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American National Standard

Fossil Fuel Power Plant Instrument Piping Installation



ANSI/ISA-S77.70, Fossil Fuel Power Plant Instrument Piping Installation

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ISA
67 Alexander Drive
P.O. Box 12277
Research Triangle Park, North Carolina 27709

Preface

This preface is included for informational purposes and is not part of ISA-S77.70.

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The ISA Standards and Practices Department is aware of the growing need for attention to the metric system of units in general, and the International System of Units (SI) in particular, in the preparation of instrumentation standards, recommended practices, and technical reports. The Department is further aware of the benefits to USA users of ISA standards of incorporating suitable references to the SI (and the metric system) in their business and professional dealings with other countries. Toward this end, this Department will endeavor to introduce SI-acceptable metric units in all new and revised standards to the greatest extent possible. *The Metric Practice Guide*, which has been published by the Institute of Electrical and Electronics Engineers as ANSI/IEEE Std. 268-1992, and future revisions, will be the reference guide for definitions, symbols, abbreviations, and conversion factors.

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1 Scope

This standard covers the mechanical design, engineering, fabrication, installation, testing, and protection of fossil power plant instrumentation sensing and control lines. The boundaries of this standard span the process tap root valve to the instrument connection. This standard applies to all fluid media (liquid, gas, or vapor).

2 Purpose

This standard establishes the applicable installation requirements and limits of instrumentation sensing and control lines and their instruments in fossil power plants.

This standard addresses the requirements of maintaining the pressure boundary integrity of the instrumentation sensing line (in accordance with the appropriate parts of American National Standards Institute [ANSI] standards).

3 Definitions and terminology

For the purposes of this standard, the following definitions apply.

3.1 anchor: A reliable support that fastens the sensing line in place and prevents movement in all directions.

3.2 blowdown line: The pipe or tubing located below the instrument connection for draining the condensate or steam to a safe location.

3.3 blowdown valve: The valve in instrument sensing lines used to discharge undesirable fluids.

3.4 breakable fitting: A fitting that is easily removed without damaging the tubing or pipe.

3.5 capillary: A small diameter tubing that runs from the process connection to the instrument.

3.6 condensate pots: Reservoirs that are used in the measurement of steam or other vapors for condensing to the liquid state at ambient temperature.

3.7 control piping: The piping that is used to interconnect pneumatically or hydraulically operated control apparatus, as well as signal transmission systems used to interconnect instruments. This applies to all instrument valves, fittings, tubing, and piping.

3.8 credible events: Those events considered environmental, geographical, or atmospheric in nature, such as earthquakes, tornadoes, hurricanes, etc.

3.9 instrument: A device used directly or indirectly to measure and/or control a process variable. The term includes primary elements, final control elements, measuring devices, computing devices, and electrical devices such as annunciators, switches, and push buttons. The term does not apply to parts that are internal components of an instrument (e.g., a receiver bellows or a resistor).

3.10 instrument isolation valve: The valve or valve manifold in the sensing line that is available to personnel during normal plant operation for isolating the instrument from the process. The root valve may or may not perform the function of the isolation valve, depending upon the instrument location.

3.11 instrument piping: All valves, fittings, tubing, and piping used to connect instruments to main piping, other instruments, apparatus, or measuring equipment.

3.12 manifolds: An assembly of two, three, or more valves, often in one package, used to facilitate calibration and maintenance.

3.13 root valve: The first valve located on the instrument sensing line after it taps off the main process. The root valve is sometimes referred to as the shutoff valve.

3.14 seal chambers: The chambers used in the measurement of fluids that, due to their corrosive or viscous properties, are preferably prevented from entering the instrument body.

3.15 slide: The device that supports the dead weight of the instrument piping but allows axial movement.

3.16 welded fitting: A type of fitting used to permanently connect by welding tubing with tubing, tubing with pipe, or pipe with pipe.

4 Mechanical design

The design of instrument sensing and sampling lines in a power plant is covered by ANSI B31.1, "Power Piping," latest version with addenda. This code allows either tubing or pipe to be used for these lines. All pressure-boundary connections, tubing, piping, fittings, valves, in-line devices, and equipment shall be specified by the engineer in accordance with the requirements of ANSI B31.1. Regarding interpretation of pressure-boundary requirements, the latest version of ANSI B31.1 with addenda shall be the governing document.

4.1 Instrument lines

4.1.1 Process tap connections

All of the material between the root valve(s), including the root valve(s) and process connection, shall be the same material as the process pipe or vessel or shall be a material compatible with the process fluid, pressure, temperature, and connection methods. The connection shall be a minimum of ½ inch (12.7 mm) nominal pipe size for service conditions when pressures are 900 psig (6.21 MPa) or less, and temperatures are 800°F (426.67°C) or less. The minimum size shall be ¾ inch (19.05 mm) for conditions that exceed either of those limits. Shutoff valves shall be designed for maximum design pressure and temperature of the piping system and shall be

located as close as possible to the process tap connections. If the process line is smaller than the appropriate takeoff connection size, the connection shall be the same size as the source.

4.1.2 Lines between shutoff valves and instruments

The lines between the shutoff valves (root valve) and the instruments shall have design pressures as follows:

For sub-critical steam services, the lines shall be designed for process design pressure at saturated temperature; for all other services, the line shall be designed for process piping design pressure and temperature.

To prevent plugging and obtain sufficient mechanical strength, the inside diameter of the tube or pipe shall not be less than 0.360 inch (9.14 mm) and shall have a minimum wall thickness of 0.049 inch (1.25 mm). Deviations from the inside diameter are allowed for technical reasons based upon design calculations.

4.1.3 Blowdown valves

Blowdown valves shall be the gradual opening type. For steam service, these valves shall be suitable for the maximum design pressure of the process line and its corresponding saturated steam temperature. For all other services, the blowdown valve shall be designed for the process piping design pressure and temperature.

