Entegris

CYNERGY® SYSTEM TECHNICAL GUIDE

Engineering design validation guide

Table of Contents

(Continued on Page 2)

Graphs

Fluid Management Solutions

Entegris, a worldwide leader in providing high performance, nonmetallic fluid handling components, provides solutions for corrosive environments and sensitive processes.

For more than 35 years, Entegris has been assuring materials integrity with quality products, systems and related services to the semiconductor and chemical processing industries. It is with this materials management expertise that we are able to meet the needs of biopharmaceutical, as well as bulk and finishing pharmaceutical industries – specifically in steam-in-place (SIP) and clean-in-place (CIP) applications.

Keeping pace with your market and technology demands, Entegris continually invests in next generation product development. One such investment is our on-site steam chamber where all Cynergy products are prequalified. Our extensive qualification testing guarantees product reliability and safety, so you can confidently sterilize Cynergy products using your standard SIP conditions.

Our state-of-the-art manufacturing facilities include Class 100 and Class 1000 cleanrooms, controlled manufacturing environments, sophisticated process control equipment, computerized in-process inspections and highly trained personnel. With manufacturing facilities in the United States, Germany and Japan, along with customer support on six continents, we are positioned to service your needs around the world.

Cynergy Component CAD Library

2D and 3D CAD drawings of Cynergy valves and fittings are available online. To decrease system design time, visit Entegris' Web site at *www.entegrisfluidhandling.com* for component specifications and CAD files.

Cynergy products received the DuPont Plunkett Award for Innovation with Teflon material in 2000.

R&D 100 Award Winner
Cynergy products have been recognized by R & D Magazine *as one of the 100 most technologically significant new products of 1998.*

For Additional Information

To review our complete line of fluid handling products, log on to *www.entegrisfluidhandling.com* or contact Entegris Customer Service for your free *Fluid Handling Products* catalog on CD-ROM.

Section 1: Material Information

Polymer Definitions

PFA: perfluoroalkoxy
Teflon PFA (DuPont)

$$-[(CF_2CF_2)nCF_2CF]m-$$
$$|$$
$$O$$
$$|$$
$$C_3F_7$$

PFA is a fully fluorinated fluorocarbon polymer.

PEEK™: polyaryletherketone
(Victrex plc)

$$-[(C_6H_4)CO(C_6H_4)O(C_6H_4)O]n-$$

PEEK is a high performance engineering thermoplastic.

PES: polyethersulfone

$$-[(C_6H_4)SO_2(C_6H_4)O]n-$$

PES is a high performance engineering thermoplastic.

PVDF: polyvinylidine fluoride
Kynar® (Elf Atochem)
Solef (Solvay)

$$-[(CH_2CF_2)n-$$

PVDF is a partially fluorinated fluoropolymer.

Resin Approvals

Entegris uses only virgin resins to manufacture components that contact the fluid stream. We do not add stabilizers, plasticizers, colorants or filler to the resin; nor do we use mold release agents. The injection molding and extrusion processes we use to convert the resins do not alter the material chemical composition or physical characteristics.

Teflon PFA Material

Teflon PFA has been extensively tested to comply with the needs of the pharmaceutical and biotechnology industries. This resin meets the standard requirements of the FDA, USP, 3-A and USDA.

TABLE 1: RESINS COMPLY WITH FDA REGULATIONS

Resins	DuPont Teflon PFA Resins 440HP, 445HP and 450HP Grades
21 CFR 177.1550	Yes
21 CFR 175.300	Yes
21 CFR 176.170	Yes
21 CFR 176.180	Yes

Articles Intended to Contact Food

Reference: 21 CFR 177.1550 Perfluorocarbon Resins

Teflon PFA type fluoropolymer resins listed in Table 1 have been approved by the FDA for repeated-use food contact articles such as tubing, hoses, components of valves, etc., as well as for coatings for articles intended for repeated food contact use in compliance with this regulation.

Components of Resinous and Polymeric Coatings

Reference: 21 CFR 175.300 Resinous and Polymeric Coatings

Most Teflon fluoropolymer resins may be used as release agents in compliance with this regulation as long as the finished coating meets the extractives limitations of the regulation.

Components of Paper and Paperboard

Reference: 21 CFR 176.170 Components of Paper and Paperboard in Contact with Aqueous and Fatty Foods

Most Teflon fluoropolymer resins may be used as release agents in compliance with this regulation as long as the finished coating meets the extractives limitations of this regulation.

Reference: 21 CFR 176.180 Components of Paper and Paperboard in Contact with Dry Food.

Most Teflon fluoropolymer resins may be used as release agents in compliance with this regulation.

USDA Acceptance

The United States Department of Agriculture (USDA) has accepted Teflon PFA fluoropolymer resins that comply with 21 CFR 177.1550 as components of materials in direct contact with meat or poultry food products prepared under Federal inspection. Resins that comply with this regulation are shown in Table 1.

3-A Sanitary Standards

HP grades of Teflon PFA fluoropolymer resin comply with the criteria in 3-A Standards for Multiple-Use Plastic Materials Used as Product Contact Surfaces for Dairy Equipment, Number 20-17.

Compliance with the 3-A Standard assures that the component material is noncontaminating and can be cleaned and sanitized using current cleaning procedures and sanitizing chemicals.

US Pharmacopoeia (USP) Class VI

Representative samples of Teflon PFA have been tested in accordance with USP protocol, and Teflon PFA meets the requirements of a USP Class VI plastic.

USP testing was done to support use of these fluoropolymers in pharmaceutical processing and food processing applications. While USP Class VI certification is not required for pharmaceutical processing, many pharmaceutical customers seeking ISO 9000 certification have requested it.

Medical Use

Caution: Do not use Teflon fluoropolymers in medical applications involving permanent implantation in the human body. For other medical applications, see DuPont Medical Caution Statement, H-50102.

DuPont does not make surgical or medical grades of Teflon resin and does not guarantee continuity of process in their manufacturing operations as changes may occur from time to time.

Source: DuPont Product Information Bulletin H-22779-5.

Victrex PEEK Material

Polyaryletherketone resins may be safely used as articles or components of articles intended for repeated use in contact with food subject to the provisions of 21 CFR Section 177.2415.

PES Material

Polyethersulfone resins may be safely used as articles or components of articles intended for repeated use in contact with food, in accordance with 21 CFR Section 177.1560.

FDA compliant additives are used to enhance strength and appearance. Glass fibers and black pigment are cleared for use in accordance with 21 CFR 177.1050 and 21 CFR 175.3000 respectively.

Solef PVDF Material

Articles Intended to Contact Food

Solef PVDF resins are cleared for use as articles or components of articles intended for repeated use in contact with food, in accordance with section 21 CRF 177.2510-Polyvinylidene Fluoride Resins of the code of Federal Regulations, volume 21, which gives the requirements of the Food and Drug Administration for Food Additives.

3-A Sanitary Standards

The following Solef material grades conform to the criteria in *3-A Standards for Multiple-Use Plastic Materials Used as Product Contact Surfaces for Dairy Equipment, Number 20-17*.

- Solef 1008/0001
- Solef 3208/0150
- Solef 11010/0000

Source: Solvay Polymers, Inc. Bulletin 1217-121AC 10/91 5000, and Solvay Polymers, Inc

Chemical Compatibility

Cynergy products are constructed from polymers that are resistant to a variety of chemicals. A comprehensive chemical compatibility list follows. All data is taken from information supplied by material manufacturers and available published information. Entegris, Inc. is not responsible for the accuracy of this data and disclaims any obligation or liability in connection.

TABLE 2: CHEMICAL COMPATIBILITY OF CYNERGY PRODUCT MATERIALS

A = Recommended (little or no chemical attack)
B = Satisfactory* (minor chemical attack)
C = Not recommended (severe chemical attack)
*use will depend on the application

Chemical	Teflon PFA	PEEK	PES	Solef PVDF
Acetaldehyde	A to 93°C (200°F)	A to 93°C (200°F)	C	C
Acetic Acid, Conc.	A to boiling	A to 100°C (212°F)	A 10% to 82°C (180°F)	A to 50°C (122°F)
Acetic Acid, Glacial	A to boiling	A to 100°C (212°F)	A to 23°C (73°F)	A to 50°C (122°F)
Acetone	A to 93°C (200°F)	A to 100°C (212°F)	C	C
Acetonitrile	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 49°C (120°F)
Acetylene	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 121°C (250°F)
Aluminum Chloride (100%)	A to boiling	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Aluminum Sulfate (100%)	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 100°C (212°F)
Ammonia Anhydrous	A to boiling	A to 200°C (392°F)	A to 20°C (68°F)	A to 138°C (280°F)
Ammonia Aqueous	A to boiling	A to 200°C (392°F)	A to 20°C (68°F)	A to 135°C (275°F)
Ammonium Chloride, 10% Conc.	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	
				A to 135°C (275°F)
Ammonium Hydroxide, Conc.	A to 139°C (282°F)	A to 21°C (70°F)	A 10% to 82°C (180°F)	C
Ammonium Nitrate	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Amyl Acetate	A to 93°C (200°F)	A to 100°C (212°F)	B to 20°C (68°F)	A to 50°C (122°F), B to 75°C (167°F), C at 110°C (230°F)
Aniline	A to 185°C (365°F)	A to 100°C (212°F)	C	A to 21°C (70°F), B to 66°C (150°F), C at 100°C (212°F)
Antimony Trichloride	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 21°C (70°F)
Aqua Regia	A to 120°C (248°F)	C	–	A to 100°C (212°F)
Barium Salts (Chloride, Sulfide)	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Beer	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 100°C (212°F)
Benzaldehyde	A to 179°C (355°F)	A to 21°C (70°F)	C	A to 52°C (125°F)
Benzene	A to 93°C (200°F)	A to 100°C (212°F)	A to 23°C (73°F)	A to 52°C (125°F)

TABLE 2: CHEMICAL COMPATIBILITY OF CYNERGY PRODUCT MATERIALS (CONTINUED)

