed interrupting capacity shall be 10,000 A symmetrical at 120/240 volts AC.
  2. Main circuit breakers shall be 100 A minimum at 240 volts AC, 3 pole with noninterchangeable trip elements and of panelboard manufacturers suggested type for distribution system capacity. UL listed interrupting capacity shall be 10,000 A symmetrical at 240 volts AC.
- C. Each circuit breaker shall be distinctly numbered when installed in a group with other breakers. Trip element calibration shall be indicated on each breaker.
- D. Individually mounted circuit breakers shall be enclosed in a NEMA-12 type enclosure.

XII. DISCONNECT SWITCHES, MOTOR STARTERS

- A. Fractional HP Motor Disconnect Switch
  1. A 120 volt, single phase thermal protective switch (manual starter), Allen Bradley 600 series, Westinghouse type MS or approved equal, shall be used for disconnect means, unless otherwise noted.
  2. Disconnect switch may be single pole, 20 A AC only toggle switch (Hubbell No. 1221 or approved equal) where:
    - a. A switch is required in addition to a thermal overload switch.
    - b. The motor runs continuously, i.e., not automatically controlled.

Switches shall be installed in a suitable type FD box.

XII. DISCONNECT SWITCHES, MOTOR STARTERS (Continued)

B. Motor controllers for 3 phase, 480 volt motors shall be combination starters, full voltage, single speed, nonreversing, circuit breaker type (22,000 A interrupting capacity) for system short circuit levels up to 22,000 A. For system short circuit levels in excess of 22,000 A, high interrupting capacity fusible disconnect switch type may be used. Starters shall be furnished in suitable NEMA 12 enclosures.

XIII. GROUNDING

A. The scope of work under this section of the specification shall include the following:

1. Design, furnish and install a ground network including rods, cable and fittings around building as outlined in Paragraph B below.
2. The Seller shall furnish and install all fittings, clamps, conduit and wire, to establish ground connections between all building services apparatus and conduits, and the ground network around building.
3. Connection of the building ground network to the existing plant ground system.

B. Suitable grounding shall be installed for:

1. Grounding for Safety of Personnel

Metallic noncurrent carrying parts of equipment connected to electrical circuits and of all major electrical equipment, such as motors, transformers, distribution panelboards, motor starters, etc., shall be grounded by the conduit or raceway connection to the power supply ground network or, if such equipment is isolated, to one or more ground rods, or other suitable grounding electrodes in accordance with NEC. Supplementary grounding shall be provided by a grounding cable connection from the equipment to the local ground network, at points indicated on contract drawings, or other suitable ground point as required by the NEC.

XIII. GROUNDING (Continued)

B. Suitable grounding shall be installed for: (Continued)

2. Grounding for Protection Against Lightning

Building protection, when specified, shall be in accordance with NFPA and local building codes.

3. Grounding for Electrical System Protection

Grounding and bonding for protection of the electrical system circuits and equipment shall be installed to minimize damage in case of ground faults by providing low fault impedance, thereby limiting the voltage to ground and facilitating the operation of overcurrent devices.

4. Instrument Signal Ground

A separate system shall be installed for grounding of all computer/instrument equipment. It shall be completely isolated from the power equipment ground network. The system shall consist of a loop of #2/0 ground cable connected to the required number of ground rods as specified in Paragraph XIII.C, installed beneath the computer floor.

C. Grounding Network (Grounding Electrode System)

1. In general, a ground network shall be installed around building and other electrical installations. The ground network shall consist of a main cable loop, aboveground connection points, and inspection points on all ground rods. Cable for main loop shall be #2/0 AWG and for branch ground runs shall be #4 AWG stranded bare copper.
2. Insofar as possible copper ground loop conductors shall be laid directly in the ground slack, without breaks or joints, and shall have 12" minimum cover. When unavoidable, underground joints shall be brazed, suitably covered and protected.
3. A ground rod shall be attached to the main cable loop at intervals as required to obtain resistance to earth not exceeding 5 ohms, except that the interval between ground rods shall not exceed 75 feet. Ground resistance shall be measured with a portable hand-cranked 40 ohm "megger" ground testing instrument. When the ground resistance exceeds 5 ohms, additional ground rods or ground mats shall be installed to meet this specification. In lieu of additional rods, extensions to the rods may be added to drive the ground rods deeper into the earth.

XIII. GROUNDING (Continued)

C. Grounding Network (Continued)

4. A protective sleeve of heavy wall PVC-schedule 40 pipe shall be used wherever grounding cable emerges to aboveground connections.
5. Ground rods shall be 3/4" diameter, length 10 feet or more as required by water table.
6. For the purpose of equipment grounding and electrical system protective grounding the grounding conductor shall be continuous from the equipment to the ground network of corresponding supply substation (by others).

D. Material

1. Ground wires shall be as specified under Section V of this specification, sized in accordance with the NEC. Main loop cable size shall be as in Section XIII.B.
2. All motors, starters, disconnect switches, and transformers covered under this specification shall have ground lugs sized to accept same size wire as its feeder.
3. Grounding connectors, for aboveground work, shall be solderless, pressure type (bolt on) as manufactured by Burndy, or approved equal.

XIV. TELEPHONE CONDUIT SYSTEM

A. General

1. The Seller shall furnish all labor, materials and equipment required to completely install an empty telephone conduit system as shown on drawings.
2. Telephone wiring and equipment installation will be by the telephone company.
3. The quality of all material and workmanship involved in the telephone conduit system shall conform to the requirements for the corresponding equipment and accessories as specified for the Lighting and Power Systems.

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XIV. TELEPHONE CONDUIT SYSTEM (Continued)

B. Telephone Outlet Box Plates

Telephone outlet boxes in masonry wall shall consist of 4" square outlet box, see Paragraph IV.E, under plaster reducer, stainless steel plate, with 7/16" cord hole in the center for single gang.

C. Drag Wires

The Seller shall install a 100 lb. test pull cord in every telephone conduit, including the feeder conduits for the use of the telephone company in pulling their wires.

XV. INSTRUMENT WIRING

A. In general, power for instruments shall be provided at 120 volts from the emergency lighting panels, or from the normal lighting panels when an emergency supply is not available. No lighting fixtures, convenience outlets or other type of utility outlets shall be connected to the instrument circuits. Where instruments are of a critical nature, such that loss of power would cause a shutdown or process upset, power shall be supplied from an uninterruptible power supply circuit.

B. Switches for field assembled instrument panels shall be as follows:

1. An instrument disconnect switch shall be provided in each branch circuit supplying a maximum of 6 non-potentiometer type instruments or recorders. Each potentiometer type instrument, electronic controller or analyzer shall have an individual disconnect switch.
2. Switches for temperature recorders and indicators shall be located on the back of the panelboards.
3. When instruments are not fused, all instrument switches shall be of the thermal overload type, 2-pole, connected to interrupt line and neutral wires.

XV. INSTRUMENT WIRING (Continued)

C. Wire and Cable

1. All wire pairs shall be twisted. The lay of the twist shall be approximately 30 times the outside diameter of the individually insulated conductor (1½" to 2½").
2. The minimum conductor size shall be #16 AWG for one pair of cables and #20 AWG for multipair cables, or as recommended by the equipment manufacturer.
3. Color Coding

- a. The thermocouple wire and cable color coding shall be in accordance with ANSI C 96.1-1964.
- b. The instrument signal wiring shall be:

Twisted pairs: White - positive  
Black - negative

Cable outer jacket: Black

- c. Intrinsically safe circuits only and no others, shall use:

Twisted pairs: Bright Blue - positive  
Light blue or white with blue stripes, negative

Cable outer jacket: Bright Blue.

4. Cable Type and Specification

- a. Thermocouple extension wire shall be solid alloy wire pair of required calibration (per ANSI C96.1) to match thermocouple well and instrument to which it is connected. #16 AWG for single pair cables. Thermocouple pairs are shielded with aluminum backed mylar tape, helically applied with 25% overlap. Aluminum shall be in continuous contact with a tinned, solid copper drain wire. Conductor insulation shall be 105°C PVC 15 mils thick. Jacket for single pair cables shall be 20 mils of 80°C PVC.

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XV. INSTRUMENT WIRING (Continued)

C. Wire and Cable (Continued)

4. Cable Type and Specification (Continued)

- b. Electronic signal cables shall be #16 AWG stranded copper twisted pair cable with 15 mils 150°C PVC insulation, shielded with aluminum backed mylar tape (as in a above) and with an overall jacket of 80°C PVC 20 mils thick.
- c. Cables for alarms shall be same as b except not shielded.

D. Grounding Practices for Equipment and Circuits

1. Instrument circuits shall be grounded to reduce the effect of electrical interference upon the signal being transmitted. Instrument manufacturer's recommendations shall be carefully followed when locating this ground.
2. In general, the following rules shall apply:
  - a. The circuit of a DC loop shall be grounded at only one point.
  - b. Normally, the ground shall be located on the negative side of the DC loop power supply.
  - c. The AC power supply shall be grounded.
  - d. In loops involving a computer, the actual physical location of the ground shall be as recommended by the multiplexer supplier.
  - e. When the connecting wiring for an instrument is of the shielded type, the shield shall be grounded at the control house end.

3. Grounding of Cable Shields

- a. All shields of shielded pairs, with the exception of thermocouples, shall be grounded at one end only, the termination point to be in the control room. Continuity of the shield shall be maintained throughout the cable run and isolated from ground at instruments, junction boxes, etc. This shall also apply to multipair cable with overall shielding.



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XV. INSTRUMENT WIRING (Continued)D. Grounding Practices for Equipment and Circuits (Continued)3. Grounding of Cable Shields (Continued)

- b. Where shielded thermocouple wire is used, the shield shall be grounded near the point of the circuit ground. For grounded junction thermocouples, this means at the thermocouple head. For underground junction thermocouples, this means at the control room.
- c. Cables of thermocouple pairs having an overall shield shall have the overall shield grounded at the panelboard for grounded and ungrounded junction thermocouples.

## 4. Thermocouple Circuit Grounding

- a. The selection of grounded junction or nongrounded junction thermocouples is usually determined by the requirements of the device to which the thermocouple is connected, i.e., grounded junction thermocouples cannot be used with transmitters, mV alarms, or recorders that do not have isolated inputs.
- b. Where nongrounded thermocouples are used, circuits shall be grounded at the receiving instrument.

E. Routing of Instrument Signal Wiring

1. Signal wiring shall be adequately separated from power wiring and electrical equipment to minimize noise. The following are minimum required separation distances between the signal wiring and the power conductors for parallel runs. Crossovers shall be made at right angles.

| POWER WIRING<br>CAPACITY | MINIMUM SEPARATION<br>SIGNAL WIRING OR        |  | THERMOCOUPLE<br>WIRING IN STEEL TRAY |
|--------------------------|-----------------------------------------------|--|--------------------------------------|
|                          | THERMOCOUPLE WIRING IN<br>RIGID STEEL CONDUIT |  |                                      |
| 125 V 10 A               | 12"                                           |  | 24"                                  |
| 250 V 50 A               | 18"                                           |  | 30"                                  |
| 440 V 220 A              | 24"                                           |  | 36"                                  |
| 5000 V 800 A             | 48"                                           |  | 60"                                  |

XV. INSTRUMENT WIRING (Continued)

E. Routing of Instrument Signal Wiring (Continued)

2. Intrinsically safe wiring shall be separated from all other control, signal, and/or power wiring, as set forth in Para. K.
3. Where a strong magnetic field is known to exist, signal wiring shall be routed with respect to this field to minimize interference (parallel to the magnetic flux lines).
4. Signal wiring shall not normally be routed through areas where ambient temperatures exceed 176 F (80 C).
5. No joints or splices shall be permitted in signal conductors except at terminal junctions in junction boxes.

F. Instrument Wiring - General

- i. For intrinsically safe wiring, unfused paralleling of transmitters on one DC power supply shall be avoided; a separate pair of wires shall be used. This is also advisable for non-intrinsically safe wiring.
2. Controllers, recorders, indicators, computer inputs, alarm relays, etc. shall operate on the voltage signal measured across vendor specified calibrated resistors. Resistors shall remain in the loop when any of these devices are disconnected for servicing. Milliammeters in a loop shall have a shunt.
3. Manufacturer's recommendation shall be followed when wiring special equipment such as turbine meters, magnetic flow transmitters, analyzers, etc.
4. Each pair of wires shall be adequately identified at any junction where other wires are present. All terminals shall be clearly identified. Terminals on the back of the main control panel shall be labeled with identification containing the instrument loop number.

G. Wiring of Controls

1. The instrument manufacturer's published limits on the resistive load which can be put on each signal generator shall not be exceeded. Allowance shall be made for low power supply voltage level.
2. Voltage signal receivers shall have an input impedance of more than 100 times the impedance in the rest of the circuit. This includes the wiring and the output impedance of the signal source.

XV. INSTRUMENT WIRING (Continued)

H. Wiring of Controls and Computers

1. In transmission circuits containing both control and computer signals, the wiring practices shall be governed by the needs of the computer, as long as these practices do not conflict with intrinsic safety requirements.
2. The interface between computer and controls using a milliamper signal is a vendor specified precision resistor. The location of this resistor shall be the grounded side of the transmission loop or as recommended by the equipment manufacturer.
3. No loads other than computer loads shall be connected to the secondary of the computer isolation transformer.
4. All connections from the computer to the process controller shall be through circuits so designed that an open or short circuit on any computer input will minimize upset of the conventional control loop.

J. Wiring of Thermocouples

1. The impedance of receiving instruments shall be at least 100 times the sum of the impedance of the sensor and the connecting wire.
2. A thermocouple may be wired to two receiving instruments in parallel, such as a signal multiplexer and a temperature alarm, if both devices have an input impedance of one megohm or greater.
3. Grounding of thermocouples shall be as specified in Para. D.4.
4. Thermocouple terminal box connections shall be with tubular screw-type terminals and connections to make drain wire continuous from thermocouple to instrument, with isolation from ground in the terminal box.

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XV. INSTRUMENT WIRING (Continued)

K. Wiring of Intrinsically Safe Equipment

1. Intrinsically safe equipment shall not be connected with systems.
  - a. Operating at different voltage levels
  - b. Having different signal ground reference points
  - c. Approved for different hazardous location groups, unless approved electronic safety barrier devices are used.
2. Intrinsically safe equipment of different manufacturers shall not be mixed without investigating of compatibility of certification.
3. The installation of safety electronic barriers shall comply with the following:
  - a. Segregation of intrinsically safe leads and terminals
  - b. Protection of the barrier from dust, moisture, and exposure to an ambient temperature exceeding 120 F and severe vibrations. Exposure to direct sunlight or sources of radiant heat shall be prevented.
  - c. Proper mounting and grounding of the barrier.
  - d. Cable shielding, when used, shall not bridge over the barrier.
4. To ensure an intrinsically safe system when using barriers:
  - a. There shall be no intrusion of outside power sources exceeding the barrier rating on the nonhazardous location side of the barrier.
  - b. There shall be no intrusion of outside power sources, including other intrinsically safe circuits, on the hazardous location side of the barrier.
  - c. There shall be no energy storage system (capacitive or inductive), in excess of the maximum permitted by the barrier design, on the hazardous location side of the barrier.

XV. INSTRUMENT WIRING (Continued)

K. Wiring of Intrinsically Safe Equipment (Continued)

5. Generally, the safety barrier resistance represents a high percentage of the load capability of a transmitter or a controller. Therefore, a check shall be made to ensure that the resistance required for cabling plus other series connected devices, does not exceed the maximum load impedance of the instrument.

XVI. ELECTRICAL FIELD TESTS

Refer to ENG STD 70A2 for complete testing requirements

XVII. INSPECTION

For shop information requirements, refer to the purchase order.

XVIII. FOREIGN PROJECTS

The specifications, codes, equipment ratings, material sizes, etc., referred to herein, are standard for the United States. In the case of projects located in foreign countries, it is understood the specifications, codes, equipment ratings, material sizes, etc., which apply in said country and are equivalent to those specified herein, shall complement those referred to in this country.

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REASON FOR REVISION:

Standard Computerized

## I. SCOPE

This standard specifies Foster Wheeler's general responsibilities and procedures for the testing of electrical installations at a process plant jobsite, prior to completely energizing an integrated electrical system. Electrical testing at the jobsite will consist of 2 associated phases; the investigation (test analysis) and the inspection (perceptual analysis). Tests which are necessary to retain the manufacturer's guarantee will be conducted in accordance with instructions from the electrical equipment (material) manufacturer. In the absence of specific manufacturer's instructions, electrical field tests will be limited to those hereinafter specified for the various materials and equipment. The inspection will consist of the combined physical examinations for unusual conditions of overheating, vibration, etc., mechanical and material defects prior to, during and after the energizing of an electrical installation.

## II. GENERAL INSTRUMENTS AND PROCEDURES

In addition to normal testing equipment (voltmeters, ammeters, etc.) the following instruments and procedures are required for the tests hereinafter specified:

- A. Short time insulation resistance measurements, hereinafter described shall be made with megohmmeter testers, (Megger). Resistance measurements shall be recorded after 60 seconds of applied voltage preferably during dry temperate weather. Test voltages shall conform to the following requirements:
  1. Equipment rated 1000 V or less shall be tested using a 500-volt "Megger."
  2. Equipment rated 2300 V and above shall be tested using a 2500-volt "Megger" with range up to 200 megohms.
  3. Equipment rated above 5000 V preferably should be tested at a voltage equal to 50% of the equipment rating but in no case should it be tested at less than 5000 V.
- B. Grounding connection resistance will be measured with a portable low resistance "Megger" ground testing instrument: Associated Research Inc. Vibraground Tester, Biddle Co. Earth Resistance Tester, or equal.
- C. Temperature measurements shall be taken by a mercury thermometer or by a thermal-sensitive resistor circuit.

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D. When available, service personnel under contract to Foster Wheeler from local agencies shall perform the following tests:

1. Dielectric strength testing of insulating liquids.
2. Current leakage tests on cable for services above 5000 V.

Where local agencies are not available, the necessary tests shall be performed by Foster Wheeler personnel in accordance with this standard.

E. Prior to using testing and instrument devices, personnel shall be completely familiar with applicable manufacturer's instructions.

F. Setting and calibrating of protective relays shall be performed by service personnel under contract to Foster Wheeler from a local agency capable of performing this function.

### III. GENERATORS AND MOTORS

#### A. Insulation Resistance

1. All alternating current synchronous and inductive type machinery rated 10,000 HP and below shall be subjected to an insulation test prior to connecting the machine terminals to the motor feeder. A one minute "Megger" reading not less than the following minimum values at a machine temperature of 40 C shall be observed before energizing:

MINIMUM MEGOHM VALUES FOR MACHINES  
10,000 HORSEPOWER & BELOW - CLASS A & B INSULATION

| Volts:   | 110  | 440 | 550 | 2300 | 3000 | 4000 |
|----------|------|-----|-----|------|------|------|
| Megohms: | 1.11 | 1.5 | 1.6 | 3.3  | 4.0  | 5.0  |

For all other voltage ratings, the minimum insulation resistance value shall be determined from the following formula:

$$R_m = kV + 1$$

Where  $R_m$  = recommended minimum insulation resistance in megohms at 40 C of the entire machine winding

$kV$  = rated machine potential in kilovolts

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If the winding is not at a temperature of 40 C, the observed one minute resistance must be reduced by multiplying the observed value by the temperature coefficient of insulation resistance (Kt40C) found in the following table:

| Winding<br>Temp. C | 0     | 5    | 10   | 15   | 20   | 25   | 30   | 35   | 40  |
|--------------------|-------|------|------|------|------|------|------|------|-----|
| Kt40C              | 0.065 | 0.09 | 0.13 | 0.19 | 0.25 | 0.36 | 0.50 | 0.70 | 1.0 |

2. The value of insulation resistance for low-voltage motors may be determined by a single measurement.
3. The representative value of insulation resistance for medium-voltage motors shall be determined by the dielectric absorption ratio calculated from 2 megohmmeter readings taken during the same test in accordance with the following requirements:
  - a. For motors rated 750 kW (1000 HP) or less, the representative value of insulation resistance shall be the ratio of the 60 second reading to the 30 second reading.
  - b. For motors rated over 750 kW (1000 HP) the representative value of insulation resistance shall be the ratio of the 10 minute reading to the 1 minute reading (Polarization Index).

The minimum acceptable values are 1.25 for the 60 to 30 second ratio and 2.0 for the 10 to 1 minute ratio, provided the 30 second and 1 minute readings of the respective ratios equals or exceeds the requirement of Paragraph III.A.1.

4. Three-phase machines with only 3 leads brought out shall have the insulation resistance measured with all 3 leads connected together.

Three-phase machines with all 6 leads brought out shall have the insulation resistance of each phase measured separately with the other 2 phases grounded. The observed resistance of each phase shall be divided by 2 to obtain a value, which after correction for temperature, can be compared with the recommended minimum value of insulation resistance.

5. If the corrected insulation resistance is below the minimum value, the machine must be dried out, as specified below.

It should be noted that for machines in good condition, insulation resistance readings of 10 to 100 times the recommended minimum values are not uncommon.



## B. Drying Out Process

- Machine windings shall be dried out by supplying heat from electric strip heaters, from heat lamps or by passing current through machine windings until a sufficiently high, rising insulation resistance is obtained. When current is applied through the windings, it shall not exceed the nameplate rating. The temperature maintained during the drying out process should not exceed the following:

## a. Class A Insulation

|                                                                    |      |
|--------------------------------------------------------------------|------|
| By a thermometer                                                   | 80 C |
| By resistance bridge or a thermal-sensitive resistor circuit (RTD) | 90 C |

## b. Class B Insulation

|                                                                      |       |
|----------------------------------------------------------------------|-------|
| By a thermometer                                                     | 90 C  |
| By a resistance bridge or a thermal-sensitive resistor circuit (RTD) | 110 C |

- Wound rotor induction machines rated 2300 V and above will be dried out by mechanically locking the rotor then applying a 440 V, 3-phase, AC supply to the stator. Regulation shall be obtained from a resistance inserted in the rotor circuit.
- The applied voltage to produce drying current for other synchronous and induction machines rated 2300 V and above should not exceed 10% of the nameplate voltage and should not cause more than 60% of nameplate full load current to pass through the windings. The voltage may be increased to 15% of nameplate, after a low insulation resistance increases to 1/2 of the minimum value.
- The insulation resistance shall be periodically recorded during the drying out process. In large high voltage machines the initial cold coil resistance value will be high (20 megohms 20 C).\* As the drying process continues and water vapor is boiled out from the internals of the machines, the insulation resistance will rapidly fall to a minimum (6 megohms 90 C).\* As the drying process nears completion the insulation resistance will reverse its downward trend and settle at a steady higher value (12 megohms 90 C).\* As the coils cool, after the drying process has been completed, the insulation resistance will rapidly rise (150 megohms 20 C).\*

\* values for comparative purposes only.

5. A period of 24 hours will usually be found sufficient for drying machines rated 600 to 2000 horsepower. Less time will be required for drying smaller machines. Windings which have been exposed to moisture will take longer to dry out than machines which have been properly stored.

C. Inspection

1. Prior to energizing the machine, all foreign objects between the rotor and the stator field coils should be removed. Brushes must move freely in their holders making a firm and even contact with collector rings. Voltage and frequency on the nameplate of the machine must correspond with the terminal line voltage and frequency. Belts for directly connected exciters (auxiliaries) shall be in proper running condition. All bearings must be properly filled with oil or grease. Machine shafts (rotors) shall be checked for alignment, shaft end play and rotation before being coupled to other machinery.
2. Drain plugs furnished on totally enclosed motors shall be removed and replaced with approved electrical drain fittings.
3. During the machine test-run, inspect for smoke, unusual noises, vibration and overheating. Operating conditions must be investigated and corrective action taken when the total temperature (ambient plus rise) exceeds the following values:
  - a. For Class A insulation - 90 C
  - b. For Class B insulation - 110 C
  - c. For Class H insulation - 150 C

IV. TRANSFORMERS

- A. Transformer windings shall have their insulation resistance tested:
  - a. Primary to ground
  - b. Secondary to ground
  - c. Primary to secondary
- B. Sealed tank type transformers shipped assembled and filled with oil shall have an oil sample tested. For transformers shipped without oil, samples of oil shall be tested before filling the transformer. Transformer insulation shall be tested by a megohmmeter prior to filling and if required, insulation shall be dried using an approved method.



C. Test samples of liquids insulating immersed transformer windings rated for 150 kVA service and above must undergo a dielectric strength test. The test sample must withstand the following minimum voltage stress without an insulation breakdown when tested with a standard testing device:

ASTM D 877 Method

|              |       |
|--------------|-------|
| Oil          | 30 kV |
| Silicon      | 30 kV |
| RTE mp Fluid | 30 kV |

ASTM D 1816 Method

|       |
|-------|
| 22 kV |
| 22 kV |
| 26 kV |

If the voltage causing a breakdown is less than the minimum value, the liquid must be (dried) passed through a suitable filter press until the minimum voltage stress can be sustained.

D. ASTM D 977 method is generally suitable for testing service-aged liquid dielectrics. Dielectric strength is tested with a standard testing device consisting of a test cup, instruments, control and high voltage power supply. The test cup internals shall support 2 butted electrodes, separated by a 0.1" gap. Each electrode shall have a polished 1" diameter circular disc parallel to the other electrode at the gap interface. Sixteen ounces of liquid will be required for the test. After the electrode spacing has been checked with a standard round gage, having a diameter of 0.100", the electrodes will be locked in position. After a suitable rinsing procedure, the test cup will be immediately filled with the liquid sample to be tested. The liquid should be at a temperature of 40 C. During the test the uniform rate of voltage increase should be about 2,000 volts per second. One breakdown should be made on each of 5 fillings of the test cup. Any individual test which deviates from the average by more than 25% will be test recorded and replaced by an additional test. An average of the first 5 tests within the allowable deviation will be taken as the dielectric strength of the liquid.

E. ASTM D 1816 method is similar to the method described above with the exception that it prescribes the use of spherically capped electrodes, separated by a 0.04" gap. It is primarily suitable for testing new oils.

F. Completely assembled, factory-sealed-tank transformers shipped with an insulating liquid successfully passing the preliminary dielectric strength test without filtering, may be put into the service after inspection if the cold coil insulation resistance between windings and between windings and ground tests above 6 megohms. In the event that the insulation resistance value falls below 6 megohms the transformer coils must be dried.

G. Coils for factory sealed-tank-transformers shipped with an insulating liquid failing the dielectric strength test (before filtering) and coils for tank type transformers shipped separately without insulating liquid must undergo an out-of-liquid short-time "Megger" test for insulation resistance to ground and to other windings at a temperature between 60-70 C. The out-of-liquid insulation resistance must measure above one megohm per thousand volts of rated line voltage. Coils with insulation resistance values failing this requirement must be dried.

H. In the event that drying is necessary, the transformer coils will be heated to a temperature of 60-70 C for a period of 24 hours by circulating current through the windings. This may be accomplished by short circuiting either winding (HV or LV) and impressing 1/2% to 1% of nameplate voltage (at normal frequency) across the other. Current should be limited to 1/5 of the rated normal full load current by a reostat in series with the exciting winding. As the maximum coil temperature is approached, the circulating current should be gradually reduced until a steady state temperature condition is reached within the 60-70 C range.

I. The transformer tank and all fittings shall be inspected and tested for adequate sealing to prevent leakage of insulating liquid, entrance of moisture and loss of inert gas protection before the transformer is energized. During a leakage test the transformer tank shall not be subjected to a pressure greater than the amount specified on the nameplate. If there is no nameplate pressure specified a test pressure of 5 psi will be used. The liquid dielectric will be slowly pumped into the sealed transformer until the pressure reads 5 psi. Joints, connections and gaskets will be checked with chalk dust to detect leaks. Any appreciable leakage will cause a pressure drop within a few hours.

J. The following precautions should be taken before placing the transformer in service.

1. Check liquid level, bushings and other externally connected or gasketed devices, such as oil temperature and level gauges.
2. Check no-load tap changer to be sure it is in operating condition and at proper tap setting.
3. If provided, check operation of temperature alarm and level alarm.
4. If provided, check operation of cooling fan relay and circuit, and fault pressure relay.
5. Check grounding of transformer.



## V. SWITCHGEAR AND MOTOR CONTROL EQUIPMENT

A. Before connecting cable leads to switchgear and motor control equipment terminals, internal bus bars and connections shall undergo a short time "Megger" test. "Megger" tests should be made preferably during dry, temperate weather.

The switchgear and motor control equipment must be dried before going into service if the insulation resistance to ground falls below the following minimum values.

Tests will consist of megohmmeter measurements between each phase and grounded between phases.

| 600 volts<br>and below | 601 volts<br>to<br>15,000 volts | above<br>15,000 volts |
|------------------------|---------------------------------|-----------------------|
|------------------------|---------------------------------|-----------------------|

|                            |                              |                               |
|----------------------------|------------------------------|-------------------------------|
| 3 megohms<br>(breakers in) | 50 megohms<br>(breakers out) | 200 megohms<br>(breakers out) |
|----------------------------|------------------------------|-------------------------------|

Precautions required to obtain reliable insulation measurements will include disconnecting lightning arrestors, capacitors, potential transformers and secondary ground connections on current transformers.

On completion of the wire and cable terminations, a final insulation measurement using a megohmmeter shall be obtained for the entire system. Preferably, the measurement should be obtained just prior to the equipment being energized or, where applicable, prior to being turned over to the Client as being mechanically complete.

B. Oil immersed contactors or circuit breakers must undergo the dielectric strength test. (See Section IV)

C. Prior to energizing the switchgear bus, the following items shall be inspected and tested for proper operation:

1. Control, protective and metering circuits.
2. Contact alignment on all contactors and circuit breakers.
3. Setting and calibrating all overcurrent relays as hereinafter described where this is a part of Foster Wheeler responsibility.



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4. Tanks for oil circuit breakers must be filled before tests begin. Place the circuit breaker in its "Test Position", (use a plug jumper where necessary) and make the following tests:
  - a. Close and trip the breaker with its control switch.
  - b. Manually trip the breaker.
  - c. Close and trip the breaker from any remote control positions.
5. Where the switchgear is arranged for a secondary selective system with automatic transfer scheme, the transfer circuits shall be tested by simulated fault and undervoltage conditions.
6. Operate other auxiliary devices.
7. Bolted bus joints, terminals and other connections for each separate equipment installation shall be checked for tightness.

#### VI. RELAY AND PROTECTIVE DEVICES

- A. Relay settings and coordination curves shall be furnished to field personnel. The following instructions apply where Foster Wheeler is responsible for setting and calibrating relays:
  1. All relays will be set in accordance with the relay tabulations furnished.
  2. Relays with time characteristics shall be tested at 2 points on the time coordination curves to verify conformance with the manufacturer's data.
  3. Protective relay settings and adjustments shall be made in accordance with manufacturer's applicable instruction booklets.
  4. Circuit protective devices that have adjustable settings, such as molded case circuit breakers, shall be set in accordance with the system coordination requirements.
  5. Heater elements of thermal overload relays used for motor protection shall be individually checked to ensure the proper element has been selected, installed and set for the motor nameplate full-load current. Where fuses are used, their ampere rating and NEMA class shall be checked for conformance with design requirements.
  6. Other devices having variable timing characteristics, such as time-delay relays used in the automatic restart of motor drivers, shall be set and tested in accordance with the intended control function.

## VII. BATTERY AND BATTERY CHARGER

A. The following precautions should be taken before placing the battery in service: (CAUTION: Type of battery should be checked in advance: Lead-Acid or NI-CAD).

1. Check the battery cells for proper level of electrolyte, for specific gravity of electrolyte by using a hydrometer, and for cracked jars. (Do not use hydrometer if it is a NI-CAD Battery).
2. Check the cell connections and wiring for continuity and polarity.
3. Check all protective devices for proper rating.
4. Check the battery output voltage.