4.2 Tubing wall thickness

ANSI B31.1, Section 104, provides the formula for calculating minimum wall thickness required for a given pressure and temperature. The minimum wall thickness calculation has been replicated in Annex B. The calculation is based on a bending allowance of three (3) diameters and includes no mechanical strength or corrosion allowance. Refer to ANSI B31.1 for supplemental information.

4.3 Tubing material

Tubing material shall be compatible with the process that meets the requirements of ANSI B31.1. Either tubing or piping may be used for the instrument sensing lines. The following are materials commonly used for instrument sensing lines.

4.3.1 Stainless steel tubing, ASTM A213, Grade TP304

This material should be limited to non-corrosive applications not exceeding 1000°F (537.78°C).

4.3.2 Stainless steel tubing, ASTM A213, Grade TP316

This material should be limited to non-corrosive applications not exceeding 1200°F (648.89°C).

4.3.3 Stainless steel tubing, ASTM A213, Grade TP316L

This material is not as readily available as TP304 and TP316. Its use should be limited to corrosive conditions. The design temperature shall not exceed 850°F (454.44°C).

4.3.4 Copper ASTM B88 or B75 drawn or annealed soft temper

Copper may be used in dead-end water, air, or gas service. However, for continuous service, these lines shall not be used above 406°F (207.78°C). Copper or copper alloy pipe is not recommended for steam or ammonia service.

4.3.5 Carbon steel ASTM A210, Grade A1

This material should be limited to non-corrosive applications with temperatures not exceeding 775°F (412.78°C) and annealed to R_C 72 max* or manufacturer's recommendation for fittings.

4.4 Fittings

4.4.1 Fitting material

The fittings shall be manufactured from material that is suitable for the application and is compatible with the tubing or pipe used. Compatibility criteria should be based on the requirements of ANSI B31.1, as well as the process requirements. When "O" ring seals are required, they shall be suitable for the application.

4.4.2 Prohibited material

Fittings and fitting components shall contain no metallic mercury or mercury compounds and shall be free from mercury contamination, except as alloying elements of the required base or bonding corrosion-resistant plating.

Fittings and fitting components shall not contain low melting-point metals (such as lead, antimony, arsenic, bismuth, cadmium, magnesium, tin, or zinc) in concentrations greater than 250 ppm, except as alloying elements of the required base materials.

4.4.3 Design

The design dimensions of the fittings shall be in accordance with the manufacturer's standard design.

4.4.4 Flow area reduction

Installation of a fitting shall be in accordance with the vendor's standard makeup procedures with no special tools or mandrels and should not significantly reduce flow area.

4.4.5 Reuse

Makeup of a fitting should not damage or modify the fitting in any manner that would prevent or hinder its reuse. Welded or brazed fittings shall not be reused.

4.4.6 Finish

The use of anti-galling coatings, as provided by the manufacturers for stainless steel fittings, is recommended in accordance with the manufacturers' published procedures.

*R_C = Rockwell hardness (C-scale); a unit of metal hardness according to the Rockwell hardness test.

4.5 Instrument valves and manifolds

4.5.1 Design pressure and temperature

When blowdown valves are not used, the instrument valves and manifolds shall have the same design rating as stated in 4.1.2. The valves shall be of the gradual opening type and shall be capable of operation during maximum design differential pressure and temperature.

4.5.2 Materials of construction

Materials for pressure-retaining parts such as the body, bonnet, disc, pipe plugs, fittings, tube stubs, or bolting shall be as required by ANSI B31.1. Packing materials shall be rated for the pressure and temperature service intended. Asbestos shall not be used.

4.6 Condensate pots

Condensate pots, also referred to as reservoirs, shall be designed in accordance with ANSI B31.1.

5 Installation

5.1 Tubing preparation

To straighten coiled tubing, it shall be laid on a flat, smooth surface to prevent scratches. The tubing should be straightened by hand without pulling or hitting the material, which can change the inside diameter (I.D.) and cause deformation of the tubing. Only the necessary amount of tubing shall be uncoiled since repeated uncoiling will cause distortion, hardening, and stiffening.

Coiled tubing can also be straightened using multiple rollers—four or five sets on both sides of the tubing.

5.2 Tube cutting

Copper, carbon steel, and stainless steel tubing shall be cut with a fine-toothed hacksaw when tubing is to be flared. If tubing is connected using compression-type fittings, then the tubing shall be cut with either a fine-toothed hacksaw or the appropriately sized tube cutter. The cutting wheel of the tube cutter shall be sharp and in good condition to prevent damage to the tubing. When cutting tubing with a hacksaw, use a fine-toothed hacksaw with a tubing sawing vise or guide blocks. All tubing cuts shall be squared off with a fine file, and all internal and external burrs shall be removed without causing damage to the tubing. The tubing surface shall not be scratched when removing burrs. After cutting and squaring, all areas of the tubing on inside and outside areas shall be free of all foreign material.

5.3 Tube bending

Where directional changes for tubing lines are made by bends, the bends shall be performed at ambient temperature using the appropriate bending tool, not by free hand. All tube bends shall be free of deformation, kinks, wrinkles, flat spots, or scoring. The minimum bending radius shall be $2\frac{1}{4}$ times the tubing outside diameter (O.D.) for tubing less than $\frac{1}{2}$ inch (12.70 mm) O.D. and 3 times the tubing O.D. for tubing $\frac{1}{2}$ inch (12.70 mm) and larger. Fittings shall be at least three tubing diameters away from a bend.

5.4 Joining tubing and tube fittings

Tube fitting installation shall be in accordance with both ANSI B31.1 and the manufacturer's recommendations.

Breakable tube fittings should be used for process and control signal connections to the instrument to allow for instrument removal.

5.5 Welding

Welding procedures and welding performance qualifications shall be in accordance with the latest edition and addenda of ANSI B31.1, Section IX at the time of qualification. Filler material used for qualification and installations shall meet the requirements of ANSI B31.1, Section II, Part C, and IX, as applicable.