A = Recommended (little or no chemical attack)
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Chemical	Teflon PFA	PEEK	PES	Solef PVDF
Benzene Sulfonic Acid	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 21°C (70°F), C at 50°C (122°F)
Benzoic Acid	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A 10% to 120°C (248°F)
Benzyl Alcohol	A to 205°C (401°F)	A to 21°C (70°F)	–	A to 135°C (275°F)
Boric Acid (10%)	A to boiling	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Bromine (Dry)	A to 59°C (138°F)	C	B to 20°C (68°F)	A to 100°C (212°F)
Bromine (Wet)	A to 93°C (200°F)	C	C	A to 100°C (212°F)
Butane	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 93°C (200°F)
Butyl Acetate	A to 127°C (260°F)	A to 21°C (70°F)	B to 20°C (68°F)	B to 52°C (125°F), C at 75°C (167°F)
Calcium Carbonate	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Calcium Chloride (Saturated)	A to 149°C (300°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Calcium Hydroxide 30%	A to 149°C (300°F)	A to 21°C (70°F)	–	C
Calcium Hypochlorite	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Calcium Nitrate	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Calcium Sulfate	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Carbonic Acid	A to 93°C (200°F)	A to 100°C (212°F)	C	A to 100°C (212°F)
Carbon Dioxide (Dry)	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 135°C (275°F)
Carbon Disulfide	A to 93°C (200°F)	A to 100°C (212°F)	A to 23°C (73°F)	B to 50°C (122°F)
Carbon Monoxide (Gas)	A to 93°C (200°F)	A to 200°C (392°F)	–	B to 135°C (275°F)
Carbon Tetrachloride	A to 93°C (200°F)	A to 100°C (212°F)	A to 23°C (73°F)	A to 135°C (275°F)
Chlorine (Dry)	A to 120°C (248°F)	C	C	A to 100°C (212°F)
Chlorine (Gas-Dry)	A to 120°C (248°F)	C	–	A to 100°C (212°F)
Chlorine (Gas-Wet)	A to 120°C (248°F)	A to 100°C (212°F)	–	A to 100°C (212°F)
Chlorine (Liquid)	A to 93°C (200°F)	C	C	B to 93°C (200°F)
Chlorine (Wet)	A to 93°C (200°F)	C	C	A to 100°C (212°F)
Chloroacetic Acid	A 50% to 93°C (200°F)	A to 100°C (212°F)	–	A conc. to 21°C (70°F), A 50% to 100°C (212°F), C conc. at 100°C (212°F)

TABLE 2: CHEMICAL COMPATIBILITY OF CYNERGY PRODUCT MATERIALS (CONTINUED)

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Chemical	Teflon PFA	PEEK	PES	Solef PVDF
Chloroform	A to 93°C (200°F)	A to 100°C (212°F)	A 15% to 20°C (68°F), C Conc.	A to 100°F (38°), C at 176°F (80°)
Chlorosulfonic Acid	A to 151°C (304°F)	C	C	C
Chromic Acid, Conc.	A to 120°C (248°F)	C	C	A 50% to 49°C (120°F), C 50% at 100°C (212°F)
Citric Acid	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 120°C (248°F)
Copper Cyanide	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Copper Fluoride	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Copper Nitrate	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Copper Sulfate	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Crude Oil	A to 93°C (200°F)	A to 21°C (70°F)	A to 82°C (180°F), C to 149°C (300°F)	A to 135°C (275°F)
Cuprous Chloride	A to 93°C (200°F)	A to 100°C (212°F)	–	A 25% to 21°C (70°F)
Cyclohexane	A to 93°C (200°F)	A to 100°C (212°F)	A to 23°C (73°F)	A to 135°C (275°F)
Cyclohexanol	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 75°C (167°F), B at 100°C (212°F)
Cyclohexanone	A to 156°C (312°F)	A to 21°C (70°F)	C	A to 21°C (70°F), C at 50°C (122°F)
Detergent Solutions (non-phenolic)	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	–
Dibutyl Phthalate	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	C
Dichlorobenzene	A to 93°C (200°F)	A to 21°C (70°F)	C	B to 52°C (125°F)
Dichloroethane	A to 93°C (200°F)	A to 21°C (70°F)	C	A to 21°C (70°F), C at 100°C (212°F)
Diesel Oil	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Diethylamine	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 21°C (70°F), C at 75°C (167°F)
Diethylether	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	B to 50°C (122°F)
Dimethyl Formamide (DMF)	A to 154°C (309°F)	A to 21°C (70°F)	C	C
Dimethyl Phthalate	A to 200°C (392°F)	A to 21°C (70°F)	C	A to 21°C (70°F), C at 93°C (200°F)

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Chemical	Teflon PFA	PEEK	PES	Solef PVDF
Dimethylsulfoxide (DMSO)	A to 189°C (372°F)	B to 100°C (212°F)	C	–
Dioctyl Phthalate	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	B to 21°C (70°F)
Dioxane	A to 101°C (214°F)	A to 21°C (70°F)	B to 20°C (68°F)	C
Dowtherm® A	A to 93°C (200°F)	C at 200°C (392°F)	–	–
Ethane	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	–
Ether	A to 93°C (200°F)	A to 100°C (212°F)	–	B to 21°C (70°F), C at 93°C (200°F)
Ethyl Acetate	A to 93°C (200°F)	A to 21°C (70°F)	C	A to 21°C (70°F), C at 50°C (122°F)
Ethylene Dichloride	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 135°C (275°F)
Ethylene Glycol	A to 93°C (200°F)	A to 100°C (212°F), B at 200°C (392°F)	A 50% to 129°C (264°F)	A to 135°C (275°F)
Ethylene Oxide (EtO)	A to 93°C (200°F)	A to 21°C (70°F)	A to 23°C (73°F)	A to 21°C (70°F), B at 50°C (122°F), C at 75°C (167°F)
Fatty Acids	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Ferric Chloride	A to 104°C (220°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Ferric Nitrate	A to 149°C (300°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Ferric Sulfate	A to 149°C (300°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Ferrous Chloride	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Ferrous Sulfate	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Fluorine (Gas-Dry)	A to 93°C (200°F)	C	C	A to 21°C (70°F)
Formaldehyde (Formalin)	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 49°C (120°F), C at 100°C (212°F)
Formic Acid	A to 100°C (212°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 50°C (122°F), B at 100°C (212°F)
Freon® (Dry)	A to 93°C (200°F)	A to 21°C (70°F)	A to 23°C (73°F) C at 149°C (300°F)	A to 100°C (212°F)
Fuel Oil	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	B to 135°C (275°F)
Gas (Natural)	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Gasoline (Unleaded-Refined)	A to boiling	A to 21°C (70°F)	A to 23°C (73°F)	A to 135°C (275°F)

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Chemical	Teflon PFA	PEEK	PES	Solef PVDF
Gelatin	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 100°C (212°F)
Glycerine (Glycerol)	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 135°C (275°F)
Heptane	A to 93°C (200°F)	A to 21°C (70°F)	A to 23°C (73°F)	A to 135°C (275°F)
Hexane	A to boiling	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Hydraulic Fluid	A to 93°C (200°F)	A to 21°C (70°F)	B to 20°C (68°F)	–
Hydrazine	A to boiling	A to 100°C (212°F)	C	A 48% to 135°C (275°F)
Hydrobromic Acid	A 50% to 93°C (200°F)	C	–	A 37% to 135°C (275°F)
Hydrochloric Acid, 10% Conc.	A to 120°C (248°F)	A to 100°C (212°F)	A to 20°C (68°F), C at 149°C (300°F)	A to 135°C (275°F)
Hydrochloric Acid, Conc.	A to 120°C (248°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Hydrocyanic Acid	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Hydrofluoric Acid, Conc.	A to 120°C (248°F)	C	–	A to 100°C (212°F)
Hydrogen Peroxide	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A 90% to 21°C (70°F), A 30% to 50°C (122°F)
Hydrogen Sulfide (Gas)	A to 93°C (200°F)	A to 200°C (392°F)	A to 20°C (68°F)	A to 135°C (275°F)
Iodine	A to 93°C (200°F)	B to 21°C (70°F)	B to 20°C (68°F)	A to 100°C (212°F)
Iso-Octane	A to 99°C (210°F)	A to 21°C (70°F)	B to 20°C (68°F)	A to 135°C (275°F)
Isopropanol	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 50°C (122°F), B to 70°C (158°F)
Kerosene	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Ketones	A to 149°C (300°F)	A to 372°C (702°F)	C	C
Lactic Acid	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A 50% to 50°C (122°F), B to 50°C (122°F), C 75% at 100°C (212°F)
Lead Acetate	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Lime	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 93°C (200°F)
Linseed Oil	A to 93°C (200°F)	A to 21°C (70°F)	A to 23°C (73°F)	A to 135°C (275°F)
Lubricating Oil	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Magnesium Chloride	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)

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Chemical	Teflon PFA	PEEK	PES	Solef PVDF
Magnesium Hydroxide	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 100°C (212°F)
Magnesium Sulfate	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Maleic Acid	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 121°C (250°F)
Mercuric Chloride	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 120°C (248°F)
Mercury	A to 149°C (300°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Methane (Gas)	A to 93°C (200°F)	A to 200°C (392°F)	–	A to 110°C (230°F)
Methanol	A to 93°C (200°F)	A to 100°C (212°F)	A to 23°C (73°F)	A to 135°C (275°F)
Methylene Chloride	A to 93°C (200°F)	A to 21°C (70°F)	C	B to 50°C (122°F)
Methylethyl Ketone (MEK)	A to 93°C (200°F)	A to 100°C (212°F), C to 200°C (392°F)	C	C
Milk	A to 100°C (212°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 100°C (212°F)
Mineral Oil	A to 180°C (356°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Molasses	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 66°C (150°F)
Motor Oil	A to 93°C (200°F)	A to 200°C (392°F)	A to 150°C (302°F)	A to 135°C (275°F)
Naphtha	A to 100°C (212°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Naphthalene	A to 218°C (424°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Nickel Chloride	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Nickel Nitrate	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Nickel Sulfate	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Nitric Acid, Conc.	A to boiling	C	C	A 40% to 93°C (200°F), C Conc.
Nitrobenzene	A to 210°C (410°F)	A to 21°C (70°F), C at 200°C (392°F)	C	A to 21°C (70°F), B at 50°C (122°F)
Nitrogen	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 93°C (200°F)
Nitrous Acid, 10%	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 100°C (212°F)
Nitrous Oxide	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	C
Oils (Petroleum)	A to 93°C (200°F)	A to 100°C (212°F)	B to 20°C (68°F)	A to 138°C (280°F)
Oils (Vegetable)	A to boiling	A to 100°C (212°F)	A to 20°C (68°F)	A to 100°C (212°F)

TABLE 2: CHEMICAL COMPATIBILITY OF CYNERGY PRODUCT MATERIALS (CONTINUED)

A = Recommended (little or no chemical attack)
B = Satisfactory* (minor chemical attack)
C = Not recommended (severe chemical attack)
*use will depend on the application

Chemical	Teflon PFA	PEEK	PES	Solef PVDF
Oleic Acid	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 120°C (248°F)
Oleum	A to 204°C (400°F)	C	C	C
Olive Oil	A to boiling	A to 100°C (212°F)	–	A to 21°C (70°F), C at 100°C (212°F)
Oxalic Acid	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 49°C (120°F), C at 93°C (200°F)
Oxygen	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Ozone	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 100°C (212°F)
Pentane	A to 93°C (200°F)	A to 21°C (70°F)	–	–
Perchloric Acid	A to 93°C (200°F)	A to 100°C (212°F)	–	A 72% to 50°C (122°F)
Perchloroethylene	A to 121°C (250°F)	A to 100°C (212°F)	B to 20°C (68°F)	A to 77°C (170°F), B to 100°C (212°F)
Petrol	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 132°C (270°F)
Petroleum Ether	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	B to 66°C (150°F)
Phenol (Carbolic Acid)	A to boiling	–	C	A to 50°C (122°F), A 10% to 100°C (212°F)
Phosphoric Acid, 80% Conc.	A to boiling	A to 100°C (212°F)	A 40% to 60°C (140°F), B to 20°C (68°F)	A to boiling
Phosphorous Chlorides	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 100°C (212°F)
Phthalic Acid	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 100°C (212°F)
Picric Acid	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 21°C (70°F)
Potassium Aluminum Sulfate	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Potassium Bicarbonate	A to 93°C (200°F)	A to 21°C (70°F)	–	–
Potassium Bromide	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Potassium Carbonate	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 135°C (275°F)
Potassium Chlorate	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Potassium Chloride	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Potassium Dichromate	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 135°C (275°F)
Potassium Ferricyanide	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 135°C (275°F)