B. Before energizing the battery charger, the battery should be connected across the output terminal in such a manner that the positive battery terminal is connected to the positive terminal of the charger. If the polarity of the battery terminals has been lost in a cable run, a polarity check can be made by opening the A.C. supply switch to the charger and connecting the battery leads to the output terminals of the charger. Observe the deflection of the voltmeter on the battery charger. If it reads on scale, the battery is connected correctly to the output terminals. If the voltmeter reads off scale, reverse the battery leads at the charger output terminals.

## VIII. EMERGENCY POWER

Emergency generation facilities shall be checked for automatic starting, generation and power transfer during a simulated loss of voltage.

## IX. WIRE AND CABLE

A. Before being connected to equipment, installed wire and cable having all splices, potheads, stress cones, and metallic insulation shielding completed, shall be checked in accordance with the following requirements:

1. Test for continuity of all conductors and, where applicable, continuity of metallic insulation shielding to ground.
2. Test of insulation resistance of low-voltage and unshielded medium-voltage wire and cable using a megohmmeter according to the table in Paragraph IX.D. Measurements shall be made between phases and between each phase conductor and ground.

3. Test of insulation resistance of metal-clad, metal-sheathed and shielded medium-voltage wire and cable using high-voltage direct current in accordance with the requirements of Paragraph IX.B. Tests on metal-clad and metal-sheathed cable having no metallic insulation shielding shall be made between each phase and metallic covering and between phases. Tests on wire and cable having metallic insulation shielding shall be made between each phase conductor and the metallic insulation shielding for that conductor.

B. In addition, cables rated above 5000V, shall be tested for current leakage using a suitable DC high potential testing set. The initially applied direct current voltage shall be not greater than 3 times the rated AC voltage of the cables; preferably, it shall be 2.4 times the rated voltage.

Test results shall be recorded on the "DC High Potential Test Report" (see Appendix). The cable shall be gradually stressed to minimize harmful surge currents. High voltage ozone resistance, rubber type cable must be capable of withstanding the following voltage stresses:

DC MAXIMUM TEST VOLTAGE \*\*

| RATED AC RMS VOLTAGE OF CABLE | CONDUCTOR SIZE, AWG | 100% INSULATION LEVEL (GROUNDED NEUTRAL) | 133% INSULATION LEVEL (UNGROUNDED NEUTRAL) |
|-------------------------------|---------------------|------------------------------------------|--------------------------------------------|
| * 5000 V                      | 8 & over            | 25 kV                                    | 25 kV                                      |
| 8000 V                        | 6 & over            | 35 kV                                    | 35 kV                                      |
| 15000 V                       | 2 & over            | 35 kV                                    | 65 kV                                      |
| 25000 V                       | 1 & over            | 80 kV                                    | 100 kV                                     |
| 28000 V                       | 1 & over            | 85 kV                                    | --                                         |
| 35000 V                       | 1/0 & over          | 100 kV                                   | --                                         |

\*Only when required for the specific project.

\*\*These values are 80% of factory test values.

The above shall apply to the following insulations: Rubber type (EPR), Thermoplastic (XLPE); all with insulation shield.

The following procedures apply for this testing:

1. Leakage currents should be observed during voltage build-up. Faulty installations will cause leakage values to steadily rise after 30 seconds.



After application of the initial voltage, the voltage shall be raised uniformly to the test voltage in not less than 10 seconds nor more than 60 seconds. (The test apparatus may, however, require a slightly longer time to raise the voltage in some cases). Potheads and terminators isolated by switches, etc. from other equipment may be stressed at the test voltage along with the cable.

2. Immediately upon reaching the test voltage, the time and current reading shall be noted and recorded on the "DC High Potential Test Report" (see Appendix). The test shall be for a 15 minute duration during which current readings shall be made for the time intervals shown on the Test Report.
3. After the test voltage has been reached, the current readings should show a decreasing amount of current with time until a fairly steady current flows toward the end of the test time. If the current begins to increase during this time, the cable will be considered inadequate and must be corrected or replaced.
4. If the test must be interrupted for any reason before the required test interval is complete, the cable shall be grounded for an interval at least equal to that time voltage was applied to the cable, before a new test can be started.
5. After completing the test, the cable shall be grounded for a time interval at least equal to the amount of time voltage was applied before the cable can be considered safe.

C. Short runs of cable (below 200 feet) rated for service above 5000 volts will be considered as satisfactorily installed if the meggered insulation resistance reads above the following minimum values:

| CABLE SIZE      | GROUNDED NEUTRAL | UNGROUNDED NEUTRAL |
|-----------------|------------------|--------------------|
| #6 - #4 AWG     | 5 megohms        | 6 megohms          |
| #2 - #1/0 AWG   | 4 megohms        | 5 megohms          |
| #4/0 - #250 MCM | 3 megohms        | 3 megohms          |
| #500 - 750 MCM  | 2 megohms        | 3 megohms          |
| #1000 MCM       | 1.5 megohms      | 2 megohms          |

D. Cable for service, 1,000 volts and below, shall be tested with a 500-volt, megohm instrument. Insulation resistance for satisfactory power installations shall not be lower than the following minimum values.

MINIMUM PERMISSIBLE INSULATION RESISTANCE  
IN MEGOHMS FOR 1000 FEET RUNS AND BELOW

| CABLE<br>SIZE | VOLTAGE RATING |           |           |
|---------------|----------------|-----------|-----------|
|               | 600 V MAX.*    | 3 KV MAX. | 5 KV MAX. |
| #12 AWG       | 1.5            | 5.0       | --        |
| #10 AWG       | 1.5            | 4.0       | --        |
| #8 AWG        | 1.5            | 4.0       | 5.0       |
| #6 AWG        | 1.0            | 3.0       | 4.0       |
| #4 AWG        | 0.4            | 3.0       | 3.0       |
| #2 AWG        | 0.4            | 2.0       | 3.0       |
| #1 AWG        | 0.4            | 2.0       | 2.0       |
| #1/0 AWG      | 0.4            | 2.0       | 2.0       |
| #4/0 AWG      | 0.3            | 1.5       | 2.0       |
| #250 MCM      | 0.3            | 1.5       | 2.0       |
| #500 MCM      | 0.2            | 1.0       | 1.5       |
| #1000 MCM     | 0.2            | 1.0       | 1.0       |

Example: 600 Volt maximum, 350 MCM, length below 1000 feet - 0.3 megohm minimum insulation resistance.

E. For minimum permissible insulation resistance for cable runs more than 1000 feet, multiply the table values by the ratio 1000 feet divided by actual feet of run.

\* Minimum permissible values of insulation resistance for lighting branch circuits (600 V) shall be 1/2 of the indicated values when fixtures (before lamping) and receptacles are included in the test.

X. GROUNDING

The ground system shall be checked using a suitable "Megger" to insure that ground resistance values comply with requirements of the electrical specification (ENG STD 70A1).

FOSTER



WHEELER

PROCESS PLANTS DIVISION

ELECTRICAL TESTING  
STANDARD  
DC HIGH POTENTIAL REPORT

ENG STD 70A2  
 PAGE Appendix No. 1  
 REVISION 0  
 DATE May 1, 1978

Customer: \_\_\_\_\_

Location: \_\_\_\_\_

Plant: \_\_\_\_\_

Foster Wheeler Contract: \_\_\_\_\_

CABLE

Cable No: \_\_\_\_\_

From: \_\_\_\_\_

To: \_\_\_\_\_

Length: \_\_\_\_\_ Ft.

Cable Description:

Manufacturer: \_\_\_\_\_

Insulation Type: \_\_\_\_\_

Shielded? \_\_\_\_\_

Conductor Size: \_\_\_\_\_

3 - 1/c, or

1 - 3/C: \_\_\_\_\_

Rated Voltage: \_\_\_\_\_ kV

Operating Voltage: \_\_\_\_\_ kV

Rated Temp.: \_\_\_\_\_ °C

TEST

Initial DC Voltage: \_\_\_\_\_ kV

Test DC Voltage: \_\_\_\_\_ kV

Temperature at Test: \_\_\_\_\_ °C

Comments: \_\_\_\_\_

DATE: \_\_\_\_\_

Tested By: \_\_\_\_\_ Witnessed By: \_\_\_\_\_

Company: \_\_\_\_\_ Company: \_\_\_\_\_

APPENDIX D.9  
PROTECTIVE COVERING



JOB SPECIFICATION NO. 60863-82A1

INSULATION

The subject specification is issued herewith per index of pages noted below. If this is a later revision than now in your possession, please destroy superseded pages and insert the revised pages.

Initial issue X  
Entire specification reissued \_\_\_\_\_  
Revised pages only attached \_\_\_\_\_

REVISION INDEX

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\* Pages revised for this issue are noted by asterisk.

Issue No. 1 Date 4/25/79

Basis: Dow Chemical Co.  
Specification

## INSULATION

### 1.0 GENERAL

- 1.1 Furnish and install insulation and finishes as shown on the pipeline schedule and as specified herein.
- 1.2 The preparatory work of others shall be examined and objections thereto reported to the owner's representative before proceeding with the work. The contractor shall ascertain if any surfaces are to be painted before insulating, and shall not proceed with the insulating work until painting is completed.
- 1.3 Lines are to be tested and made tight before insulation is applied. Under no circumstances shall lines or fittings be covered while wet or in frosted condition. No threaded fittings or connections shall be covered until inspected and approved by the Dow representative as being in accordance with the drawings and specifications and made up tight with the proper thread sealant.
- 1.4 Unpainted surfaces shall be brushed clean before applying insulation, using wire brush where necessary, and all loose material, dirt, and grease shall be removed from surface before covering is applied.
- 1.5 Insulation shall fit the surface of the pipe and equipment snugly and shall be fabricated or molded so as to leave not more than 1/8" void between the surface to be insulated and the insulation itself.
- 1.6 All metal protrusions through insulation shall be flashed to prevent entrance of water.
- 1.7 Joints shall be close fitting and water-tight.
- 1.8 All materials and accessories shall be installed per manufacturer's recommendations.
- 1.9 All insulation shall be kept dry and protected from the weather at all times. Any insulation found to be wet or damaged shall be replaced by the contractor at no cost to Dow.
- 1.10 Do not cover lines that are in a wet or frosted condition.
- 1.11 Wherever possible, pre-molded insulation blocks shall be used to cover valves, pipe fittings, etc.
- 1.12 Insulation shall not interfere with any moving parts of valves, etc.
- 1.13 Thermowells and resistance devices shall not be completely covered.
- 1.14 On single layer insulation tie-ins to existing insulations, the new weather coating or outer jacket shall overlap the existing covering by at least 6 inches.

INSULATION

## INSULATION

### 1.0 GENERAL (CONTINUED)

- 1.15 The type and thickness of insulation required to meet the temperature and service conditions which are to prevail on the various surfaces to be covered shall be according to the class table in the respective insulation specification. The materials and thickness specified in these classes indicate the minimum of insulation value acceptable, and the contractor shall furnish the materials specified with commercial dimensions in closest accord with, but not less than, the specified thickness. Substitute materials may not be used without prior written approval of the Owner's representative.
- 1.16 The materials used, methods of application, and quality of work done shall at all times be subject to the inspection and approval of the Owner's representative.
- 1.17 The Contractor shall make available scaffolding and/or rigging and assist the Owner's representative in making any tests or inspections when, in the opinion of the representative, such assistance is necessary or required.
- 1.18 Safety Rules, All insulating operations shall be conducted in conformance with the Owner's approved safety regulations.
- 1.19 Operating areas shall be kept free of accumulated waste materials or rubbish caused by this work.
- 1.20 All wires and bands used to secure insulation in place shall be applied in accordance with the quoted insulation specification. Ends of bands and tie wires shall be tucked under to minimize hazards to personnel.
- 1.21 All weather barrier materials and vapor barrier materials shall be either black or gray as specified in the specific insulation specification.

### 2.0 APPLICATION

- 2.1 Pipe insulation shall be in sectional or segmented form. Insulation for fittings and irregular surfaces shall be segmented, pre-formed, block, or insulating cement. All joints shall be tight fitting and all voids filled with broken block insulation or with insulating cement and thoroughly sealed.
- 2.2 Pipe
  - 2.2.1 Insulation shall be applied in single layer construction to the thicknesses specified.
  - 2.2.2 All joints shall be butted tightly together and securely wired or banded on 9" centers.
  - 2.2.3 Ends of wire loops shall be twisted together, bent over, and driven into the insulation so as to leave no projections.

## INSULATION

## INSULATION (CONTINUED)

### 2.0 APPLICATION (CONTINUED)

2.2.4 Insulation shall be applied by the broken joint method. For multiple layer construction, the second layer shall be applied so that both circumferential and longitudinal joints are staggered.

2.2.5 On multiple layer construction, each layer shall be wired or banded separately.

### 2.3 Fittings, Valves, and Flanges

2.3.1 Fittings on piping  $2\frac{1}{2}$ " and larger and the bodies of the flanged valves shall be insulated with block insulation to a thickness equal to that on adjacent piping.

2.3.2 Flanges shall be covered with sectional pipe or block insulation to a thickness equal to that of the insulation on the adjacent piping.

2.3.3 The block insulation on the bodies of  $2\frac{1}{2}$ " and larger fittings and valves and on all flanges shall be securely wired or banded in place. On flanges, the insulation shall be of such length as to extend not less than 2" or a distance equal to the insulation thickness, whichever is greater, over the adjacent pipe insulation on each side of the flange. All voids shall be filled with insulation material and shall be thoroughly sealed. The total thickness of the insulation shall be equal to that on the adjacent piping.

2.3.4 The insulation for fittings and the bodies of valves on pipe 2" and smaller shall consist of a built-up layer of insulating cement. Total thickness of insulation shall be equal to that on adjoining pipe. Valve and fitting insulation shall be extended over the piping insulation a distance equal to the insulation thickness.

### 2.4 Bends

2.4.1 Bends shall be covered by mitered sectional insulation or pre-formed bends. Each section shall be securely wired or banded in place. All joints shall be thoroughly sealed.

## 3.0 FINISH-WEATHERPROOF

### 3.1 Pipe

3.1.1 Pipe insulation shall be covered or finished with Hu-Al style TGH-1000-VB Weatherproof jacketing. Alpha Associates, Woodbridge, New Jersey.

3.1.2 The jacketing shall be securely lapped and stapled on 2" centers to the insulation. The lap shall be turned down to shed water. The minimum longitudinal and circumferential lap shall be 2".

3.1.3 Circumferential joints shall be securely taped to prevent entry of any moisture.

## INSULATION (CONTINUED)

### 3.0 FINISH-WEATHERPROOF (CONTINUED)

3.2 Fittings, valves, flanges, and beads shall be finished with a weather-proof mastic. Edges shall be lapped at least 2" and the insulation finish shall be smooth, neat, and pinhole free.

### 4.0 WIRES AND BANDS

#### 4.1 Wire and Band Materials

4.1.1 For securing all single and outer layer insulation and for all weatherproof finishes using a roofing jacket, wires and bands shall be Type 302 or 304 stainless steel.

4.1.2 Bands and wires for securing inner layer insulation shall be galvanized steel.

4.1.3 Wires and bands shall be spaced on 9" centers.

## 5. INSULATION MATERIALS

### 5.1 PIPE INSULATION

PHILIP CAREY CORP. CAREYTEMP 1500  
OWENS CORNING KAYLO 10

### 5.2 WEATHERPROOF JACKETING (WITH VAPOR BARRIER)

ALPHA ASSOCIATES, INC. HU-AL STYLE TGH-1000-VB (WHITE)  
WOODBRIDGE, NEW JERSEY

### 5.3 PRE-MOLDED ONE PIECE PVC INSULATING FITTINGS

ZESTON FITTINGS - ZESTON, INC.  
CERTAINTeed/ST. GOBAIN FITTINGS - CERTAINTeed/ST. GOBAIN

### 5.4 INSULATING CEMENTS

CELOTEX - MW-50 CEMENT  
KEENE CORP. - SUPERPOWERHOUSE CEMENT  
P. K. INSUL. MFG. CO. - QUIK-COTE

### 5.5 ELASTOMERIC MASTICS (VAPOR BARRIER)

FOSTER DIV. OF AMCHEM PRODUCTS - MONOLAR 60-36 (WHITE)

### 5.6 SEALANTS

PORTER PAINT CO. FLASHING INSULMASTIC 4010

### 5.7 FASTENING MATERIALS

#### 5.7.1 STAPLES

1/2" LEG LENGTH MONEL OUTWARD CLINCH TYPE .050" WIDE X  
.019" THICK

#### 5.7.2 WIRE

MONEL, SOFT ANNEALED, 16 Ga.

#### 5.7.3 BANDING

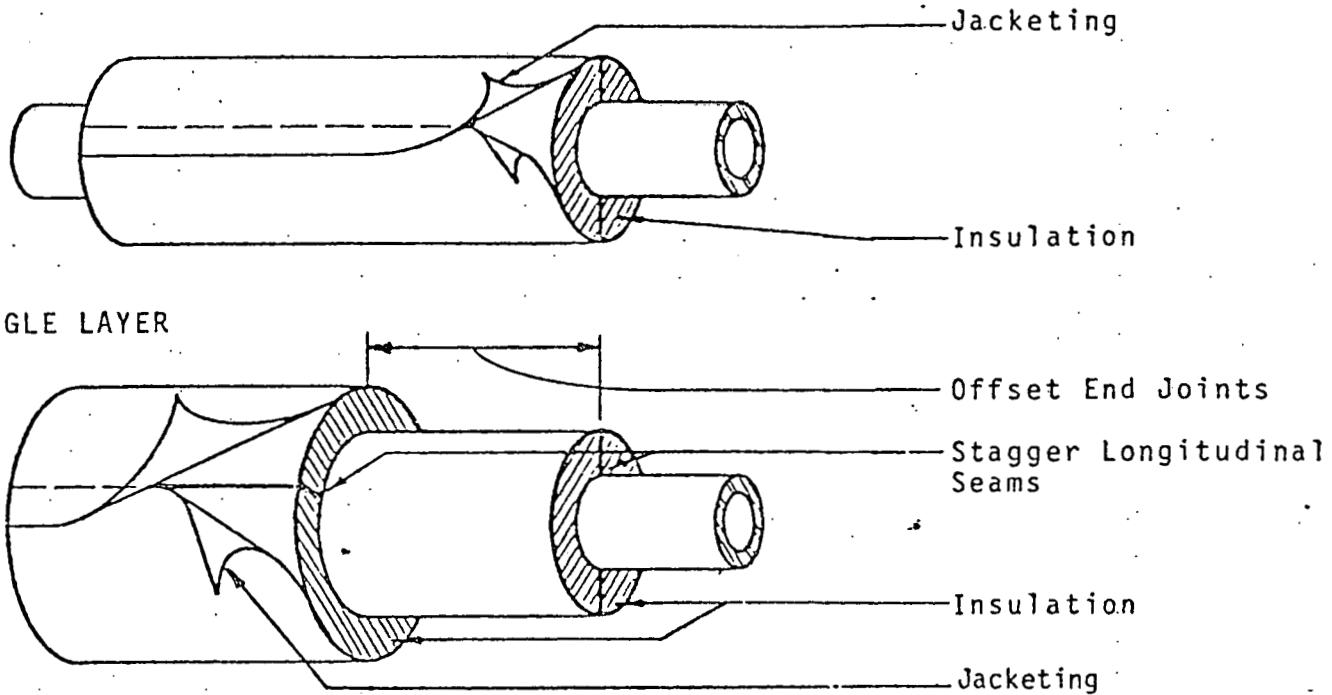
304 STAINLESS STEEL, 5/8" WIDE X .015" THICK -  
A. J. GERRARD CO.

#### 5.7.4 TAPE (SHELL - WHITE)

DU-ALL TAPE - ZESTON, INC.

CERTAINTeed TAPE - CERTAINTeed/ST. GOBAIN

APPLICATION OF RIGID INSULATION ON PIPE  
(High Temperature)



DOUBLE LAYER

APPLICATION NOTES

1. For materials see Project Specifications.
2. Insulation shall be applied over a clean, dry surface. Joints shall be closely butted and all voids filled with insulating cement.
3. Single Layer
  - 3.1 Up to 12" dia. pipe Fasten Sections with wire.
  - 3.2 Over 12" dia. pipe Fasten sections or segments with bands.
4. Double Layer
  - 4.1 Up to 8" dia. pipe Fasten inner & outer layers with wire.

4.2 Over 8" dia. pipe      Fasten inner layer with wire and sections or segments of outer layer with bands.

5. All wiring or banding shall be on approximately 9" centers, using a minimum of 4 loops per 3 ft. length of insulation.

6. Mechanical Contractor will install hard block insulation complete with jacketing at all hangers, same thickness as specified in pipe line schedule.

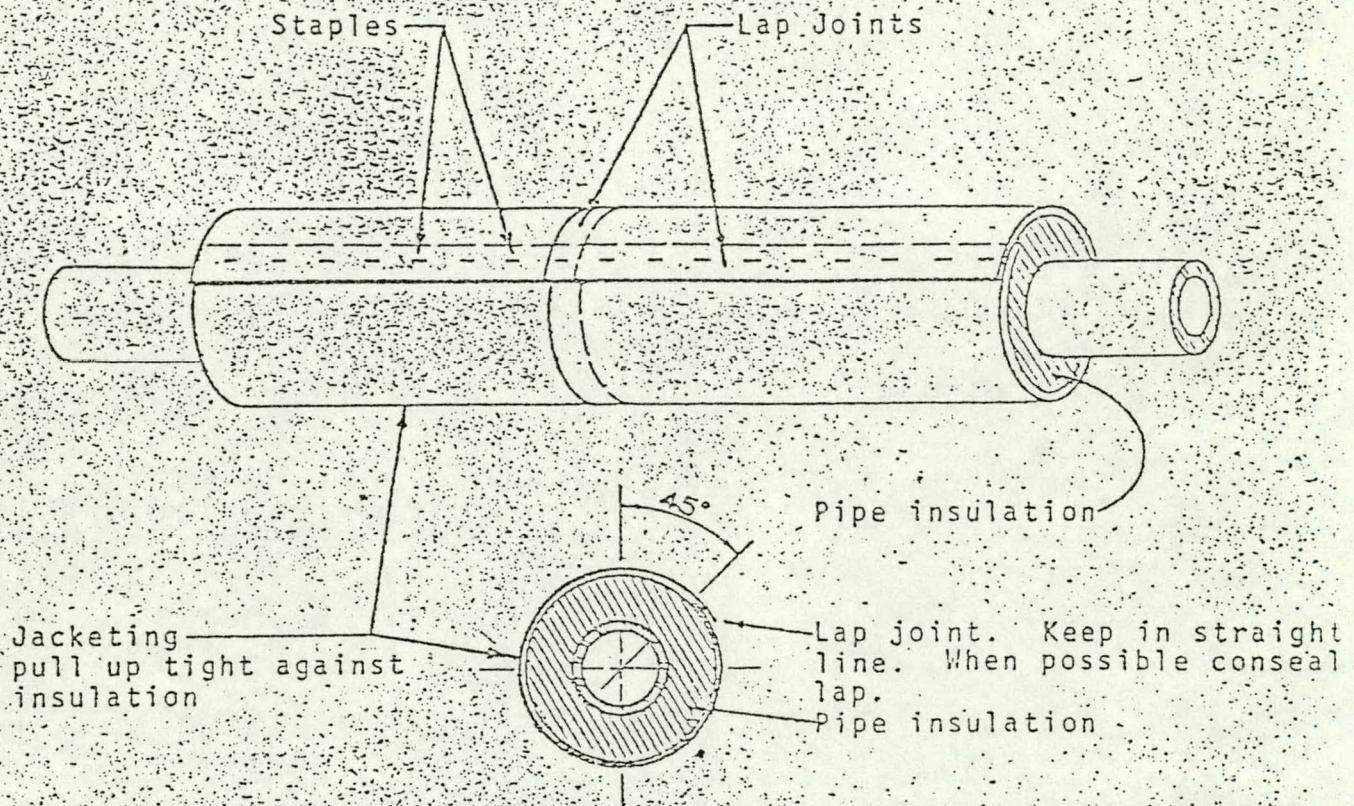
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Design Notes (Not part of project specifications)

1.0 This practice should be used primarily for the application of Calcium Silicate, Rigid Insulation.

APPLICATION OF WEATHERPROOF JACKETING ON  
PIPE INSULATION



APPLICATION NOTES

1. For materials see Project Specifications.
2. Each section of jacketing shall be applied snugly to the insulation. Lap both longitudinal and circumferential joints a minimum of 2".
3. On vertical lines sections of jacketing shall overlap the outside of the sheet below.
4. Fastening
  - 4.1. Staple the longitudinal lap every 2".

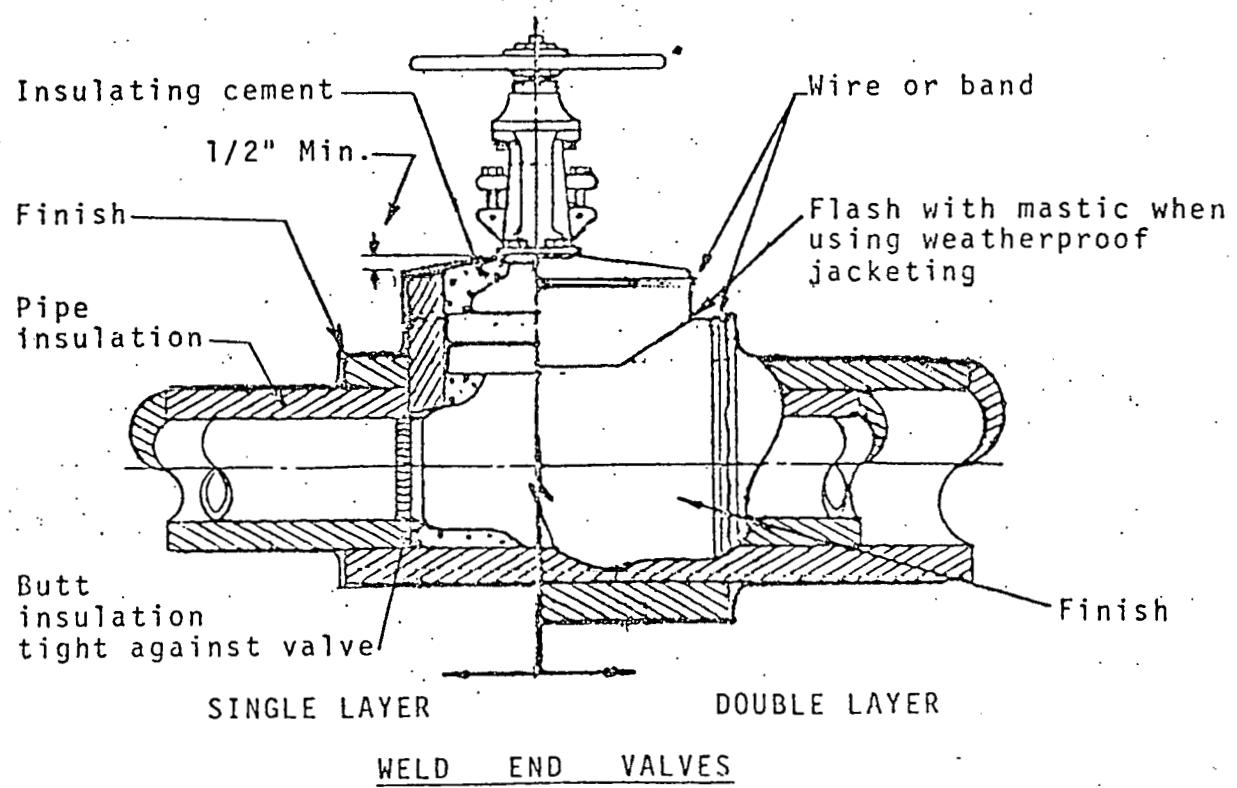
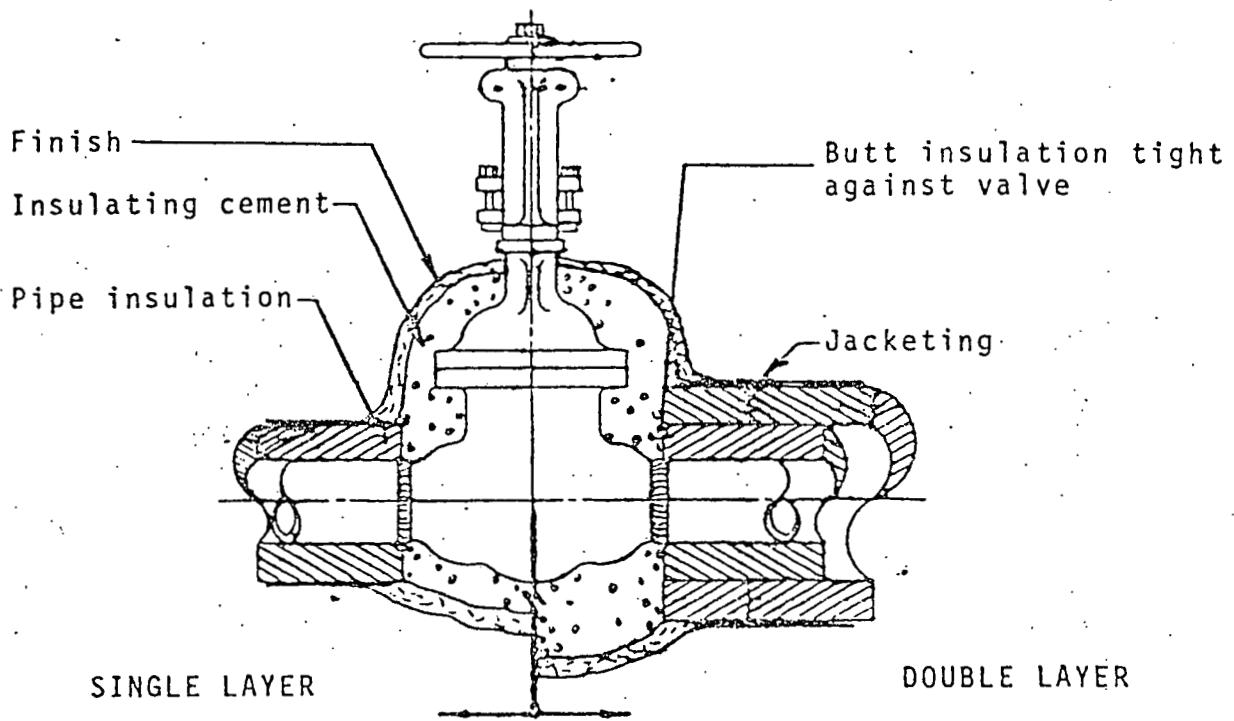
4.2. Longitudinal and circumferential joints shall be taped after stapling, use weatherproofing tape that matches the jacketing being used. Refer to manufacturers' literature for specific application instructions and allowable installation temperature ranges.