5.6 Threaded connections

Tape-type sealants may generally be used up to a temperature of 450°F (232.22°C) on clean air, water, and steam service. Manufacturer's recommendations shall be followed for the actual limitations on the installation of the tape. If tape-type sealants are used, the tape shall not extend beyond the smallest taper thread. Non-tape-type thread sealant compounds applied in accordance with the manufacturer's recommendations shall be used on all other pipe connections. Sealant compounds shall not be used on the tubing side of breakable tube fittings.

To prevent seizing and galling, the fitting manufacturer's recommendations should be followed. Thread damage or galling can occur on stainless steel or other special alloy fittings. Galling can be prevented on the tube end of the fitting by special treatment of the nuts during manufacture.

5.7 Tubing slope instrument installation

Routing of sensing lines shall ensure that the function of these lines is not affected by the entrapment of gas (fluid-sensing line) or liquid (gas-sensing line). One of the following methods shall be used to ensure that the sensing line is not affected: [Method (a) is preferred.]

- a) For liquid measurement it is preferred that the downward slope from the tap to the instrument of the sensing line be 1 inch or more per foot (80 mm or more per meter of run; for gas measurement it is preferred that the upward slope from the tap to the instrument of the sensing line be 1 inch or more per foot (80 mm or more per meter of

run. Where the preferred minimum slope cannot be obtained in the two cases above, the lines shall be installed to the maximum slope available, and in no case shall the slope be less than ¼ inch per foot (20 mm per meter).

- b) High point vents or low point drains, or both, shall be provided to ensure that all entrapped gas or liquid can be purged from the sensing line.
- c) A combination of items (a) and (b).

5.7.1 Steam and water service

Instruments shall be located below the root valve whenever possible. The purpose of running the sensing line downward from the root valve is to limit the penetration of gas bubbles into the system and to limit the temperature at the instrument. This location also facilitates the downward slope of the sensing line, minimizing the need for high point vents.

5.7.2 Vacuum service

For applications in which the line pressure is negative during operation (e.g., a vacuum), the instrument shall be located above the process connection. The purpose of this location is to eliminate the condensed liquid in the sensing line, which could cause an error in the measurement.

5.7.3 Air and gas service

Instruments measuring air or gas in process piping should be located above the process connection, with the sensing line sloped downward to the process connection. This arrangement will allow any condensed moisture to drain back into the process rather than into the instrument, which could cause error in measurement. Otherwise, condensate pots shall be required.

5.8 Condensate pots

Condensate pots are used in the measurement of steam or other vapors for condensing the vapor to a liquid state to minimize errors due to gas trapped in the instrument piping. Condensate pots installed in a horizontal position should be installed level and be protected from excessive vibration. Those installed in vertical positions are used for collecting liquid drained from a sensing line.

5.9 Supports

5.9.1 Support requirements

5.9.1.1 Material and stresses

Support elements shall be capable of bearing the total weight of insulation, instrument piping with fluid, and a safety margin. This design loading ensures that the tubing or pipe is not stressed beyond a safe limit. If installed outdoors, additional loading factors shall be considered; for example, wind load, ice buildup in cold climates, heat tracing, credible events, and vibration.

5.9.1.2 Thermal expansion

Changes of tubing dimensions due to temperature or to environmental or process fluid conditions that cause changes in the length shall be allowed for and compensated for in the routing of the tubing.

All instrument sensing lines and fittings shall be arranged to provide for thermal expansion. The instrument and the first rigid support should be mounted on the same structure with a minimum of two feet of free tubing between them. To mitigate the effect of thermal expansion, "S" and coil tubing configurations may be utilized.

5.9.1.3 Vibration

To mitigate the effects of vibration, support elements shall be added at irregular intervals to withstand and dampen vibration effects.

5.9.2 Support spacing

Support spacing and the selection of anchors and slides shall be specified by the engineer. Spacing of multiple tubes shall be wide enough, and at properly even distances, to allow each tube to expand independently and to allow access to tube fittings.

5.9.3 Support types

Tube clips and clamps shall be rigid enough to secure but not damage the tubing. Support and clamp materials shall be selected to avoid galvanic corrosion.

5.10 Use of heat trace and insulation

5.10.1 Condensate protection

Tubing and piping that will be cold enough in service to sweat or frost shall be installed with clearances for 1 inch (25.4 mm) thick anti-sweat insulation and shall be routed so that condensed moisture will not damage other equipment by dripping, running, or accumulating. Instrument line trays, if used, shall be positioned to prevent accumulations of moisture within them.

5.10.2 Freeze protection

Instruments and instrument piping located in areas subject to freezing shall be provided with suitable freeze protection. Such protection may consist of steam or electric heat tracing with temperature control for the instrument piping and insulated enclosures with strip heaters and temperature control for the instruments. Heat tracing on instrument piping shall be designed to withstand maximum process temperature. All heat-traced lines must be insulated with a suitable insulation material.

5.10.3 Process maintenance

Freeze-protected instrument piping requiring process maintenance shall be either steam or electric heat traced with temperature control. Designs shall not allow the heat tracing to exceed instrument piping or fluid temperature limitations.

5.11 Coating of tubing or fittings

Tubing and tube fittings shall not be covered with a potentially flammable or combustible coating.

5.12 Instrument piping routing

Instrument piping shall not be installed in walkways or near stairways. Instrument piping shall be routed so that:

- a) It provides the minimum recommended height clearances of
 - 8 feet (2.44 m) within structures,
 - 10 feet (3.05 m) within yard areas,
 - 14 feet (4.27 m) over secondary roads, and
 - 22 feet (6.71 m) over railroads and main plant buildings.
- b) It does not interfere with instrument removal, calibration, or indication.
- c) It has a suitable design that protects the instrument and tubing as well as personnel.
- d) It does not obstruct equipment-handling areas or spaces for equipment removal.

5.13 Syphons and loops

Pressure instruments for steam or hot fluids service shall have a loop (pigtail) or other suitable isolator between the gage and the source of pressure when mounted on the process piping. This isolation protects the instrument from excessive temperature. Syphons shall not be used on differential pressure instruments.