TABLE 2: CHEMICAL COMPATIBILITY OF CYNERGY PRODUCT MATERIALS (CONTINUED)

A = Recommended (little or no chemical attack)
B = Satisfactory* (minor chemical attack)
C = Not recommended (severe chemical attack)
*use will depend on the application

Chemical	Teflon PFA	PEEK	PES	Solef PVDF
Potassium Ferrocyanide	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 135°C (275°F)
Potassium Hydroxide	A 100% to 93°C (200°F)	A 70% to 21°C (70°F)	A 10% to 20°C (68°F)	C
Potassium Nitrate	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Potassium Permanganate	A to boiling	A to 21°C (70°F)	–	A to 135°C (275°F)
Potassium Sulfate	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Potassium Sulfide	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 135°C (275°F)
Propane	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Propanol	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 50°C (122°F), B at 70°C (158°F)
Pyridine	A to 116°C (240°F)	A to 100°C (212°F)	C	C
Propylene Glycol	A to 93°C (200°F)	–	B to 23°C (73°F)	A to 66°C (150°F)
Sewage	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 107°C (225°F)
Silicone Fluids	A to 93°C (200°F)	A to 100°C (212°F)	A to 23°C (73°F)	–
Silver Nitrate	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Skydrol® Hydraulic Fluid	A to 93°C (200°F)	A to 21°C (70°F)	–	–
Soap Solution	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 100°C (212°F)
Sodium Acetate	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 135°C (275°F)
Sodium Bicarbonate	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 135°C (275°F)
Sodium Carbonate	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Sodium Chlorate	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Sodium Chloride	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Sodium Hydroxide, 50% Conc.	A to 120°C (248°F)	A to 200°C (392°F)	A 5% to 90°C (194°F), A 10% to 20°C (68°F)	C
Sodium Hypochlorite	A to 93°C (200°F)	A to 100°C (212°F)	A 25% to 90°C (194°F), B at 25°C (77°F)	B 13% at 25°C (77°F)
Sodium Nitrate	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Sodium Nitrite	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Sodium Peroxide	A to boiling	A to 100°C (212°F)	–	A to 135°C (275°F)

TABLE 2: CHEMICAL COMPATIBILITY OF CYNERGY PRODUCT MATERIALS (CONTINUED)

A = Recommended (little or no chemical attack)
B = Satisfactory* (minor chemical attack)
C = Not recommended (severe chemical attack)
*use will depend on the application

Chemical	Teflon PFA	PEEK	PES	Solef PVDF
Sodium Silicate	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Sodium Sulfate	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Sodium Sulfide	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Sodium Sulfite	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Stannic Chloride	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Stannous Chloride	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 135°C (275°F)
Starch	A to 93°C (200°F)	A to 100°C (212°F)	–	–
Steam	A to 149°C (300°F)	A to 200°C (392°F)	A to 100°C (212°F)	A to 100°C (212°F)
Styrene (Liquid)	A to 93°C (200°F)	A to 21°C (70°F)	–	–
Sulfur	A to molten	A to 100°C (212°F)	–	A to 120°C (248°F)
Sulfur Chloride	A to 93°C (200°F)	A to 100°C (212°F)	–	A to 21°C (70°F)
Sulfur Dioxide	A to 93°C (200°F)	A to 200°C (392°F)	B to 23°C (73°F)	A to 100°C (212°F)
Sulfur Trioxide	A to 93°C (200°F)	A to 100°C (212°F)	–	C
Sulfuric Acid, <40% Conc.	A to 204°C (400°F)	A to 100°C (212°F), B at 200°C (392°F)	A 25% to 90°C (194°F)	A to 30% to boiling
Sulfuric Acid, >40% Conc.	A to 100% to 204°C (400°F)	C	A 50% at 60°C (140°F), C Conc.	A 96% to 50°C (122°F)
Sulfurous Acid	A to 93°C (200°F)	A to 21°C (70°F)	C	A to 100°C (212°F)
Tallow	A to 93°C (200°F)	A to 100°C (212°F)	–	–
Tannic Acid, 10% Conc.	A to 93°C (200°F)	A to 100°C (212°F)	–	B to 230° (110°C)
Tar	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	–
Tartaric Acid	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	B to 121°C (250°F)
Tetraethyl Lead	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 135°C (275°F)
Tetrahydrofuran (THF)	A to 93°C (200°F)	A to 21°C (70°F)	C	B to 21°C (70°F), C at 50°C (122°F)
Toluene	A to 110°C (230°F)	A to 21°C (70°F)	C	A to 21°C (70°F)
Transformer Oil	A to 93°C (200°F)	A to 100°C (212°F)	A to 23°C (73°F)	–
Trichloroethylene	A to 93°C (200°F)	A to 100°C (212°F)	C	A to 21°C (70°F)

TABLE 2: CHEMICAL COMPATIBILITY OF CYNERGY PRODUCT MATERIALS (CONTINUED)

A = Recommended (little or no chemical attack)
B = Satisfactory* (minor chemical attack)
C = Not recommended (severe chemical attack)
*use will depend on the application

Chemical	Teflon PFA	PEEK	PES	Solef PVDF
Trichlorotrifluoroethane	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 100°C (212°F), C at 121°C (250°F)
Turpentine	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 135°C (275°F)
Urea	A 50% to 93°C (200°F)	A to 100°C (212°F)	–	A 50% to 120°C (248°F)
Varnish	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	–
Vinegar	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 77°C (170°F)
Water, Fresh	A to 93°C (200°F)	A to 200°C (392°F)	A to 23°C (73°F)	A to 135°C (275°F)
Water, Distilled	A to 93°C (200°F)	A to 100°C (212°F)	A to 23°C (73°F)	A to 135°C (275°F)
Water, Sea/Salt	A to 93°C (200°F)	A to 100°C (212°F)	A to 23°C (73°F)	A to 135°C (275°F)
Wax	A to molten	A to 21°C (70°F)	A to 20°C (68°F)	–
White Spirit	A to 93°C (200°F)	A to 21°C (70°F)	–	A to 21°C (70°F)
Wines and Spirits	A to 93°C (200°F)	A to 21°C (70°F)	A to 20°C (68°F)	A to 93°C (200°F)
Xylene®	A to 93°C (200°F)	A to 21°C (70°F)	B to 23°C (73°F)	A to 100°C (212°F)
Zinc Chloride	A 25% to 100°C (212°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)
Zinc Sulfate	A to 93°C (200°F)	A to 100°C (212°F)	A to 20°C (68°F)	A to 135°C (275°F)

Material Properties: Teflon PFA

TABLE 3: TYPICAL PROPERTY DATA FOR TEFLON PFA FLUOROCARBON RESIN GRADE 440HP

Property		ASTM Standard	Value
Thermal Properties			
Nominal Melting Point		DTA-E-168	302–310°C (575–590°F)
Coefficient of Linear Thermal Expansion:		D696	
21–100°C (70–212°F)			14×10^{-5} mm/mm/°C (7.6×10^{-5} in/in/°F)
100–149°C (212–300°F)			17×10^{-5} mm/mm/°C (9.2×10^{-5} in/in/°F)
149–208°C (300–408°F)			21×10^{-5} mm/mm/°C (11.5×10^{-5} in/in/°F)
Upper Service Temperature		260°C (500°F)	
Mechanical Properties			
Tensile Strength	23°C (73°F) 250°C (482°F)	D3307	25 MPa (3,600 PSI) 12 MPa (1,800 PSI)
Specific Gravity		D792	2.12-2.17
Tensile Yield Strength	23°C (73°F)	D3307	13.8 MPa (2,000 PSI)
Ultimate Elongation	23°C (73°F) 250°C (482°F)	D3307	300% 480%
Flexural Modulus	23°C (73°F) 250°C (482°F)	D790	590 MPa (85,000 PSI) 55 MPa (8,000 PSI)
Hardness Durometer		D2240	D55
MIT Folding Endurance	0.18–0.20 mm (0.007–0.008 in)	D2176	50,000 cycles
Electrical Properties			
Dielectric Strength Short Time	0.25 mm (0.010 in)	D149	80 kV/m (2,000 V/mil)
Dielectric Constant	60-10^6 Hz	D150	2.03
Dissipation Factor	60-10^6 Hz	D150	0.0001
Volume Resistivity		D257	1018 ohm-cm
General Properties			
Water Absorption	24 h	D570	<0.03%
Weather and Chemical Resistance	—	Outstanding	
Limiting Oxygen Index		D2863	>95

Notes: Grade 440HP is AS D3307, Type 1. Typical properties are not suitable for specification purposes. Statements or data regarding behavior in a flame situation are not intended to reflect hazards presented by this or any other material when under actual fire conditions.

Weathering Resistance

Tensile bar specimens of Teflon PFA resins have been weathered out-of-doors in Hialeah, Florida and Troy, Michigan for 10 years. There were no significant changes in tensile properties, specific gravity or melt flow rate after this exposure. Tests are continuing.

Response to High Energy Ionizing Radiation

The results of preliminary tests using a General Electric Transformer to evaluate the radiation resistance of Teflon PFA to high energy ionizing radiation in air are presented in Table 4.

TABLE 4: MANUAL VALVES 1" ORIFICE

Response to High Energy Ionizing Radiation

Teflon PFA (AS D 1708)

Exposure, Megarads	Tensile Strength (MPa)	Elongation
Control	30 (4,390 PSI)	358%
0.5	28 (4,090 PSI)	366%
1.0	25 (3,620 PSI)	333%
2.0	21 (3,080 PSI)	302%
5.0	15 (2,110 PSI)	35%
20	*	*
50	*	*

Samples: 0.25 mm (10 mil) compression molded films of Teflon PFA type 340.

* Elongation less than 5%

Extractable Trace Metals

In certain bioprocesses, metallic ions contributed by the process components can reduce yield. Components manufactured from Teflon PFA materials virtually eliminate ionic contamination.

The analytical technique of choice for determination of metallic impurities in materials or chemicals is inductively coupled plasma-mass spectrometry (ICP/MS). ICP/MS is used almost universally to generate quantitative data on virtually all elements in the periodic table. Ions are extracted into liquids from distribution system materials, and the liquid is commonly evaporated to eliminate background interference. The trace metals are then dissolved into dilute nitric acid and analyzed.