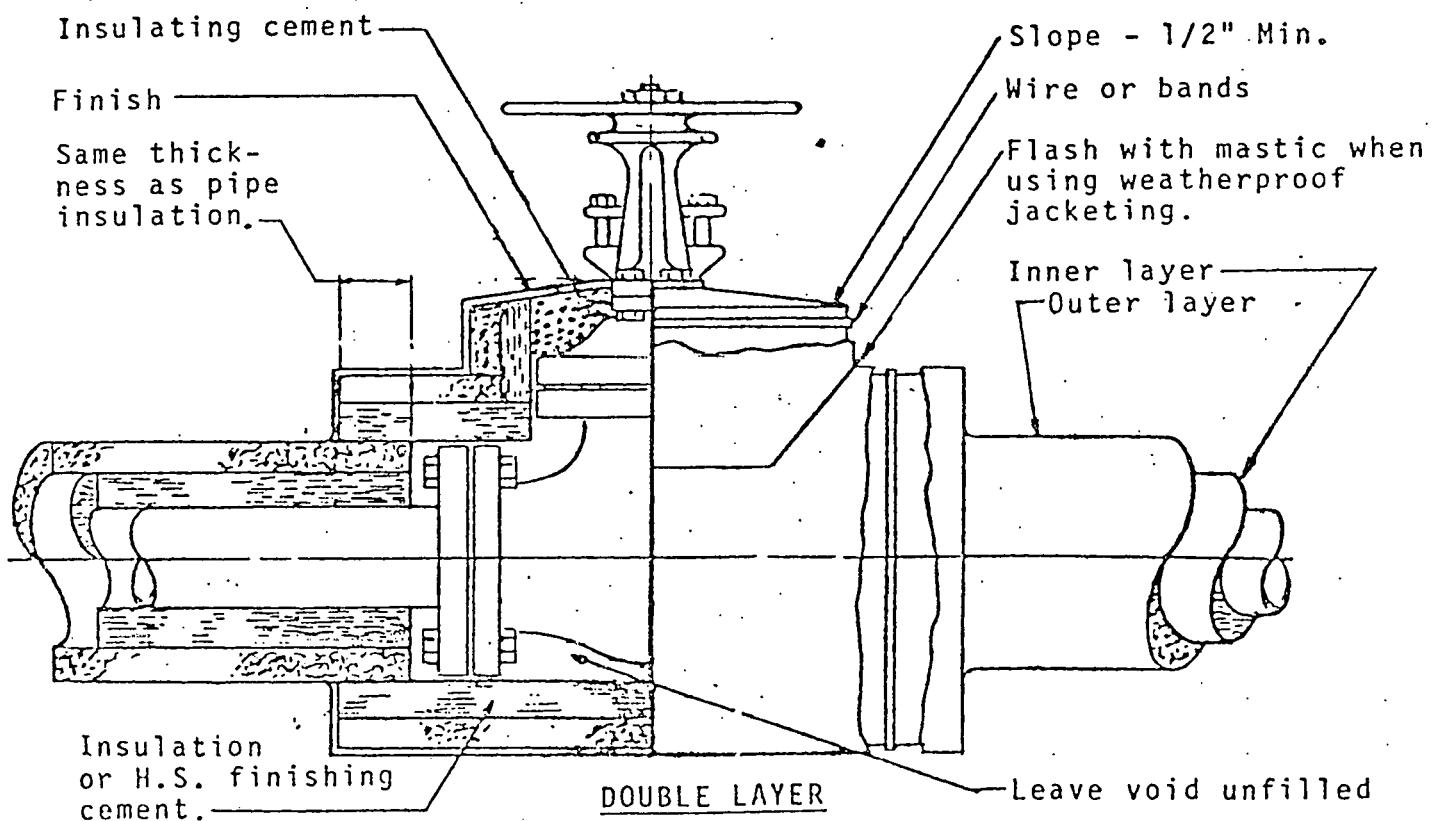
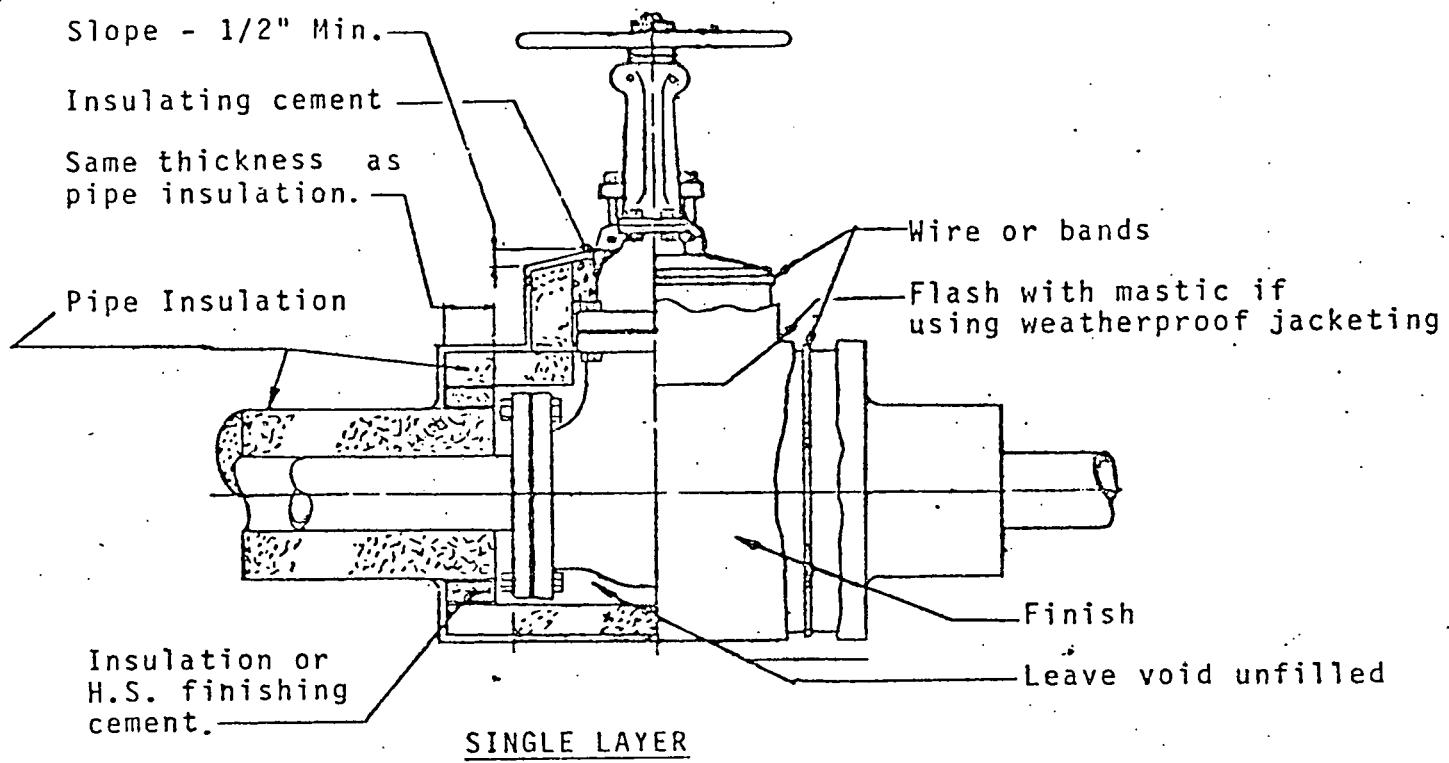
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DESIGN NOTES (Not part of Project Specifications)

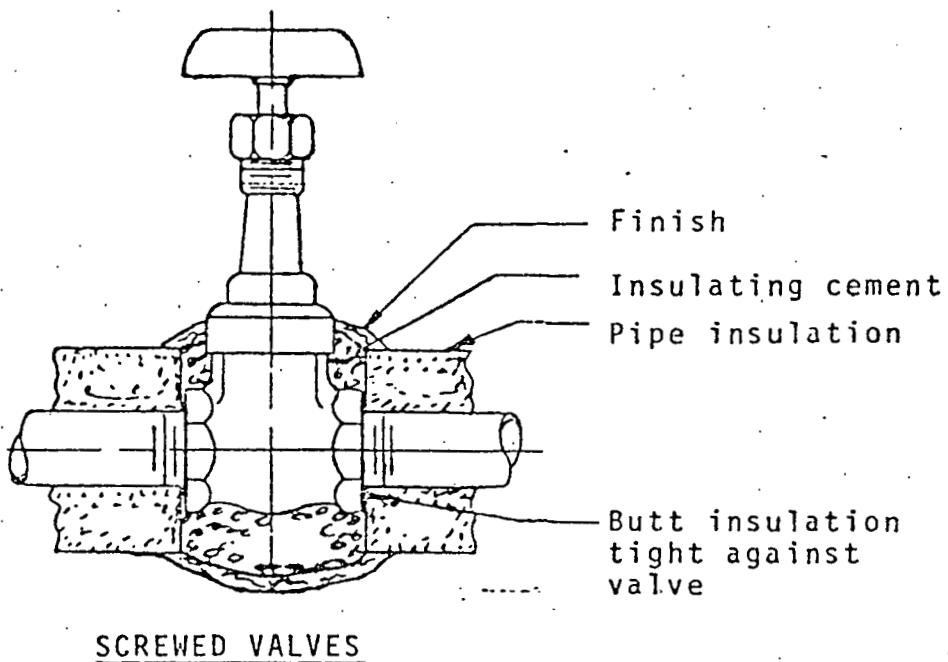
1. See specific weatherproof material practices for a particular products general use and limitations.

APPLICATION OF INSULATION ON VALVES





FLANGED VALVES



#### APPLICATION NOTES

1. For materials see project Specifications.
2. Mitered or sectional blocks of insulation shall be of the same material as adjacent pipe insulation and installed as shown on sketch.
3. Spot insulating cement to valve as shown, applying approximately same thickness as adjoining pipe insulation.
4. Fasten mitered or sectional blocks across valve body securely as follows:
  - 4.1 Single Layer, thru 10" valves: Fasten with wire.
  - 4.2 Single Layer, 12" valves and over: Fasten with Bands.
  - 4.3 Double Layer, thru 10" valves: Fasten inner and outer layers with wire.
  - 4.4 Double Layer, 12" valves and over: Fasten inner layer with wire and outer layer with bands.
5. Bonnets
- 5.1 On sizes less than 2½", either single or double layer use only insulating cement. For sizes 2½" and larger use mitered or sectional blocks. The thickness of either shall be equal to the adjoining pipe insulation.

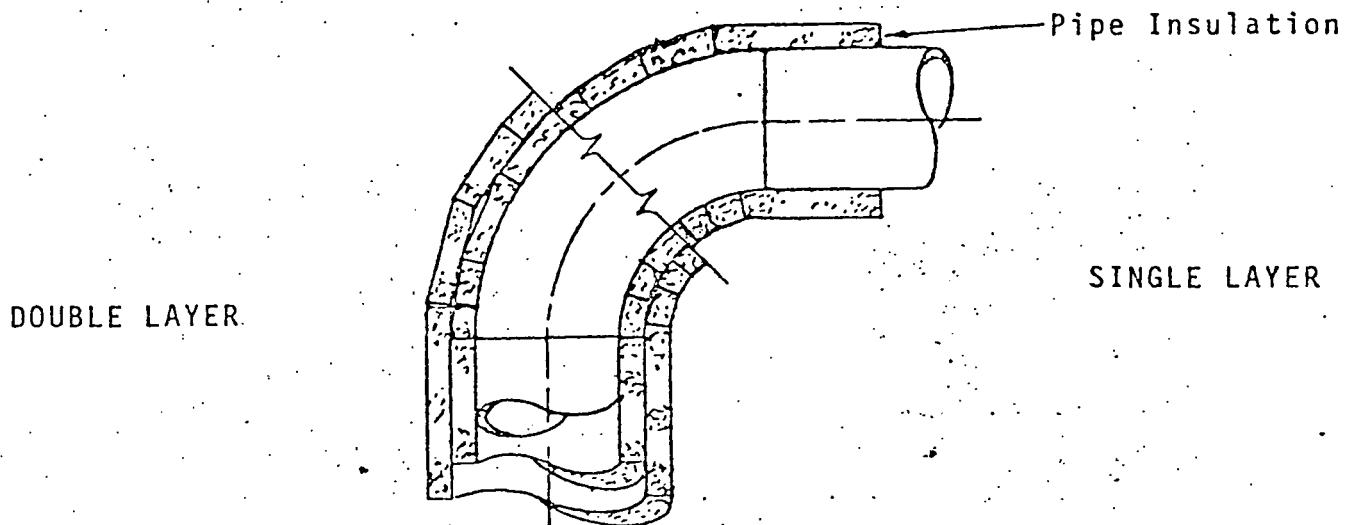
- 5.2 Single Layer - Insulate all bonnets operating above 350°F.
- 5.3 Double Layer - Insulate all bonnets.
6. Alternate insulation - All sizes:
  - 6.1 Install pre-fabricated insulation fittings of same insulation material & thickness as on adjacent pipe. Fasten same as above, and point all voids with insulating cement.

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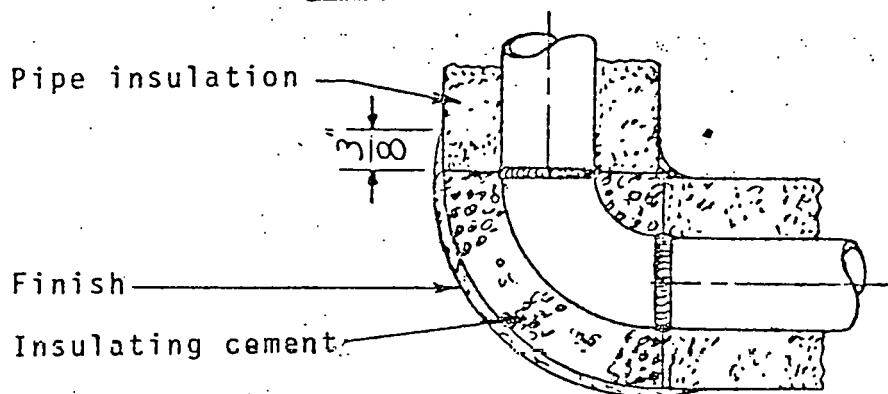
DESIGN NOTES (Not part of project Specifications)

1. These application methods are intended to be used with high temperature, rigid type, insulation systems, (above 450°F) or as alternates to the pre-cut factory made fittings, such as, Zeston Fittings.
2. This practice should not be used for valves operating below 35°F.

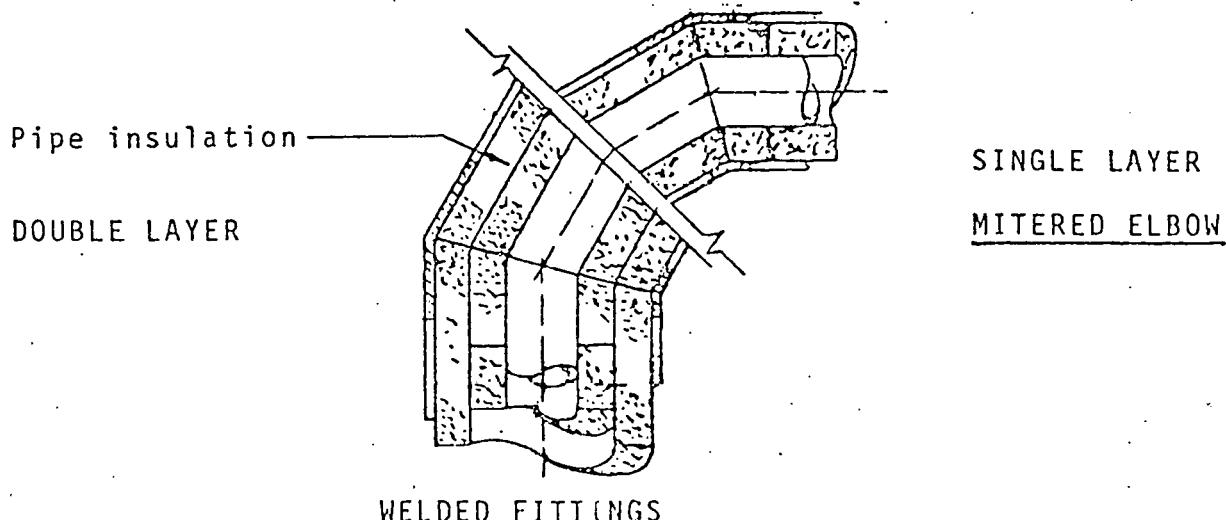
APPLICATION OF INSULATION ON FITTINGS

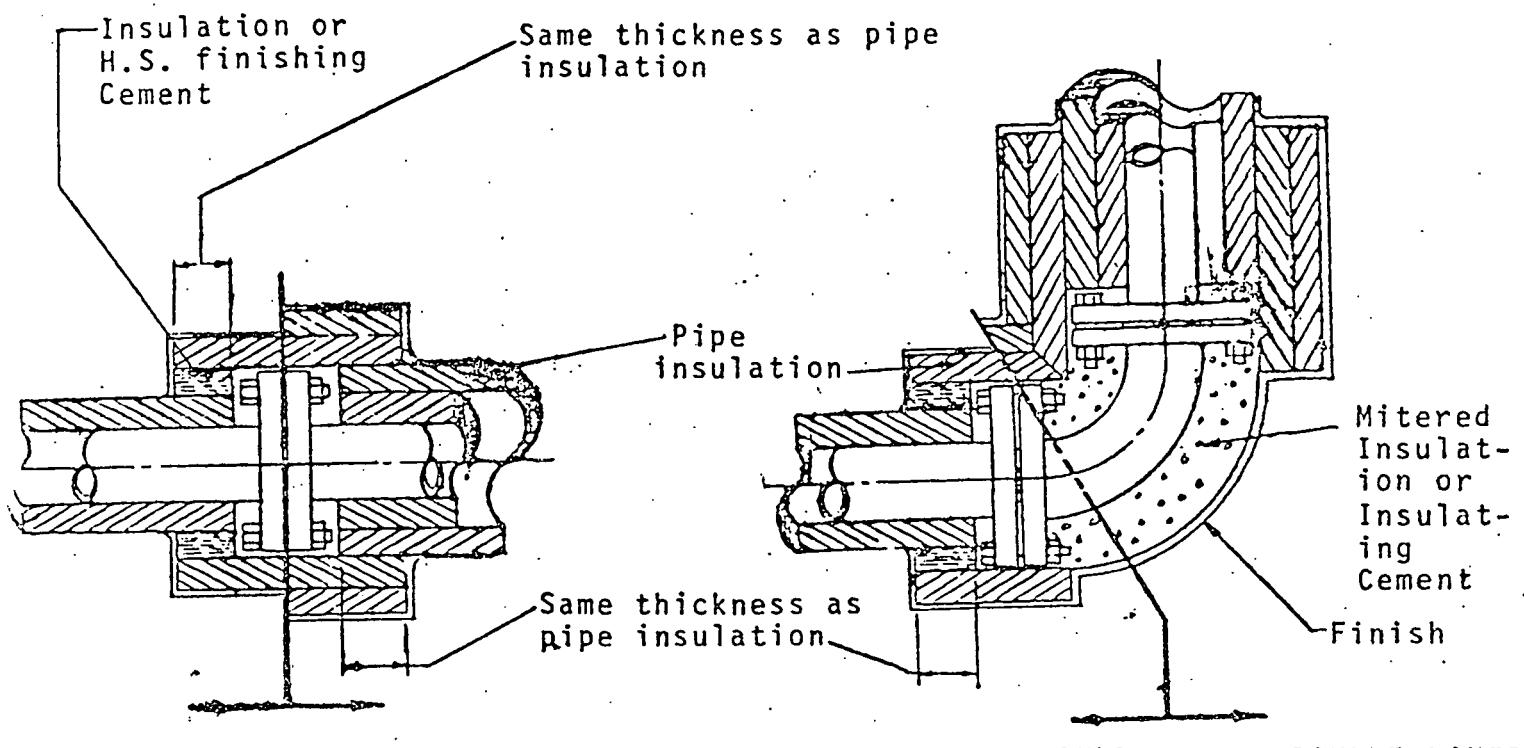


WELDING ELLS 3" AND LARGER

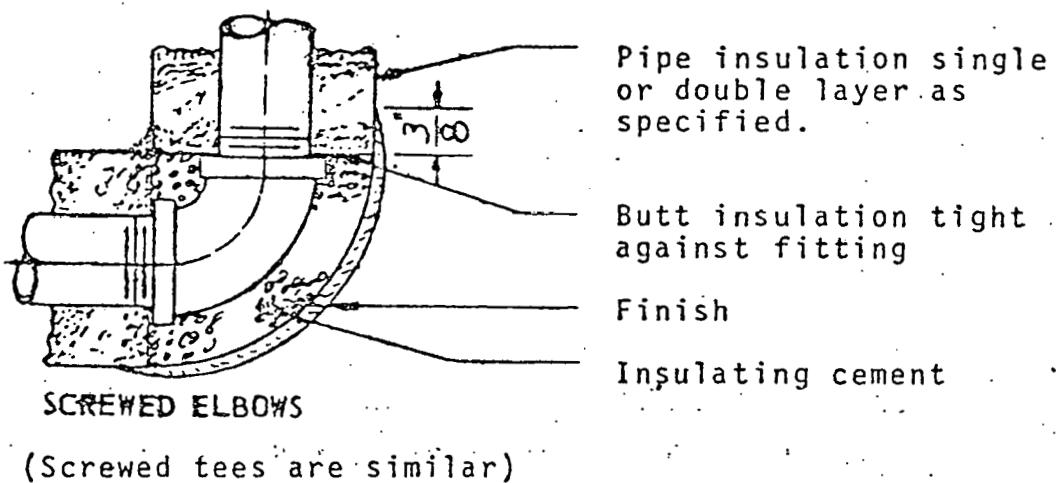


WELDING ELLS THRU 2-1/2"





FLANGED FITTINGS



Note: Do not insulate screwed unions unless specified otherwise.

#### SCREWED FITTINGS

#### APPLICATION NOTES

1. For materials see Project Specifications.
2. Mitered or sectional blocks of insulation shall be of the same material as adjacent pipe insulation and installed as shown on sketch.
3. Spot insulating cement to fitting as shown, applying approximately same thickness as adjoining pipe insulation.
4. Fasten mitered or sectional blocks on fittings securely as follows:
  - 4.1 Single layer, thru 10": Fasten with wire.
  - 4.2 Single layer, 12" and over: Fasten with bands.
  - 4.3 Double layer, thru 10": Fasten inner and outer layer with wire.
  - 4.4 Double layer, 12" and over: Fasten inner layer with wire and outer layer with bands.

6. Alternate insulation - all sizes:

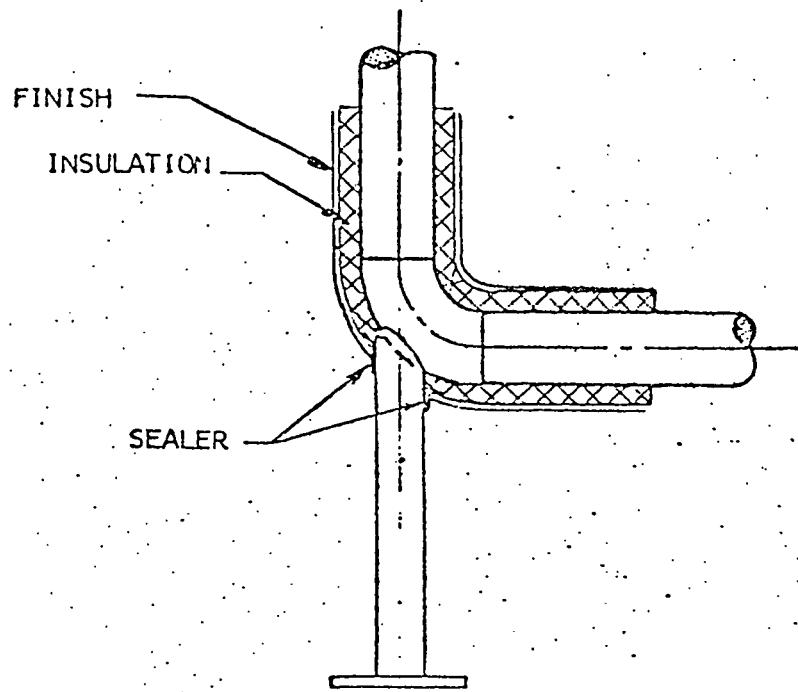
- 6.1 Install pre-fabricated insulation fittings of same insulation material & thickness as on adjacent pipe. Fasten same as above, and point all voids with insulating cement.

---

DESIGN NOTES (Not part of Project Specifications)

1. These application methods are intended to be used with high temperature, rigid type, insulation systems, (above 450° F) or as alternates to the pre-cut factory made fittings, such as, Zeston Fittings.
2. This practice should not be used for fittings operating below 35° F.

HOT INSULATION  
BASE ELBOW SUPPORT



NOTE:

1. FOR MATERIALS SEE JOB SPECIFICATIONS.

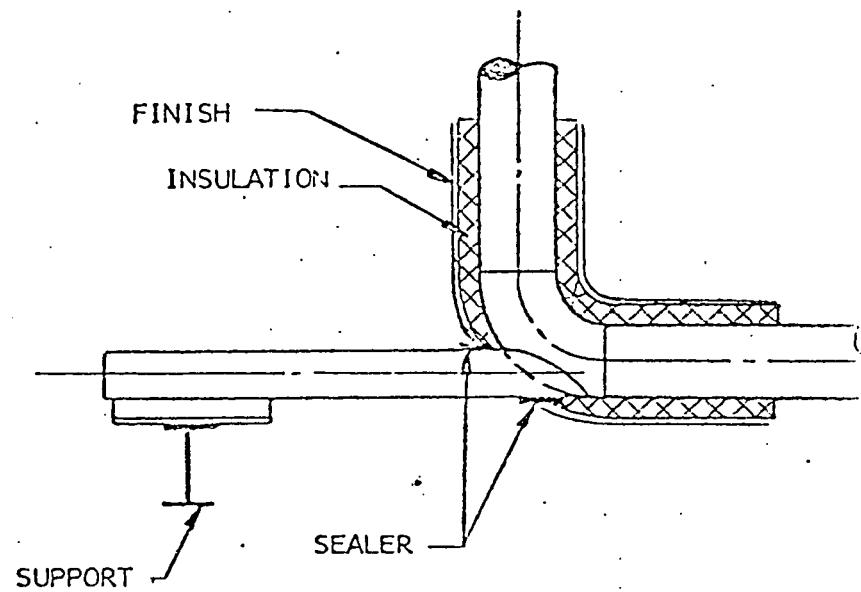
HOT INSULATION  
BASE ELBOW SUPPORT  
DETAIL E56-020



THE DOW CHEMICAL COMPANY  
DOW ENGINEERING SPECIFICATION

E56-012  
1-3-73

HOT INSULATION  
DUMMY LEG PIPE SUPPORT

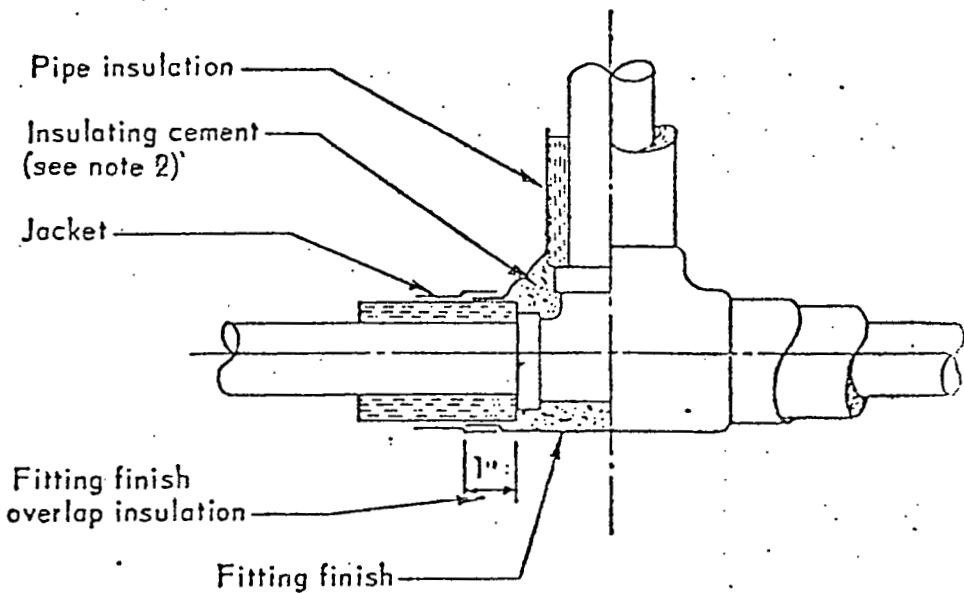


NOTE:

1. FOR MATERIALS SEE JOB SPECIFICATIONS.

HOT INSULATION  
DUMMY LEG PIPE SUPPORT

HOT INSULATION.  
DETAIL AT SMALL SCREWED OR WELDED FITTINGS



NOTES:

1. For materials see job specifications.
2. Premolded fittings may be used in lieu of insulating cement.



JOB SPECIFICATION NO. 60863-83A1

PAINTING

The subject specification is issued herewith per index of pages noted below. If this is a later revision than now in your possession, please destroy superseded pages and insert the revised pages.

Initial issue X  
Entire specification reissued \_\_\_\_\_  
Revised pages only attached \_\_\_\_\_

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| 9           | 0           | 8/26/76     |
| 10          | 0           | 8/26/76     |
| 11          | 0           | 8/26/76     |
| 12          | 0           | 8/26/76     |

\* Pages revised for this issue are noted by asterisk.

Issue No. 1 Date 4/25/79

Basis: Dow Chemical Co.  
Specification

## 18.0 PAINTING

### 18.1 Scope

18.1.1 The Contractor shall furnish all supervision, labor, materials (including paints, thinners, cleaners, and sandblast sand), tools, compressed air, scaffolding, and equipment necessary to satisfactorily complete the work as defined in these specifications and by the drawings and equipment list.

### 18.2 Structural and Miscellaneous Steel

18.2.1 The term, "structural and miscellaneous steel", as used herein, includes steel structures (ladders and platforms) and all manner of supports for piping, instrumentation, and electrical work. Miscellaneous pipe and instrument supports are not all shown on drawings.

18.2.2 Owner furnished structural steel (ladders and platforms) and miscellaneous Contractor furnished steel will be primer coated in accordance with Dow Engineering Specification 57-247.

18.2.3 Grating shall be galvanized per Dow Standard 57-270.

18.2.4 Galvanized coatings, if damaged prior to or during erection, shall be repaired in accordance with Dow Engineering Specification 57-271.

### 18.3 Piping

18.3.1 Carbon steel piping, not to be insulated, with an operating temperature of 250°F or less, and steel piping that will be insulated for personnel protection only (indicated by symbol "\*" on line schedule), shall be painted as follows.

18.3.1.1 Sandblast to near white metal, NACE No. 2 surface finish, and prime with inorganic zinc in accordance with Dow Engineering Specification E57-247.

18.3.1.2 Valves shall be hand or power tool cleaned to remove all dirt, dust, grease, rust, loose paint, and/or other foreign material, and primed with inorganic zinc primer in accordance with Dow Engineering Specification E57-247.

18.3.1.3 Primed piping shall be spot primed after erection, and painted in accordance with Dow Engineering Specification E57-223.

## 18.0 PAINTING (CONTINUED)

### 18.3 Piping (Continued)

- 18.3.5 Carbon steel piping to be insulated, having an operating temperature above 250°F, will not require sandblasting and painting.
- 18.3.6 Surfaces of heat traced piping that will be covered with insulation shall be sandblasted and primed per details of Paragraph 12.3.1.1. The primed piping, including valves, shall be spot primed with inorganic zinc after erection. No further painting will be required.

### 18.4 Safety Shower and Eyewash Installations

- 18.4.1 Galvanized surfaces shall be cleaned and phosphatized as follows:

Galvanized surfaces shall be cleaned with chlorothene to remove any residual oil or grease and phosphatized with a ten per cent solution of phosphoric acid in water applied to the galvanized surfaces. The surfaces shall be kept wet or damp with the acid solution until a matte (dull) finish is formed, and then shall be rinsed with clean water to remove all zinc salts. Surfaces shall be allowed to dry thoroughly before being painted.

- 18.4.2 Safety shower and eyewash installations shall be painted with alkyd paint in accordance with Dow Specification E57-223. The color scheme to be as specified by Owner's representative.

### 18.5 Carbon Steel Surfaces of Owner Furnished Vessels

- 18.5.1 Unless otherwise specified on equipment drawings, these items will be furnished primed with inorganic zinc (57-247).
- 18.5.2 Dirt, dust, grease, oil, rust, or other foreign matter shall be removed before painting.
- 18.5.3 The exposed primed surfaces of vessels that are not to be insulated, including the inside surface of vessel skirts, shall be spot primed with inorganic zinc and painted with alkyd paint in accordance with Dow Engineering Specification E57-223.
- 18.5.4 Surfaces shall be spot primed with inorganic zinc after erection of vessels which will be insulated.