6 Quality assurance and control

6.1 Receipt

Prior to unloading equipment, a visual inspection should be made to determine if any obvious damage occurred during shipment.

Upon receipt, the contents of all shipments should be examined, as appropriate, for the following:

- a) Compliance with purchase specification documents
- b) Physical damage
- c) Proper storage protection
- d) Conformance to dimensional and physical property specifications
- e) Proper identification and marking

Materials found to be deficient during the examination shall be clearly identified and segregated from the acceptable materials. Rejected materials should be returned to the vendor or disposed of in accordance with established procedures.

6.2 Material handling

Handling of materials should be controlled to prevent possible damage. Parts should be kept free from extraneous matter such as oil, grease, dirt, and chips.

Tubing and fittings should be carefully handled during receipt, storage, and installation to prevent scratching, gouging, and nicking, which could affect proper seals and cause leaks.

Tubing should not be pulled across hard surfaces such as truck or shelf edges, concrete, gravel, or asphalt.

6.3 Storage of parts

Parts or assemblies in storage should be suitably protected from dirt, dust, water, oils, solvents, and other contaminants, as well as possible damage from handling. Containers used for storage of parts should be labeled to identify their contents, material designation, part number, and packaging date code. Unless otherwise authorized by responsible authority, parts in stock shall be used on a first-in, first-out basis.

6.4 Cleanliness requirements

Equipment should be packaged or protected from corrosion, contamination, physical damage, or any other condition that would cause the item to deteriorate during shipment, handling, and storage.

Tubing ends should be sealed at all times except when they must be unsealed for installation.

The interior of pipes, tubing, valves, and fittings shall be smooth, clean, and free from foreign material. All lines shall be cleaned after installation before being placed in service.

Cleanliness classification for all sensing lines shall be consistent with main process cleanliness as established by the user of this standard. The cleanliness of air supply and pneumatic signal lines shall be in accordance with ISA-S7.3, Quality Standard for Instrument Air.

Cleanliness may be achieved by pneumatic blowdown with compressed air or inert gas or by flushing with water that is clean enough to minimize corrosion of the materials in the installed system.

6.5 Pre-testing inspection

Each completed installation shall be visually inspected prior to testing. This inspection shall ensure compliance with design drawings and specifications.

All joints shall be left uninsulated and exposed for examination during pressure testing. All welded connections shall be visually examined. Examinations and testing shall be in accordance with ANSI B31.1.

The visual inspection should verify the following:

- a) Correct materials were used.
- b) Installation drawing details were followed.
- c) Proper slopes were maintained.

- d) Supports are adequate, and vibration was mitigated.
- e) Connections were properly made.
- f) Welded connections were visually inspected.
- g) Valves and instruments were properly tagged.
- h) High-point vents and low-point drains were provided as required.

6.6 Pressure tests

Pressure tests should be conducted to ensure the pressure integrity of sensing and control lines. Tests shall be in accordance with the latest edition and addenda of ANSI B31.1, which provides additional guides to this testing.

6.6.1 Pressure test boundaries

The pressure test boundaries shall be:

- a) From, but not including, the root valve on the process side to the instrument isolation valve.
- b) From, but not including, the root valve on the process side to the first connection at the instrument.

The connecting welds to the root valves or process connections defined by this subsection are considered within the pressure-test boundary.

6.6.2 Hydrostatic testing

The following items should be considered when planning a hydrostatic test program:

- a) An indicating pressure gauge that is visible at all times to the operator controlling the applied pressure shall be provided.
- b) For systems composed of austenitic stainless steels, testing shall be performed with demineralized water.
- c) During hydrostatic testing, leakage from temporary gaskets and seals that were installed for test purposes and will be replaced later should be permitted only if such leakage does not exceed the capacity to maintain the required system test pressure for the required time. Leakage from permanent seals, seats, and gasketed joints should not be permitted.

6.6.3 Pneumatic testing

Pneumatic testing of control piping should be performed in accordance with ISA-RP7.1, Pneumatic Control Circuit Pressure Tests, except for the following:

- a) Commercial leak-testing fluids should be used for testing.
- b) Soapsuds or household detergent and water are not satisfactory leak-test fluids, since they may mask leaks.
- c) The fluids used should not bubble except in response to a leak.
- d) Leak detection compounds containing ammonia shall not be used on brass fittings because a chemical reaction could occur, causing the brass tube fittings to crack.

6.7 Material certification

6.7.1 Materials of construction

All material used in construction of piping and components shall be certified by the manufacturer with a certificate of compliance to the ASTM/ASME specifications. The manufacturer should have a quality assurance program for material control and verification.

6.7.2 Certificates of compliance

All certificates of compliance applicable to material used in a component should be furnished by the manufacturer with the material at the time of shipment. The material should be marked wherever practical, and the package shall always be marked with the manufacturer's name or symbol and alloy grade. Documenting specific heat code and lot numbers may be required, especially for welding and brazing material, so that they are controlled and identifiable as acceptable in the welding process.

6.7.3 Tube-fitting certification

Tube-fitting certifications shall comply with ANSI B31.1 and shall include ASTM material specifications and nondestructive testing as required. Specific heat traceability is not required except on weld-ended bodies as required for weld documentation. The installer shall inspect and certify proper installation of fittings per ANSI B31.1.

6.7.4 Tube-fitting material identification

Tube-fitting manufacturers do not mark alloy numbers on carbon steel. Most use multiple alloys under the ASTM A 108 broad category for free machining qualities of leaded carbon steels. To ensure proper chemistry and weld compatibility of carbon steel weld fittings, use only those fittings where manufacturers mark or tag alloy identification. Manufacturers normally mark stainless and nickel alloys and other special corrosion-resistant alloys as standard procedure. Tube fittings having registration numbers can be used for material identification.

6.7.5 Tube and pipe identification

Tubing and pipe shall be marked with permanent ink on the O.D. with alloy, grade, size, and wall thickness or pipe schedule, as required for proper identification prior to installation.