Tubing extraction results are shown in Table 5. Measured values below the detection limit are replaced by the detection limit.

TABLE 5: ICP/MS EXTRACTION ANALYSIS OF CYNERGY TUBING

19 Day Extraction in 10% Nitric Acid

Element	Detection Limit (ng/cm^2)	Concentration (ng/cm^2)
Boron	0.043	0.043
Sodium	0.112	<0.112
Magnesium	0.012	<0.012
Aluminum	0.015	0.058
Potassium	4.569	<4.569
Calcium	0.348	<0.348
Titanium	0.016	<0.016
Chromium	0.006	0.087
Manganese	0.005	0.015
Iron	0.721	<0.721
Nickel	0.016	0.122
Zinc	0.028	<0.028
Copper	0.008	0.016
Zirconium	0.001	0.003
Niobium	0.001	0.002
Molybdenum	0.008	<0.008
Tungsten	0.001	<0.001
Lead	0.001	<0.001
Total (>DL)		0.346

Total Oxidizable Carbon Extractables

Total oxidizable carbon (TOC) present in process systems may contribute to biofilm growth by providing a food source for microorganisms. Components manufactured from Teflon PFA have very low extractable TOC levels.

TOC extraction was performed on extruded samples of PFA tubing 1.3 cm (0.50˝) in diameter and 152 cm (60.0˝) in length. The sections were rinsed with 18 mΩ ultrapure water and then refilled with water and extracted for five days at 25°C (77°F). The extraction results indicate a TOC concentration of ≤30 ppb.

Material Properties: PEEK

TABLE 6: TYPICAL PROPERTY DATA FOR PEEK MATERIAL

Property		ASTM Standard	Value
General Properties			
Form		_	Granules
Color		_	Gray
Relative density	(crystalline) (amorphous)	D792 D792	1.30 1.26
Filler content			0%
Typical level of crystallinity		_	35%
Water absorption	24 hr @ 23°C (73°F) Equilibrium @ 23°C (73°F)	D570 D570	0.5% 0.5%
Mechanical Properties			
Tensile strength	@ 23°C (73°F) (yield) @ 250°C (482°F) (yield)	D638 D638	100 MPa (14,500 PSI) 12 MPa (1740 PSI)
Elongation at break	@ 23°C (73°F)	D638	20%
Elongation at yield	@ 23°C (73°F)	D638	4.9%
Flexural modulus	@ 23°C (73°F) @ 120°C (248°F) @ 250°C (482°F)	D790 D790 D790	4099 MPa (594,500 PSI) 4000 MPa (580,000 PSI) 300 MPa (43,500 PSI)
Flexural strength	@ 23°C (73°F) @ 120°C (248°F) @ 250°C (482°F)	D790 D790 D790	170 MPa (24,650 PSI) 100 MPa (14,500 PSI) 13 MPa (1813 PSI)
Shear strength (ultimate)		D3846	53 MPa (7685 PSI)
Izod impact strength Notched 0.25 mm radius 3.5 mm depth	@ 23°C (73°F)	D256	1.5 J/m² (1.12 ft lb/in²)
Poisson's ratio	@ 23°C (73°F) with flow across flow	D638 D638	0.4 0.4
Rockwell hardness	R scale M scale	D785 D785	126 99
Thermal Properties			
Melting point (peak of melting endotherm)		DSC	343°C (649°F)
Glass transition temperature Tg (onset value)		DSC	143°C (289°F)

TABLE 6: TYPICAL PROPERTY DATA FOR PEEK MATERIAL (CONTINUED)

Property		ASTM Standard	Value
Coefficient of Thermal Expansion			
	<Tg	D696	26×10^{-6}/°F
	>Tg	D696	60×10^{-6}/°F
Heat distortion temperature 1.82 MPa	D648	156°C (313°F)	
Thermal conductivity		C177	1.75 BTU in/hr ft^2°F
UL continuous use temperature			
	(mechanical)	UL746B	241°C (464°F)
	(electrical)		260°C (500°F)
Flammability			
Underwriters flammability rating (mm thickness)		UL94	V-0 (1.45)
Electrical Properties			
Volume resistivity		D257	4.9×10^{16} ohm

Weathering Resistance

Like most linear polyaromatics, PEEK material suffers from the effects of UV degradation during outdoor weathering. However, testing has shown that this effect is minimal over a 12 month period for both natural and pigmented moldings. In more extreme weathering conditions, painting or pigmenting of the polymer will protect it from excessive property degradation.

Table 7 shows the constancy of tensile strength during one year's weathering of natural and pigmented injection molded PEEK 450G.

TABLE 7: WEATHERING PERFORMANCE OF PEEK 450G

Material	Tensile Strength After Time Shown				
	Unaged	3 months	6 months	9 months	12 months
PEEK 450G (Pigmented*)	PSI $\times 10^3$	PSI $\times 10^3$	PSI $\times 10^3$	PSI $\times 10^3$	PSI $\times 10^3$
Natural	14.4	14.5	14.5	13.9	13.9
Black	14.1	14.2	13.9	14.1	14.1
White	14.1	14.1	14.2	13.9	14.2
Yellow	14.1	14.1	14.1	13.8	13.6
Green	14.4	14.2	14.2	13.8	13.9
Blue	14.4	14.5	14.4	14.1	14.2

*Pigment loading 1-2% (wt./wt.)

Response to High Energy Ionizing Radiation

PEEK material shows excellent resistance to hard (gamma) irradiation absorbing over 1000 Mrads of irradiation without suffering significant damage. It is believed that PEEK material will resist dose levels of well over 10,000 Mrads of particle (alpha or beta) irradiation without significant degradation of properties. Fiber reinforced grades are expected to show even better performance than this. PEEK material is significantly more radiation stable than polystyrene, otherwise the most radiation resistant thermoplastic.

Material Properties: PES

TABLE 8: TYPICAL PROPERTY DATA FOR PES

Property		ASTM Standard	Value
Physical Properties			
Specific Gravity		D792	1.510
TG	Glass Transition	D3418	230°C (446°F)
Water Absorption		D570	0.38%
Mechanical Properties			
Tensile strength		D638	124 MPa (18,000 PSI)
Tensile elongation		D638	1.0–3.0%
Flexural strength		D790	172 MPa (25,000 PSI)
Flexural modulus		D790	5861 MPa (850,000 PSI)
Izod impact	Cut notch	D256	3 N•m (1.50 PSI)
Izod impact	Unnotched	D256	11–14 N•m (8.0–10.0 PSI)
Thermal Properties			
H.D.T.U.L.	Deg F: @ 264 PSI	D648	770°C (410°F)
Thermal linear expansion coefficient		D696	1.400 in/in/ft 10^{-5}
Thermal conductivity		CENCO	2.3 BTU-in/hr ft 2F

Material Properties: Solef PVDF

TABLE 9: TYPICAL PROPERTY DATA FOR SOLEF PVDF

Property		AS Standard	Value
Physical Properties			
Density		D792	1.78 g/cc
Water Absorption	24 hr @23°C (73°F)	D570	<0.04%
Mechanical Properties			
Tensile strength @ yield	(2 mm sheet)	D638M	52–57 MPa (7600–8250 PSI)
Ultimate tensile strength		D638M	30–50 MPa (4350–7250 PSI)
Elongation at break		D638M	20–50%
Tensile modulus	(E modulus)	D638M	255 MPa (37,000 PSI)
Flexural modulus	(4 mm sheet)	D790	2200 MPa (319,000 PSI)
Shore D hardness	(2 mm thick)	D2240	78
Izod impact strength	(23°C, notched, 4 mm thick)	D256	1.63 N•m (1.2 ft lb/in)
Abrasion resistance		Taber CS 10/kg	5-10 mg/1000 cycle
Friction coefficient (dynamic)		D1894	0.2-0.3
Thermal Properties			
Crystalline melting point		D3418	175°C (347°F)
VICAT point	(4 mm thick, 5 kg)	D1525	150°C (302°F)
Deflection temperature under load	(4 mm, 264 PSI)	D648	115°C (239°F)
Glass transition		DMTA	-30°C (-22°F)
Brittleness temperature		D746A	8°C (46°F)
Thermal linear expansion coefficient		D696	13×10^{-5}°K^{-1}
Thermal conductance	(20 to 100°C)	C177	0.2 W/m K

Material Properties: Solef PVDF (Continued)

TABLE 9: TYPICAL PROPERTY DATA FOR SOLEF PVDF (CONTINUED)

Property		ASTM Standard	Value
Fire Resistance			
Oxygen index	(3 mm thick)	D2863	44%
UL classification	UL94	V-0	
Flame rating	D2863	S-E	
Electrical Properties			
Surface resistivity		D257	>1 × 10^{14} ohm
Volume resistivity		D257	>1 × 10^{14} ohm-cm
Dielectric constant	@ 1 MHz @ 5 MHz @ 10 MHz	D150	7.1 5.9 4.9
Dissipation factor	@ 1 MHz @ 5 MHz @ 10 MHz	D150	0.15 0.26 0.29

The above information gives typical properties only and is not to be used for specification purposes.

Weathering Resistance

Natural aging in Arizona and Florida on 80 µm films made of PVDF 1008 show no property alteration after several years (see Table 10).

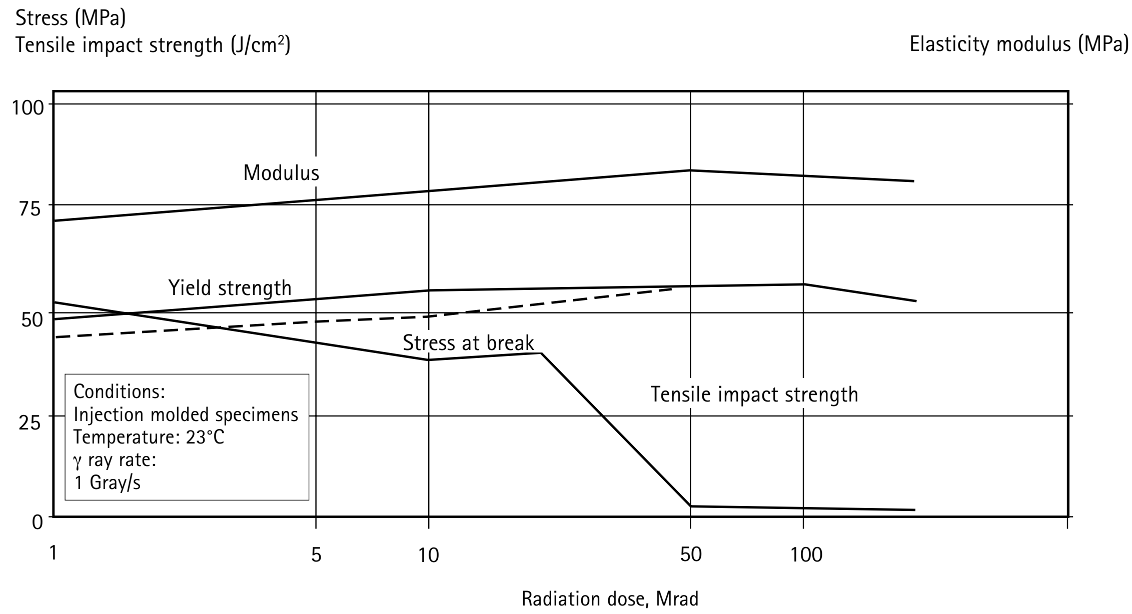
TABLE 10: ACCELERATED NATURAL AGING OF PVDF 1008 GRADES

	Aging Period (Years)				
	0	**0.5**	**1**	**6**	**9**
Yellowing index (AS 1925)	1.7	3.3	4.2	0.9	1.8
Melting temperature-DSC	174	174	174	173	175
Tensile test at 50 mm/min:					
• tensile yield stress	40	41	39	42	44
• strength at break	63	48	35	60	59
• elongation at break	520	440	320	450	425
• modulus*	1280	1350	1150	1350	1370
Tensile impact strength (DIN 53448)	450	450	250	400	–