## 18.0 PAINTING (CONTINUED)

- 18.6 Exposed metal surfaces of field instruments and electrical devices. Caution -- protect vents, glass, valve stems, threads, etc. Do not plug vent holes. Do not paint valve stems.
  - 18.6.1 Iron and steel surfaces shall be cleaned and painted in accordance with Dow Engineering Specification E57-223.
- 18.7 Touch-up of existing painted surfaces marred by work on this contract.
  - 18.7.1 All foreign matter shall be removed and the marred surfaces shall be painted to match the existing paint system.
- 18.8 The following surfaces will not require field painting:
  - 18.8.1 Concrete.
  - 18.8.2 Galvanized steel grating.
  - 18.8.3 Galvanized steel piping, except for safety shower and eye-wash installations.
  - 18.8.4 Stainless steel surfaces, except surfaces to be insulated.
  - 18.8.5 Surfaces of steam lines (line number prefixed by S) that will be covered with insulation, including steam traps and steam trap drain piping.
  - 18.8.6 Insulation.
  - 18.8.7 Vendor furnished equipment with shop finished paint systems such as pumps, motors, etc., except where touch-up of marred surfaces is required.
  - 18.8.8 Cable tray.
  - 18.8.9 Switchgear and instruments inside buildings.
  - 18.8.10 Transformers, electrical switches, and switchgear.
  - 18.8.11 Instruments, instrument cases, and vendor finished panel boards.
  - 18.8.12 Electrical switch boxes.
  - 18.8.13 Plastic surfaces.

## 18.0 PAINTING (CONTINUED)

### 18.9 Paint Materials

- 18.9.1 Paint materials shall be delivered to the job site in original unopened containers with labels attached.
- 18.9.2 Paint materials shall be adequately stored and protected against freezing or deterioration.

### 18.10 Application

- 18.10.1 Surface preparation and priming should normally be performed prior to installation or erection, with completion of the painting after erection. However, where it is advantageous to do so, some or all of the finish painting may also be performed prior to installation or erection. In such cases, damaged areas of primer and paint shall be spot primed and/or spot painted after installation or erection so that, when completed, painted surfaces shall have the number of coats and total film thickness specified.
- 18.10.2 Paint shall be applied only to clean, dry, non-contaminated surfaces.
- 18.10.3 Damaged areas of primer shall be cleaned and spot primed in accordance with the paint system specified before the items are insulated or painted out.
- 18.10.4 Burned or otherwise damaged galvanizing shall be repaired in accordance with Dow Engineering Specification 57-271.
- 18.10.5 Sufficient signs to convey adequate information, such as spray painting, men working overhead, no smoking, sand-blasting, or similar signs where applicable shall be furnished and posted at work areas.
- 18.10.6 Reasonable care shall be exercised in spraying paints that contain volatile and/or flammable solvents. No welding, sparks, or open flame shall be in the immediate area.
- 18.10.7 Materials, scaffolds, and equipment shall not be left in the way of plant operation activities. Ladders, pencil boards, scaffolds, and similar items, if left in place, shall be securely tied.
- 18.10.8 Sand and debris shall be kept out of sumps, drains, sewer lines, drainage ditches, trenches, and similar places.

## 18.0 PAINTING (CONTINUED)

### 18.10 Application (Continued)

- 18.10.9 Paint skimmings and cleaning solvents shall be collected and removed to disposal grounds. Dumping these materials on the ground, in ditches, or in sewers will not be permitted.
- 18.10.10 Paint misplaced on items that are not to be painted, or on items which are to be finished a different color, shall be promptly removed by the Contractor, leaving the surface clean, unstained, and undamaged. On painted items, the Contractor will have an option of removing the misplaced paint or painting over same, furnishing labor and materials, leaving a neat appearance satisfactory to the Owner's representative.
- 18.10.11 Protect bearings, mechanical equipment, instruments, switchgear, etc. from damage by sand and sandblasting operations.
- 18.10.12 Valve stems, packing gland bolt threads, pump and motor shafts, sprinkler heads and actuating devices, instruments, glass surfaces, and other similar items shall not be painted. Such items shall be protected or the paint removed by the Contractor, leaving the surface undamaged. Hot surfaces such as light fixtures and similar items shall be protected from paint with non-combustible materials.
- 18.10.13 Painting shall be done only when weather conditions permit the surface to be free from moisture and above the manufacturer's minimum temperature requirements.
- 18.10.14 Reasonable caution shall be exercised to avoid painting immediately prior to rain.
- 18.10.15 Each coat of paint, except where specified otherwise, shall be a full coat.
- 18.10.16 Spot coats of first coat primer shall cover exposed bare (unpainted) metal surfaces.
- 18.10.17 Subsequent spot coats of paint shall completely cover previous spot coats.

## 18.0 PAINTING (CONTINUED)

### 18.10 Application (Continued)

- 18.10.18 Minimum film thicknesses specified are the minimum acceptable dry film thicknesses of each paint, or paint system, as determined by measurement on a flat surface with a mikrotest film thickness gage, as manufactured by the Nordson Corporation or Owner approved equal. Areas in any coat of paint which are determined by measurement to be less than the minimum dry thickness specified shall have sufficient paint added to attain the specified dry thickness.
- 18.10.19 Spray painting shall not be done where overspray and/or drips cannot be controlled.
- 18.10.20 Mixing, thinning, and application shall be done in accordance with the paint manufacturer's written instructions and these specifications.
- 18.10.21 Overspray, skips, sags, runs, drips, and holidays shall be kept to a minimum. Additional coats shall be applied to holidays and thin areas to bring them up to specifications at no extra cost to the Owner.
- 18.10.22 Colors shall be cut in a neat, straight line where two colors meet.

18.11 The finish colors shall conform to the existing plant color scheme. The Owner's representative will designate color coding scheme.



THE DOW CHEMICAL COMPANY  
DOW ENGINEERING SPECIFICATION

PROTECTIVE COATINGS  
SILICONE-ALKYD

Maximum Temperature: Dry 300°F

|                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                              |                                                              |
|--------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|--------------------------------------------------------------|
| SURFACE PREPARATION<br>(For maintenance painting surface preparation, see Remarks Section) | <p>All carbon steel or cast iron surfaces to be coated with this material, except items that have been shop sandblasted and primed, shall be sandblasted to near white metal (NACE No. 2 finish) or pickled and phosphatized before being coated.</p> <p>Shop primed carbon steel or cast iron items, before being field painted, shall have all dirt, dust, weld flux, grease, oil, stratified rust (rust scale), loose rust, and/or other foreign material removed.</p> <p>See Note 5 in Paint Materials Section when surfaces other than carbon steel or cast iron are specified to be painted.</p>                                                                       |                                                                                              |                                                              |
| PAINT MATERIAL                                                                             | <p>The paint materials shall be selected from one of the paint systems in the following table:</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                              |                                                              |
|                                                                                            | <p>THE MINIMUM NUMBER OF COATS<br/>SHALL BE AS LISTED AND<br/>NOTED BELOW:</p> <p>One coat of primer (see Notes 1 and 2)</p> <p>One coat of intermediate guide coat gray (see Note 4)</p> <p>One coat of one of the following colors:</p> <ul style="list-style-type: none"> <li>Black</li> <li>Blue-Green</li> <li>Light Gray</li> <li>Very Light Gray (Tex. Div.)</li> <li>Vermilion</li> <li>White</li> </ul> <p>Where so specified, the following O.S.H.A. Safety Colors shall be applied in lieu of the foregoing finish colors:</p> <ul style="list-style-type: none"> <li>Red</li> <li>Orange</li> <li>Yellow</li> <li>Blue</li> <li>Purple</li> <li>Green</li> </ul> | PPG                                                                                          | NAPKO                                                        |
|                                                                                            | <p>Thinner: Brush - Mineral Spirits<br/>Spray - VM&amp;P Naphtha</p> <p>Cleaner: Naphtha or Toluene</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | UC-40054<br>UC-40061<br>UC-42220<br>UC-42450<br>UC-40115<br>UC-43057<br>UC-40046<br>UC-40114 | 1340<br>5763<br>5762<br>5772<br>5770<br>5771<br>5773<br>5773 |



THE DOW CHEMICAL COMPANY  
DOW ENGINEERING SPECIFICATION

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PAINT  
MATERIALS  
(Continued)

Notes:

1. Primed Steel: In field one spot coat of silicone-alkyd primer shall be applied in lieu of a full coat, except items primed with inorganic zinc, or galvanized and phosphatized, shall have a spot coat of inorganic zinc applied before applying a guide coat of PPG Aquapon and finish coat of silicone-alkyd.
2. Over vendor finish paint one coat of PPG multiprime or Napko 1340 shall be applied in lieu of the silicone-alkyd primer before applying the guide and finish coats of silicone-alkyd.
3. The color coat shall be omitted from all surfaces that are to be insulated with Class G, H, J or K insulation. All painting shall be omitted from surfaces to be insulated with Class F insulation and hotter and Class L insulation and colder.
4. For white color coat, a white guide coat, tinted with one-half pint of gray per gallon of white shall be used.
5. The following surfaces shall be coated only when so specified in the material specifications, the job specifications, or in the purchase order. When these surfaces are specified to be coated, they shall be cleaned and primed as indicated below before the guide and finish coats are applied.

| TYPE SURFACE             | SURFACE PREPARATION                                                                                                                                             | PRIMER                           |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| Aluminum                 | Surfaces shall be treated with Amchem Alodine 1200 or owner-approved equal chromate conversion coating. A dull matte finish is required. Rinse.                 | PPG<br>UC-40054<br>(Multi-prime) |
| Copper and Copper Alloys | Surfaces shall be treated with 38% concentrated HCl, one gallon to one gallon, 40% by weight ferric chloride, in water. A dull matte finish is required. Rinse. | PPG<br>6-204<br>Zinc chromate    |



THE DOW CHEMICAL COMPANY  
DOW ENGINEERING SPECIFICATION

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| PAINT MATERIALS<br>(Continued) | TYPE SURFACE                                                                                                                                                                                                                                                                                                | SURFACE PREPARATION                                                                                                                                                                                                                                                                     | PRIMER                                          |
|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|
|                                | Dowmetal (Mag Alloys)                                                                                                                                                                                                                                                                                       | After fabrication, surfaces shall be treated with Dow Magnesium Chemical Treatment 1, 7, 17, or 19.                                                                                                                                                                                     | PPG 6-204<br>Zinc Chromate; or Napko 5616       |
|                                | Galvanized Steel                                                                                                                                                                                                                                                                                            | Surfaces shall be degreased with solvent and treated with a 10% solution of phosphoric acid in water. Surfaces shall be kept wet or damp, with the acid solution until a matte (dull) finish is obtained. All zinc salts and acid residue shall be removed by rinsing with clean water. | PPG UC-34851<br>Galvanize primer; or Napko 5616 |
|                                | Stainless Steel                                                                                                                                                                                                                                                                                             | Surfaces shall be sandblasted to remove all foreign material and to obtain a dull matte finish.                                                                                                                                                                                         | Same as Steel                                   |
|                                | Wood                                                                                                                                                                                                                                                                                                        | All dirt, dust, grease, oil and/or other foreign material shall be removed.                                                                                                                                                                                                             | PPG UC-33718<br>Wood Primer; or Napko 1340      |
| APPLICATION                    | <p>The coatings shall be mixed and applied in accordance with the coating manufacturer's printed application instructions and as specified herein.</p> <p>The first coat of primer shall be brush applied.</p> <p>All other coats may be applied by brush, roller, conventional spray or airless spray.</p> |                                                                                                                                                                                                                                                                                         |                                                 |



THE DOW CHEMICAL COMPANY  
DOW ENGINEERING SPECIFICATION

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| FILM<br>THICKNESS<br>AND %<br>SOLIDS BY<br>VOLUME |                                                                                                                                                                                                                                                                                                                          | FILM THICKNESS        |                       | APPROXIMATE<br>% SOLIDS<br>BY VOLUME |       |
|---------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|--------------------------------------|-------|
|                                                   |                                                                                                                                                                                                                                                                                                                          | PPG                   | NAPKO                 | PPG                                  | NAPKO |
| Primer:                                           | Wet<br>Dry                                                                                                                                                                                                                                                                                                               | 5 mils<br>1.5 mils    | 5.5 mils<br>1.5 mils  | 30%                                  | 27%   |
| Guide and Finish<br>Coats:                        | Wet<br>Dry                                                                                                                                                                                                                                                                                                               | 4.7 mils<br>2 mils    | 5 mils<br>2 mils      | 40-44%                               | 40%   |
| Minimum Total:                                    | Wet<br>Dry                                                                                                                                                                                                                                                                                                               | 14.4 mils<br>5.5 mils | 15.5 mils<br>5.5 mils |                                      |       |
| REMARKS                                           | <p>Solvents in these materials are volatile and flammable. Keep containers closed and away from heat, open flame, or sparks.</p> <p>Do not apply these materials when the temperature is below 50° F.</p> <p>Maintenance Painting:<br/>The job specifications will specify the type of surface preparation required.</p> |                       |                       |                                      |       |

PROTECTIVE COATING FOR FIELD CUTS AND WELDS  
ON GALVANIZED ITEMS

|                 |                                                                                                                                                                                                                                                                                                                                |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Paint Materials | 1 heavy coat of ZRC (The Sealube Company, Wakefield, Massachusetts) or Galvanox, Type I (Subox, Inc.)<br>Thinner For ZRC, mineral spirits; for Galvanox, Xylol<br>Cleaner For ZRC, kerosene or varsol; for Galvanox, Xylol                                                                                                     |
| Application     | Remove all slag, weld spatter, burned zinc coating, rust, and all other foreign matter by hand or power tools and apply one heavy brush coat of thoroughly mixed zinc coating the same day cuts and welds are made. Max temp. of metal shall be 16°. The coating shall overlap the undamaged galvanized areas a minimum of 2". |
| Film Thickness  | Wet 4 mils total, minimum<br>Approximate coverage 300 square feet per gallon, or 12 square feet per pound.                                                                                                                                                                                                                     |
| Remarks         | Solvents in these materials are volatile and flammable. Keep containers closed and away from heat, open flame, or sparks.                                                                                                                                                                                                      |



THE DOW CHEMICAL COMPANY  
DOW ENGINEERING SPECIFICATION

5/24/74  
5-31-74  
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PROTECTIVE COATINGS  
INORGANIC ZINC COATING

Maximum Continuous Temperature: Bare - 600°F  
With High Heat Topcoat - 750°F

| SURFACE PREPARATION           | <p>All surfaces to be coated with this material shall be sandblasted to near-white metal (NACE No. 2 Finish, NACE Standard TM-01-70).</p> <p>The surface profile depth shall not be less than 3/4 mils, nor more than 2 mils.</p> <p>Cleaning procedures other than sandblasting will require prior written approval of the owner.</p> <p>For field use, surfaces shop-coated with inorganic zinc shall have all dirt, dust, weld flux, grease, oil, rust and/or other foreign matter removed before being spot coated with inorganic zinc.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|----------------|--------------|-----------------|---------------|----------------------|--------------------------|-----------|--------|---------|--------|---------|-------|--------------|-------------|-----------|--------------------|--------------|-------|----|-----------|------------|--------|-----------------|----------------|---------|-------------------------------|------------------------------|
| PAINT MATERIALS               | <p>The same day cleaning is done, while surfaces are still dry and uncorroded, one coat of one of the following inorganic zinc coatings shall be applied:</p> <table> <thead> <tr> <th><u>Manufacturer</u></th><th><u>Product</u></th></tr> </thead> <tbody> <tr> <td>Ameron Corp.</td><td>Dimetcote No. 6</td></tr> <tr> <td>Carboline Co.</td><td>Carbo-Zinc 11, Green</td></tr> <tr> <td>Cook Paint &amp; Varnish Co.</td><td>411-A-100</td></tr> <tr> <td>DuPont</td><td>Ganicin</td></tr> <tr> <td>Engard</td><td>No. 521</td></tr> <tr> <td>Exxon</td><td>Rust Ban 188</td></tr> <tr> <td>Glidden Co.</td><td>Glid-Zinc</td></tr> <tr> <td>Mobil Finishes Co.</td><td>Mobil Zinc 7</td></tr> <tr> <td>Napko</td><td>5Z</td></tr> <tr> <td>Plas-Chem</td><td>Zinc-ite G</td></tr> <tr> <td>Porter</td><td>Porter Zinc 311</td></tr> <tr> <td>PPG Industries</td><td>UC40103</td></tr> <tr> <td>Wisconsin Protective Coatings</td><td>Plasite Plasti-Zinc No. 1000</td></tr> </tbody> </table> | <u>Manufacturer</u> | <u>Product</u> | Ameron Corp. | Dimetcote No. 6 | Carboline Co. | Carbo-Zinc 11, Green | Cook Paint & Varnish Co. | 411-A-100 | DuPont | Ganicin | Engard | No. 521 | Exxon | Rust Ban 188 | Glidden Co. | Glid-Zinc | Mobil Finishes Co. | Mobil Zinc 7 | Napko | 5Z | Plas-Chem | Zinc-ite G | Porter | Porter Zinc 311 | PPG Industries | UC40103 | Wisconsin Protective Coatings | Plasite Plasti-Zinc No. 1000 |
| <u>Manufacturer</u>           | <u>Product</u>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
| Ameron Corp.                  | Dimetcote No. 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
| Carboline Co.                 | Carbo-Zinc 11, Green                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
| Cook Paint & Varnish Co.      | 411-A-100                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
| DuPont                        | Ganicin                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
| Engard                        | No. 521                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
| Exxon                         | Rust Ban 188                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
| Glidden Co.                   | Glid-Zinc                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
| Mobil Finishes Co.            | Mobil Zinc 7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
| Napko                         | 5Z                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
| Plas-Chem                     | Zinc-ite G                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
| Porter                        | Porter Zinc 311                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
| PPG Industries                | UC40103                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
| Wisconsin Protective Coatings | Plasite Plasti-Zinc No. 1000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |
| APPLICATION                   | <p>The inorganic zinc coating shall be spray applied in accordance with the coating manufacturer's printed application instructions.</p> <p><u>Note:</u> It is suggested that shops unfamiliar with the application of inorganic zinc coatings contact the coating manufacturer for assistance in the proper application of same.</p> <p><u>CAUTION:</u> The dry film thickness of the inorganic zinc coating must not exceed 5 mils. Thicker coatings must be removed and replaced with coatings having a dry film thickness of not more than 5 mils. The thicker coatings tend to mud crack.</p> <p>A dry film thickness of 3 mils is preferred.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                     |                |              |                 |               |                      |                          |           |        |         |        |         |       |              |             |           |                    |              |       |    |           |            |        |                 |                |         |                               |                              |

WELDING REQUIREMENTS  
FOR EQUIPMENT AND PIPING

JOB SPECIFICATION 60863-88C1

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| 5           | 0           | 9/1/78      |
| 6           | 0           | 9/1/78      |
| 7           | 0           | 9/1/78      |
| 8           | 0           | 9/1/78      |
| 9           | 0           | 9/1/78      |
| 10          | 0           | 9/1/78      |
| 11          | 0           | 9/1/78      |
| 12          | 0           | 9/1/78      |
| 13          | 0           | 9/1/78      |
| 14          | 0           | 9/1/78      |
| 15          | 0           | 9/1/78      |
| 16          | 0           | 9/1/78      |
| 17          | 0           | 9/1/78      |
| 18          | 0           | 9/1/78      |

\* PAGES REVISED FOR THIS ISSUE ARE NOTED BY ASTERISK.

REASON FOR REVISION:

Standard Computerized

## I. SCOPE

- A. This standard outlines requirements for welding, including preheat and postweld heat treatment of vessels, heat exchangers, piping, piping components, heater tubing and other equipment. Requirements for weld overlay cladding, fabrication of integral clad plate and tube to tubesheet welding are also included.
- B. Except as supplemented in this standard, welding shall conform to the requirements of the latest revision and addenda of the following codes:
  1. ANSI B31.3 - Chemical Plant and Petroleum Refinery Piping Code
  2. ANSI B31.1 - Power Piping Code
  3. ASME Boiler and Pressure Vessel Code, Sections I, VIII and IX
  4. State and local codes
- C. In no case is this standard to be used to supersede, delete and/or lower applicable code requirements.
- D. Any conflict between this standard and other Foster Wheeler drawings, specifications, standards, codes, etc. shall be brought to the attention of Foster Wheeler in writing, for clarification prior to any action by the vendor. The more stringent requirements shall govern until written resolution is provided by Foster Wheeler.

## II. WELDING - REQUIREMENTS AND RESTRICTIONS

### A. General

1. Acceptable welding processes are given below. Requests to use any other welding processes shall be submitted to Foster Wheeler for review.
  - a. SMAW - Shielded Metal Arc Welding
  - b. GTAW - Gas Tungsten Arc Welding
  - c. GMAW - Gas Metal Arc Welding
  - d. FCAW - Flux-Cored Arc Welding
  - e. SAW - Submerged Arc Welding
  - f. FGW - Fuel Gas Welding
  - g. PAW - Plasma Arc Welding
  - h. ESW - Electroslag Welding
2. The strength of deposited weld metal shall be at least equal to the specified minimum tensile strengths of the material being welded.

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3. Where hardness limits are prescribed in the job specification for welded equipment, weld metal and heat affected zone hardnesses shall not exceed those values. Hardness limits for piping shall not exceed the following values:

| BASE METAL<br>P - NUMBER | MAXIMUM<br>HARDNESS,<br>BRINELL |
|--------------------------|---------------------------------|
| 1                        | 200                             |
| 3                        | 225*                            |
| 4                        | 225*                            |
| 5                        | 241*                            |
| 6                        | 241*                            |

\* Required by ANSI B31.3

When welding dissimilar metals, the maximum hardness allowed shall be the hardness prescribed for the higher alloy.

4. Unless otherwise approved in writing by Foster Wheeler only low hydrogen electrodes shall be used for shielded metal arc welding all carbon and low alloy steels, except for root pass welding of single welded joints (See Paragraph 5 below).

5. Where access precludes the use of double welded butt joints, single welded joints shall be made using a root pass deposited by the GTAW (TIG) or GMAW (short arc) processes, except that for carbon steel piping, the use of E6010 electrodes for root pass welding by SMAW is also acceptable. The use of consumable insert rings for gas tungsten arc welding is an exception.

6. Unless specifically approved in writing by Foster Wheeler, non-removable backing rings or strips shall not be used for butt joints.

7. All full-penetration butt joints which are accessible from both sides shall be back gouged or ground to sound metal after welding the first side and then back welded on the reverse side, unless the welding procedure otherwise assures that full penetration will be achieved.

8. All welds of nozzles and manways to equipment shells and heads shall be full penetration welds.

9. Internal purging with inert gas is required for gas tungsten arc welding of single-welded butt joints in non-ferrous metals, and ferrous metals with over 3% total alloy content. When consumable inserts are used, internal purging is required for all materials.

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10. Self-shielded flux-cored arc welding, without external shielding gas, of carbon or low alloy steels is not acceptable for pressure joints or for welds subject to vibration.
11. The use of neutral flux (non-voltage sensitive) is required for submerged arc welding of all materials other than carbon steels, and carbon steels over one inch thick.
12. For submerged arc welding, the use of alloy wire and neutral flux, rather than alloying through the flux, is required where an alloy weld deposit is desired.
13. For submerged arc welding, the flux and wire combination actually used shall be the same as used in the procedure qualification.
14. Use of manual submerged arc welding is not permitted for pressure joints.
15. Submerged arc flux shall be specified by manufacturer.
16. For gas metal arc welding, the CO<sub>2</sub> spray transfer technique shall not be used for the root pass of welds which are not back gouged.
17. The oxy-fuel gas process is restricted to butt or socket welding of heat exchanger carbon steel tubing not over two inches nominal diameter.
18. Welding of proprietary items such as alonized pipe, etc. is not permitted without prior Foster Wheeler approval.

B. Short Arc Welding Restrictions

1. Pressure Vessels

Manual short-arc or pulsed arc welding is:

- a. Allowed for root pass welding of butt joints in any material regardless of thickness.
- b. Allowed for full thickness butt welds and fillet welds in pressure parts, structural supports, and equipment internals if the thickness of either material at the joint does not exceed 3/8".
- c. Not allowed where large material mass heat sinks can affect the integrity of welds, such as nozzle welds, reinforcing pads, and flange welds where the thickness of either material at the joint exceeds 3/8".

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2. Piping

- a. Manual short arc or pulsed arc welding is allowed for full thickness butt welds in piping, with the following limitations:
  - (1) It may be used for root pass welding of butt joints in any material regardless of thickness.
  - (2) It may be used provided the wall thickness does not exceed 3/8" nominal.
  - (3) It cannot be used for pipe with diameters less than 3".
  - (4) It may be used provided the direction of travel is indicated in the procedure.
  - (5) 5% of welds performed shall be radiographed in addition to any applicable code requirements. Inspection shall be performed as stated in Section V of this standard.
- b. Automatic short arc or pulsed arc welding is allowed for full thickness butt welds in piping within the following limitations:
  - (1) No limit on thickness.
  - (2) No restriction on diameter.
  - (3) 1G (Rolled) position only.
  - (4) For thicknesses over 3/8", a minimum current of 170 amperes is required for all passes after the root pass.
  - (5) Use of an automatic arc oscillator is recommended for joint thicknesses over 3/8".
  - (6) 5% of welds in thicknesses up to 3/8" and 10% of welds in thicknesses over 3/8" must be radiographed in addition to any applicable code requirements. Technique and acceptance standards shall be as stated in Section V of this standard.
  - (7) Not allowed where large material mass heat sinks can affect the integrity of welds, such as couplings, weldoletts, branch welds, fillet welds on slip-on flanges, socket-welded flanges and fittings, etc. where the thickness of either material at the joint exceeds 3/8".

C. Base Metal Preparation

1. Joint preparations for welding may be performed by machining, grinding, thermal cutting or combinations thereof. Excessively deep or sharp irregularities in joint edges shall be removed by machining or by grinding. Joint edges shall be crack and lamination free prior to welding.
2. Prior to welding, all oil, grease, dirt, rust or loose scale shall be removed from the surfaces of the joint and the adjacent base metal within one inch from the edge of the joint.

D. Welding Clad & Overlay Materials

1. Weld overlay procedures shall be qualified in accordance with the requirements of ASME Code, Section IX, Paragraph QW-214 and QW-381. Qualification weld test specimens shall be subjected to PWHT, if required, equivalent to that anticipated for fabrication, including aggregate time at temperature, with appropriate allowance for repair cycles.
2. The minimum clad or overlay thickness shall be as specified on drawings and requisitions.
3. Weld overlays shall meet the chemical requirements for the specified type or grade.
4. Where specifications require chemical analysis of stainless steel overlays in production, and where such overlays will experience post weld heat treatment in the temperature range from 1200 F to 1350 F, the ferrite number for Type 309L/308L, and the ferrite number and Cb/C ratio for Type 347 shall not exceed the following values depending upon the chromium content.

| CHROMIUM CONTENT<br>OF OVERLAY | FERRITE<br>NUMBER | Cb/C<br>RATIO |
|--------------------------------|-------------------|---------------|
| Up to 20%, incl.               | 4-12              | 35 Max.       |
| 20% to 22% incl.               | 4-9               | 25 Max.       |
| Greater than 22%               | 4-9               | 15 Max.       |

5. Ferrite number may be determined by chemical analysis and reference to a DeLong or Schaeffler diagram or by measurement with calibrated magnetic instruments.

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E. Heat Exchanger Tube to Tubesheet Welds

1. Tube to tubesheet seal welds are required for any of the following conditions:
  - a. When specified in the job specification.
  - b. When design pressure is 1500 psig and greater but differential pressure is less than 1000 psig.
2. Tube to tubesheet strength welds are required for any of the following conditions:
  - a. When specified in the job specification.
  - b. For waste heat boilers.
  - c. When design pressure is 1500 psig and greater with differential pressure of 1000 psig and greater.
  - d. When design temperatures are greater than 750 F.
3. When tube to tubesheet seal welds are specified in the job specification, they shall be in accordance with Figure PFT-12.1 (e), Section I of the ASME Boiler and Pressure Vessel Code. When strength welds are specified they shall be in accordance with Figure PFT-12.1 (g). For exchanger designs where the tubes are considered as stays, only strength (not seal) welds shall be used.
4. For exchangers in aqueous hydrogen sulfide service, carbon steel tubesheets shall have 0.21% C maximum (SA-516 Gr 55 or 60) and carbon steel tubes 0.18% C maximum. Hardness of welds and heat affected zone (HAZ) shall not exceed 225 HB.
5. Tube to tubesheet mock-up samples shall be submitted to Foster Wheeler for any of the following conditions:
  - a. When specified on the Material Requisition.
  - b. Any material combination involving P-numbers of 21 or greater. (P number from ASME code, Section IX, Table QW-422).
  - c. When strength welds are specified.
6. Tube to tubesheet mock-up samples shall be constructed using actual production welders, materials and procedures for the piece of equipment involved.
7. Tube to tubesheet mock-up samples shall have a minimum of 6 tubes 3 inches in length from the backside of the tubesheet, using the same pitch arrangement as the piece of equipment involved.

F. Selection of Welding Filler Metals

1. Ferritic Steels

Recommended filler metals for similar and dissimilar welds in ferritic steels are given in Table 2 and Table 3.

2. Austenitic Stainless Steels and High Nickel Alloys

Recommended filler metals for joining similar and dissimilar stainless steels and high nickel alloys are given in Table 4.

3. Aluminum and Aluminum Alloys

Recommended filler metals for joining similar and dissimilar aluminum and aluminum alloys are given in Table 5.

4. Integral Clad materials

Recommended filler metals for welding integrally clad materials are given in Table 6.

5. Ferritic Steels to Austenitic Stainless Steels and to High-Nickel Alloys

a. For carbon and low alloy steels welded to 300 series austenitic stainless steels use Type 309 or 309L stainless steels, or nickel-chromium-iron alloy filler metals such as ENiCr Fe-3 (Inconel 182), ENiCrFe-2 (Inco-Weld A), or ERNiCr-3 (Inconel 82).

Where thermal cycling conditions and operating temperatures over 800 F exist, the Inconel filler metals are preferred, except where the environment contains sulfur.

b. For carbon and low alloy steels welded to Inconel or Incoloy alloys, use Inconel welding filler metals ENiCrFe-3 (Inconel 182), ENiCrFe-2 (Inco-Weld A), or ERNiCr-3 (Inconel 82).

c. For carbon and low alloy steels welded to Monel (nickel-copper alloy) use Monel filler metals ENiCu-7 (Monel 190) or ERNiCu-7 (Monel 60).

6. Deviation from the listed tables shall be indicated in the welding procedures.

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### III. PREHEAT

#### A. Ferritic Steels

1. Vessels and Exchangers: Preheat shall be in accordance with ASME Boiler and Pressure Vessel Code, Section VIII; Appendix R recommendations as a minimum, or the applicable requirements of the Code.
2. Piping: Preheat shall be in accordance with the requirements or recommendations, as applicable, of ANSI B31.3. Chemical Plant and Petroleum Refinery Piping Code, or ANSI B31.1 Power Piping Code.

#### B. Austenitic Stainless Steels and High Nickel Alloys

For all thicknesses of austenitic stainless steels, HK, HT, Incoloy and high nickel alloys preheat shall be 50 F minimum. The maximum interpass temperature shall be 350 F.