Annex A — Interface standards and documents

This annex is included for information only and is not a part of this standard.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

B2.1 (1984)	Specifications, Dimensions and Gaging for Taper and Straight Pipe Threads (Including Certain Special Applications—Except Dryseal)
B16.5 (1988)	Pipe Flanges and Flanged Fittings (ASME)
B31.1 (1992)	Power Piping (ASME)

Available from: ANSI

11 West 42nd Street
New York, NY 10036

Tel. (212) 642-4900

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

PTC 19.11 (1984)	Performance Test Codes, Part 11, Water and Steam in the Power Cycle (Purity and Quality, Leak Detection, and Measurement)
PTC 23 (1992)	Performance Test Codes, Atmospheric Water-Cooling Equipment

Available from: ASME

345 East 47th Street
New York, NY 10017

Tel. (212) 705-7722

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

A210/A210M (1991)	Specification for Seamless Medium-Carbon Steel Boiler and Superheater Tubes
A213/A213M (1992)	Specification for Seamless Ferritic and Austenitic Alloy Steel Boiler, Superheater, and Heat-Exchanger Tubes
B88M-(1993)	Specification for Seamless Copper Water Tube
D1192-70 (R 1977)	Specification for Equipment for Sampling Water and Steam

Available from: ASTM

1916 Race Street
Philadelphia, PA 19103

Tel. (215) 299-5585

ISA

ANSI/ISA-S67.01 (1979)	Transducer and Transmitter Installation for Nuclear Safety Applications (Reaffirmed: July 26, 1987)
ANSI/ISA-S67.02 (1980)	Nuclear Safety-Related Instrument Sensing Line Piping and Tubing Standards for Use in Nuclear Power Plants
ANSI/ISA-S67.10 (1986)	Sample Line Piping and Tubing for Use in Nuclear Power Plants
ISA-S7.3 (1981)	Quality Standard for Instrument Air
ISA-RP7.1 (1956)	Pneumatic Control Circuit Pressure Test

Available from: ISA

67 Alexander Drive
P.O. Box 12277

Research Triangle Park, NC 27709

Tel. (919) 549-8411

MANUFACTURERS' STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY, INC. (MSS)

SP-25-78 (1993)	Standard Marking System for Valves, Fittings, Flanges, and Unions
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Available from: MSS

127 Park Street NE
Vienna, VA 22180

Tel. (703) 281-6613

UNITED STATES CODE OF FEDERAL REGULATIONS (CFR)

10CFR50: Title 10 Code of Federal Regulations, Part 50
Listing of Production of Utilization Facilities

Available from: U.S. Government Printing Office

Superintendent of Documents
Washington, DC 20402

Annex B — ASME/ASTM wall thickness and operating pressure tables (calculation excerpted from ANSI B31.1)

This annex is included for information only and is not a part of this standard. Consult tube-fitting manufacturer's recommended maximum allowable tubing wall thickness and hardness. Some heavy wall tubing in smaller O.D. sizes may only be suitable for tube weld fittings.

Minimum wall thickness formula

$$T_m = (\{PD_o/2 * [S + (P * Y)]\} + A) * F$$

Maximum pressure formula

$$P = 2S * [(T_m/F) - A]/D_o - 2Y * [(T_m/F) - A]$$

NOTE: When calculating maximum pressure, T_m = actual wall thickness or use 87 percent of nominal wall thickness (for piping).

where

A = Allowance for corrosion or mechanical strength (designer to specify);

D_o = Outside diameter of tubing;

F = Correction factor for size of bends;

Diameter Bend		F
3 in	(76.20 mm)	1.25
4 in	(101.60 mm)	1.14
5 in	(127.00 mm)	1.08
6 in	(152.4 mm)	1.06

P = Internal design pressure in psi;

S = Allowable stress value from ANSI B31.1;

T_m = Minimum wall thickness; and

Y = Correction for Temperature.

Temperature °F	900 & Below	950	1000	1050	1100	1150 & above
Temperature °C	482 & Below	510	538	566	593	621 & Above
Ferritic Steel	0.4	0.5	0.7	0.7	0.7	0.7
Austenitic Steel	0.4	0.4	0.4	0.4	0.5	0.7

Table B.1 — Stainless Steel ASME/ASTM A213 Type TP304
Minimum Wall Thickness, 0.049 (1.24 mm)
Maximum Operating Pressure, psig (MPa)

Temperature, Degrees F (Degrees C)										
OD in. (mm)	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)	900 (482.22)	1000 (537.78)
1/2 (12.70)	3145 (21.68)	2626 (18.11)	2359 (16.26)	2175 (14.99)	2041 (14.07)	1907 (13.15)	1857 (12.80)	1773 (12.22)	1706 (11.76)	1639 (11.30)
5/8 (15.88)	2483 (17.12)	2073 (14.29)	1862 (12.84)	1717 (11.84)	1611 (11.11)	1506 (10.38)	1466 (10.11)	1400 (9.65)	1347 (9.29)	1294 (8.92)
3/4 (19.05)	2051 (14.14)	1713 (11.81)	1538 (10.60)	1418 (9.78)	1331 (9.18)	1244 (8.58)	1211 (8.35)	1156 (7.97)	1113 (7.67)	1069 (7.37)

Stainless Steel ASME/ASTM A213 Type TP304 (cont.)
Minimum Wall Thickness, 0.065 (1.65 mm)
Maximum Operating Pressure, psig (MPa)

Temperature, Degrees F (Degrees C)										
OD in. (mm)	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)	900 (482.22)	1000 (537.78)
1/2 (12.70)	4265 (29.41)	3562 (24.56)	3199 (22.06)	2949 (20.33)	2768 (19.08)	2586 (17.83)	2528 (17.43)	2405 (16.58)	2314 (15.95)	2223 (15.33)
5/8 (15.88)	3351 (23.10)	2799 (19.30)	2514 (17.33)	2317 (15.98)	2175 (15.00)	2032 (14.01)	1979 (13.64)	1890 (13.72)	1818 (12.53)	1747 (12.05)
3/4 (19.05)	2760 (19.03)	2305 (15.89)	2070 (14.27)	1909 (13.46)	1791 (12.35)	1674 (11.54)	1630 (11.24)	1556 (10.73)	1497 (10.32)	1439 (9.92)