Notes: 0 µm thick films produced by flat die extrusion on chill roll
Mechanical properties measured in the machine direction
* Rate = 1 mm/min

Response to High Energy Ionizing Radiation

TABLE 11: MECHANICAL PROPERTIES OF SOLEF PVDF 1010 VS. DOSES OF γ RADIATION



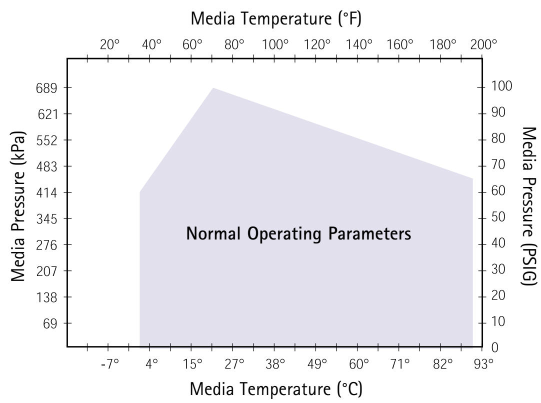
Section 2: Product Performance

Performance Specifications

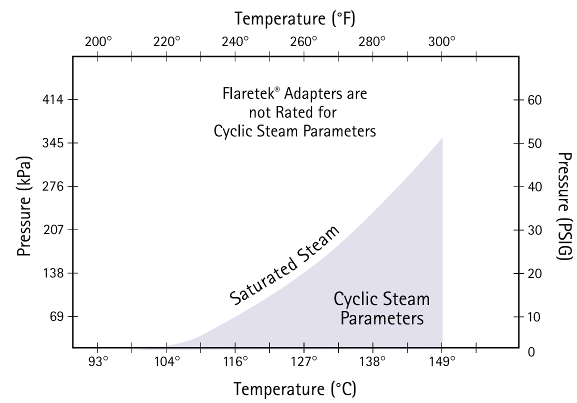
All Cynergy welds, valves, tubing and fitting products will perform as specified below whether clamped to an equivalent fitting or a stainless steel component.

FIGURES 3 AND 4: PERFORMANCE SPECIFICATIONS FOR NORMAL AND CYCLIC STEAM OPERATING CONDITIONS

For Normal Continuous Operating Conditions



For Cyclic Steam Conditions



Autoclavability

Disassemble valves and unclamp connections before autoclaving. 124°C (255°F) is the maximum autoclave temperature.

Cynergy PVDF Tube Adapter*

Maximum pressure:	41 kPa (6 PSIG) @ room temperature
Maximum temperature:	Room temperature

*The silicone tubing dictates these product specifications. The working pressure of the PVDF tube adapter connection meets or exceeds performance specification of the silicone tubing.

Vacuum

Full static vacuum capability at 149°C (300°F).

Introduction to Qualification Test Procedures

Entegris products are designed and manufactured to meet the stringent requirements of our customers. Entegris believes in providing high quality products that meet those needs. To ensure this, Entegris puts all standard new products through a series of qualification tests. The purpose of the test series is to:

- Fully qualify and validate performance specifications
- Determine extended life via accelerated means
- Identify design deficiencies

Entegris' Product Test Laboratory protocol includes:

- Control valve integrity
- Functional capability
- Seat integrity
- Thermal transition
- Cyclic fatigue
- Hydraulic burst pressure
- Seal leakage

Extensive qualification testing in Entegris' Product Test Laboratory ensures products meet reliability, safety, durability and functionality requirements for use in even the harshest environments – before the product ever arrives on site. Every week Entegris dedicates more than 300 technical staff hours and more than 2500 equipment hours to the functional evaluation of our products.

Entegris performs an environmental characterization as new products are developed. This characterization determines the environments to which the products will be exposed such as media type, media pressure, media temperatures, ambient temperatures, etc. Once the environmental characterization is complete, a test strategy is determined based on those conditions or environments. Test strategies for Cynergy valves, fittings, tubing and other Entegris products are described in this section.

Entegris Test Standards and Protocols

We use the following standards for the qualification and ongoing testing of our fluid handling products. In conjunction with these standards, Entegris has developed numerous other testing programs to accommodate our unique product designs and materials.

TABLE 12: TEST STANDARDS AND PROTOCOLS

ASTM Standards	
D1598-86	Time-to-failure of plastic pipe under constant internal pressure.
D1599-88*	Standard test method for short-time hydraulic failure pressure of plastic pipe, tubing and fittings.
D2837-88	Obtaining hydrostatic design basis for thermoplastic pipe materials.
E432-71*	Standard guide for leak testing method selection.
E479-73 (R1984)*	Standard guide for preparation of a leak testing specification.
E515-90*	Standard test method for leaks using bubble emission techniques.
PPI Standard	
TR-3/92	Policies and procedures for developing recommended hydrostatic design stresses for thermoplastic pipe materials.
ISO Standards	
ISO/TR 9080	Extrapolation method of hydrostatic stress rupture data.
SEMI Standards	
F7	Test method to determine the tensile strength of tube fitting connections made of fluorocarbon materials.
F8	Test method for evaluating the sealing capabilities of tube fitting connections made of fluorocarbon materials when subjected to tensile forces.
F9	Test method for evaluating the leakage characteristics of tube fitting connections made of fluorocarbon materials when subjected to a side load condition.
F10	Test method to determine the internal pressure required to produce a failure of a tube fitting connection made of fluorocarbon materials.
F11	Test method to obtain an indication of the thermal characteristics of tube fitting connections made of fluorocarbon materials.

TABLE 5: ICP/MS EXTRACTION ANALYSIS OF CYNERGY TUBING

F12	Test method to determine the sealing capabilities of tube fitting connections made of fluorocarbon materials after being subjected to a heat cycle.
F18	Guide for determining the hydrostatic strength of and design basis for thermoplastic pipe and tubing.
Entegris Test Method (E Standard)	
E-101A	Test method for automatic hydraulic burst pressure.
E-101B	Test method for manual hydraulic burst pressure.
E-102	Test method for pressure envelope cyclic fatigue testing.
E-103	Test method for thermal transition testing of piping products.
E-104A	Test method for valve seal leakage using the "bubble leak" method.
E-105	Test method for tensile testing pipe components.
E-106	Test method for pressure cyclic fatigue testing valves.
E-107	Test method for seal integrity of tube fitting connections using the "bubble leak" method.
E-108	Test method for cyclic fatigue testing valve actuators.
E-109	Deviations/additions to ISA-SMS.02 (control valve capacity test procedure).
E-110	Test method to perform thermal cycle bake testing.
E-111	Test method to determine the sensing range of fluid level sensing components.
E-112	Test method to determine the sealing integrity of sensing components.
E-113	Test method to determine the functional capability of sensing components.

Valve Qualification Testing Summary

The following qualification tests have been performed on each valve type and size. Only after the valves successfully complete the tests are they released to market.

Functional Evaluation

Test Method

The objective of this test is to identify the tilt angle that produces optimum valve drainability.

Conditions

- Fill valve with water
- Place valve at a 2% (1°) slope with operator in vertical position
- Fill valve inlet cavity with water and incrementally tilt valve until all water drains through valve outlet

Evaluation Criteria

- Tilt angle selected must completely drain valve

Sanitary Valve Cyclic Test Characterization

Test Method

The objective of this test is to determine the cyclic fatigue and steam exposure life for each valve size when subjected to repeated, simulated bioprocess exposures.

Summary of Method

Each valve configuration is subjected to two different bioprocess cycles designed to simulate low and high temperature processing. Each bioprocess cycle includes a CIP and SIP operation.

Conditions

Cycles #1 and #2 consist of the following phases:

Bioprocess Cycle #1

Phase 1 60 minute exposure to deionized (DI) water at 2°C (35°F) and 414 kPa (60 PSIG). Ambient temperature 10°–16°C (50°–60°F).

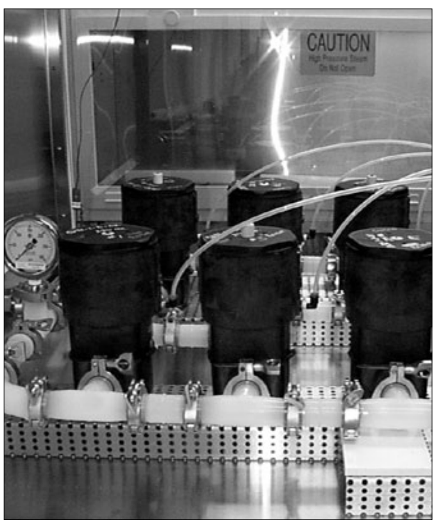
Phase 2 2 minute DI water purge at 16°C (60°F) and 414 kPa (60 PSIG). Ambient temperature 21°C (70°F).

Phase 3 3 minute air purge at 21°C (70°F) and 138 kPa (20 PSIG). Ambient temperature 21°C (70°F).

Phase 4 60 minute exposure to saturated steam at 149°C (300°F) at 359 kPa (52 PSIG). Maximum ambient temperature 52°C (125°F).

Phase 5 15 minute air purge at 21°C (70°F) and 414 kPa (60 PSIG). Ambient temperature 21°C (70°F).

- Valves are actuated intermittently during Phases 1, 2 and 4
- Valves are subjected to a total of 730 process cycles
- Diaphragm is acceptable after 365 process cycles



Bioprocess Cycle 1

Bioprocess Cycle #2

Phase 1 60 minute exposure to DI water at 82°C (180°F) and 414 kPa (60 PSIG). Ambient temperature 32°C (90°F).

Phase 2 2 minute DI water purge at 16°C (60°F) and 414 kPa (60 PSIG). Ambient temperature 21°C (70°F).

Phase 3 60 minute exposure to saturated steam at 149°C (300°F) and 359 kPa (52 PSIG). Maximum ambient temperature 52°C (125°F).

Phase 4 3 minute air purge at 21°C (70°F) and 414 kPa (60 PSIG). Ambient temperature 21°C (70°F).