### IV. POSTWELD HEAT TREATMENT

- A. For all equipment and piping, postweld heat treatment shall be in accordance with the appropriate ASME code and Foster Wheeler Heat Treatment Engineering Standards.
- B. Vessels: Postweld heat treatment shall be in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, or Section I as applicable.
- C. Exchangers: Postweld heat treatment shall be in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, and the TEMA Class specified on the Material Requisition.
- D. Piping: Postweld heat treatment shall be in accordance with the requirements of ANSI B31.3, or ANSI B31.1 as applicable.
- E. When postweld heat treatment is specified for chemical or refinery process reasons no welding nor arc strikes are permitted after final postweld heat treatment, regardless of Code provisions to the contrary.

### V. QUALITY CONTROL REQUIREMENTS

- A. All welds shall have a workmanlike finish to satisfy the requirements of the applicable Code and/or the intended application.
- B. Reinforcement of butt welds shall be in accordance with the requirements of the applicable Code.

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C. Weld repairs shall comply with the requirements of the applicable code, including preheat requirements or recommendations, postweld heat treatment requirements, and nondestructive examination.

D. For pressure containing items, all required repairs of base metal shall be reported to Foster Wheeler for review and approval, prior to making the repair.

E. Inspection shall be performed on all full thickness butt welds as stated below:

1. Piping

a. Radiographic technique and acceptance standards shall conform to ANSI B31.3, or ANSI B31.1 as applicable.

b. Three-fifths of the welds examined shall consist of welds joining a welding neck flange to another component if the fabrication involves such joints.

c. The work of all welders and welding operators for each P-number shall be included in radiography.

2. Vessels and Exchangers

a. Radiographic technique and acceptance standards shall conform to ASME Boiler and Pressure Vessel Code, Section VIII, Paragraph UW-51 or UW-52 as applicable; or ASME Boiler and Pressure Vessel Code, Section I, Paragraph PW-11, PW-41, and PW-51.

b. The work of all welders employed on the job shall be included in this radiography.

c. When submerged arc welding has been used for main seams, all intersections of seams, and all stopping and starting points of weld beads shall be radiographed.

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F. Right of Access

Representatives of Foster Wheeler, the Authorized Inspection Agency, and the client or his agent, shall have access to the vendor's facilities and equipment for the purpose of inspection and audit of work and materials. The Foster Wheeler representative shall have free entry, at all times while work on this Contract is being performed, to all parts of the vendor's works that concern the fabrication, assembly and/or installation. The vendor shall afford the inspector all reasonable facilities to satisfy him that the work is being furnished in accordance with the Contract. All inspection shall be conducted so as not to interfere unnecessarily with the operation of the works.

VI. PROCEDURE SUBMITTAL REQUIREMENTS

- A. Welding procedures shall be submitted to Foster Wheeler for approval for any one of the following conditions:
  1. Any items which receive postweld heat treatment for either process reasons or per the ASME Boiler and Pressure Vessel Code.
  2. All materials or material combinations with P Numbers of 3 or greater. (P-number from ASME Boiler and Pressure Vessel Code, Section IX, Table QW-422).
  3. Any item containing pressure greater than 1000 psig, and temperatures which are greater than 800 F, or less than -20 F.
- B. Vendor shall prepare and qualify welding procedures in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code. The vendor shall submit an index of all weld procedures required for the job accompanied by four copies of each procedure (including the Procedure Qualification Record). In addition, weld maps shall be submitted for vessels and exchangers.
- C. All procedures shall be in accordance with the edition of Section IX of the Boiler and Pressure Vessel Code in effect on the date the Foster Wheeler Purchase Order is placed.
- D. Postweld heat treatment procedures for field PWHT and/or local PWHT for lined, clad or weld overlayed equipment shall be submitted to Foster Wheeler for review and approval.
- E. All procedures shall be submitted at least one month prior to required fabrication date. Submittals shall be made in accordance with the Job General Notes Requisition.
- F. All procedures shall contain the specific information required in Table 1.

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TABLE 1 - SPECIFIC ITEMS TO BE INCLUDED IN WELDING PROCEDURES

DESCRIPTION

- a Welding current type, polarity, amperages and voltages including appropriate ranges
- b Filler metal size, type, classification, A-number and F-number where classified. If no classification is available, give manufacturer's designation
- c Nonconsumable electrode type
- d Arc starting aids or devices
- e Shielding gas composition and flow rate (as applicable)
- f Composition and flow rate of internal gas purging (as applicable)
- g AWS classification, if any, and manufacturer's trade name of designation for welding flux
- h Travel speed for mechanized welding
- i Special requirements such as constant potential power sources, pulse setting, wire feed or oscillation rates, electrode stick-out, etc. (as applicable)
- j Single or multiple arcs
- k Specific precautions that will be taken for field welding, if applicable, to prevent wind or drafts from interfering with the shielding gas protection

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TABLE 2  
 RECOMMENDED FILLER METALS FOR WELDING  
 FERRITIC STEELS

(Code Letter Definitions are given in Table 3)

| MAT'L'S<br>TO BE<br>WELDED | CARBON<br>STEEL | C-1/2 Mo | Mn-Mo | 1 1/4 Cr-<br>1/2 Mo |
|----------------------------|-----------------|----------|-------|---------------------|
| Carbon<br>Steel            | A/B             | B/C      | B/D   | B/E                 |
| C-1/2 Mo                   |                 | C        | C/D   | C/E                 |
| Mn-Mo                      |                 |          | D     | D/E                 |
| 1 1/4 Cr-<br>1/2 Mo        |                 |          |       | E                   |

| MAT'L'S<br>TO BE<br>WELDED | 2 1/4 Cr-<br>1 Mo | 5 Cr-<br>1/2 Mo | 7 Cr-<br>1/2 Mo | 9 Cr-<br>1 Mo | 410S |
|----------------------------|-------------------|-----------------|-----------------|---------------|------|
| Carbon<br>Steel            | B/F               | B/G             | B/H             | B/H           | I    |
| C-1/2 Mo                   | C/F               | C/G             | C/H             | C/H           | I    |
| Mn-Mo                      | D/F               | D/G             | D/H             | D/H           | I    |
| 1 1/4 Cr-<br>1/2 Mo        | E/F               | E/G             | E/H             | E/H           | I    |
| 2 1/4 Cr-<br>1 Mo          | F                 | F/G             | F/H             | F/H           | I    |
| 5 Cr-<br>1/2 Mo            |                   | G               | G/H             | G/H           | G/I  |
| 7 Cr-<br>1/2 Mo            |                   |                 | H               | H             | H/I  |
| 9 Cr-<br>1 Mo              |                   |                 |                 | H             | H/I  |
| 410S                       |                   |                 |                 |               | I    |

TABLE 3 - RECOMMENDED FILLER METALS FOR JOINING FERRITIC STEELS

| FILLER<br>CODE<br>FROM<br>TABLE 2 | MANUAL<br>SHIELDED<br>METAL<br>ARC               | SUBMERGED<br>ARC<br>WIRE<br>(6) | GAS<br>CORED<br>ARC | GAS<br>TUNGSTEN<br>ARC | GAS<br>METAL<br>ARC |
|-----------------------------------|--------------------------------------------------|---------------------------------|---------------------|------------------------|---------------------|
| A                                 | E6010(1)<br>E6011(1)                             | Carbon<br>Steel<br>(7) (8)      | E70T-1<br>E70T-5    | E70S-3<br>E70S-2       | E70S-3<br>E70S-3    |
| B                                 | E7018<br>E7015<br>E7016                          | Carbon<br>Steel<br>(7) (8)      | E70T-1<br>E70T-5    | E70S-3<br>E70S-2       | E70S-3<br>E70S-2    |
| C                                 | E7018-A1<br>E7015-A1<br>E7016-A1                 | EA2,<br>EA3                     | C-1/2 Mo            | E70S-1B<br>(Mn-Mo)     | E70S-1B<br>(Mn-Mo)  |
| D                                 | E9018-D1(2)<br>E9015-G(3)                        | EA3                             | ---                 | E70S-1B<br>(Mn-Mo)     | E70S-1B<br>(Mn-Mo)  |
| E                                 | E8015-B2<br>E8015-B2L(4)<br>E8016-B2<br>E8018-B2 | EB2                             | 1 1/4 Cr-1/2 Mo     | Type 515               | Type 515            |
| F                                 | E9015-B3<br>E9015-B3L(4)<br>E9016-B3<br>E9018-B3 | EB3                             | 2 1/4 Cr-1 Mo       | Type 521               | Type 521            |
| G                                 | E502-15(5Cr)                                     | ER 502                          | 5 Cr-1/2 Mo         | ER 502                 | ER 502              |
| H                                 | E7Cr-15(7Cr)<br>(E505-15<br>(7Cr of 9Cr)         | ---                             | ---                 | ER 505<br>ER 505       | ER 505<br>ER 505    |
| I                                 | E309-15<br>E309-16                               | ER 309L                         | ---                 | ER 309L                | ER 309L             |

NOTES FOR TABLE 3:

1. Use only as root pass.
2. For hydrogen service, special order resulting in welds with 0.40 to 0.60% Mo content must be used.

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3. This refers to special E9015-G electrode developed by Champion to weld Mn-Mo steel.
4. For equipment operating in creep range do not use low carbon grade of filler metal.
5. Where austenitic stainless steel filler metal is used for dissimilar metal joints, thermal stresses resulting from difference in coefficients of thermal expansion shall be considered.
6. Alloy welding electrodes shall have the alloying agents in the wire and not in the flux.
7. Manganese - Molybdenum steel electrode wires may be used provided the weld metal hardness does not exceed a hardness of 200 BHN.
8. Electrodes specified in ASME SA5.7, and electrode classifications EL12 or EM12K, specified in ASME SFA5.23, shall not be used for submerged arc welding carbon steels having a minimum specified tensile strength of 70,000 psi or higher, where postweld heat treatment is specified.

TABLE 4 - RECOMMENDED FILLER METALS FOR JOINING AUSTENITIC STAINLESS STEELS AND HIGH-NICKEL ALLOYS (1), (2), (3), (4)

| MAT'L'S<br>TO BE<br>WELDED | 301<br>302<br>304 | 304L | 309<br>309S | 310<br>210S | 316 | 316L |
|----------------------------|-------------------|------|-------------|-------------|-----|------|
| 301                        | 308               | 308  | 308         | 308         | 308 | 308  |
| 302                        |                   |      |             | 309         |     |      |
| 304                        |                   |      |             |             |     |      |
| 304L                       |                   | 308L | 308         | 308<br>309  | 308 | 308L |
| 309                        |                   |      | 309         | 309         | 309 | 316  |
| 309S                       |                   |      |             | 309         | 316 | 309  |
| 310                        |                   |      |             | 310         | 309 | 309  |
| 310S                       |                   |      |             |             | 316 | 316  |
| 316                        |                   |      |             |             | 316 | 316  |
| 316L                       |                   |      |             |             |     | 316L |

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TABLE 4 (Continued)

| MAT'L'S<br>TO BE<br>WELDED | 317 | 321         | 347         | 348         | INCOLOY<br>800        | MONEL               |
|----------------------------|-----|-------------|-------------|-------------|-----------------------|---------------------|
| 301                        | 308 | 308         | 308         | 308         | NiCrFe-3<br>ERNiCr-3  | ---                 |
| 302                        |     |             |             |             |                       |                     |
| 304                        |     |             |             |             |                       |                     |
| 304L                       | 308 | 308L        | 308L        | 308L        | ENiCrFe-3<br>ERNiCr-3 | ---                 |
| 309                        | 317 | 321         | 347         | 348         | ENiCrFe-3<br>ERNiCr-3 | ---                 |
| 309S                       | 309 | 309         | 309         | 309         | ENiCrFe-3<br>ERNiCr-3 | ---                 |
| 310                        | 309 | 309         | 309         | 309         | ENiCrFe-3<br>ERNiCr-3 | ---                 |
| 310S                       |     |             |             |             |                       |                     |
| 316                        | 316 | 316         | 316         | 316         | ENiCrFe-3<br>ERNiCr-3 | ---                 |
| 316L                       | 316 | 316L<br>321 | 316L<br>347 | 316L<br>348 | ENiCrFe-3<br>ERNiCr-3 | ---                 |
| 317                        | 317 | 317<br>321  | 317<br>347  | 317<br>348  | ENiCrFe-3<br>ERNiCr-3 | ---                 |
| 321                        |     | 321<br>357  | 321<br>347  | 321<br>348  | ENiCrFe-3<br>ERNiCr-3 | ---                 |
| 347                        |     |             | 347         | 347<br>348  | ENiCrFe-3<br>ERNiCr-3 | ---                 |
| 348                        |     |             |             | 348         | ENiCrFe-3<br>ERNiCr-3 | ---                 |
| Incoloy<br>800             |     |             |             |             | ENiCrFe-3<br>ERNiCr-3 | ---                 |
| Monel                      |     |             |             |             |                       | ENiCu-7<br>ERNiCu-7 |

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WELDING REQUIREMENTS  
FOR EQUIPMENT AND PIPING

FOSTER  WHEELER  
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NOTES FOR TABLE 4:

1. Deposited Type 300 stainless steel weld metal shall have a delta ferrite number as indicated in Paragraph II.D.4.
2. Filler metals used in welding 316, 316L or 317 parts in fatty acid service shall contain a minimum Mo content of 2.5% and a maximum carbon content of 0.03%.
3. Where Type 321 filler metal is specified, this applies to bare welding filler metal. For coated electrodes, use Type 347.
4. Filler metals used in welding Monel parts in hydrofluoric acid service shall contain no columbium.

TABLE 5 - RECOMMENDED FILLER METALS FOR JOINING ALUMINUM AND ALUMINUM ALLOYS (1)

| MAT'L'S<br>TO BE<br>WELDED | 1060             | 1100             | 3003             | 3004             | 5050             | 5052               |
|----------------------------|------------------|------------------|------------------|------------------|------------------|--------------------|
| 1060                       | ER1260<br>ER4043 | ER1100<br>ER4043 | ER1100<br>ER4043 | ER4043           | ER1100<br>ER4043 | ER4043             |
| 1100                       |                  | ER1100<br>ER4043 | ER1100<br>ER4043 | ER4043<br>ER5356 | ER4043<br>ER5356 | ER4043<br>ER5356   |
| 3003                       |                  |                  | ER1100<br>ER4043 | ER4043<br>ER5356 | ER4043<br>ER5356 | ER4043<br>ER5356   |
| 3004                       |                  |                  |                  | ER4043<br>ER5356 | ER4043<br>ER5356 | ER4043<br>ER5356   |
| 5050                       |                  |                  |                  |                  | ER4043<br>ER5356 | ER4043<br>ER5356   |
| 5052<br>5652               |                  |                  |                  |                  |                  | ER5654<br>ER5356 * |

TABLE 5 (Continued)

| MAT'L'S<br>TO BE<br>WELDED | 5083             | 5086             | 5154<br>5254       | 5456               | 6061<br>6063       |
|----------------------------|------------------|------------------|--------------------|--------------------|--------------------|
| 1060                       | ER5356<br>ER4043 | ER5356<br>ER4043 | ER4043<br>ER5183   | ER5356<br>ER4043   | ER4043             |
| 1100                       | ER5356<br>ER4043 | ER5356<br>ER4043 | ER4043<br>ER5183   | ER5356<br>ER4043   | ER4043             |
| 3003                       | ER5356<br>ER4043 | ER5356<br>ER4043 | ER4043<br>ER5183   | ER5356<br>ER4043   | ER4043             |
| 3004                       | ER5356<br>ER5556 | ER5356<br>ER5556 | ER5654<br>ER5356 * | ER5356<br>ER5556   | ER4043<br>ER5356 * |
| 5050                       | ER5356<br>ER5556 | ER5356<br>ER5556 | ER5654<br>ER5356 * | ER5356<br>ER5556   | ER4043<br>ER5356 * |
| 5052<br>5652               | ER5356<br>ER5556 | ER5356<br>ER5556 | ER5654<br>ER5356 * | ER5356<br>ER5556 * | ER5356<br>ER5556 * |
| 5083                       | ER5183<br>ER5356 | ER5356<br>ER5556 | ER5356<br>ER5556   | ER5183<br>ER5556   | ER5356<br>ER5556   |
| 5086                       |                  | ER5356<br>ER5556 | ER5356<br>ER5556 * | ER5356<br>ER5556   | ER5356<br>ER5556   |
| 5154<br>5254               |                  |                  | ER5654<br>ER5356 * | ER5356<br>ER5556 * | ER5356<br>ER5556 * |
| 5456                       |                  |                  |                    | ER5556<br>ER5356   | ER5356<br>ER5556   |
| 6061<br>6063               |                  |                  |                    |                    | ER4043<br>ER5356 * |

NOTES FOR TABLE 5:

1. The filler metal listed on the top line of each combination is the preferred wire. The filler metal listed on the bottom line of each combination is an acceptable alternate.

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\* The choice of filler metal may be limited by service conditions such as immersion in fresh or salt water, exposure to specific chemicals, or to a sustained temperature between 150 F and 450 F. Contact Foster Wheeler Technical Services and Quality Control Department if such conditions exist for specific recommendations.

TABLE 6 - RECOMMENDED FILLER METALS FOR WELDING INTEGRALLY CLAD MATERIALS

| CLADDING MATERIAL               | SPECIFIC REQUIREMENTS | FILLER METALS FOR OVERLAYING WELDED JOINT (4) |
|---------------------------------|-----------------------|-----------------------------------------------|
| 70 Ni-30 Cu<br>(Annealed Monel) |                       | ASME SFA-5.11<br>Class ENiCu-7 (1)            |
| 12Cr                            | Type 410              | Do Not Overlay                                |
|                                 | Type 410S             | ASME SFA-5.11<br>Class ENiCrFe-3 (2)          |
|                                 |                       | ASME SFA-5.4<br>Class E309L (3)               |
|                                 | FIRST PASS            | SUBSEQUENT PASSES                             |
| Austenitic                      | Type 304              | 308L                                          |
| Stainless Steel                 | Type 304L             | 308L                                          |
|                                 | Type 316              | 316                                           |
|                                 | Type 316L             | 316L                                          |
|                                 | Type 321              | 347                                           |
|                                 | or                    |                                               |
|                                 | Type 347              |                                               |

NOTES FOR TABLE 6:

1. ENiCu-7 (Monel welding electrode 190, or equal)
2. ENiCrFe-3 (Inconel welding electrode 182, or equal) preferred for temperatures above 800 F or where thermal cycling conditions are anticipated. Consult Foster Wheeler Technical Services and Quality Control Department if environment contains sulfur above 800 F.
3. For operating temperatures below approximately 800 F and/or where thermal cycling conditions are not severe.
4. Overlays usually require a minimum of two layers; however single-layer overlays are acceptable provided dimensional requirements are met and chemical composition and soundness are satisfactory. The number of layers in production shall not be less than the number of layers in the procedure qualification test.



JOB SPECIFICATION NO. 60863-89A1

PRESSURE TESTING

The subject specification is issued herewith per index of pages noted below. If this is a later revision than now in your possession, please destroy superseded pages and insert the revised pages.

Initial issue X  
Entire specification reissued         
Revised pages only attached       

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\* Pages revised for this issue are noted by asterisk.

Issue No. 1 Date 4/25/79

Basis: Dow Chemical Co.  
Specification

## PIPING TESTING PROCEDURE

## 1. Scope

- 1.1 To provide definite requirements for testing piping systems to be installed for or by The Dow Chemical Company. Various classes of testing are included in order to obtain a stringent test of important lines, or a less rigorous test of secondary lines, as required by the service.
- 1.2 The term "piping system" as used herein is intended to include pipe, valves, and fittings. Vessels, instruments, and relief devices are not included.
- 1.3 The acceptance of piping systems under this specification includes approval for pressure tightness only.
- 1.4 Vessels and flanged items not included in the tests shall be isolated by line blinds. Line blinds shall be installed between existing piping and new piping under test to prevent application of pressure to existing lines. The Dow representative shall be notified in advance by the contractor of test schedules and test conditions.

## 2. Materials and Services

- 2.1 Dow will furnish water for test purposes at existing pressures within the block or plant limits when available. Dow will furnish all required Freon R-12. If a recording instrument is required for the test, Dow will furnish the instrument and the contractor shall install and remove same. The contractor shall furnish all miscellaneous pipe, gauges, fittings, test pumps, or compressors, line blinds, valves, etc., necessary to provide the proper testing equipment. All such materials shall be removed upon completion of testing unless shown on the drawings as part of the finished work. The contractor shall furnish all piping or hose from the source of water to the point of test connection and shall be responsible, when bidding, for determining the nearest source of water and what equipment will be needed. Air compressors shall be equipped with discharge filters for removal of water, oil, and foreign matter. Maximum discharge temperature of oil lubricated air compressors shall be 300°F.
- 2.2 The contractor shall furnish experienced test crews of adequate size, equipped with sufficient and proper hand tools, to handle properly the testing operations. The Dow representative shall determine the adequacy of all equipment used by the test crews.
- 2.3 The contractor shall be responsible for the removal of water used in testing from all piping systems. Where ditches or temporary lines to ditches are necessary, the contractor shall provide them; after their use, such ditches or lines shall be removed leaving the area in its original, or equal, condition.

- 2.4 If special drying or special cleaning is required after testing is completed, it will be done by Dow unless otherwise specified in the job specifications.
- 2.5 Blowdown of all steam lines preparatory to test or putting into service shall be done by the Dow Power Department outside block limits or by the Dow plant superintendent inside block limits. All valves connecting to existing water mains, process lines, etc., shall be opened only by Dow's proper representative.
- 2.6 Where large vapor or gas lines are to be hydrostatically tested, the contractor shall not start the test until he has assurance from the Dow representative that the line will support the weight of the test liquid.

### 3. Specification of Class Required

Classes of test will be specified as follows:

- 3.1 The line schedule issued giving general specifications for each line such as material, size, insulation, etc., will also contain a designation of the class of test required and the test pressure.
- 3.2 In the absence of a line schedule, the class of test and pressure required may be covered in the job specification, construction order, or for maintenance jobs by an AVO.

### 4. Details of Test

#### 4.1 General

- 4.1.1 Air and instrument air supply piping shall not be cleaned or tested with water. Before the final connection is made to instrument, accessory or equipment, the lines shall be blown free of all dirt, scale, filings, or other extraneous matter. Instrument air supply piping is defined as piping that connects instruments to the air supply system (Note: This does not include instrument pneumatic transmission tubing or pipe, which is to be cleaned and tested per 61-110 and 61-150).

All other piping shall be thoroughly cleaned and flushed with water before testing. This shall include instrument process piping, which is defined as piping that connects instruments to process lines or vessels and is to contain process fluids. Instrument process piping shall not be connected to the instrument or accessory during cleaning. After washing and prior to connection to instruments, etc., the instrument process piping shall be blown free of all water and extraneous matter.

- 4.1.2 Control valves, safety valves, rupture discs, reducing valves, level controllers, level switches, orifice plates, and other instruments or fittings designated by the Dow representative shall be removed from the lines before cleaning and replaced before testing. All such items, except safety valves, after removal shall be cleaned separately by the contractor. The line bore orifice spacers and gaskets or spare rings furnished with meter runs shall be installed prior to cleaning and remain in place until after testing. Safety valves and rupture discs shall be installed for fit-up, removed during the test and reinstalled. New gaskets shall be used when reinstalling all flanged items. Where control valves are to operate normally shut, the test crew shall not test the line until the valve has been opened by the Dow representative.
- 4.1.3 The contractor shall be responsible for venting piping and vessels while cleaning and testing and, after testing, while draining to insure against their collapse by vacuum.
- 4.1.4 The contractor shall be responsible for any and all damage resulting from test pressures more than 10% higher than specified by Dow. A safety valve or relief valve may be used at the pressure source to protect systems under test. The test crew shall be responsible for venting all sections of piping system and vessels not under direct test to prevent overpressuring any part of system through valve leakage or excess flows.
- 4.1.5 Overtightening of a valve in an effort to make it hold may be cause for rejection of the valve by the Dow representative.
- 4.1.6 For hydrostatic tests, every precaution shall be taken for the removal of trapped air.
- 4.1.7 Pressure gauges shall be of a suitable scale capacity for the pressure, having a dial at least  $4\frac{1}{2}$ " in diameter. The maximum pressure capacity shall not exceed three times the particular test pressure. The gauges shall be checked against a standard gauge by the Dow Instrument Department.
- 4.1.8 Variations of pressure and volume due to temperature changes shall be taken into account by the Dow representative in determining whether pressure during test is satisfactory. Visual checks of short duration may be made at intermediate pressures at the option of the Dow representative.
- 4.1.9 All hydrostatic tests are assumed to be made, using water, unless otherwise stated.

- 4.1.10 Presence of the Dow representative is not necessary while initial going-over of lines for leaks is progressing.
- 4.1.11 No insulation shall be allowed on systems under test except on those parts which have had a certified shop test.
- 4.1.12 The test fluid shall not be allowed to freeze. When testing steel piping below 40°F, a written Safe Work Procedure will be required to protect against brittle fracture hazards.
- 4.1.13 Pressure tests shall include as much instrument process piping as possible. Where an instrument process line contains more than one block valve, all valves should be open except that nearest the instrument.
- 4.1.14 All instruments and similar special equipment are to be protected against overpressure during cleaning and testing by disconnecting the piping between the closed block valves and the instruments. Direct operated or self-contained regulators are to be removed or blocked and vented. Special care is to be exercised in the protection of float actuated devices, such that float is not subjected to collapsing pressure.
- 4.1.15 Expansion joints having tie-rods may be tested as part of the piping system unless otherwise specified. The tie-rods must be hand tight, with no slack under the outside nuts. Expansion joints not having tie-rods shall be removed or isolated from the test. The contractor shall check the drawings and specifications for any specific installation or operating instructions pertaining to the expansion joint.
- 4.1.16 A written Safe Work Procedure shall be submitted by the contractor for approval of the Dow representative and manufacturing representative prior to beginning of Class D Pneumatic or Class K Ultrasonic tests if the test pressure is to exceed 15 psig. The procedure shall cover a minimum of the following items: Pretest visual inspection, areas to be roped off, time schedule, and indoctrination of personnel on hazards involved.
- 4.1.17 At the completion of the test, all blinds, plugs, caps, etc. used to isolate vessels, instruments, etc. shall be removed, flange faces and threads inspected for damage and piping re-connected. Gaskets removed after tests shall not be re-used. Special care is required when reconnecting these points to avoid leaks.

## 5. Classes of Tests

### 5.1 Class B - Hydrostatic:

- 5.1.1 Each valve shall be pressure tested to the satisfaction of the Dow representative. Valve test shall not exceed 20 minutes. Where valves occur in headers, both sides shall be tested at the option of the Dow representative.
- 5.1.2 After all valves have been tested, the entire system shall hold the designated pressure for a period of four hours.

### 5.2 Class C - Hydrostatic:

- 5.2.1 Complete line or section of line containing several valves and branches may be tested at one time. The duration of test shall not exceed four hours. Generally, the Dow representative shall fix the duration of test as only sufficient to examine the line and satisfy himself that there is no leakage.

### 5.3 Class D - Pneumatic:



CAUTION: Pneumatic testing should be used only as a last alternative. Carefully planned and supervised procedures shall be used to guard against the hazards of latent energy of compressed gases. (See 4.1.16)

This class covers tests made with air, nitrogen, or other gases for piping designed in accordance with ANSI B31.3, Code for Petroleum Refinery Piping. Where applicable, the test shall meet the requirements of OSHA 1910.106, Flammable and Combustible Liquids, and 1910.110, Storage and Handling of Liquified Petroleum Gases. Piping designed by other Codes shall be tested in accordance with those Codes.

#### 5.3.1 Low Pressure Test - Maximum 15 psig.

- 5.3.1.1 Prior to testing, a thorough visual inspection shall be made for defects such as improper materials, poor gasket installation, loose joints, etc. All bolts must be made up tight.
- 5.3.1.2 All flanged joints shall be taped shut using a suitable adhesive coated paper tape with a small vent hole punched in the tape. The tape shall be applied very carefully to insure an airtight seal all around both flanges.



5.3.1.3 Soapsuds made from mild soap or a commercial bubble test fluid shall be applied to each vent hole for flanged joints and all around each screwed or welded joint. Any leak detected shall be marked for the subsequent inspection of the Dow representative if he is not immediately present.

5.3.1.4 The first leakage check shall be made at 5 psig max. Any detectable leaks shall be eliminated before proceeding. The leakage test may be repeated at higher pressures not to exceed 15 psig or the specified test pressure, whichever is lower, as directed by the Dow representative.

5.3.2 High Pressure Test - Above 15 psig

CAUTION: Special precautions required. (See 4.1.16)

Joints are not to be taped for this test. All personnel shall be kept clear of the immediate area while the test pressure is being raised. The pressure shall be raised slowly in stepwise fashion in increments of not more than 20% of the maximum test pressure (10 psig steps are acceptable up to 50 psig test pressure). Pause 5 minutes minimum at each step to allow for inspection and equalization of strains. Leak detector used shall be ultrasonic type per 5.8.3. If there is evidence of leakage, the pressure will be reduced by a minimum of 20% or as required to locate and correct any leakage detected. The testing shall continue stepwise until the final test pressure is reached and held for 10 minutes minimum without evidence of leakage.

5.4 Class F - Fire Mains, Sprinkler and Spray Systems

5.4.1 Wet Pipe Sprinkler Systems (See Eng. Spec. 47-101 and NFPA 13, 1973, Chapt. 1, Sect. 1-11)

Prior to connection to the sprinkler riser entering the building, the fire water mains shall be flushed at an approximate rate as follows, until clear:

|     |          |
|-----|----------|
| 6"  | 750 gpm  |
| 8"  | 1000 gpm |
| 10" | 1500 gpm |
| 12" | 2000 gpm |

After flushing, connect the main to the riser and flush all piping with heads in place or plugged and bulk-main flush connections open, using full line pressure. Where necessary, flush by sections for adequate flow through all openings. Hydrostatically pressure test entire system for 2 hours with heads in place at 200 psig minimum or 50 psig in excess of max. static line pressure where max. line pressure exceeds 150 psig.

5.4.2 Water Spray Fixed Systems (deluge)  
(See Eng. Spec. 47-102 and NFPA 15, 1973, Chapt. 5)

Prior to connection to the deluge valve, the fire water mains shall be flushed at an approximate rate as follows, until clear.

|     |                        |
|-----|------------------------|
| 4"  | 390 gpm (10 ft./Sec.)  |
| 6"  | 880 gpm (10 ft./Sec.)  |
| 8"  | 1560 gpm (10 ft./Sec.) |
| 10" | 2440 gpm (10 ft./Sec.) |
| 12" | 3520 gpm (10 ft./Sec.) |

After flushing, connect the main to the deluge system and flush all spray piping down stream at full line pressure with spray nozzles removed, until clear. Where necessary, flush by sections for adequate flow through all openings.

Pilot air system piping shall be cleaned and tested as follows:

With the air filter, pressure regulator and pilot valve omitted from the test, hydrostatically pressure test the piping at 70 psig for 1 hour with all pilot heads in place. After completion of test, drain water and blow out one branch at a time by introducing 50-75 psig air and releasing the air at the most remote pilot head opening of the branch, with all other openings closed.

A final acceptance test in operation shall be made, to be witnessed by a representative from Loss Prevention Engineering

5.5 Class G - Hydrostatic (Gravity):

5.5.1 This test for vents, standpipes, etc., requires the filling of the piping system with water and visual inspection for leaks. No pressure shall be applied by pump, by supply line, or other external source. The test crew shall be responsible for filling such a system at a rate low enough to prevent pressuring due to restricting outflow of air.

5.6 Class H - Boiler Code:

5.6.1 Boiler piping shall be tested in accordance with the ASME Power Boiler Code. Boiler piping includes all piping attached to the boiler, up to and including the second valve from the boiler, for multiple-boiler installations. For single boilers, the piping may include all piping up to the first valve only.

5.7 Class J - Halogen:

5.7.1 Halogen leak detector shall be used to detect leaks at all welds, seams, joints, and other areas of possible leakage.