Stainless Steel ASME/ASTM A213 Type TP304 (cont.)
Minimum Wall Thickness, 0.083 (2.11 mm)
Maximum Operating Pressure, psig (MPa)

Temperature, Degrees F (Degrees C)										
OD in. (mm)	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)	900 (482.22)	1000 (537.78)
1/2 (12.70)	5587 (38.52)	4666 (32.17)	4190 (28.89)	3863 (26.63)	3625 (24.99)	3388 (23.36)	3299 (22.75)	3150 (21.72)	3031 (20.90)	2912 (20.08)
5/8 (15.88)	4366 (30.10)	3646 (25.14)	3274 (22.57)	3019 (20.82)	2833 (19.53)	2647 (18.25)	2578 (17.77)	2461 (16.97)	2369 (16.33)	2276 (15.69)
3/4 (19.05)	3583 (24.70)	2992 (20.63)	2687 (18.53)	2477 (17.08)	2325 (16.03)	2172 (14.98)	2115 (14.58)	2020 (13.93)	1944 (13.40)	1868 (12.88)

Stainless Steel ASME/ASTM A213 Type TP304 (cont.)
Minimum Wall Thickness, 0.095 (2.41 mm)
Maximum Operating Pressure, psig (MPa)

Temperature, Degrees F (Degrees C)										
OD in. (mm)	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)	900 (482.22)	1000 (537.78)
1/2 (12.70)	6506 (44.86)	5434 (37.47)	4880 (33.65)	4499 (31.02)	4222 (29.11)	3945 (27.20)	3842 (26.49)	3668 (25.29)	3530 (24.34)	3392 (23.39)
5/8 (15.88)	5065 (34.92)	4230 (29.17)	3799 (26.19)	3502 (24.15)	3287 (22.66)	3071 (21.17)	2990 (20.62)	2856 (19.69)	2748 (18.95)	2640 (18.20)
3/4 (19.05)	4146 (28.59)	3463 (23.88)	3110 (21.44)	2867 (19.77)	2691 (18.55)	2514 (17.33)	2448 (16.88)	2338 (16.12)	2250 (15.51)	2161 (14.90)

Stainless Steel ASME/ASTM A213 Type TP304 (cont.)
Minimum Wall Thickness, 0.109 (2.77 mm)
Maximum Operating Pressure, psig (MPa)

Temperature, Degrees F (Degrees C)										
OD in. (mm)	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)	900 (482.22)	1000 (537.78)
1/2 (12.70)	7621 (52.55)	6364 (43.88)	5716 (39.41)	5270 (36.33)	4945 (34.09)	4621 (31.86)	4499 (31.02)	4297 (29.63)	4135 (28.51)	3972 (27.39)
5/8 (15.88)	5905 (40.71)	4931 (34.00)	4429 (30.54)	4083 (28.15)	3832 (26.42)	3581 (24.69)	3486 (24.04)	3329 (22.95)	3204 (22.09)	3078 (21.22)
3/4 (19.05)	4820 (33.23)	4025 (27.75)	3615 (24.92)	3333 (22.98)	3128 (21.57)	2923 (20.15)	2846 (19.62)	2718 (18.74)	2615 (18.03)	2513 (17.33)

Stainless Steel ASME/ASTM A213 Type TP304 (cont.)
Minimum Wall Thickness, 0.12 (3.05 mm)
Maximum Operating Pressure, psig (MPa)

Temperature, Degrees F (Degrees C)										
OD in. (mm)	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)	900 (482.22)	1000 (537.78)
1/2 (12.70)	8529 (58.81)	7123 (49.11)	6397 (44.11)	5898 (40.67)	5535 (38.16)	5172 (35.66)	5036 (34.72)	4809 (33.16)	4628 (31.91)	4446 (30.65)
5/8 (15.88)	6584 (45.40)	5499 (37.91)	4938 (34.05)	4553 (31.39)	4273 (29.46)	3993 (27.53)	3888 (26.81)	3713 (25.60)	3572 (24.63)	3432 (23.66)
3/4 (19.05)	5362 (36.97)	4478 (30.87)	4021 (27.72)	3708 (25.57)	3480 (23.99)	3251 (22.41)	3166 (21.83)	3023 (20.84)	2909 (20.07)	2795 (19.27)

Table B.2 — Stainless Steel ASME/ASTM A213 Type TP316
Minimum Wall Thickness, 0.049 (1.24 mm)
Maximum Operating Pressure, psig (MPa)

OD in. (mm)	Temperature, Degrees F (Degrees C)									
	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)	900 (482.22)	1000 (537.78)
1/2 (12.70)	3145 (21.68)	2710 (18.68)	2442 (16.84)	2242 (15.46)	2091 (14.42)	1974 (13.61)	1890 (13.03)	1840 (12.69)	1807 (12.46)	1773 (12.22)
5/8 (15.88)	2483 (17.12)	2139 (14.75)	1928 (13.29)	1770 (12.20)	1651 (11.38)	1558 (10.74)	1492 (10.29)	1453 (10.02)	1426 (9.83)	1400 (9.65)
3/4 (19.05)	2051 (14.14)	1767 (12.18)	1593 (10.98)	1462 (10.08)	1364 (9.40)	1287 (8.87)	1233 (8.50)	1200 (8.23)	1178 (8.12)	1156 (7.97)

Stainless Steel ASME/ASTM A213 Type TP316 (cont.)
Minimum Wall Thickness, 0.12 (3.05 mm)
Maximum Operating Pressure, psig (MPa)