- Valves are actuated intermittently during Phases 1, 2 and 3
- Valves are subjected to a total of 730 process cycles
- Diaphragm is acceptable after 365 process cycles

Bioprocess Cycle 2

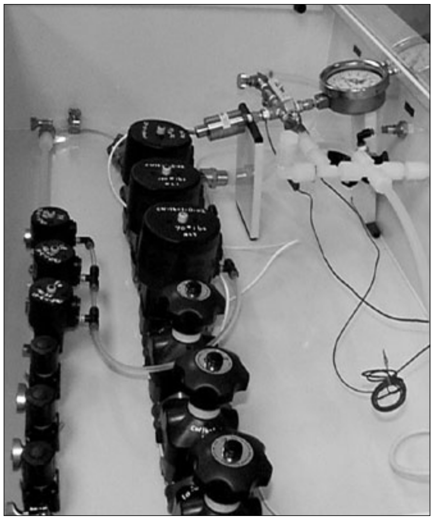
Evaluation Criteria

- Each valve to maintain acceptable port-to-port and external bubble leak performance throughout and at conclusion of the specified bioprocess cycle
- Diaphragm will not crease or develop cracks that could harbor bacteria for a minimum of 365 cycles

Pressure Envelope Cyclic Test

Test Method

Utilize E-102 test method. The objective of this test is to determine the fatigue strength of the media containing envelope for each valve size and style.



Pressure Envelope Cyclic Test

Summary of Method

This test subjects the internal area of the valve containing the fluid media to a minimum of 1,000,000 internal hydraulic pressure cycles at accelerated conditions.

Conditions

- Ambient temperature is maintained at 23°C (73°F)
- The cycle test pressure is 1.5 times the maximum pressure rating at the coinciding temperature rating
- Conducted at two media temperature and pressure levels: 23°C (73°F) @ 1034 kPa (150 PSIG) and 90°C (194°F) @ 673 kPa (97.5 PSIG)
- Pressure cycle rate is 0.5 Hz
- The pressure trace is recorded using an oscilloscope and pressure transducer

Evaluation Criteria

- No fluid leakage outside the valve pressure containing envelope (observed while on test or during the inspection following the completion of the required test cycles)
- No valve component fracture or failure as a result of stresses induced from the operating conditions

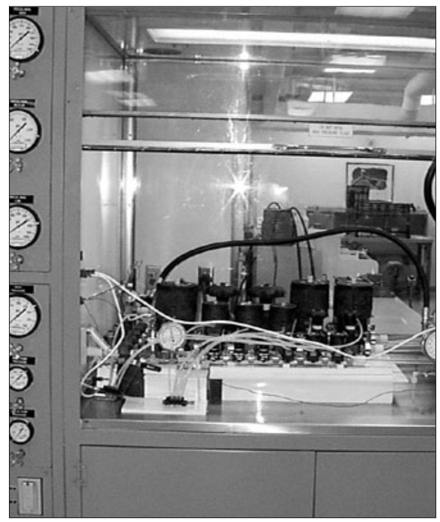
Burst Pressure Test

Test Method

Utilize E-101A test method. The objective of this test is to determine the valve's maximum hydraulic burst pressure capability.

Summary of Method

This test subjects the internal area of the valve containing the fluid media to internal hydraulic pressure, while in a controlled environment, until failure.



Burst Pressure Test

Conditions

- Ambient temperature is maintained at 23°C (73°F)
- Conducted at two media temperatures: 23°C (73°F) and 149°C (300°F)
- Failures are to occur within 60 to 70 seconds from initial exposure to the high pressure fluid
- Peak pressure is recorded on an instrument such as a strip chart recorder, oscilloscope or data acquisition system

Evaluation Criteria

- Any external fluid leakage
- Any instantaneous or rapid pressure loss that interrupts the continuous and uniform pressure increase
- Valve component distortion as a result of the stresses induced by the hydraulic pressure
- 95% confidence and reliability at achieving 1379 kPa (200 PSIG) and 717 kPa (104 PSIG) burst ratings at 23°C (73°F) and 149°C (300°F) respectively

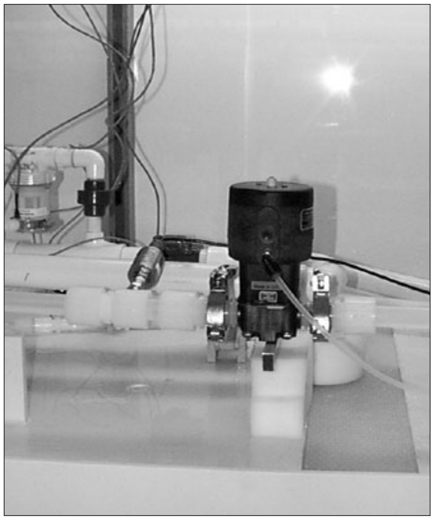
Flow Versus Differential Pressure, Water Media

Test Method

Performed per ISA-S75.02 (also utilize E-109) test procedure for control valve capacity. The objective of this test is to determine the flow capacity (C_V) of a valve as well as provide the necessary data to establish a flow versus differential pressure curve.

Summary of Method

This test measures the pressure losses across a valve with various flow rates.



Flow Versus Differential Pressure

Conditions

- Water media at 23°C (73°F)
- Installation of test valve and pressure tap locations are per ISA requirements
- Flow rate is controlled by upstream throttling valves
- Flow rate is monitored by in-line turbine meters which send an electronic signal to a digital meter
- Pressures are monitored by transducers that send an electronic signal to a digital meter

Evaluation Criteria

- Use flow versus pressure differential to calculate valve sizing coefficient (C_V)
- Generate pressure drop versus flow rate curves

Fitting Qualification Testing Summary

Entegris uses several tests to determine the published performance and life expectancy specifications for each fitting type. While all fittings undergo most of the tests described below, tests are performed based on the fitting's intended use; therefore, not all tests apply to all fittings. Only after the fittings successfully complete targeted tests are they released to market.

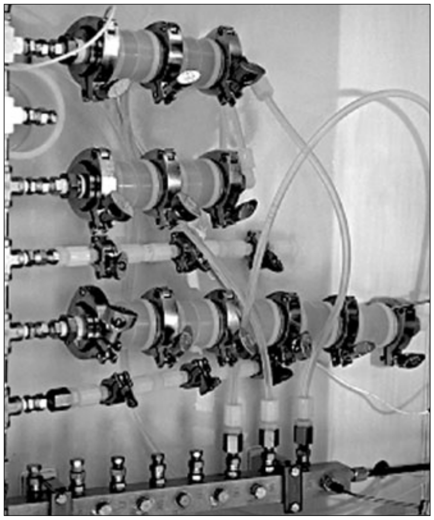
Pressure Envelope Cyclic Test

Test Method

Utilize E-102 test method. The objective of this test is to verify the fatigue pressure rating of a fitting connection.

Summary of Method

This test subjects the fitting connection to a minimum of 1,000,000 internal hydraulic pressure cycles at accelerated conditions, while maintaining fluid and ambient temperatures.



Pressure Envelope Cyclic Test

Conditions

- The cycle test pressure is 1.5 times the maximum pressure rating at the corresponding temperature rating
- Conducted at two media temperature and pressure levels: 23°C (73°F) @ 1034 kPa (150 PSIG) and 90°C (194°F) @ 673 kPa (97.5 PSIG)
- Pressure cycle rate is 0.5 Hz for all products
- The pressure trace is recorded using an oscilloscope and pressure transducer

Evaluation Criteria

- Any external fluid leakage from tube fitting connection
- Tubing separation from the tube fitting connection
- Nut torque or clamp relaxation on fitting body
- Fitting body, nut or tubing fracture

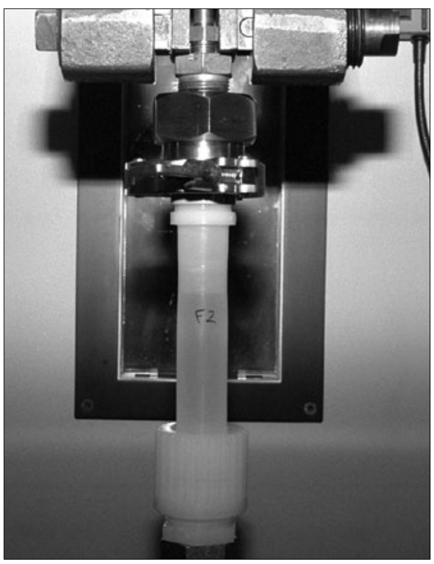
Determine Maximum Tensile Strength Capability

Test Method

Utilize SEMI Document #F7 (similar to E-105). The objective of this test is to determine the tensile capability of the fitting connection.

Summary of Method

This test subjects fitting connections made of fluorocarbon materials to extreme tensile forces until a failure occurs.



Maximum Tensile Strength

Conditions

- Ambient temperature is maintained at 23°C (73°F)
- Tensile pull rate is 2.5 cm (1 in) per minute

Evaluation Criteria

- Tubing separation from the tube fitting connection
- Tubing tears
- Fitting fracture
- Separation of fitting components

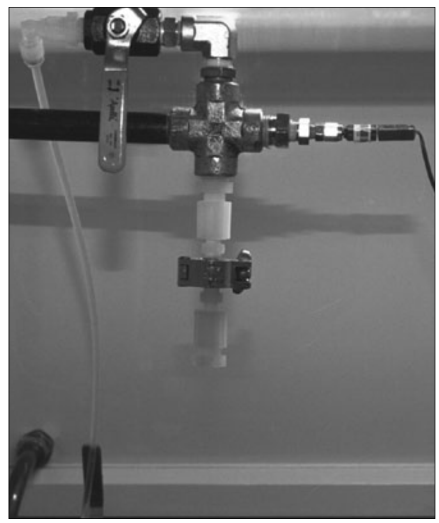
Pressure Envelope Burst (Maximum Proof Pressure) Test

Test Method

Utilize SEMI Document #F10 (similar to E-101A). The objective of this test is to determine the maximum pressure capability of the fitting connection.

Summary of Method

This test subjects fitting connections to internal hydraulic pressure until failure. A separate setup is required at each specific elevated fluid temperature condition. Failures are to occur within 60 to 70 seconds from initial exposure to the high pressure fluid.



Pressure Envelope Burst Test

Conditions

- Ambient temperature is controlled from 23°C (73°F) to 38°C (110°F)
- Internal fluid is circulated through the test specimens at temperatures controlled from 23°C (73°F) to 200°C (392°F)
- Peak pressure is recorded on an instrument such as a strip chart recorder, oscilloscope or data acquisition system

Evaluation Criteria

- Any external fluid leakage
- Burst of tube wall causing catastrophic failure
- Tubing separation from the fitting connection
- Tubing and nut separation from fitting body
- Fitting fracture
- Separation of fitting components

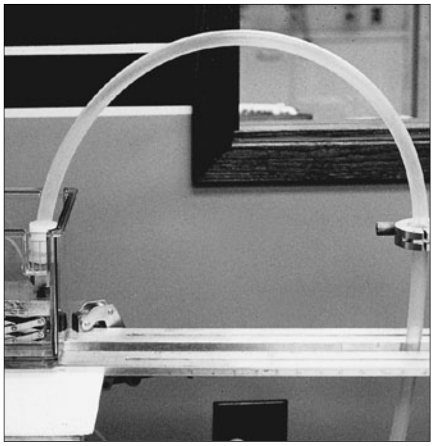
Side Load Characterization

Test Method

Utilize SEMI Document #F9. The objective of this test is to determine leak integrity of the fitting connection as it is subjected to a side load.