5.7.2 This test shall be made by pressuring up the piping system to be tested to 13 psig by use of a compressed air source; then increasing the pressure to 15 psig with Freon R-12. The pressure shall be held at 15 psig until testing is completed.

5.7.3 All flanged joints shall be taped shut using a suitable adhesive coated paper tape with a small vent hole punched at one point, preferably on top. All bolts or studs must be made up tight. Tape shall be carefully applied to insure an airtight seal all around both flanges.

5.7.4 The Halogen testing equipment shall be General Electric Halogen Leak Detector, Type H-2, or approved equal, and used in accordance with the manufacturer's recommendations.

5.8 Class K - Ultrasonic:

5.8.1 Ultrasonic leak detector shall be used to detect leaks at all welds, seams, joints, and other areas of possible leakage.

5.8.2 This test shall be made by pressuring up the system to be tested to 15 psig by use of a compressed air source. The pressure shall be held at 15 psig until testing is completed. This test may be conducted at pressures above 15 psig if proper safety procedures are observed per 4.1.16 and 5.3.2.

5.8.3 The Ultrasonic testing equipment shall be Delcon Model 4918A, Euphonics Model 500, or approved equal, and used in accordance with the manufacturer's recommendations.

5.9 Class L - Operating Pressure:

5.9.1 CAUTION: This test, in general, is limited to sea water, river water, and potable water systems.

5.9.2 Complete lines, section of lines, or complete systems may be tested at one time.

5.9.3 This test shall be made by putting the lines to be tested into operation.

5.9.4 Instrument pneumatic transmission tubing or pipe shall be tested per Engr. Spec. 61-110 and 61-150.

## 6. Retests

6.1 In the event that a piping system or any part fails to pass the test prescribed, a new test shall be applied after repairs and corrections have been made. This retest shall include all parts of a connected system which may have passed a test previously, but which in the opinion of the Dow representative have been affected by the corrections made or by a delay attending to the corrections.

## 7. Acceptance

7.1 The Dow representative shall signify his acceptance by initialing the approved portions of the piping system on the contractor's set of prints or by any other definite means mutually agreed upon.

APPENDIX D.10  
ADMINISTRATIVE

JOB SPECIFICATION 60863-96A1

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## PLANT COMPLETION

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**I. SCOPE**

This standard is intended to define when the responsibility for care, custody and control of various units, systems or facilities of a plant is transferred from Foster Wheeler to the Client. The general principles differentiating the limits and responsibilities for the work for both parties are defined and a tabulation of the specific work performance responsibilities required to place common process equipment or systems into operation is presented.

**II. DEFINITIONS**

(1) This section presents definitions which, along with the General and Specific Procedures given in Paragraphs III and IV, serve to clarify the basic principles associated with the transfer of responsibility from the contractor to the Client at commissioning time.

(1) A. Pre-commissioning. Pre-commissioning activities are the nonoperating adjustments and cold alignment checks made by the contractor as detailed in Paragraphs III and IV.

(1) B. Ready for Commissioning. The date when the plant or part thereof is "ready for commissioning" occurs when the plant, unit or facility or part thereof has been erected in accordance with drawings, specifications, and applicable codes, to the extent necessary to permit commissioning, and pre-commissioning activities have been completed by contractor as detailed in Paragraphs III and IV.

(1) C. Commissioning. Basically, commissioning activities are associated with the running or operating of the plant and are the Client's responsibilities unless specifically directed otherwise by the contract.

The commissioning period by the Client follows the completion of the pre-commissioning activities performed by Foster Wheeler. During commissioning, the Client makes operating adjustments required before the plant may be satisfactorily operated, and commences operation of the plant or part thereof, performing any further adjustments, settings, etc., that may be required.

D. Completion of Construction. Completion of construction means that the contractor has:

1. Provided erection in accordance with drawings and specifications.
2. Completed pre-commissioning work.
3. Completed final cleanup, painting, and thermal insulation work.

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### III. GENERAL PROCEDURES

General work procedures tabulated in Table I outline the work to be performed by Foster Wheeler and by the Client. Procedures applicable to specific systems or items of equipment are separately covered in Paragraph IV.

(1)

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III. GENERAL PROCEDURES

TABLE I

| Item                               | By Foster Wheeler                                                                                                                                                                                                                                                                             | By Client                                                                                                                                                                                                                                                                           |
|------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A<br>Vendor and Service Assistance | Obtain manufacturer's (vendor) assistance when deemed necessary to render a satisfactory installation, as mutually agreed between Foster Wheeler and the Client.                                                                                                                              | Obtain manufacturer's (vendor) assistance if desired, for operating, or run-in by the Client's operating and maintenance personnel; and for training, or other informational and operating purposes.                                                                                |
| B<br>Leak and Pressure Tests       | <p>Make non-operating field leak or pressure tests on piping and field fabricated equipment. All testing will be conducted in accordance with ENG STD 89A1.</p> <p>Dispose of any special test media in accordance with Client instructions.</p> <p>Notify Client of test schedule.</p>       | <p>Provide any special media for test purposes and facilities for disposal.</p> <p>Witness tests when notified by Foster Wheeler.</p> <p>Conduct all operational tightness testing.</p>                                                                                             |
| C<br>Inspection                    | <p>Provide inspection of the plant to check conformity of erected facilities to flow diagrams, construction drawings, vendor prints, and specifications.</p> <p>Shop inspected equipment will not be reopened for inspection in the field except as specifically noted in Paragraph IV.D.</p> | <p>Provide for special inspections such as required by insurance or governmental agencies and obtain required approvals.</p> <p>Perform shop inspection as desired.</p> <p>Verify and approve plant check with any exceptions noted on a separate work order list (punch list).</p> |

III. GENERAL PROCEDURES

TABLE I (contd)

| Item                                               | By Foster Wheeler                                                                                                                                                                                                                                  | By Client                                                                                                                                                                                                                                                                                                                                                  |
|----------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (2) D<br>Permits                                   | <p>Secure permits and certifications required by or for his design work or for his erection work.</p> <p>Assist client in the procurement of all permits and certifications required to be secured by the client for initial use of the plant.</p> | <p>Make applications for and procure all permits issued in his name and required for plant installation, use, occupancy, and operation.</p>                                                                                                                                                                                                                |
| (2) E<br>Removal of<br>Rust<br>Preventives         | <p>Remove all rust preventives and oils used to protect the equipment during the construction period when such material will be detrimental to operation.</p> <p>Maintain record of removal.</p>                                                   |                                                                                                                                                                                                                                                                                                                                                            |
| (2) F<br>Operating<br>Supplies<br>and<br>Chemicals | <p>Inspect vessel interior before loading of inert packing materials or chemicals to insure vessel is ready for proper installation.</p>                                                                                                           | <p>Procure and install all inert packing materials and beds and/or all materials in apparatus containing chemicals, resins, dessicants, catalysts, and other such operating materials except as specifically noted in Paragraph IV.</p> <p>Inspect vessel internals and operating materials during the loading.</p> <span style="float: right;">(1)</span> |

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## III. GENERAL PROCEDURES

TABLE I (contd)

| Item                        | By Foster Wheeler                                                                                                                                                                                                                                           | By Client                                                                                                                                                                                                           |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (2) G<br>Lubricants         | <p>Include vendor's lubricant recommendations in the mechanical catalog.</p> <p>Install initial charge only of all lubricants as provided by the Client.</p>                                                                                                | <p>Develop lubrication list with lubricant supplier and equipment vendor.</p> <p>Maintain lubrication after initial charge.</p>                                                                                     |
| H<br>Rotation and Alignment | <p>Check rotating machinery for correct direction of rotation and freedom of moving parts before connecting driver.</p> <p>Make only cold alignment to manufacturer's tolerances.</p> <p>Foster Wheeler will not operate or run any piece of equipment.</p> | <p>Operate equipment and make vibration checks, trip checks, governor checks, and safety device check, and other operating tests and adjustments required.</p> <p>Make hot alignment and any doweling required.</p> |
| J<br>Packing and Seals      | Install mechanical seals, permanent packing and accessories when required.                                                                                                                                                                                  | Make necessary adjustments and replacements to mechanical seals, packing, and accessories during commissioning period.                                                                                              |
| K<br>Safety Devices         | <p>Install all safety devices e.g., pressure relief valves, after testing and adjustment by the Client.</p> <p>Provide Client with proper settings of safety devices.</p>                                                                                   | <p>Test and adjust all safety devices and seal where necessary or desirable.</p> <p>Maintain the necessary records.</p>                                                                                             |

III. GENERAL PROCEDURES

TABLE I (contd)

| Item                                         | By Foster Wheeler                                                                                                                          | By Client                                                                                                                                                                                                                   |
|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (I) L<br>Flushing and Chemical Cleaning      | Turn systems over to the client free of trash and construction debris (not necessarily free of welding slag.)                              | Conduct all flushing, blowing and chemical cleaning operations and provide circulating media and chemicals required except as noted in paragraphs IV.B, IV.G, and IV.H. Dispose of any resultant wastes and cleaning media. |
| M<br>Temporary Strainers, Screens and Blinds | Provide and install all required temporary strainers.                                                                                      | Clean strainers as required during circulation and remove when warranted.<br><br>Provide, install, and remove all blinds required for flushing or operation.<br><br>Maintain required records.                              |
| N<br>Drying Out                              | Dry out when required to complete further construction or where facilities supplemental to those required for normal operation are needed. | Dry out systems, refractories and linings when such drying can be accomplished with permanently installed equipment or as part of the commission-activities.                                                                |
| P<br>Purging                                 | Install purge connections.                                                                                                                 | Provide purge materials and conduct necessary purge operations.                                                                                                                                                             |

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## III. GENERAL PROCEDURES

TABLE I (cont'd)

| Item                                 | By Foster Wheeler                                                                                                                                                                                                 | By Client                                                                                                                                                                                                                      |
|--------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (2) Q<br>Maintenance and Spare Parts | <p>Protect equipment from normal weather conditions, corrosion, or damage prior to commissioning.</p> <p>Include vendors recommended spare parts lists in Mechanical Catalogs.</p>                                | <p>Provide adequate maintenance for equipment, including such items as the cleaning of strainers and the repairing of steam traps, after pre-commissioning is complete.</p> <p>Maintain adequate spare parts and supplies.</p> |
| R<br>Housekeeping                    | <p>Provide construction cleanup including removal of excess materials, temporary facilities and scaffolding, rough sweeping or raking the area, and trash pickup. Washing or further cleanup is not included.</p> | <p>Maintain adequate housekeeping practices after pre-commissioning is complete as required for safe operation.</p>                                                                                                            |
| S<br>Tie-ins at Unit Limits          | <p>Obtain Client's approval and make the necessary tie-ins at the unit limits as required by the specifications.</p>                                                                                              | <p>Prepare all systems for safe tie-ins and observe same.</p>                                                                                                                                                                  |
| T<br>Instructions                    | <p>Transmit to client any vendor's or manufacturer's instructions and drawings, as applicable.</p> <p>Provide client with any special instructions such as requirements for drying liners.</p>                    | <p>Maintain adequate vendor instruction file so that the information may readily be retrieved as may be required.</p>                                                                                                          |

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### III. GENERAL PROCEDURES

TABLE I (contd)

| Item                                                          | By Foster Wheeler                                                                                                                                                                                                                                                                                                              | By Client |
|---------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| U<br>Removal of<br>Temporary<br>Bracing,<br>Supports,<br>etc. | Remove all temporary supports,<br>bracing, or other foreign objects<br>which have been installed in equipment<br>to prevent damage during<br>shipping, storage, and erection.<br>e.g., vessels, transformers, rotating<br>machinery, etc., including other<br>items specified elsewhere for the<br>appropriate equipment type. |           |

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IV. SPECIFIC PROCEDURES

In addition to the work to be performed in accordance with Paragraph III, General Procedures, the detailed procedures outlined in Table II below further define the work responsibilities of Foster Wheeler and Client for specific systems and items of equipment.

TABLE II

| Item                                           | By Foster Wheeler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | By Client                                                                                                                                                                                                                                                                                                                                                                                                                            |
|------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (2) A<br>Electrical Power and Lighting Systems | <p>Notify client of test schedule.</p> <p>Test electrical installations in accordance with ENG STD 70A2.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <p>Witness tests when notified and record test data if desired.</p>                                                                                                                                                                                                                                                                                                                                                                  |
| B<br>Instrument Systems                        | <p>Foster Wheeler will not field calibrate any instrument component unless required by the job specifications. He will, however, make such non-operating checks which will assure instrument operability i.e., remove all shipping stops, check pointer travels, and verify instrument capability to measure, operate, and stroke in the direction and manner required by the process application.</p> <p>Install and connect all system components and verify their conformance with specifications and design criteria for function and range using dummy transmitted signals as needed.</p> <p>Clean all transmission and control tubing by blowing with cooled and filtered clean air prior to connecting to instrument components.</p> <p>Clean all air supply headers by blowing with clean air and check for tightness.</p> <p>Leak test pneumatic control circuits in accordance with ISA Recommended Practice RP 7.1.</p> <p>Check process lead piping for tightness.</p> | <p>As dictated by his practice, calibrate instruments with standard test equipment and make all required adjustments and control point setting.</p> <p>Fully pressurize and energize the transmitting and control signal system, opening process connections at primary sensors and final regulators and making control mode settings for automatic operation of equipment as the process unit is charged and brought on stream.</p> |

IV. SPECIFIC PROCEDURES

TABLE II (contd)

| Item                        | By Foster Wheeler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | By Client                                                                                                                                                                                                                                               |
|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (1) B<br>Instrument Systems | <p>Check all electrical signal and alarm wiring for continuity, correct source of power, and polarity.</p> <p>Check thermocouples for proper joining of wires, position of elements in wells, proper polarity and continuity of receiving instruments.</p> <p>Identify orifice plates by tagging and deliver to Client.</p> <p>Isolate, or remove if necessary in-line components such as control valves, positive displacement meters, turbine meters, etc. for pressure testing and reinstall such items.</p> | <p>Check bores of orifice plates and install such plates after completion of testing and flushing operations.</p> <p>Isolate or remove in-line components for Client's flushing operations and reinstall them on the completion of such operations.</p> |
| (2) C<br>Piping Systems     | <p>Notify client of test schedule.</p> <p>Hydrostatically or pneumatically test all piping as required by the drawings or specifications in accordance with ENG STD 89A1.</p>                                                                                                                                                                                                                                                                                                                                   | <p>Witness field pressure tests when notified by Foster Wheeler.</p> <p>Perform all operational tightness testing.</p>                                                                                                                                  |

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## IV. SPECIFIC PROCEDURES

TABLE II (contd)

| Item                                 | By Foster Wheeler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | By Client                                                                                                                                         |
|--------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| (1) D<br>Vessels                     | <p>Unhead after erection to place internals requiring field installation except as noted in Paragraph III. F. These internals will be inspected at time of installation.</p> <p>External manways on vessels will be opened for inspection, witnessed by client, even if they have been shop inspected. For these shop inspected vessels, internal manways will not be opened unless required by the job specifications.</p> <p>Head up upon proper execution of closure permits.</p> <p>When vessels have been subjected to a shop test they will not be further tested in the field but may be included as part of a piping system test.</p> | <p>Witness inspections to the extent desired.</p> <p>Unhead after dryout and charge materials as designated in Paragraph III. F. and head up.</p> |
| E<br>Shell and<br>Tube<br>Exchangers | <p>Shop inspected exchangers will not be reopened in the field.</p> <p>When exchangers have been subjected to a shop test they will not be further tested in the field but may be included as part of a piping system test.</p>                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                   |
| F<br>Air Cooled<br>Exchangers        | <p>Inspect to assure that temporary shipping supports and erection material have been removed.</p> <p>When exchangers have been subjected to a shop test they will not be further tested in the field but may be included as part of a piping system test.</p>                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                   |

IV. SPECIFIC PROCEDURES

TABLE II (contd)

| Item                                                 | By Foster Wheeler                                                                                                                                                                                                                                                                                                                            | By Client                                                                                                                                                                                                                                                                                                                                                                 |
|------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| G<br>Fired<br>Heaters                                | <p>Pressure test in accordance with the applicable code, if required.</p> <p>Provide all nonoperating prefiring checks in accordance with manufacturer's instructions.</p> <p>Blow fuel oil lines, check for cleanliness, and connect burner piping.</p> <p>Check operation of registers and dampers, and verify position of indicators.</p> | <p>Dry refractories during initial firing by following the manufacturer's temperature cycles.</p> <p>Conduct boil-out, and chemical cleaning and flushing operations as required.</p> <p>Obtain and charge liquid heat transfer media, if required.</p> <p>Conduct light-off, drying and purging operations.</p> <p>Obtain service engineer for start-up, if desired.</p> |
| H<br>(1)<br>Pumps,<br>Compressors,<br>and<br>Drivers | <p>Level baseplates and sole plates and grout all bearing surfaces.</p> <p>Check for and remove any excess piping stresses which may be imposed on the equipment.</p> <p>Chemically clean the completed installation of any seal and lube oil system, when specified.</p> <p>Charge the lube and seal oil systems with oil.</p>              | <p>Circulate for flushing and cleaning purposes the appropriate medium for the seal, lube and cooling systems.</p> <p>Obtain service engineer for start-up, if desired.</p>                                                                                                                                                                                               |

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IV. SPECIFIC PROCEDURES

TABLE II (contd)

| Item                                                                                                                           | By Foster Wheeler                                                                                                                                                                                                                                                                                                 | By Client                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|--------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| J<br>Miscellaneous<br>(Agitators,<br>Mixers<br>Rotary Filters<br>Weigh Scales,<br>Materials<br>Handling<br>Equipment,<br>Etc.) | <p>Fully assemble rotary filters except for final filter media (cloth or screen).</p> <p>Level and calibrate weigh scales with assistance of the manufacturer's representative and set tare weights where possible.</p> <p>Manually check materials handling equipment for freedom and direction of movement.</p> | <p>Install all final filter media (cloth, precoat, etc.)</p> <p>Make all final adjustments during run-in and any performance tests required.</p> <p>Obtain service engineer for start-up, if desired.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                |
| K<br>Boilers                                                                                                                   | <p>Make nonoperating pressure test in accordance with applicable codes, if required.</p> <p>Inspect installation for completeness and correctness of installation and make other nonoperating pre-firing checks.</p> <p>Check proper damper positioning and travel.</p>                                           | <p>Dry refractories during initial firing by following the manufacturers temperature cycles.</p> <p>Purge, flush, and drain steam mains as necessary.</p> <p>Obtain and charge treated water for boil-out and initial operation as required.</p> <p>Commission auxiliaries as detailed elsewhere under the appropriate equipment type.</p> <p>Conduct boil-out and chemical cleaning and flushing operations, as required.</p> <p>Conduct initial light-off with associated checks and adjustments.</p> <p>Obtain a service engineer for start-up, if desired.</p> <p>Conduct all operating tests and obtain required certification.</p> |

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IV. SPECIFIC PROCEDURES

TABLE II (contd)

| Item                                                                                   | By Foster Wheeler                                                                                                                                                                                                                                                                                                                                                                      | By Client                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| L<br>Water<br>Treating<br>Plants                                                       | <p>Inspect for completeness and correctness of installations and make any nonoperating checks which may be required.</p> <p>Provide and install initial charge of ion-exchange resins and inert bed material.</p>                                                                                                                                                                      | <p>Make the necessary operating tests and adjustments to water treatment systems.</p> <p>Provide all water treatment chemicals except initial charge of ion-exchange resins.</p> <p>Obtain services of water consultant to advise and monitor the water treatment operation as desired.</p>                                                                                                                                                                                                                                                                      |
| (1) M<br>Water Systems<br>(service wells, cooling towers, sea water, fire water, etc.) | <p>Inspect for completeness and correctness of installations and make any nonoperating checks which may be required.</p> <p>Initially clean cooling tower basin and install screens in suction pit, before water circulation, when specified on the drawings.</p> <p>Provide test pump for wells and test well delivery and flush wells when wells are provided by Foster Wheeler.</p> | <p>Flush, drain, and clean cooling tower basins.</p> <p>Clean intake screens.</p> <p>Operate fire pumps to check output of systems.</p> <p>Fill reservoirs, head towers, etc.</p> <p>Provide insurance company inspection of fire system as required.</p> <p>Obtain and install all fire fighting chemicals, as required and portable equipment such as hoses, fire extinguishers and related equipment.</p> <p>Establish water treating program.</p> <p>Obtain services of water consultant to advise and monitor the water treatment operation as desired.</p> |

IV. SPECIFIC PROCEDURES

TABLE II (contd)

| Item                                             | By Foster Wheeler                                                                                                                                                                                                                                                                                                  | By Client                                                                                                                                              |
|--------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| N<br>Waste<br>Disposal,<br>Flares, and<br>Stacks | Inspect facilities for completeness and correctness of installation and make any nonoperating checks to ensure conformance with specifications.                                                                                                                                                                    | Operate all equipment and supply all chemicals, agents, etc. related to waste treatment.                                                               |
| P<br>Buildings<br>and<br>Accessories             | Check installation of any buildings and accessories including all heating, ventilating, and air conditioning equipment to assure completeness and conformance with specifications.<br><br>Obtain certification that all plumbing and elevator installations are in compliance with local governmental regulations. | Operate heating, ventilating, and air conditioning units and make all performance tests.<br><br>Obtain certificate for occupancy and use, if required. |



PROCESS PLANTS DIVISION

PREPARATION OF MATERIAL  
FOR SHIPMENT

JOB SPECIFICATION 60863-97A1

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\*PAGES REVISED FOR THIS ISSUE ARE NOTED BY ASTERISK  
REASON FOR REVISION:

Standard Computerized

**I. SCOPE**

- A. This specification covers the essential instructions for proper preparation and packaging of equipment, materials and supplies to insure delivery in satisfactory condition regardless of destination. All shipments, whether scheduled for immediate use or for delivery to storage, shall comply with these requirements and instructions.
- B. Any deviation from this specification must have the prior approval of Foster Wheeler. This specification is applicable to prime vendors and all sub-vendors.
- C. Information and specifications stated in the inquiry, material requisition, or purchase order shall TAKE PRECEDENCE over the requirements set forth herein.

**II. PURPOSE**

The requirements are specified so that material as shipped will endure the rigors of:

- A. Handling, stacking and transport to plant construction site.
- B. Outdoor storage for a period of twelve months on Domestic (U.S.A. and Canada) jobsites and eighteen months on Export jobsites (including Alaska and Hawaii).
- C. Outdoor weather exposure from the time equipment is uncrated and set on its foundation until plant start-up which may be as much as one year later. This general requirement may not apply to all equipment; e.g. pumps and compressors (particularly non-lubricated) for which vendor's bid shall propose for Purchaser's consideration and approval recommended methods and materials of preservation, allowable exposure time and other necessary requirements.

**III. TYPE OF PACKAGING**

- A. The type of packaging to be used is best determined by the vendor and may consist of boxing or crating, bundles, bags, fibreboard boxes, barrels, metal drums, or merely skids. The selection should be based upon suitability to the type of material to be packed and cost.
- B. Table A is a guide which tabulates methods of packing acceptable for categories of material as well as destination. Final selection for each project shall be given in the inquiry, material requisition or purchase order.

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PREPARATION OF MATERIAL  
FOR SHIPMENT

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IV. PREPARATION OF MATERIAL

- A. All equipment and material shall be cleaned internally and externally to remove all weld spatter, scale, rust, cuttings, filings, etc., as well as any and all foreign material.
- B. Critical wearing surfaces, highly stressed parts, and highly finished surfaces shall be further cleaned by dipping or brushing with a suitable solvent, such as petroleum naphtha or alkaline cleaning compound. Critical functioning or close tolerance surfaces shall be additionally cleaned to insure removal of perspiration and fingerprint stains, using any commercially available oil fingerprint remover.
- C. After hydrotesting, operation, and/or performance test, all fluids, i.e., lubricating oil, fuels, water, etc. shall be completely drained from all tanks, vessels, jacketing, piping, etc. and wiped or blown dry. Lint free rags shall be used for wiping.

V. PRESERVATION

A. Painting

1. Primer and finish coat shall be applied only when specified by painting JOB STANDARD.
2. Cast machinery shall be given at least one coat of primer and one coat of paint. Paints which combine a primer with the finish coat are acceptable and one coat of such paint is sufficient. In any case, both primers and paints shall be suitable for a minimum of 50°F more than the design temperature as specified on the requisition.
3. Smooth surfaces such as fabricated sheet metal, blower casings, etc. must have separate coats of primer and paint (minimum of one coat of each). However, corrosion resistant materials such as stainless steel shall not be primed nor painted.
4. Do not apply filler to cast surfaces or weldments.
5. Masking tape applied to such items as gage glasses, nameplates, etc., shall be left in place after painting.
6. External machined or highly finished surfaces, external rotating or reciprocating shafting, packed valve stems and linkages must be kept free from paint.

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V. PRESERVATION (continued)

B. Rust Prevention

All unpainted machined metal surfaces, both external and internal shall be cleaned and dried as specified above, and amply coated with a rust preventative which will maintain a protective coating for a minimum of twenty-four months provided the coating is not burned, dissolved or mechanically rubbed off.

1. For surfaces which are external, the rust preventative should be a heavy application of grease or liquid film which dries to a tough coating and which conforms with the performance requirements of U.S. Defense Department Specifications for Preservatives as listed below:

Spec. Designation - Mil-C-11796 Class 1

Application Method - Hot application, brush or dip, maximum temperature of application 200°F.

Description and Use - Thick, hard drying, greasy film. For protection of highly finished parts of simple design for long periods.

Acceptable preservatives are available from the major oil companies and their dealers, for example:

|                    |                              |
|--------------------|------------------------------|
| Gulf               | Gulf No-Rust #1              |
| Esso (Enjay Chem.) | Rust-ban 385                 |
| Shell              | Ensis 264                    |
| Mobil              | Mobilcoat 601                |
| Texaco             | Texaco Rust-Proof Compound L |
| Valvoline          | Tectyl 506                   |

Other brands are available and are acceptable providing they conform with the performance requirements above.

2. For internal machined surfaces of an assembled unit, the rust preventative should be of a type which does not require removal before operation of the equipment and which conforms with the performance requirements of U. S. Defense Department Specifications for Preservatives as listed below:

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V. PRESERVATION (Continued)

B. Rust Prevention (Continued)

Spec. Designation - Navy Mil-L-21260, Grade 1, 2, or 3

Application Method - Brush, dip, or spray, 60 to 120°F

Description - Engine lube oil with corrosion inhibitors, including hydrobromic acid neutralizers.

Acceptable preservatives are available from the major oil companies and their dealers, for example:

|                    |                           |
|--------------------|---------------------------|
| Gulf               | Gulf No-Rust Engine Oil   |
|                    | Grade 2 or Nox Rust 310AC |
| Shell              | Ensis Engine Oil Grade 20 |
| Mobil              | Mobilcoat - 501 or 503    |
| Texaco             | Preservative Oil 10W      |
| Esso (Enjay Chem.) | Rustban # 623             |

Other brands are available and are acceptable, providing they conform with the performance requirements above.

Acceptable methods of applying rust preventative are spraying, brushing, filling, flushing, etc. through all available openings, or by disassembly if necessary, to completely coat and protect all unpainted internal surfaces. Particular attention should be paid to journal surfaces of sleeve bearings and complete anti-friction bearings, so they are completely coated.

3. The manufacturer shall wire a large red tag to the machine which states: "Caution - This equipment has been treated with a rust preventative and no parts should be disturbed until ready to place in service. If protective coating film is broken, it should be restored for continued storage".
4. Any piping disassembled from equipment for ease of shipment shall have internal surfaces cleaned free of scale and all other foreign matter and coated with a rust preventative which conforms with Navy Mil-L-21260, Grade 1, 2, or 3 per Paragraph V.B.2. above. Pickling and cleaning per Engineering Standard 50A6 is also acceptable. In either case, all pipe ends shall be securely sealed with moistureproof paper and wooden flange covers or metal caps.

V. PRESERVATION (Continued)

B. Rust Prevention (Continued)

5. After application of rust preventative, exposed machined surfaces shall be wrapped with a heavy "VPI" treated paper, or other heavy waterproof paper (or plastic) enclosing "VCI" (Vapor Corrosion Inhibitor) crystals. In all cases, pH of wrapping shall be neutral. The wrapping shall be secured tightly with tape or twine. Sharp edges shall be cushioned to prevent puncture of wrapping.

Spare parts and replacement parts shall be covered with a second wrapping of heavy waterproof paper.

6. Because of possible damaging effect, care should be exercised in applying rust preventatives lest items fabricated of leather, rubber, mica, and similar items be coated with the preservative compound.

c. Protection of Openings

1. Flanged openings shall be protected with bolted-on wooden outdoor plywood (min.  $\frac{3}{4}$ " thickness) or metal covers, using at least three bolts. (Wiring-on covers is not acceptable). A sealer, Permatex No. 2 or equal, shall be used between the flange and the cover. After openings have been covered, the joint shall be wrapped with waterproof tape.
2. Porous bags filled with dessicant shall be hung on the inside of the wooden or metal bolt-on covers on all major connections of rotating equipment unless physical size is restrictive.
3. Unconnected pipe threads used in normal operation shall be closed with threaded metal plugs or caps. These shall be identified with metal tags explaining purpose and/or providing connection number used on Foster Wheeler and vendor's drawings.

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PREPARATION OF MATERIAL  
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V. PRESERVATION (Continued)

C. Protection of Openings (Continued)

4. All closures that are part of original equipment shall be tight fitting.
5. Plastic closures and thread protectors are specifically prohibited unless their use receives prior approval from Foster Wheeler.

D. Flexible Connections

All flexible connections subject to possible damage during shipment shall be disconnected and loose ends adequately supported or protected to prevent damage.

E. Shaft Couplings

Flexible couplings shall be broken and adequately supported and protected to prevent damage. Rigid couplings shall be in accordance with the manufacturer's recommendation, as required to provide full protection and safety in transit and storage.

F. Dehydration

1. The use of desiccant crystals within an enclosed piece of equipment is of particular importance in high humidity areas subject to wide variation in temperature over a twenty-four (24) hour period. Location of desiccant should be at suitable internals to provide uniform distribution.
2. The quantity of dehydrating agent to be used shall be determined on the basis of the surface area of the moisture barrier, the moisture vapor transmission rate, and the volume of the enclosed space. Additional desiccant should be used if other moisture-absorbing dunnage or supporting structures are included within the enclosed volume.
3. All equipment shipped utilizing dehydrating materials shall be labeled or tagged with an easily observed red sign, reading: "Caution - Desiccant materials are enclosed within this equipment. Do not operate before removing. Should the integrity of the enclosure be broken before operation, the desiccant must be replaced and the enclosure resealed for continued storage".

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VI. SHIPPING ENCLOSURE

A. Domestic Shipment

1. Very large and complicated machinery such as compressors, generators, large motors, engines, pressure vessels, etc. not supplied with self-supporting baseplates, shall be bolted to a skid formed of heavy timbers suitable for sling lift or fork lift truck handling, as applicable. This equipment shall be wrapped with heavy waterproof paper, heavy plastic, or tarpaulin so as to be enclosed on top and sides and ventilated underneath to permit air circulation. This covering shall be secured to the skid or baseplate in such a manner that it will not extend beyond the outside edge and thus be torn when a sling or fork lift handles the equipment.

Equipment supplied with lifting lugs or specific directions for lifting shall have such identification or instructions stenciled or securely affixed at prominent locations.

2. Very large and/or complicated equipment mounted on self-supporting baseplates will not require skids. Coverings shall be as listed in the preceding paragraph.
3. Medium or small size equipment whether on self-supporting baseplates or not, shall be bolted to skids formed of timbers suitable for sling lift or fork lift truck handling. All equipment shall be wrapped with heavy waterproof paper or plastic, so as to be enclosed on top and sides but ventilated underneath to permit breathing. This covering shall be securely attached to the equipment with tape, twine, or staples.