OD in. (mm)	Temperature, Degrees F (Degrees C)									
	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)	900 (482.22)	1000 (537.78)
1/2 (12.70)	8529 (58.81)	7350 (50.68)	6624 (45.67)	6079 (41.91)	5671 (39.10)	5353 (36.91)	5127 (35.35)	4991 (34.41)	4900 (33.78)	4809 (33.16)
5/8 (15.88)	6584 (45.40)	5674 (39.12)	5113 (35.25)	4693 (32.36)	4378 (30.19)	4133 (28.50)	3958 (27.30)	3853 (26.57)	3783 (26.08)	3713 (25.60)
3/4 (19.05)	5362 (36.97)	4620 (31.85)	4164 (28.71)	3822 (26.35)	3565 (24.58)	3365 (23.20)	3223 (22.22)	3137 (21.63)	3080 (21.24)	3023 (20.84)

Table B.3 — Stainless Steel ASME/ASTM A213 Type TP316L
Minimum Wall Thickness, 0.049 (1.24 mm)
Maximum Operating Pressure, psig (MPa)

OD in. (mm)	Temperature, Degrees F (Degrees C)							
	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)
1/2 (12.70)	2626 (18.11)	2292 (15.80)	1991 (13.73)	1807 (12.46)	1807 (12.46)	1573 (10.85)	1506 (10.38)	1472 (10.15)
5/8 (15.88)	2073 (14.29)	1809 (12.47)	1572 (10.84)	1426 (9.83)	1426 (9.83)	1241 (8.56)	1189 (8.20)	1162 (8.01)
3/4 (19.05)	1713 (11.81)	1495 (10.31)	1298 (8.95)	1178 (8.12)	1178 (8.12)	1025 (7.07)	982 (6.77)	960 (6.62)

Stainless Steel ASME/ASTM A213 Type TP316L (cont.)
Minimum Wall Thickness, 0.065 (1.65 mm)
Maximum Operating Pressure, psig (MPa)

OD in. (mm)	Temperature, Degrees F (Degrees C)							
	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)
1/2 (12.70)	3562 (24.56)	3108 (21.43)	2700 (18.62)	2450 (16.89)	2450 (16.89)	2133 (14.71)	2042 (14.08)	1997 (13.77)
5/8 (15.88)	2799 (19.30)	2442 (16.84)	2121 (14.62)	1925 (13.27)	1925 (13.27)	1676 (11.55)	1604 (11.06)	1569 (10.82)
3/4 (19.05)	2305 (15.89)	2011 (13.87)	1747 (12.05)	1586 (10.94)	1586 (10.94)	1380 (9.51)	1321 (9.11)	1292 (8.91)

Stainless Steel ASME/ASTM A213 Type TP316L (cont.)
Minimum Wall Thickness, 0.083 (2.11 mm)
Maximum Operating Pressure, psig (MPa)

OD in. (mm)	Temperature, Degrees F (Degrees C)							
	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)
1/2 (12.70)	4666 (32.17)	4071 (28.07)	3536 (24.38)	3209 (22.13)	3209 (22.13)	2793 (19.26)	2675 (18.44)	2615 (18.03)
5/8 (15.88)	3646 (25.14)	3181 (21.93)	2763 (19.05)	2508 (17.29)	2508 (17.29)	2183 (15.05)	2090 (14.41)	2044 (14.09)
3/4 (19.05)	2992 (20.63)	2611 (18.00)	2268 (15.64)	2058 (14.18)	2058 (14.18)	1791 (12.35)	1715 (11.82)	1677 (11.56)

Stainless Steel ASME/ASTM A213 Type TP316L (cont.)
Minimum Wall Thickness, 0.095 (2.41 mm)
Maximum Operating Pressure, psig (MPa)

OD in. (mm)	Temperature, Degrees F (Degrees C)							
	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)
1/2 (12.70)	5434 (37.47)	4741 (32.69)	4118 (28.39)	3738 (25.77)	3738 (25.77)	3253 (22.43)	3115 (21.48)	3046 (21.00)
5/8 (15.88)	4230 (29.17)	3691 (25.45)	3206 (22.10)	2910 (20.06)	2910 (20.06)	2532 (17.46)	2425 (16.72)	2371 (16.35)
3/4 (19.05)	3463 (23.88)	3021 (20.83)	2624 (18.09)	2382 (16.42)	2382 (16.42)	2073 (14.29)	1985 (13.68)	1941 (13.38)

Stainless Steel ASME/ASTM A213 Type TP316L (cont.)
Minimum Wall Thickness, 0.109 (2.77 mm)
Maximum Operating Pressure, psig (MPa)

Temperature, Degrees F (Degrees C)								
OD in. (mm)	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)
1/2 (12.70)	6364 (43.88)	5553 (38.29)	4824 (33.26)	4378 (30.19)	4378 (30.19)	3810 (26.27)	3648 (25.15)	3567 (24.59)
5/8 (15.88)	4931 (34.00)	4303 (29.67)	3738 (25.77)	3392 (23.39)	3392 (23.39)	2953 (20.36)	2827 (19.49)	2764 (19.06)
3/4 (19.05)	4025 (27.75)	3512 (24.21)	3051 (21.04)	2769 (19.09)	2769 (19.09)	2410 (16.62)	2307 (15.91)	2256 (15.55)

Stainless Steel ASME/ASTM A213 Type TP316L (cont.)
Minimum Wall Thickness, 0.12 (3.05 mm)
Maximum Operating Pressure, psig (MPa)

Temperature, Degrees F (Degrees C)								
OD in. (mm)	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)
1/2 (12.70)	7123 (49.11)	6216 (42.86)	5399 (37.23)	4900 (33.78)	4900 (33.78)	4265 (29.41)	4083 (28.15)	3992 (27.52)
5/8 (15.88)	5499 (37.91)	4798 (33.08)	4168 (28.74)	3783 (26.08)	3783 (26.08)	3292 (22.70)	3152 (21.73)	3082 (21.25)
3/4 (19.05)	4478 (30.87)	3907 (26.94)	3894 (26.85)	3080 (21.24)	3080 (21.24)	2681 (18.48)	2567 (17.70)	2510 (17.31)