Summary of Method

This test subjects tube fitting connections to a side load condition resulting from bending the tube in a uniform arc. The side load is applied while maintaining a specified pressure to the internal cavity of the fitting and tube.



Determine Leakage Characteristics When Subject to a Side Load

Conditions

- Ambient temperature is maintained at 23°C (73°F)
- A constant pressure of 250 kPa (36 PSIG) is maintained in the internal cavity of the fitting and tube
- The fitting body is fixtured to a special apparatus that also clamps to the free end of the tube to maintain a tube bend radius. This apparatus allows the test specimen to be internally pressurized
- Observations are documented at each specified tube bend radius
- Leakage is observed for one minute at each position with the fitting connection submersed in IPA

Evaluation Criteria

- Bubble leakage from the fitting connection
- Tubing separation from the fitting connection
- Kinking of the tube

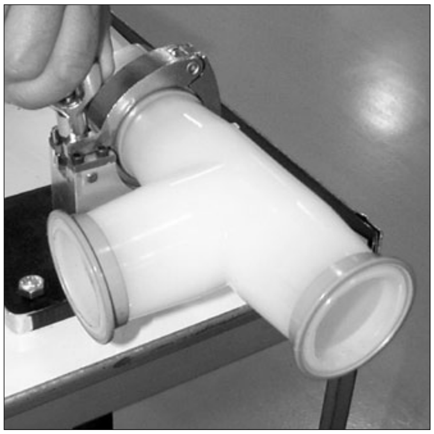
Functional Evaluation

Test Method

The objective of this test is to determine the fit of mating parts and fitting integrity after repeated assembly and disassembly.

Summary of Method

This evaluation determines how well Cynergy clamp fittings assemble with stainless steel sanitary clamp fittings. This test further evaluates the integrity of the Cynergy clamp fitting after 250 assemble and disassemble conditions.



Fitting Fit and Integrity Test

Conditions

- Evaluation performed at ambient conditions
- Evaluation is performed on all Cynergy clamp fitting sizes
- Evaluation performed using EPDM gaskets and standard Tri-Clamp® clamps
- Bubble leak test fitting connections using 100 PSIG air at initial assembly and 100, 200 and 250 assembly intervals

Evaluation Criteria

- Cynergy clamp assembly difficulties
- Excessive wear of Cynergy clamp connection
- Bubble leakage from Cynergy clamp connection

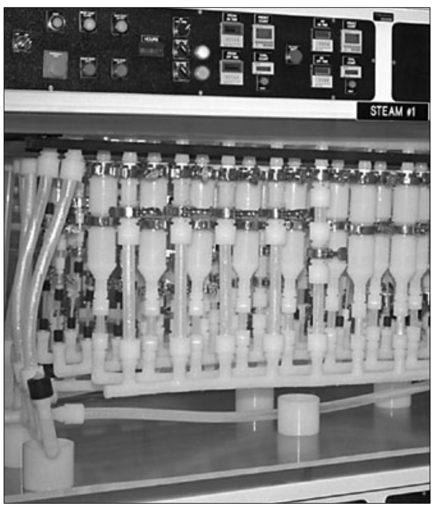
Saturated Steam Exposure Evaluation

Test Method

The objective of this test is to determine the effects of multiple saturated steam cycles on the performance of Cynergy clamp fittings.

Summary of Method

This evaluation subjects the Cynergy clamp fittings to a total of 730 steam-in-place cycles. At various SIP intervals, fittings are evaluated for seal face flatness, media leak integrity, media seal location and maximum proof pressure.



Saturated Steam Exposure

Conditions

- Expose fitting connections to saturated steam at 149°C (300°F) and 359 kPa (52 PSIG) for one hour. Cool for one hour using air. Repeat for a total of 730 cycles.
- Test specimens include Cynergy clamp fitting-to-Cynergy clamp fitting, Cynergy clamp fitting-to-stainless steel Tri-Clamp clamp fitting.
- Evaluation performed using all Cynergy clamp fitting sizes
- Measure fitting seal face flatness after 365 SIP cycles and after conclusion of the 730 SIP cycles
- Bubble leak test fitting connections using 689 kPa (100 PSIG) air after 365 and 730 SIP cycles
- Determine media seal location by introducing fluorescent additive into steam and viewing with black light after 365 and 730 SIP cycles
- Determine ambient temperature maximum proof pressure (burst) of fitting connections after 730 SIP cycles

Evaluation Criteria

- Deflection of fitting seal face
- Bubble leakage from fitting connection
- Migration of seal point
- Reduction of ambient temperature maximum proof pressure

Tubing and Weld Qualification Testing Summary

Entegris tubing pressure ratings were established using ASTM D2837. This test exposes the tubing to long-term, constant pressures at various temperature settings. From the analysis, a hydrostatic design basis (HDB) value is multiplied by a safety design factor to obtain a hydrostatic design stress. The HDB value is used to determine the operating parameters of tubing. Entegris tubing made from Teflon 440HP, has completed this extensive testing. A description of the test method follows.

Long-term Hydrostatic Strength Determination (Tubing Only)

Long-term Hydrostatic Strength Determination

Test Method

Utilize test method ASTM D1598, which is the industry approved means of characterizing plastics in the form of tube or pipe. This test method is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems. The objective of this test is to expose tubing specimens to a constant internal pressure and measure the time-to-failure.

Summary of Method

This test exposes the tubing to a constant internal pressure while in a controlled environment. The environment may be accomplished by, but is not limited to, immersing the specimen in a controlled temperature water or air bath. Testing is continued for 10,000 hours (approximately 13.6 months) and a minimum of 18 failure stress-time data points are obtained for each environment.

The hoop stress on each specimen is calculated from the pressure by means of a tube/pipe design calculation:

$$S = \frac{P\,(D - t)}{2t}$$

Where:
S = hoop stress, PSI
P = pressure, PSIG
D = average O.D. (inches)
t = minimum wall thickness (inches)

Linear plots of hoop stress vs. time-to-rupture on log-log coordinates are derived from each environment tested.

Once all the data points are obtained the hydrostatic design basis (HDB) value is determined (using ASTM D2837). The stress rupture data is analyzed by statistical regression to generate a hoop stress vs. time equation. This equation provides a means to mathematically extrapolate the data out to 100,000 hours (approximately 11.4 years) to obtain a HDB value. The HDB value becomes the fundamental stress from which working stress is calculated.

Evaluation Criteria

This equation has yielded proven HDB values for our tubing of:

- 1600 PSI @ 73°F
- 1000 PSI @ 160°F
- 800 PSI @ 250°F

These values have been recognized and approved by the Plastic Pipe Institute (PPI), division of the Society of the Plastics Industry, Inc. for listing in TR-4. This is a technical report published by the PPI that specifies the recommended hydrostatic strengths and design stresses for thermoplastic tubing and pipe materials. Entegris is the only manufacturer to establish an HDB valve rating for extruded products made from Teflon material.

Safety Factor

Safety Factor Defined

Safety factor or service (design) factor (SF) is used to compensate for a number of variables involved in each application. If different conditions are anticipated, such as pressure or temperature cycling, undue stress caused by improper installation or support, corrosive environment, etc., consideration must be given to the adverse affects they may have on the material's long-term strength.

Hydrostatic Design Stress (HDS) Defined

The Hydrostatic Stress Committee of the PPI recommends a minimum Safety Factor of 2.0×. Taking the HDB value and factoring in the Safety Factor results in a hydrostatic design stress (HDS). The HDS is defined as the maximum hoop stress in the tube wall resulting from internal hydrostatic pressure. Hydrostatic pressure can be continuously applied with a high degree of certainty that tube failure will not occur within a long time. These values are also listed in TR-4.

Pressure Rating

Design Pressure Rating Calculation

Published design pressure ratings for tubing and pipe were derived from the following formula

$$P = \frac{2St}{D\text{-}t}$$

Where:
P = internal pressure, PSIG
D = average O.D. (inches)
t = minimum wall thickness (inches)
S = hydrostatic design stress*

* 640 @ 73°F   315 @ 250°F
500 @ 160°F   85 @ 350°F

Example: Determine maximum working pressure of 1″ Cynergy tubing @ 73°F
Part Number: SAT16-X

$$\frac{2 \times 640 \times 0.075}{1.006 - 0.075} = 103 \text{ PSIG}$$

Pressure Envelope Cyclic Test

Test Method

Utilize E-102 test method. The objective of this test is to determine the fatigue strength of Cynergy tubing and beadless weld.

Summary of Method

This test subjects the internal area of the tube and weld to a minimum of 1,000,000 internal hydraulic pressure cycles at accelerated conditions.

Pressure Envelope Cyclic Test

Conditions

- Ambient temperature is maintained at 23°C (73°F)
- The cycle test pressure is 1.5 times the maximum pressure rating at the coinciding temperature rating
- Test pressure is conducted at two media temperature and pressure levels: 23°C (73°F) @ 134 kPa (150 PSIG) and 90°C (194°F) @ 673 kPa (97.5 PSIG)
- Pressure cycle rate is 0.5 Hz
- The pressure trace is recorded using an oscilloscope and pressure transducer

Evaluation Criteria

- No tube/weld fracture or leakage observed while on test or during the inspection following completion of the required test cycle

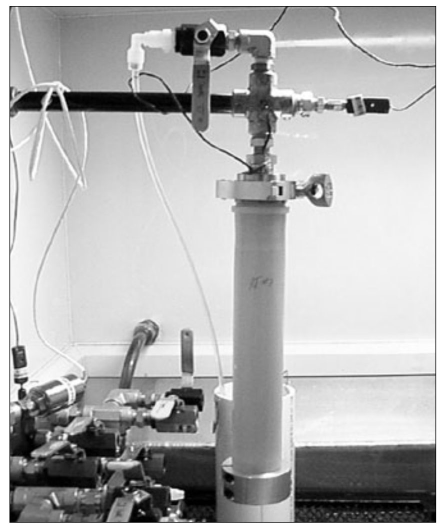
Maximum Proof Pressure (Before Steam Exposure)

Test Method

Utilize test method E-101A. The objective of this test is to determine the internal pressure required to produce a tube or weld failure.