This equipment, if required, shall then be enclosed within a wooden crate or box of ample size and strength to protect the equipment (including affixed piping and accessories) against damage during transportation and handling at the job-site.

4. Bulk materials may be bundled, enclosed in burlap sacks, waterproof bags, waterproof fibre box, fibre drums, or metal drums. The type of material will govern the best method for shipment. Shipment shall then be palletized in convenient quantities.

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VI. SHIPPING ENCLOSURES

A. Domestic Shipment (Continued)

5. Piping may be shipped as loose pieces except that all piping 2" and smaller shall be bundled and strapped in order to make more rigid structures for shipment.

Piping shall be consolidated as required by Foster Wheeler for shipment. Any piping specially cleaned internally prior to shipment shall have ends capped or taped to make them watertight, and shall be desiccant protected.

6. When equipment is shipped in a "blocked-up" condition the requirements of Paragraph VI-B2-C below shall also apply.

B. For Overseas Export Shipment

1. In general, all equipment shall be enclosed in nailed, wooden boxes supplemented with steel strapping. Crating shall be of adequate strength to permit stacking. The crate shall be reinforced with steel strapping.

2. Box Construction

- a. Waterproof paper shall be used to line top, ends, and sides of all boxes.
- b. Each box shall be equipped with screened vent openings of a size commensurate with size of box located on the sides with internal splash boards, so as to prevent entrance of rain as well as to prevent sweating from fluctuations in temperature.
- c. Any finish machined part that is blocked for shipment using wood chocks or wood framing shall be isolated from the wood using copper sheathing or some other moisture impervious material to prevent moisture penetration from the wood through to the metal surface.

3. Large volume equipment such as pressure vessels, large machinery pieces, structural steel, large size pipe, etc., which are inherently weather resistant and capable of withstanding the rigors of transportation may be shipped without being boxed.

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VI. SHIPPING ENCLOSURES (Continued)

B. For Overseas Export Shipment (Continued)

4. Any equipment containing stainless steel parts must be boxed and marked: "This material to be stored below deck and not as deck cargo".
5. Any special shipping fixtures, tarpaulins, etc. are considered to be expendable items and will not be returned to supplier.

VII. SMALL LOOSE PARTS

Small loose parts shall be packed in a separate, sturdy wood box with steel strapping & each part marked with waterproof ink for proper identification. Any such box may be shipped with the main equipment, provided that it is securely attached to the main skid or within the main box. Secure attachment consists of strapping or bolting. Tieing or wiring are prohibited.

VIII. SPECIAL TOOLS

Tools shall be packed in an individual, steel strapped, rugged, wood box and marked as "special tools". However, large pieces, such as disassembly cradles, may be packed the same as the main equipment.

IX. SPARE AND REPLACEMENT PARTS

- A. Small spare and replacement parts shall be packed in an individual, steel-strapped, rugged wood box for rail or truck shipment. A steel-strapped, sturdy, well packed carton is permissible for parcel post and air freight shipment.
- B. Large spare and replacement parts, such as rotor assemblies, are to be prepared and enclosed the same as the main machinery unless otherwise directed by the purchase order or requisition.

X. CEMENT AND REFRactory MATERIALS

These materials shall not be shipped to the construction site more than 6 months prior to use. High alumina refractories rapidly deteriorate particularly in a hot climate and special shipping scheduling shall be made for this material.

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XI. LONG TERM STORAGE

Material to be prepared for long term storage is beyond the scope of this specification. Such requirements will be handled on an individual basis.

XII. INSTALLATION INSTRUCTIONS AND DRAWINGS

One set of installation instructions and drawings shall be included with the shipment in a sealed waterproof envelop firmly attached directly to the equipment within the packing container.

XIII. MARKINGS, COMMERCIAL DOCUMENTS

- A. The shipper shall stencil on the outside of the shipping case appropriate instructions for the handling, transport, and storage of equipment.
- B. Other marking of shipment, supply of packing lists, invoices, et. shall be as specified on the purchase order.

- TABLE A -  
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| CLASS OF MATERIAL                                     | NAILED<br>WOODEN<br>BOX | FIBRE<br>BOX | FIBRE<br>DRUM | METAL<br>DRUM | SKIDDED | PLYWOOD<br>DRUM | TEXTILE<br>BAGS | MULTI-WALL<br>SHIPPING | BUNDLE<br>or COIL | LCOS<br>SACKS |
|-------------------------------------------------------|-------------------------|--------------|---------------|---------------|---------|-----------------|-----------------|------------------------|-------------------|---------------|
| 1. Structural Parts<br>metal or wood                  |                         | D, E         |               |               |         |                 |                 |                        |                   | D, E          |
| 2. Major Items<br>a. Large Machinery                  |                         | D, E         |               |               |         | D, E            |                 |                        |                   |               |
| b. Medium-Small Machinery                             |                         | D, E         |               |               |         | D               |                 |                        |                   |               |
| 3. Tools & Machine Parts                              |                         | D, E         | D             |               |         |                 |                 |                        |                   |               |
| 4. Pipe<br>a. 3" and above                            |                         |              |               |               |         |                 |                 |                        |                   | D, E          |
| b. 2" and below                                       |                         | -E           |               |               |         |                 |                 |                        |                   | D, E          |
| 5. Metal rods & sheets                                |                         | D, E         |               |               |         |                 |                 |                        |                   |               |
| 6. Bulk Materials - Solids                            |                         |              | D             | D             | D, E    |                 | D               | D                      | D, E              |               |
| 7. Loose articles not subject<br>to damage in transit |                         |              |               |               |         | D               | D               |                        |                   | D             |
| 8. Hardware & Fittings                                |                         | -E           | D             | D             |         |                 | D               |                        |                   |               |
| 9. Wire & Cable                                       |                         | -E           |               |               |         |                 |                 |                        |                   | D             |
| 10. Furniture-Office & Field                          |                         | -E           |               |               |         |                 |                 |                        |                   | D             |
| 11. Instruments                                       |                         | -E           | D             |               |         |                 |                 |                        |                   |               |
| 12. Liquids - in bulk                                 |                         |              |               |               | D, E    |                 |                 |                        |                   |               |
| 13. Liquids - in containers                           |                         | D, E         | D             |               |         |                 |                 |                        |                   |               |
| 14. Chemicals - in bottles                            |                         | D, E         |               | D             |         |                 |                 |                        |                   |               |
| 15. Chemicals - Inert,<br>Granular - in bulk          |                         |              |               | D             | D, E    |                 |                 | D                      | D                 |               |
| 16. Chemicals, Inert,<br>Granular - in container      |                         |              |               |               |         |                 |                 |                        |                   |               |
| 17. Pressure Vessels<br>a. 3' Diameter and above      | D, E                    |              | D             | D             |         |                 |                 |                        |                   |               |
| b. 3' Diameter and below                              |                         |              |               |               |         |                 |                 |                        |                   | D, E          |
| 18. Heat Exchangers                                   |                         |              |               |               |         | D, E            |                 |                        |                   |               |
| 19. Spare Parts                                       | D, E                    |              |               |               |         | D, E            |                 |                        |                   |               |

NOTES:

1. "D" designates acceptable for domestic shipment.
2. "E" designates suitable for export shipment.
3. See I.C.C. regulations for chemicals and other dangerous substances.

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I. SCOPE

- A. This standard shall govern the extent of inspection of all purchased equipment and materials to be performed by Foster Wheeler at vendors' plants.
- B. The following inspection percentages are related to the quantity of the items of equipment and materials on a given project and are not intended to indicate the degree of inspection to be performed.
  1. Where 100% inspection is specified, each item will be inspected.
  2. Where 10% inspection is specified, only 10% of the total quantity purchased on each order will be inspected.
- C. In the event of a conflict between quality standards and delivery schedules, the Chief Inspector's decision shall govern.
- D. Customer notification for inspection shall be for final inspection only and limited to only those items that are specifically intended to be inspected by the customer, the list of which is to be included in the contract coordination procedure.
- E. Typewritten Foster Wheeler equipment/material inspection reports will be transmitted to the customer on a regular basis as inspection visits are made.

II. EXTENT OF INSPECTION OF VESSELS-SECTION 1100

A. Towers, Reactors, Regenerators, Tanks, Drums and Deaerators

100% inspection which will consist of the following:

1. Identify all materials against material test certificates, including verification of plate thicknesses to assure all conform to purchase order requirements.
2. Review all radiographs.
3. Witness crack detection, hardness checks, ultrasonic tests, etc. which may be specified. If unable to witness these tests, a shop certification of satisfactory completion shall be obtained for inspection records. If any doubt exists as to the validity of the certification, spot checks will be requested.
4. Witness hydrostatic tests jointly with the code inspector.

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II. EXTENT OF INSPECTION OF VESSELS-SECTION 1100 (Cont'd)

A. Towers, Reactors, Regenerators, Tanks, Drums and Deaerators (Cont'd)

5. Dimensionally check for accuracy and visually inspect for cleanliness and quality of workmanship.
6. Check for completeness of installation of internal and external attachments, except for the installation of trays which will be inspected at the jobsite during or after installation into their respective towers.

B. Tower Internals

1. Except for prototypes or new vendors, no inspection of internals will be required at vendor's plant. Internals, except trays, shall be inspected during or after installation into their respective towers. Installation of trays will be inspected at the job site.
2. For prototypes or new vendors, inspection of trays will be required which will consist of the following:
  - a. Identify all materials against material test certificates including verification of plate thicknesses to assure all conform to purchase order requirements.
  - b. Witness leakage tests.
  - c. Dimensionally check for accuracy and visually inspect for quality of workmanship of 25% of each type and size.
  - d. Spot check (20% maximum) for interchangeability of parts.

C. USA Field Erected Spheres and API Storage Tanks (Erected by Vendor)

No inspection will be required.

D. Overseas Field Erected Spheres and API Storage Tanks (Erected by Others)

100% inspection which will consist of the following:

1. Identify all materials against material test certificates, including verification of plate thicknesses to assure all conform to purchase order requirements.
2. Dimensionally check all shell plate after forming.
3. Visually inspect all welding.

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II. EXTENT OF INSPECTION OF VESSELS-SECTION 1100 (Cont'd)

D. Overseas Field Erected Spheres and API Storage Tanks (Erected by Others (Cont'd))

4. If radiographs are required for sub-assemblies, they shall be reviewed.
5. Obtain chart or diagram showing field fabrication sequence or arrangement, complete with all plate numbers. This will be forwarded to the foreign office originating the purchase.

E. Miscellaneous Vessels

Inspection will be as specified in the item requisition.

III. EXTENT OF INSPECTION OF HEAT TRANSFER EQUIPT.-SECTION 1200

A. Shell and Tube Exchangers

100% inspection which will consist of the following:

1. Same as II A above, including complete inspection of the tube side.
2. For stacked exchangers, a final dimensional inspection will be performed in the shop on the complete assembly.

B. Air Cooled Exchangers

100% inspection which will consist of the following:

1. Same as II A above for the fabrication of headers and tube bundles.
2. A shop certification of satisfactory fan blade balance will be obtained for inspection records.
3. Check motor driver unit against its requisition.
4. Spot check all structural steel for dimensional accuracy and visually inspect for quality of workmanship.

C. Fired Process Heaters

100% inspection which will consist of the following:

1. Identify all materials against mill test certificates to assure all conform to Purchase Order requirements.
2. Mill inspection shall be made for all alloy tubes of 5% or greater chrome content.

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III. EXTENT OF INSPECTION OF HEAT TRANSFER EQUIPT.-SECTION 1200 (Cont'd)

C. Fired Process Heaters (Cont'd)

3. Review all radiographs.
4. Witness crack detection, hardness checks, ultrasonic tests, etc. which may be specified. If unable to witness these tests, a shop certification of satisfactory completion will be obtained for inspection records. If any doubt exists as to the validity of the certification, spot checks will be requested.
5. Witness hydrostatic tests jointly with the code inspector. For packaged unit, hydrostatic tests and final inspection will be made in the shop on the complete assembly.
6. Dimensionally check for accuracy and visually inspect for cleanliness and quality of workmanship.
7. Inspect installation of anchors and refractory lining.
8. Spot check all structural steel, ducting and stacks for dimensional accuracy and visually inspect for quality workmanship.

D. Vacuum Equipment, Including Condensers

100% inspection which will consist of the following:

1. As far as applicable, inspection of condensers will be the same as for shell and tube exchangers. See III. A.
2. Inspection of ejectors will consist of witnessing performance or other shop tests together with a dimensional and visual inspection.

E. Other Heat Exchange Equipment

Inspection will be as specified in the item requisition.

IV. EXTENT OF INSPECTION OF MECHANICAL EQUIPMENT-SECTION 1300

A. Pumps

Inspection of pumps will normally be conducted only for pumps in excess of 500 HP, special applications, prototype units and new vendors.

IV. EXTENT OF INSPECTION OF MECHANICAL EQUIPMENT - SECTION 1300 (Cont'd)

B. Compressors

Except for standard plant and instrument air compressors and small standard blowers, all compressors will be inspected, including their lubrication, sealing and cooling systems.

C. Pump and Compressor Drivers

1. Motors in excess of 500 HP will be inspected.
2. Steam turbines in excess of 500 HP, multistage turbines and turbines in excess of 5000 RPM will be inspected.

D. Mixers and Agitators

Inspection of agitators and mixers will be conducted only for special applications, prototype units and new vendors.

E. Materials Handling, Finishing and Packaging Equipment

Except for standard equipment manufactured on a stock basis, all units will be inspected.

F. Rotary Filters

All rotary and vacuum filters will be inspected.

G. Pulsation Dampers

100% inspection which will consist of the following:

Same as for II A above, with special consideration given to internal cleanliness.

H. Double Pipe Exchangers (Scraped Surfaces)

100% inspection which will consist of the following:

1. Same as II.A above, including all piping and internals.
2. Check motor driver against its requisition.
3. Witness shop running test and perform a final dimensional inspection on the complete assembly.

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EXTENT OF INSPECTION OF MECHANICAL EQUIPMENT-SECTION 1300 (Cont'd)

J. Refrigeration Systems-Package (except Air Conditioners)

1. Inspection will be as specified in the item requisition.
2. No inspection will be required for package type air conditioners.

Notes on Inspection

1. The requisition data sheet and/or referenced specification will indicate the extent of shop testing to be performed by the manufacturer and which tests will be witnessed.
1. Inspection will be conducted during assembly and/or prior to preparation for shipment and will consist of:
  - a) Check for compliance to the requirements of the Purchase Order.
  - b) Check for completeness of vendor's work and/or availability of all component parts and accessory items.
  - c) Visually inspect for cleanliness and quality of workmanship.
  - d) Complete dimensional check to assure its conformity to vendor's certified outline drawings.
  - e) Witness those tests specified to be witnessed as indicated on the requisition data sheet and/or referenced specification.

V. EXTENT OF INSPECTION OF CIVIL ENGINEERING-SECTION 1400

In general, no inspection will be required.

VI. EXTENT OF INSPECTION OF PIPING MATERIALS-SECTION 1500

A. Valves

1. 100% inspection will be required for motor operated valves, slide valves, switch valves, butterfly valves 14" and larger and any other valve as may be specified in the item requisition. Inspection will consist of the following:
  - a. Identify material against material test certificates to assure all conform to purchase order requirements.
  - b. Witness crack detection, hardness checks, Charpy tests, etc., which may be specified. If unable to witness these tests, a shop certification of satisfactory completion will be obtained for inspection records. If any doubt exists as to the validity of the certification, spot checks will be requested.
  - c. Witness hydrostatic tests of body and seat.

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VI. EXTENT OF INSPECTION OF PIPING MATERIALS-SECTION 1500 (Cont'd)

A. Valves (Cont'd)

1. (Cont'd)
  - d. Dimensionally and visually inspect to ensure conformity to standards and specifications.
  - e. Ensure valve is properly metal-tagged with item number as indicated in requisition.
  - f. For motor operated valves, visually inspect motor for conformity to requisition.
2. All other valves will not require inspection.
3. No inspection will be required for valve accessories such as chain wheels, guides, extension stems, floor stands, etc.

B. Shop Fabricated Piping

Unless otherwise indicated on piping drawings or specified in the item requisition:

1. The type and extent of required examination will be in accordance with ENG STD 50A1 Paragraph VIII., including a review of all radiographs.
2. No additional inspection will be required for carbon steel piping 12" size and smaller. For all carbon steel piping 14" size and larger and for all sizes of alloy steel and non-ferrous piping, a spot check (average 10%) inspection will be required consisting of the following:
  - a. Identify all material against mill test certificates to assure all conform to purchase order requirements.
  - b. Check to ensure that welding procedures used agree with those approved by Foster Wheeler Energy Corporation Engineering Department.
  - c. Witness hydrostatic test, if required.
  - d. Review stress relieving procedures and check Brinell hardness.
  - e. Dimensionally inspect for accuracy and visually inspect for quality of workmanship. Closely inspect the interior for cleanliness, especially the welds.
3. All sizes of compressor suction and interstage piping will be closely inspected for interior cleanliness. If special cleaning is required it will be defined in the requisition.

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VI. EXTENT OF INSPECTION OF PIPING MATERIALS-SECTION 1500 (Cont'd)

C. Random Pipe

No inspection will be required.

D. Fittings

Inspection will be required for special (non-standard) cast alloy steel and carbon steel fittings only and will be specified in the item requisition. When inspection is required, it will consist of the following:

1. Identify material against material test certificates to assure all conform to purchase order requirements.
2. Witness hydrostatic test of cast fittings only.
3. Witness crack detection, hardness checks, etc. which may be specified.
4. Dimensionally and visually inspect to ensure fittings conform to drawings and specifications.

E. Flanges

No inspection will be required.

F. Bolts, Studs & Gaskets

No inspection will be required.

G. Underground

No inspection will be required.

H. Piping Specialties

No inspection will be required.

VII. EXTENT OF INSPECTION OF INSTRUMENT-SECTION 1600

A. Instruments, Control Valves and Safety Valves

Generally, these items do not require inspection. In special cases, inspection may be required. Consideration will be based on such factors as: prototype units, new vendors, units for export, critical nature of use.

VII. EXTENT OF INSPECTION OF INSTRUMENTS-SECTION 1600 (Cont'd)

B. Analyzers

Inspection of analyzers will normally apply to prototype units, new vendors, units for export and special applications.

C. Control Panel

Normally, control panels will be inspected. The extent and nature of inspection will be defined by the Instrument Engineering Section.

D. Instrument Piping

No inspection will be required.

E. Instrument Electrical

No inspection will be required.

F. Weather Protection

No inspection will be required.

G. Supports and Racks

No inspection will be required.

VIII. EXTENT OF INSPECTION FOR ELECTRICAL-SECTION 1700

A. Underground Electrical

No inspection will be required.

B. Power Equipment

Generally, power equipment will not require inspection unless specified in the item requisition. When inspection is required, the extent and nature of inspection will be defined by the Electrical Engineering Section.

C. Power Distribution

No inspection will be required.

D. Lighting

No inspection will be required.

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VIII. EXTENT OF INSPECTION FOR ELECTRICAL-SECTION 1700 (Cont'd)

E. Communications

No inspection will be required.

F. Supports and Racks

No inspection will be required.

IX. EXTENT OF INSPECTION FOR MATERIALS PROTECTION-SECTION 1800

No inspection will be required.

X. EXTENT OF INSPECTION FOR PROJECT & MISCELLANEOUS ITEMS-SECTION 1900

A. Process Driers

100% inspection which will consist of the following:

1. Same as II. A above.
2. Witness vendor's standard shop tests and those as may be specified in the item requisition.

B. Steam Generators and Boilers

100% inspection which will consist of the following:

1. Inspection of all drums and headers will be as specified in II. A above.
2. Identify all carbon steel and low alloy tube material against mill test certificates to assure all conform to purchase order requirements.
3. Mill inspection shall be made for all alloy tubes of 5% or greater chrome content.
4. Witness crack detection, hardness checks, ultrasonic test, etc., which may be specified. If unable to witness these tests, a shop certification of satisfactory completion will be obtained for inspection records. If any doubt exists as to the validity of the certification, spot checks will be requested.
5. Dimensionally check for accuracy and visually inspect for cleanliness and quality of workmanship.

FOSTER  WHEELER  
PROCESS PLANTS DIVISION

EXTENT OF INSPECTION TO BE  
PERFORMED AT VENDORS' PLANTS

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DATE Feb. 1, 1979

X. EXTENT OF INSPECTION FOR PROJECT & MISCELLANEOUS ITEMS-SECTION 1900 (Cont'd)

B. Steam Generators and Boilers (Cont'd)

6. Spot check all structural steel, ducting and stacks for dimensional accuracy and visually inspect for quality of workmanship.
7. Witness hydrostatic tests jointly with the Code Inspector. For packaged units, hydrostatic tests and final inspection will be made in the shop on the complete assembly.
8. Inspect installation of anchors and refractory lining.

C. Cooling Towers

100% inspection of fan unit only which will consist of the following:

1. A shop certification of satisfactory fan blade balance will be obtained for inspection records.
2. Witness standard shop test or running test as specified in the requisition for the item.
3. Check motor driver unit against its requisition.

D. Other Miscellaneous Items

Inspection will be as specified in the item requisition.

APPENDIX E  
FOUNDATION DESIGN

FOSTER WHEELER DEVELOPMENT CORPORATION

JOHN BLIZARD RESEARCH CENTER  
12 PEACH TREE HILL ROAD,  
LIVINGSTON, NEW JERSEY 07039

BY .....GDG..... DATE 4/25/79... SUBJECT FOUNDATION DESIGN..... SHEET NO. ....1..... OF ...6.....  
CHKD. BY ..... DATE ..... FOR HEXCEL/SUMTEC COLLECTOR JOB NO. .... 9-41-4010....

### FOUNDATION DESIGN

FROM ANSI 58.1, DESIGN WIND LOAD FOR ATLANTA, GEORGIA SHOULD USE A WIND SPEED OF 80 MPH. ASSUME THE SAME WIND SPEED FOR DALTON, GEORGIA.

WIND LOADS ACTING ON THE FOUNDATIONS FOR VARIOUS COLLECTOR ORIENTATIONS ARE SHOWN IN FIGURE 4.1. REFERENCE (15) WAS USED FOR THIS FOUNDATION DESIGN. CYLINDRICAL CONCRETE PILES WERE SELECTED BECAUSE OF THEIR LOW INSTALLATION COSTS.

FOR THE WIND LOADS FOR IN-OPERATION COLLECTOR ORIENTATIONS, FACTOR OF SAFETY USED IS ONE. THE MAXIMUM WIND LOADS DURING OPERATION MAY OCCUR AT  $\Theta = 0^\circ$ . THESE LOADS ARE :

VERTICALLY UPWARD = 2950 LB.  
VERTICALLY DOWNWARD = 2950 LB.  
LATERAL = 1560 LB.  
DEAD LOAD, DOWNWARD = 372 LB.

FOR THE WIND LOADS IN STOWED POSITION, FACTOR OF SAFETY USED IS THREE. THE WIND LOADS UNDER THIS CONDITION ARE SHOWN IN FIGURE 4-1, FOR  $\Theta = -90^\circ$  AS :

VERTICALLY UPWARD = -164 LB.  
LATERAL = 520 LB.

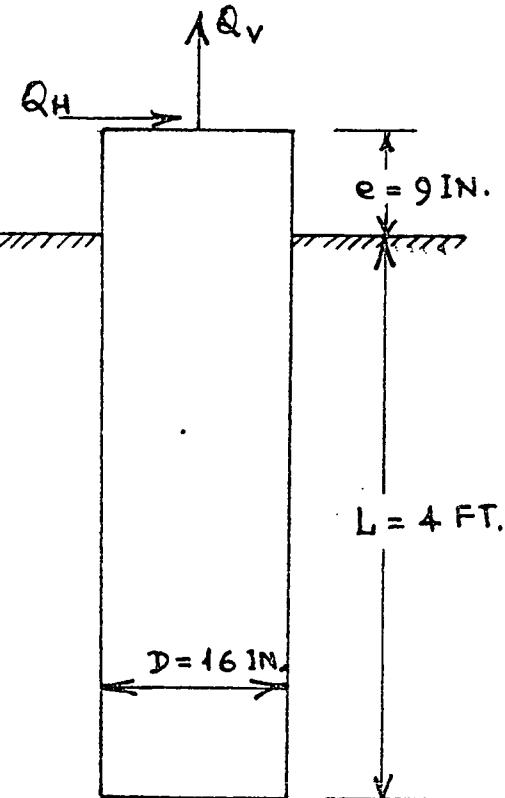
FOSTER WHEELER DEVELOPMENT CORPORATION

BY ..... GDG ..... DATE 4/25/79 ..... SUBJECT FOUNDATION DESIGN ..... SHEET NO. .... 2 .... OF 6 ....  
CHKD. BY ..... DATE ..... JOB NO. .... 9-41-4010 ....

JOHN BLIZARD RESEARCH CENTER  
12 PEACH TREE HILL ROAD,  
LIVINGSTON, NEW JERSEY 07039

I DESIGN CONFIGURATION

THE SELECTED CYLINDRICAL  
PILE IS 16 INCHES IN  
DIAMETER AND 4 FEET 9 INCHES  
DEEP. 4 FEET OF THE PILE  
IS UNDERGROUND. THE FOUNDATION  
DESIGN IN THIS CASE IS  
GOVERNED BY THE VERTICALLY  
UPWARD AND LATERAL LOADS.



$Q_v$  = VERTICALLY UPWARD LOAD  
 $Q_H$  = LATERAL LOAD

FROM REFERENCE (15), THE  
CONCRETE PILE SHOULD SATISFY  
THE FOLLOWING EQUATION —

$$\frac{Q_v}{Q_{UV}} + \left( \frac{Q_H}{Q_{UM}} \right)^2 \leq 1 \quad \dots \dots \text{ (D-1)}$$

WHERE

$Q_{UV}$  = GROSS ULTIMATE RESISTANCE FOR VERTICAL LOAD ALONE  
 $Q_{UM}$  = GROSS ULTIMATE RESISTANCE FOR LATERAL LOAD ALONE

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BY ..... GDS ..... DATE 4/25/79 ..... SUBJECT FOUNDATION DESIGN ..... SHEET NO. .... 3 ..... OF ... 6 .....  
CHKD. BY ..... DATE ..... JOB NO. .... 9-41-4010 .....

II CALCULATION OF  $Q_{UV}$

FROM REFERENCE (15) ,

$$Q_{UV} = \bar{r} \cdot A_s + W$$

WHERE

$\bar{r}$  = AVERAGE UNIT RESISTANCE TO UPLIFT

$A_s$  = EMBEDDED SURFACE AREA

$$= \pi D L = \pi \times \frac{16}{12} \times 4 = 16.75 \text{ FT.}^2$$

$W$  = WT. OF THE CONCRETE PILE INCLUDING DEAD WEIGHT ACTING ON IT.

$$= \frac{\pi D^2}{4} (L + e) \rho_c + \text{DEAD LOAD}$$

$$= \frac{\pi}{4} \left( \frac{16}{12} \right)^2 \times 4.75 \times 150 + 372$$

$$= 995 + 372 = 1367 \text{ LB.}$$

$\rho_c$  = DENSITY OF CONCRETE

$$= 150 \text{ LB/FT}^3$$

$$\bar{r} = k_c C_u + \frac{1}{2} k_u \bar{\gamma} L \tan \delta$$

WHERE

$k_c, k_u$  = UPLIFT COEFFICIENTS

$C_u$  = COHESIVE STRENGTH

=  $\frac{1}{2}$  UNCONFINED COMPRESSIVE STRENGTH

$\bar{\gamma}$  = EFFECTIVE UNIT WT. OF SOIL

$\delta$  = SKIN FRICTION. PARAMETER

$$= 0.6 \phi$$

FOSTER WHEELER DEVELOPMENT CORPORATION

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BY ..... GDG ..... DATE 4/25/79 ..... SUBJECT FOUNDATION DESIGN ..... SHEET NO. ..... 4 ..... OF ..... 6 .....  
CHKD. BY ..... DATE ..... JOB NO. ..... 9-41-4010

$\phi$  = ANGLE OF INTERNAL FRICTION

FROM REF. (15),

$$K_c = 0.5$$

$$K_u = 2.0$$

ASSUMING  $\phi = 20$  DEG.

$$\delta = 12 \text{ DEG.}$$

$$\tan \delta = 0.213$$

ASSUME  $\bar{Y} = 100 \text{ LB/FT}^3$

FROM REF. (16),

$$c_u = 1500 \text{ LB/FT}^2$$

THEREFORE,

$$z = 0.5 \times 1500 + \frac{1}{2} \times 2 \times 100 \times 4 \times 0.213$$

$$= 750 + 85.2$$

$$= 835.2 \text{ LB/FT}^2$$

$$\therefore Q_{uv} = 835.2 \times 16.75 + 1367$$

$$= 15357 \text{ LB}$$

i.e. FOR THE VERTICALLY UPWARD LOAD ALONE, THE FOUNDATION CAN TAKE 15357 LBS.

FOSTER WHEELER DEVELOPMENT CORPORATION

BY ..... G.D.G. .... DATE 4/25/79 .... SUBJECT FOUNDATION DESIGN .....  
 CHKD. BY ..... DATE ..... SHEET NO. .... 5 .... OF 6 .....  
 JOB NO. .... 9-41-4010 .....

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 LIVINGSTON, NEW JERSEY 07039

III CALCULATION OF  $Q_{UM}$

FROM REF. (15),

$$Q_{UM} = \frac{0.5 \bar{Y} D L^3 k_p}{e + L}$$

WHERE  $k_p$  = COEFFICIENT OF PASSIVE EARTH PRESSURE

$$\begin{aligned} &= \frac{1 + \sin \phi}{1 - \sin \phi} \\ &= \frac{1 + 0.342}{1 - 0.342} \\ &= 2.04 \end{aligned}$$

$$Q_{UM} = 0.5 \times 100 \times \frac{16}{12} \times (4)^3 \times \left( \frac{2.04}{4.75} \right)$$

$$= 1832 \text{ LB.}$$

i.e. FOR THE LATERAL LOAD ALONE, THE FOUNDATION  
 CAN TAKE 1832 LB'S.

IV ACCURACY OF DESIGN

a. IN-OPERATION LOAD

$$Q_v = 2950 \text{ LB.}$$

$$Q_h = 1560 \text{ LB.}$$

FOSTER WHEELER DEVELOPMENT CORPORATION

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BY ..... GDG ..... DATE 4/25/79 ..... SUBJECT FOUNDATION DESIGN ..... SHEET NO. .... 6 ..... OF 6 .....  
CHKD. BY ..... DATE ..... JOB NO. .... 9-41-4010 ....

$$\therefore \frac{2950}{15357} + \left( \frac{1560}{1832} \right)^2 = 0.192 + 0.725 \\ = 0.92$$

HENCE THE FOUNDATION SATISFIES THE IN- OPERATION LOAD REQUIREMENTS

b. STOWED LOADS

$$Q_v = 492 \text{ LB.}$$

$$Q_H = 1560 \text{ LB.}$$

$$\therefore \frac{492}{15357} + \left( \frac{1560}{1832} \right)^2 = 0.032 + 0.725 \\ = 0.757$$

HENCE THE FOUNDATION HAS A FACTOR OF SAFETY OF 3  
FOR WIND LOAD IN STOWED POSITION

APPENDIX F  
FAILURE MODES AND  
EFFECTS ANALYSIS SHEETS

Appendix D  
FAILURE MODE AND EFFECTS ANALYSIS

The failure modes and effects analysis of the solar steam generating plant is presented in this appendix. This analysis takes each subsystem and examines it by function, looking at each component or component set. The possible modes of failure are examined to determine all their possible causes, how they might be detected, and the effect of that failure--locally within the subsystem and ultimately on the operation of the plant. It delineates any existing features that compensate for that failure and makes a qualitative assessment of both the severity of the specific failure mode and its probability of occurrence. Each failure mode is accompanied, when necessary, by remarks and/or recommendations which set forth the assumptions made or further elucidate that mode analysis.