Table B.4 — Carbon Steel ASME/ASTM A210 Grade A1
Minimum Wall Thickness, 0.049 (1.24 mm)
Maximum Operating Pressure, psig (MPa)

Temperature, Degrees F (Degrees C)							
OD in. (mm)	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)
1/2 (12.70)	2509 (17.30)	2509 (17.30)	2509 (17.30)	2509 (17.30)	2509 (17.30)	2509 (17.30)	2409 (16.61)
5/8 (15.88)	1981 (13.66)	1981 (13.66)	1981 (13.66)	1981 (13.66)	1981 (13.66)	1981 (13.66)	1902 (13.11)
3/4 (19.05)	1636 (11.28)	1636 (11.28)	1636 (11.28)	1636 (11.28)	1636 (11.28)	1636 (11.28)	1571 (10.83)

Carbon Steel ASME/ASTM A210 Grade A1 (cont.)
Minimum Wall Thickness, 0.065 (1.65 mm)
Maximum Operating Pressure, psig (MPa)

Temperature, Degrees F (Degrees C)							
OD in. (mm)	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)
1/2 (12.70)	3403 (23.46)	3403 (23.46)	3403 (23.46)	3403 (23.46)	3403 (23.46)	3403 (23.46)	3267 (22.53)
5/8 (15.88)	2674 (18.44)	2674 (18.44)	2674 (18.44)	2674 (18.44)	2674 (18.44)	2674 (18.44)	2567 (17.70)
3/4 (19.05)	2202 (15.18)	2202 (15.18)	2202 (15.18)	2202 (15.18)	2202 (15.18)	2202 (15.18)	2114 (14.58)

Carbon Steel ASME/ASTM A210 Grade A1 (cont.)
Minimum Wall Thickness, 0.083 (2.11 mm)
Maximum Operating Pressure, psig (MPa)

Temperature, Degrees F (Degrees C)							
OD in. (mm)	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)
1/2 (12.70)	4458 (30.74)	4458 (30.74)	4458 (30.74)	4458 (30.74)	4458 (30.74)	4458 (30.74)	4279 (29.50)
5/8 (15.88)	3483 (24.01)	3483 (24.01)	3483 (24.01)	3483 (24.01)	3483 (24.01)	3483 (24.01)	3344 (23.06)
3/4 (19.05)	2858 (19.71)	2858 (19.71)	2858 (19.71)	2858 (19.71)	2858 (19.71)	2858 (19.71)	2744 (18.92)

Carbon Steel ASME/ASTM A210 Grade A1 (cont.)
Minimum Wall Thickness, 0.095 (2.40 mm)
Maximum Operating Pressure, psig (MPa)

Temperature, Degrees F (Degrees C)							
OD in. (mm)	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)
1/2 (12.70)	5191 (35.79)	5191 (35.79)	5191 (35.79)	5191 (35.79)	5191 (35.79)	5191 (35.79)	4984 (34.36)
5/8 (15.88)	4041 (27.86)	4041 (27.86)	4041 (27.86)	4041 (27.86)	4041 (27.86)	4041 (27.86)	3879 (26.74)
3/4 (19.05)	3308 (22.81)	3308 (22.81)	3308 (22.81)	3308 (22.81)	3308 (22.81)	3308 (22.81)	3176 (21.90)

Carbon Steel ASME/ASTM A210 Grade A1 (cont.)
Minimum Wall Thickness, 0.109 (2.77 mm)
Maximum Operating Pressure, psig (MPa)

OD in. (mm)	Temperature, Degrees F (Degrees C)							
	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)
1/2 (12.70)	6080 (41.92)	6080 (41.92)	6080 (41.92)	6080 (41.92)	6080 (41.92)	6080 (41.92)	6080 (41.92)	5837 (40.24)
5/8 (15.88)	4711 (32.48)	4711 (32.48)	4711 (32.48)	4711 (32.48)	4711 (32.48)	4711 (32.48)	4711 (32.48)	4523 (31.19)
3/4 (19.05)	3486 (24.04)	3486 (24.04)	3486 (24.04)	3486 (24.04)	3486 (24.04)	3486 (24.04)	3486 (24.04)	3692 (25.46)

Carbon Steel ASME/ASTM A210 Grade A1 (cont.)
Minimum Wall Thickness, 0.12 (3.05 mm)
Maximum Operating Pressure, psig (MPa)

OD in. (mm)	Temperature, Degrees F (Degrees C)							
	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)	500 (260)	600 (315.56)	700 (371.11)	800 (426.67)
1/2 (12.70)	6805 (46.92)	6805 (46.92)	6805 (46.92)	6805 (46.92)	6805 (46.92)	6805 (46.92)	6805 (46.92)	6533 (45.04)
5/8 (15.88)	5254 (36.23)	5254 (36.23)	5254 (36.23)	5254 (36.23)	5254 (36.23)	5254 (36.23)	5254 (36.23)	5043 (34.77)
3/4 (19.05)	4278 (29.50)	4278 (29.50)	4278 (29.50)	4278 (29.50)	4278 (29.50)	4278 (29.50)	4278 (29.50)	4107 (28.32)

Table B.5 — Copper ASME/ASTM B88 Annealed
Minimum Wall Thickness, 0.049 (1.24 mm)
Maximum Operating Pressure, psig (MPa)

OD in. (mm)	Temperature, Degrees F (Degrees C)			
	100 (37.78)	200 (93.33)	300 (148.89)	400 (204.44)
1/2 (12.70)	1004 (6.92)	803 (5.54)	803 (5.54)	786 (5.42)
5/8 (15.88)	792 (5.46)	634 (4.37)	634 (4.37)	621 (4.28)
3/4 (19.05)	655 (4.52)	524 (3.61)	524 (3.61)	513 (3.54)

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