The criticality of a failure mode is based on the interaction of severity of effect and the probability of occurrence.\* Obviously, a failure mode which may have a severe effect and which has a high probability of occurrence should be examined closely. Steps can then be taken to assure that there are adequate provisions to compensate for that failure mode, that it can be detected quickly, and that the possible causes can be eliminated wherever possible or reduced as much as practical. A failure mode which has a high probability of occurrence but negligible effects, or one that is severe but has almost no chance of occurrence, can be given a lower degree of concern than one which is both moderately severe and has a moderate probability of occurrence.

The criteria used for assigning probability levels and levels of severity are shown below:

PROBABILITY

- ① Level 1 - Failure mode probability very low. A negligible chance of occurrence during the item's lifetime.
- ② Level 2 - Failure mode probability low. Unlikely to occur during the item's lifetime.

\*No criticality ranking is provided. The definition of criticality as the product of the severity and probability of a failure mode is misleading (P. E. Vanden Dries, "Rational Risk Assessment for Defence System Safety," Proceedings, Annual Reliability and Maintainability Symposium, January 1979, IEEE, New York.

- ⑥ Level 3 - Failure mode probability medium. A random 50-50 chance of occurrence during the system's lifetime.
- ⑦ Level 4 - Failure mode probability high. Frequent occurrence likely during the item's lifetime.

#### SEVERITY CLASSIFICATION

- ⑧ Level 1 - No effect on gasifier output. Negligible effect or degradation which can be repaired by performing "adjustment type" maintenance.
- ⑨ Level 2 - Causes automatic shutdown with no consequent damage.
- ⑩ Level 3 - Minor equipment failure or damage repairable by operators.
- ⑪ Level 4 - Major equipment failure or damage not repairable by operators.
- ⑫ Level 5 - Potential on-site fire or hazard to operators.
- ⑬ Level 6 - Potential off-site fire or damage.

## Failure Modes and Effects Analysis

Level No. 1 Heat Transfer Fluid

Level No. 2 Instrumentation

Level No. 3

Level No. 4

Program: Solar Production of Industrial Process Steam  
Drawing: 60863-50-1

| Functional Description                | Failure Mode |                                         | Possible Causes                           | Symptoms Detectability                                               | Effect of Failure                               |                                              | Existing Compensating Provision                                                          | Probability | Level of Severity | Remarks                                                                                                                                          |
|---------------------------------------|--------------|-----------------------------------------|-------------------------------------------|----------------------------------------------------------------------|-------------------------------------------------|----------------------------------------------|------------------------------------------------------------------------------------------|-------------|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
|                                       | SN           | Description                             |                                           |                                                                      | Local Effect                                    | End Effect                                   |                                                                                          |             |                   |                                                                                                                                                  |
| Circulating Pump (P-101)              | 1.10         | Stops                                   | Power failure, motor failure, deadheading |                                                                      | Circulation of fluid stops                      | Ball out in solar collectors                 | Solar collectors stowed on detection of low flow/power failure                           | 3           | 2/3               |                                                                                                                                                  |
| Flow Meter                            | 1.20         | Fails indicating false low flow         | Malfunction                               | No low flow indicated on WO-101 to WO-115                            | Activation low flow alarm and shutdown          | Spurious shutdown                            |                                                                                          | 2           | 2                 |                                                                                                                                                  |
|                                       | 1.21         | Fails indicating false high flow        | Malfunction                               |                                                                      | Erroneous flows recorded                        | No low flow shutdown                         | Stowage of collectors on electrical failure or overheating of collectors                 | 2           | 3                 |                                                                                                                                                  |
| Low Flow Switch/Alarm WSL-100/WAL-100 | 1.22         | Fails off                               | Malfunction                               |                                                                      | Redundancy in low flow alarms lost              |                                              | WSLL-100/WALL-100 and WR-100                                                             | 2           | 2                 |                                                                                                                                                  |
|                                       | 1.23         | Fails on                                | Short/ malfunction                        | Alarm but low flow not indicated                                     | Possible manual shutdown                        |                                              |                                                                                          | 2           | 1                 |                                                                                                                                                  |
| Low-Low Flow Switch WSLL-100          | 1.24         | Fails off                               | Malfunction                               |                                                                      | No automatic shutdown on low flow               |                                              | Manual shutdown on alarm via WAL-100. Stowage of collectors on power failure/overheating | 2           | 3                 |                                                                                                                                                  |
| Low-Low Flow Switch WSLL-100          | 1.25         | Fails on                                | Short/ malfunction                        |                                                                      |                                                 | Spurious low flow shutdown                   |                                                                                          | 2           | 2                 |                                                                                                                                                  |
| Low-Low Level Alarm WALL-100          | 1.26         | Fails off                               | Malfunction                               |                                                                      | No alarm on low-low flow                        |                                              |                                                                                          | 2           | 1                 |                                                                                                                                                  |
|                                       | 1.27         | Fails on                                | Short/ malfunction                        | No shutdown occurs                                                   | Low flow alarm                                  |                                              | WAL-100 and WR-100                                                                       | 2           | 1                 |                                                                                                                                                  |
| RTD TT-100                            | 1.30         | Fails indicating false high temperature |                                           | Via calculations of collector performance and comparison with TR-401 | False high collector inlet temperature recorded | False low indication of collector efficiency |                                                                                          |             |                   | Recommended that frequent comparison be made with temperature recorded on TR-401 so as to avoid erroneous conclusions as to collector efficiency |

## Failure Modes and Effects Analysis

Level No. 1 Heat-Transfer Fluid Circulation

Level No. 2 Instrumentation, Lines, Collector

Level No. 3

Level No. 4

Program: Solar Production of Industrial Process Steam  
Drawing: 60863-50-1

| Functional Description         | Failure Mode |                                         | Possible Causes                         | Symptoms Detectability                                                | Effect of Failure                                         |                                                                 | Existing Compensating Provision                                                  | Probability | Level of Severity | Remarks                                                                                                                                                                                |
|--------------------------------|--------------|-----------------------------------------|-----------------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------|-----------------------------------------------------------------|----------------------------------------------------------------------------------|-------------|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                | SN           | Description                             |                                         |                                                                       | Local Effect                                              | End Effect                                                      |                                                                                  |             |                   |                                                                                                                                                                                        |
| Temperature Recorder           | 1.44         | Fails indicating false high temperature |                                         | By comparison with temperature recorded on TR-100                     | False high indication of boiler outlet temperature        | As 1.40                                                         |                                                                                  | 2           | 1                 |                                                                                                                                                                                        |
|                                | 1.45         | Fails indicating false low temperature  |                                         |                                                                       | False low indication of boiler outlet temperature         | As 1.40                                                         |                                                                                  |             |                   |                                                                                                                                                                                        |
|                                | 1.46         | Fails recording false high temperature  |                                         |                                                                       | As 1.44                                                   | As 1.44                                                         |                                                                                  |             |                   |                                                                                                                                                                                        |
|                                | 1.47         | Fails recording false low temperature   |                                         |                                                                       | As 1.44                                                   | As 1.45                                                         |                                                                                  |             |                   |                                                                                                                                                                                        |
| Valve downstream of pump P-101 | 1.50         | Valve closed                            | Error                                   |                                                                       | Deadheading of pump                                       | No flow                                                         | No flow shutdown                                                                 | 1           | 3                 |                                                                                                                                                                                        |
| Valve upstream of pump P-101   | 1.51         | Valve closed                            | Error                                   |                                                                       | Cavitation in pump                                        | No flow                                                         | No flow shutdown                                                                 | 1           | 3                 |                                                                                                                                                                                        |
| Line                           | 1.60         | Line leaks                              | Failure/leak at connections, Impact     | Possible flow reduction, fall in level of tank TK-101, spill observed | Spill heat transfer fluid                                 | Fall in level of fluid in system.                               | Low level alarm LAL-800                                                          | 2           | 2-5               | Insulation will be of the closed cell type so as to minimize the risk of auto-ignition. Valves will be placed on the bottom of pipes so that leaks will not drain into the insulation. |
| Collector SC-101/115           | 2.10         | Rupture                                 | Impact                                  |                                                                       | Damage to collector                                       | Escape of fluid                                                 | Foam and other fire protection measures                                          | 2           | 5                 |                                                                                                                                                                                        |
|                                | 2.11         | Excessive temperature in collector      | Overpressure                            |                                                                       | Possible overpressure in tube coking/degradation of fluid | Individual collectors can be isolated. Collector area is diked. | Collectors sealed if temperature too high, PSV installed to relieve overpressure | 2           | 5                 |                                                                                                                                                                                        |
| Collector SC-101/115           | 2.12         | Leaks                                   | Defects in manufacture and installation | Visual                                                                | Loss of fluid                                             | Possible fire                                                   |                                                                                  | 3           | 3                 |                                                                                                                                                                                        |

## Failure Modes and Effects Analysis

Level No. 1 Heat-Transfer Fluid

Level No. 2 Instrumentation

Level No. 3

Level No. 4

Program: Solar Production of Industrial Process Steam  
Drawing: 60863-50-1

| Functional Description      | Failure Mode |                                         | Possible Causes | Symptoms Detectability | Effect of Failure                                                                |                                                   | Existing Compensating Provision | Probability | Level of Severity | Remarks |
|-----------------------------|--------------|-----------------------------------------|-----------------|------------------------|----------------------------------------------------------------------------------|---------------------------------------------------|---------------------------------|-------------|-------------------|---------|
|                             | SN           | Description                             |                 |                        | Local Effect                                                                     | End Effect                                        |                                 |             |                   |         |
| Recorder TR-100             | 1.31         | Fails indicating false low temperature  |                 | As 1.30                | False low collector inlet temperature recorded                                   | False high indication of collector efficiency     | Temperature recorded on TR-401  | 2           | 1                 |         |
|                             | 1.32         | Fails recording false high temperature  |                 |                        | As 1.30                                                                          | As 1.30                                           |                                 |             |                   |         |
| RTD TT-101                  | 1.33         | Fails recording false low temperature   |                 | As 1.30                | As 1.31                                                                          | As 1.32                                           | 2                               | 1           |                   |         |
|                             | 1.34         | Fails indicating false high temperature |                 |                        | By comparison with temperature recorded on TR-403 and indicated on TI-101 to 115 | False high collector outlet temperature recorded  |                                 |             |                   |         |
| Temperature Recorder TR-101 | 1.35         | Fails indicating false low temperature  |                 | As 1.34                | As 1.34                                                                          | False low collector outlet temperature recorded   | 2                               | 1           |                   |         |
|                             | 1.36         | Fails recording false high temperature  |                 |                        | As 1.34                                                                          | As 1.34                                           |                                 |             |                   |         |
| RTD TT-403                  | 1.37         | Fails recording false low temperature   |                 | As 1.34                | As 1.35                                                                          | As 1.35                                           | 2                               | 1           |                   |         |
|                             | 1.40         | Fails indicating false high temperature |                 |                        | By comparison with temperature recorded on TR-101 and indicated on TI-101 to 115 | False high indication of boiler inlet temperature |                                 |             |                   |         |
| Temperature Recorder        | 1.41         | Fails indicating false low temperature  |                 | As 1.40                | As 1.40                                                                          | As 1.40                                           | 2                               | 1           |                   |         |
|                             | 1.42         | Records false high temperature          |                 |                        | As 1.40                                                                          | False low indication of boiler inlet temperature  |                                 |             |                   |         |
|                             | 1.43         | Records false low temperature           |                 | As 1.40                | As 1.41                                                                          | As 1.40                                           |                                 |             |                   |         |

## Failure Modes and Effects Analysis

Level No. 1 Heat-Transfer Fluid Circulation

Level No. 2 Collector

Level No. 3

Level No. 4

Program: Solar Production of Industrial Process Steam  
Drawing: 60863-50-1

| Functional Description        | Failure Mode |                                                  | Possible Causes                                                              | Symptoms Detectability          | Effect of Failure                                         |                              | Existing Compensating Provision                   | Probability | Level of Severity | Remarks                                              |
|-------------------------------|--------------|--------------------------------------------------|------------------------------------------------------------------------------|---------------------------------|-----------------------------------------------------------|------------------------------|---------------------------------------------------|-------------|-------------------|------------------------------------------------------|
|                               | SN           | Description                                      |                                                                              |                                 | Local Effect                                              | End Effect                   |                                                   |             |                   |                                                      |
| Collector                     | 2.13         | Entry of cool liquid into hot tube               | Mishap, late opening of isolation valves                                     |                                 | Thermal shock                                             | Leak develops                |                                                   | 2           | 3                 | Operating instructions must guard against "hot fill" |
|                               | 2.14         | Percolation of fluid into empty tube             | Valves leak                                                                  |                                 | Thermal stresses                                          | exposure of workers to fluid |                                                   | 2           | 5                 |                                                      |
|                               | 2.15         | Boiling of residual liquid in collector          | Failure to stow collector, insufficient fluid in system                      |                                 | Thermal stresses                                          |                              |                                                   | 2           | 3                 |                                                      |
|                               | 2.16         | Stress                                           | High wind                                                                    | Visual, wind speed indicator    | Foundation damage                                         |                              | Collectors stow in high wind                      | 3           | 3                 |                                                      |
| Valves that isolate collector | 2.17         | Damage to collector surfaces                     | Ball                                                                         | Visual                          | Damage to collector surfaces                              |                              | Collectors stow when insulation low               | 2           | 3                 |                                                      |
|                               | 2.20         | Closure of one valve                             | Accidental closing of wrong valve                                            |                                 | Excessive temperature in collector                        | Degradation of fluid         | Stowage of collector                              | 2           | 2                 |                                                      |
|                               | 2.21         | Closure of both isolation valves about collector | As 2.20                                                                      |                                 | As 2.20                                                   | Overpressure in collector    | Stowage of collector, PSV                         | 2           | 5                 |                                                      |
|                               | 2.22         | Opening of supposedly closed valve/leaks         | Accident on removal of collector from service/putting collector into service |                                 | Possible exposure of personnel to hot heat transfer fluid |                              | Lines will be blanked off                         | 2           | 5                 |                                                      |
| Collector drain valve         | 2.23         | Accidentally opened/falls open                   | Error                                                                        | Visual, low level alarm LAL-800 | Spill of liquid                                           | Possible fire                |                                                   | 2           | 5                 |                                                      |
| PSV-102/L15                   | 2.24         | Sticks                                           |                                                                              |                                 | Tube rupture on overpressure                              |                              | Collector stowed if temperature in collector high | 2           | 5                 |                                                      |
|                               | 2.25         | Discharge wire blocked                           | Debris/ice                                                                   |                                 | As 2.24                                                   |                              | As 2.24                                           | 2           | 5                 |                                                      |
|                               | 2.26         | Premature operation                              |                                                                              | Visual                          | As 2.23                                                   | As 2.23                      |                                                   | 2           | 5                 |                                                      |

## Failure Modes and Effects Analysis

Level No. 1 Heat-Transfer Fluid Circulation, Boiler

Level No. 2 Collector

Level No. 3

Level No. 4

Program: Solar Production of Industrial Process Steam  
Drawing: 60863-50-1

| Functional Description    | Failure Mode |                                         | Possible Causes                           | Symptoms Detectability            | Effect of Failure                                  |                                                                    | Existing Compensating Provision      | Probability | Level of Severity | Remarks                      |
|---------------------------|--------------|-----------------------------------------|-------------------------------------------|-----------------------------------|----------------------------------------------------|--------------------------------------------------------------------|--------------------------------------|-------------|-------------------|------------------------------|
|                           | SN           | Description                             |                                           |                                   | Local Effect                                       | End Effect                                                         |                                      |             |                   |                              |
| Insulation Sensor IT-001  | 2.30         | Fails on                                | Malfunction                               | Visual                            | Failure to stow collectors when insulation low     |                                                                    |                                      | 2           | 1                 |                              |
|                           | 2.31         | Fails off                               |                                           |                                   | Sensor stowed                                      |                                                                    |                                      | 2           | 2                 |                              |
| RTD on Collectors         | 2.35         | Fails indicating false high temperature |                                           | Visual                            | Collector stows                                    |                                                                    |                                      | 2           | 1                 |                              |
|                           | 2.36         | Fails indicating false low temperature  |                                           |                                   | Collector fails to stow when temperature excessive | Overheating or overpressurization of collector                     | PSV guard against overpressurization | 2           | 5                 |                              |
| Motors to stow collectors | 2.40         | Motor/drive failure                     |                                           | Visual--collector out of position | Inability to track up or stow collectors           | Overheating of collector if no/low fluid flow                      |                                      | 3           | 5                 |                              |
|                           | 2.41         | Electrical power failure                |                                           |                                   | Stowage of collectors using battery power          | Overheating of collector if not stowed                             |                                      | 3           | 5                 |                              |
| Tubes                     | 2.42         | Batteries drained                       | Stress, deflection manufacture, corrosion | Low flow alarm, etc.              | As 2.40                                            | As 2.40                                                            |                                      | 2           | 5                 |                              |
|                           | 3.10         | Leak                                    |                                           |                                   | Entry of water into leak transfer fluid            | Possible corrosion, vapor locks in system, high pressure in system | Nitrogen purge in TK-101             | 3           | 3                 |                              |
| Boiler SG-101             | 3.11         | Scale                                   | Impurities in boiler feed water           | Via TR-403                        | Reduced heat transfer                              | Increased temperature of heat transfer                             |                                      | 2           | 1                 | A chronic potential problem  |
|                           | 3.20         | Excessive temperature                   |                                           |                                   |                                                    | Increased degradation of heat transfer fluid                       |                                      | 3           | 1                 | A potential nonacute problem |

## Failure Modes and Effects Analysis

Level No. 1 Heat-Transfer Fluid Circulation, Boiler

Level No. 2

Level No. 3

Level No. 4

Program: Solar Production of Industrial Process Steam  
Drawing: 60863-50-1

| Functional Description                 | Failure Mode |                                                              | Possible Causes | Symptoms Detectability                                     | Effect of Failure                                        |                              | Existing Compensating Provision | Probability | Level of Severity | Remarks |
|----------------------------------------|--------------|--------------------------------------------------------------|-----------------|------------------------------------------------------------|----------------------------------------------------------|------------------------------|---------------------------------|-------------|-------------------|---------|
|                                        | SN           | Description                                                  |                 |                                                            | Local Effect                                             | End Effect                   |                                 |             |                   |         |
| Level Transmitter LT-400               | 3.30         | Fails indicating false low level (slightly below set point)  |                 | Indicated on LG-400                                        | High water feed rate set                                 | Boiler flooded               | Indication on LG-400            | 2           | 2                 |         |
|                                        | 3.31         | Fails indicating false very low level                        |                 |                                                            | As 3.30                                                  | As 3.30                      | As 3.30                         | 2           | 2                 |         |
| Level Transmitter                      | 3.32         | Fails indicating false high level (slightly above set point) |                 | Indicated on LG-400 and abnormal level recorded on LRC-400 | Reduced water feed rate to boiler                        | Boiler dries, thermal stress | LSSL-400 trips pump             | 2           | 4                 |         |
|                                        | 3.33         | Fails indicating false very high level                       |                 |                                                            | As 3.33                                                  | As 3.30                      | As 3.30                         | 2           | 4                 |         |
| Low Level Switch/Alarm LSL-400/LAL-400 | 3.34         | Fails on                                                     |                 | On LG-400 and abnormal indication given by LRC-400         | Low level alarm                                          |                              | LRC-400 and LG-400              | 2           | 1                 |         |
|                                        | 3.35         | Fails off                                                    |                 |                                                            | Redundancy in low level alarms cost                      |                              | As 3.34                         | 2           | 1                 |         |
| High Level Switch LSH-400/LAH-400      | 3.36         | Fails on                                                     |                 | Comparison with LG-400                                     | High level alarm                                         |                              | As 3.34                         | 2           | 1                 |         |
|                                        | 3.37         | Fails off                                                    |                 |                                                            | No high level alarm                                      |                              | As 3.34                         | 2           | 2                 |         |
| Level Recorder (LRC-400)               | 3.38         | Records false high level                                     |                 | Comparison with LG-400                                     | Redundancy to LG-400 cost                                |                              |                                 | 2           | 1                 |         |
|                                        | 3.39         | Records false low level                                      |                 |                                                            |                                                          |                              |                                 |             |                   |         |
| LSSL-400/LYLL-400                      | 3.40         | Calls for low level                                          |                 |                                                            | Boiler level falls                                       | Boiler empties               | LAL/LAIL-400, LG-400            | 2           | 3                 |         |
|                                        | 3.41         | Calls for high level                                         |                 |                                                            | Boiler water level rises                                 | Boiler floods                | LAH-400, LG-400                 | 2           | 2                 |         |
|                                        | 3.42         | Fails on                                                     | Relay short     | Malfunction                                                | Low level alarm and shutdown                             |                              |                                 | 2           | 2                 |         |
|                                        | 3.43         | Fails off                                                    |                 |                                                            | Redundancy to LG-400, no automatic shutdown if level low |                              | LSL-400, LRC-400, LG-400        | 2           | 1                 |         |

## Failure Modes and Effects Analysis

Level No. 1 Boiler

Level No. 2

Level No. 3

Level No. 4

Program: Solar Production of Industrial Process Steam  
Drawing: 60863-50-1

| Functional Description                    | Failure Mode |                                      | Possible Causes     | Symptoms Detectability                           | Effect of Failure                    |                       | Existing Compensating Provision                   | Probability | Level of Severity | Remarks |
|-------------------------------------------|--------------|--------------------------------------|---------------------|--------------------------------------------------|--------------------------------------|-----------------------|---------------------------------------------------|-------------|-------------------|---------|
|                                           | SN           | Description                          |                     |                                                  | Local Effect                         | End Effect            |                                                   |             |                   |         |
| LALL-400                                  | 3.44         | Fails on                             |                     |                                                  | Low level alarm                      |                       | LAL-400, LRC-400, LG-400                          | 2           | 1                 |         |
|                                           | 3.45         | Fails off                            |                     |                                                  | Second alarm on low level not given  |                       |                                                   |             |                   |         |
| Boiler Feed-water Flow Controller WRC-400 | 3.50         | Fails calling for low flow           |                     |                                                  | As 3.40                              | As 3.40               | As 3.40                                           | 2           | 3                 |         |
|                                           | 3.51         | Fails calling for high flow          |                     |                                                  | As 3.41                              | As 3.41               | As 3.41                                           | 2           | 2                 |         |
|                                           | 3.53         | Records false low flow               |                     |                                                  | Measurements lost                    |                       | WQI-40                                            | 2           | 1                 |         |
|                                           | 3.54         | Records false high flow              |                     |                                                  | As 3.53                              |                       | As 3.53                                           | 2           | 1                 |         |
| Flow Transmitter WI-400/WY-400            | 3.55         | Fails indicating false high flow     |                     | Abnormal flow rate indicated                     | Flow reduced until level too low     |                       | Flow control set point determined by boiler level | 2           | 2                 |         |
|                                           | 3.56         | Fails indicating false low flow      |                     | As 3.55                                          | Flow increased until level excessive |                       |                                                   |             |                   |         |
| Pressure Transmitter PT-400/PR-400        | 3.57         | Fails indicating false high pressure |                     | Pressure not in accord with recorded temperature |                                      |                       | PSV-400                                           | 2           | 1                 |         |
|                                           | 3.58         | Fails indicating false low pressure  |                     | As 3.57                                          | Indication of pressure lost          |                       |                                                   |             |                   |         |
| WV-400                                    | 3.60         | Fails closed/fails to open           | Malfunction         |                                                  | Insufficient flow boiler feedwater   | Level in boiler feeds | Bypass                                            | 2           | 3                 |         |
|                                           | 3.61         | Fails open/sticks closed             | Loss instrument air |                                                  | Excessive flow boiler feedwater      | Level in boiler rises |                                                   |             |                   |         |
| Bypass to WV-400                          | 3.62         | Opened                               | Error               |                                                  | Control over boiler feedwater        | Level in boiler rises |                                                   | 2           | 2                 |         |
| Safety Valve PSV-400                      | 3.70         | Fails to open                        |                     |                                                  | Failure to remove overpressure       | Rupture boiler        |                                                   | 2           | 5                 |         |

## Failure Modes and Effects Analysis

Level No. 1 Boiler, Heat-Transfer Fluid Circulation

Level No. 2 Dump Tank

Level No. 3

Level No. 4

Program: Solar Production of Industrial Process Steam  
Drawing: 60863-50-1

| Functional Description            | Failure Mode |                                   | Possible Causes                            | Symptoms Detectability | Effect of Failure                              |                                                                         | Existing Compensating Provision | Probability | Level of Severity | Remarks                                                     |
|-----------------------------------|--------------|-----------------------------------|--------------------------------------------|------------------------|------------------------------------------------|-------------------------------------------------------------------------|---------------------------------|-------------|-------------------|-------------------------------------------------------------|
|                                   | SN           | Description                       |                                            |                        | Local Effect                                   | End Effect                                                              |                                 |             |                   |                                                             |
| Valves on steam line              | 3.71         | Opens prematurely                 | Error                                      | Via TI-800             | Loss of steam pressure                         |                                                                         | PSV-400                         | 2           | 2                 |                                                             |
|                                   | 3.80         | Closed                            |                                            |                        | Boiler water level and temperature rises       | Pressure rises                                                          |                                 |             |                   |                                                             |
| Pressure Regulating Valve PCV-400 | 3.81         | Fails giving high pressure        | Misset/mal-function                        | Via TI-800             |                                                | Temperature in dump tank higher than anticipated                        |                                 | 2           | 1                 |                                                             |
|                                   | 3.82         | Fails giving low pressure         |                                            |                        |                                                | Temperature in dump tank lower than anticipated                         |                                 |             |                   |                                                             |
| Boiler Feed-water                 | 3.83         | Low pressure                      | Failure pump, leaks                        |                        | Low flow to boiler                             | Level in boiler falls                                                   |                                 | 2           | 3                 |                                                             |
|                                   | 3.84         | Infinities                        |                                            |                        | Promote scaling                                |                                                                         |                                 |             |                   |                                                             |
| Dump Tank                         | 4.10         | Ruptured                          | Impact, failure, corrosion                 | Visual                 | Spill of fluid                                 | Possible fire                                                           | Area diked                      | 2           | 5                 |                                                             |
|                                   | 4.11         | Drain left open                   |                                            |                        | Loss of fluid to process sewer                 | Possible fire in sewer, low level of fluid in system, low flow of fluid |                                 |             |                   |                                                             |
| Vapor Space                       |              | Contains air                      | Hooking up to wrong line<br>PVC-801 closed |                        |                                                | Possible fire or explosion if ignition occurs                           |                                 | 2           | 5                 |                                                             |
|                                   |              |                                   |                                            |                        | Flammable atmosphere created                   |                                                                         |                                 |             |                   |                                                             |
| Level Gauge                       | 4.20         | Fails indicating false high level |                                            |                        | Possible emptying/insufficient filling of tank | Low fluid in level in system                                            | LAI-800                         | 2           | 3                 | Ensure level gauge is adequately protected against breakage |

**FOSTER WHEELER DEVELOPMENT CORPORATION**

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DATE: June 1979

**Failure Modes and Effects Analysis**

Level No. 1 Heat-Transfer Fluid

Level No. 2 Dump Tank, Nitrogen Purge

Level No. 3

Level No. 4

Program: Solar Production of Industrial Process Steam  
Drawing: 60863-50-1

| Functional Description                           | Failure Mode |                                  | Possible Causes | Symptoms Detectability | Effect of Failure                    |                                                              | Existing Compensating Provision          | Probability | Level of Severity | Remarks                                                      |
|--------------------------------------------------|--------------|----------------------------------|-----------------|------------------------|--------------------------------------|--------------------------------------------------------------|------------------------------------------|-------------|-------------------|--------------------------------------------------------------|
|                                                  | SN           | Description                      |                 |                        | Local Effect                         | End Effect                                                   |                                          |             |                   |                                                              |
| ISL/LAL-800                                      | 4.21         | Fails indicating false low level | Impact          |                        | Possible over-filling of tank        | Fluid enters N <sub>2</sub> system                           | Valve off lines to level gauge<br>LG-400 | 2           | 3                 | Ensure level gauge is adequately protected against breakage. |
|                                                  | 4.22         | Broken                           |                 |                        | Release of fluid into control room   |                                                              |                                          |             |                   |                                                              |
|                                                  | 4.25         | Fails on                         |                 |                        | Shut down for low level              |                                                              |                                          |             |                   |                                                              |
|                                                  | 4.26         | Fails off                        |                 |                        | Protection against low levels lost   |                                                              |                                          |             |                   |                                                              |
| Relief Valve PSV-800                             | 4.30         | Fails to open                    |                 |                        | Protection against overpressure lost | Dump tank ruptures                                           | 2                                        | 5           |                   |                                                              |
|                                                  | 4.31         | Prematurely opens                |                 |                        | Nitrogen vented to atmosphere        |                                                              |                                          |             |                   |                                                              |
| Nitrogen Purge Pressure Regulating Valve PCV-800 | 4.40         | Fails open                       |                 |                        | High purge rate                      |                                                              | PI-802                                   | 2           | 1                 |                                                              |
|                                                  | 4.41         | Fails closed                     |                 |                        | Nitrogen purge ceases                | Accumulation of water in system--corrosion and pressure rise |                                          |             |                   |                                                              |
|                                                  | 4.42         | Fails open                       |                 |                        | Possible overpressuring of dump tank | Spill of fluid                                               |                                          | 2           | 5                 | Recommend periodic checks to ensure venting occurs           |
| Nitrogen Pressure Regulating Valve PCV-801       | 4.43         | Fails closed                     |                 |                        | Purge ceases, air enters             | As 4.41. Also potential for creation of flammable atmosphere |                                          |             |                   |                                                              |

## Failure Modes and Effects Analysis

Level No. 1 Heat-Transfer Fluid Circulation

Level No. 2 Nitrogen Purge, Heat-Transfer Fluid, Instruments

Level No. 3

Level No. 4

Program: Solar Production of Industrial Process Steam

Drawing: 60863-50-1

| Functional Description | Failure Mode |                                            | Possible Causes                                    | Symptoms Detectability | Effect of Failure                              |                                        | Existing Compensating Provision | Probability | Level of Severity | Remarks                                                                                    |
|------------------------|--------------|--------------------------------------------|----------------------------------------------------|------------------------|------------------------------------------------|----------------------------------------|---------------------------------|-------------|-------------------|--------------------------------------------------------------------------------------------|
|                        | SN           | Description                                |                                                    |                        | Local Effect                                   | End Effect                             |                                 |             |                   |                                                                                            |
| Nitrogen Supply        | 4.50         | Low pressure                               | Source pressure low, leak moisture freezes in line |                        | Nitrogen purge ceases                          | As 4.41                                |                                 | 2           | 3                 |                                                                                            |
|                        | 4.51         | High pressure                              | Source pressure high                               |                        | Possible overpressuring of dump tank           | Spill of heat transfer fluid           | PSV-400                         | 2           | 5                 |                                                                                            |
| Pump P-102             | 4.60         | Fails                                      | Motor fails, power failure                         | Filling stops          | Filling stops                                  |                                        |                                 | 2           | 1                 |                                                                                            |
| Liquid used            | 4.70         | Wrong liquid used (lower AFT/flash points) |                                                    |                        | Increased likelihood of fire                   |                                        |                                 | 2           | 5                 | Recommend that stringent precautions be made to ensure correct heat transfer fluid is used |
|                        | 4.71         | Wrong liquid used (more volatile)          |                                                    |                        | High pressure in system PSVs open/overpressure | Potential fire and overpressure damage |                                 | 2           | 5                 |                                                                                            |
| Instruments            | 5.00         | Erroneous readings                         |                                                    |                        | Erroneous information gathered                 |                                        |                                 |             |                   | Recommend that appropriate checks be made on information gathered                          |