Conditions

- Burst test samples at both 23°C (73°F) and 149°C (300°F)



Maximum Proof Pressure

Evaluation of Criteria

- The average failure pressure shall be at least 3 times the pressure rating at the temperature in which the product is evaluated

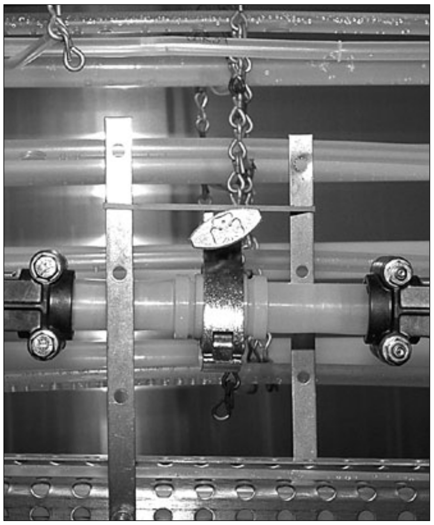
Saturated Steam Exposure/Maximum Proof Pressure (After Steam Exposure)

Test Method

The objective of this test is to determine the pressure required to produce a Cynergy tubing or weld failure after exposure to saturated steam conditions.

Conditions

- Expose the test samples to saturated steam @ 149°C (300°F) @ 359 kPa (52 PSIG) for one hour. Cool for one hour using air. Repeat for a total of 730 SIP cycles.
- After 730 SIP cycles, burst test the samples at both 23°C (73°F) and 149°C (300°F)



Saturated Steam Exposure

Evaluation Criteria

- Tubing and weld function after 730 SIP cycles, and meet a 1.25× safety factor

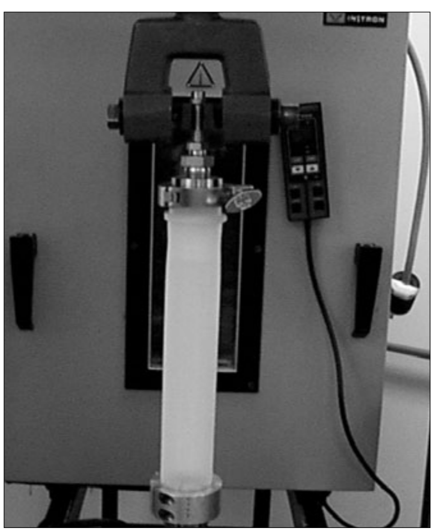
Tensile Test

Test Method

Utilize test method E-105. The objective of this test is to determine the maximum tensile capability of Cynergy tubing and weld before and after 730 SIP cycles.

Conditions

- Tests performed at ambient temperature of 23°C (73°F)



Tensile Test

Evaluation Criteria

- Ensure steam cycles have no effect on tubing and weld
- Informational data, use for reference only

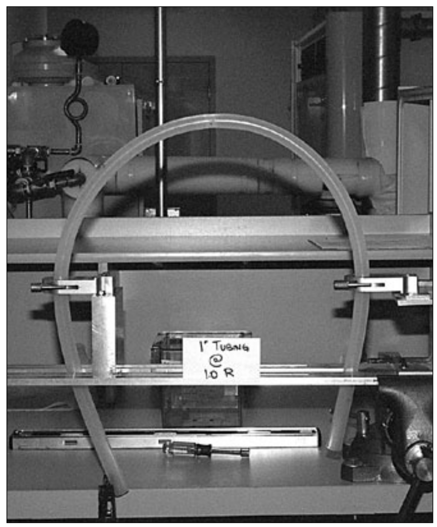
Bend Radius Test

Test Method

Utilize SEMI Document #F9. The objective of this test is to determine the minimum bend radius of tubing and weld

Conditions

- Tests are performed at ambient temperature of 23°C (73°F)



Bend Radius Test

Evaluation Criteria

- Weld will not crack or fail
- Informational data, use for reference only

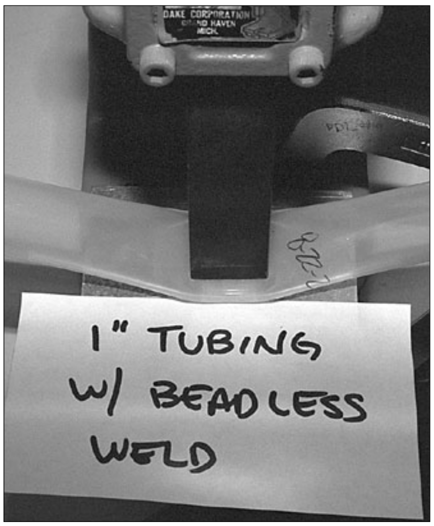
Weld Strength (Crush) Test

Test Method

The objective of this test is to determine the strength of the beadless weld when an outside force is applied to the tubing surrounding the weld to change its shape from circular to elliptical.

Conditions

- Tests are performed at ambient temperature of 23°C (73°F)



Weld Strength Test

Evaluation Criteria

- Weld is not cracked or broken

Rack and Clamp Qualification Testing Summary

Cynergy Rack and Clamp Qualification

Cynergy Rack and Clamp Qualification

Test Method

The objective of this test is to ensure the Cynergy rack/clamp assembly contains the tubing thermal expansion while maintaining complete drainability.

Conditions

- Tubing installed into rack/clamp assembly at ambient temperature of 23°C (73°F)
- Expose tubing to saturated steam at 149°C (300°F) and 359 kPa (52 PSIG) for 1 hour
- Cool for 1 hour using air
- Repeat for a total of 365 SIP cycles
- Maximum ambient temperature is maintained at 52°C (125°F)

Evaluation Criteria

- No tubing slippage at clamps
- No tubing abrasion
- Complete tubing drainability at ambient and steam temperatures and 2% (1°) slope

System Design

Cynergy Tubing

Cynergy tubing has an exceptionally smooth bore, accounting for its excellent flow capabilities. There is low drag and no corrosion of the Teflon PFA material. It is also resistant to bacterial growth because no nutrients or organics are present.

Tables 13 and 14 can be used to determine if the pressure loss through a given sized Cynergy system is acceptable based on flow requirements.

TABLE 13: FLOW RATE VS. FRICTION LOSS OF WATER

Flow Rate		Tubing Size ¼"		½"		¾"		1"		1½"		2"	
LPM	(GPM)	v	ΔP_{100}	v	ΔP_{100}	v	ΔP_{100}	v	ΔP_{100}	v	ΔP_{100}	v	ΔP_{100}
0,8	(0.2)	1.31	1.72										
1,5	(0.4)	2.62	6.21	1.20	0.92								
2,3	(0.6)	3.93	13.14	1.79	1.96	0.64	0.16						
3,0	(0.8)	5.24	22.37	2.39	3.33	0.85	0.27	0.45	0.06				
3,8	(1)	6.54	33.81	2.99	5.03	1.06	0.41	0.56	0.09	0.22	0.01		
7,6	(2)	13.09	121.89	5.98	18.13	2.13	1.48	1.12	0.31	0.44	0.03	0.24	0.01
11,4	(3)			8.96	38.39	3.19	3.13	1.67	0.66	0.67	0.07	0.36	0.02
15,1	(4)			11.95	65.37	4.26	5.33	2.23	1.12	0.89	0.12	0.47	0.03
18,9	(5)					5.32	8.05	2.79	1.69	1.11	0.18	0.59	0.04
22,7	(6)					6.38	11.28	3.35	2.37	1.33	0.25	0.71	0.06
26,5	(7)					7.45	15.00	3.91	3.15	1.56	0.34	0.83	0.07
30,3	(8)					8.51	19.21	4.47	4.03	1.78	0.43	0.95	0.09
34,1	(9)					9.85	23.89	5.02	5.01	2.00	0.54	1.07	0.12
37,9	(10)					10.64	29.03	5.58	6.09	2.22	0.65	1.19	0.14
45,4	(12)					12.77	40.67	6.70	8.53	2.67	0.91	1.42	0.20
53,0	(14)							7.81	11.35	3.11	1.21	1.66	0.26
60,6	(16)							8.93	14.53	3.56	1.55	1.90	0.34
68,1	(18)							10.05	18.06	4.00	1.93	2.14	0.42
75,7	(20)							11.16	21.95	4.45	2.35	2.37	0.51
94,6	(25)									5.56	3.55	2.97	0.77
113,6	(30)									6.67	4.97	3.56	1.08
132,5	(35)									7.79	6.61	4.16	1.44
151,4	(40)									8.90	8.46	4.75	1.84
170,3	(45)									10.01	10.53	5.34	2.29
189,3	(50)									11.12	12.79	5.94	2.78
208,2	(55)									12.23	15.26	6.53	3.32
227,1	(60)											7.12	3.90
265,0	(70)											8.31	5.18
302,8	(80)											9.50	6.63
340,7	(90)											10.69	8.25
378,5	(100)											11.87	10.02

v = fluid velocity, ft/sec
ΔP_{100} = friction loss of water per 100 feet pipe, PSIG

The above values were calculated using the Hazen and Williams Formula.

$$\Delta P_{100} = \frac{452\,(Q^{1.85})}{C^{1.85}\,(D^{4.86})}$$

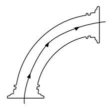
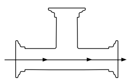
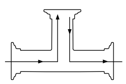
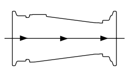
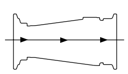
Where:
Q = flow rate (GPM)
D = pipe I.D. (inches)
C = friction factor (for Teflon PFA, C=155)
ΔP_{100} = pressure drop/100 feet of pipe (PSIG)

Section 2: Product Performance

Cynergy Fittings

TABLE 14: FRICTION LOSS THROUGH FITTINGS

Equivalent Length of Straight Pipe in Feet

Fitting Type		Fitting Size 1/4"	1/2"	3/4"	1"	1 1/2"	2"
	Sweep Elbow	0.3	0.5	0.8	1.1	1.8	2.5
	Tee (Flow Through Run)	0.4	0.6	1	1.4	2.3	3.1
	Tee (Flow Through Branch)	1.3	1.9	3.1	4.3	6.8	9.3
	Reducer (Gradual Contraction)	Equivalent Length (In Feet)					
	1/2" → 1/4"	0.5					
	3/4" → 1/2"	0.8					
	1" → 3/4"	1.1					
	1 1/2" → 1"	1.8					
	2" → 1 1/2"	2.5					
	Reducer (Gradual Enlargement)	Equivalent Length (In Feet)					
	1/4" → 1/2"	0.8					
	1/2" → 3/4"	1.4					
	3/4" → 1"	1.9					
	1" → 1 1/2"	3.1					
	1 1/2" → 2"	4.2					

Pressure Loss of Water Through Valves

K_V and C_V Factor

"K_V" flow factor is the number of liters per minute of water that pass through a given orifice area at a pressure drop of 1 bar.

"C_V" flow factor is the number of gallons of water that pass through a given orifice area in one minute at a pressure drop of one PSIG.

K_V and C_V Formulas

$$Q = K_V \sqrt{\frac{\Delta P}{Y}}$$

Q = Flow (l/min.)
ΔP = Pressure drop (bar)
Y = Specific gravity in kg/cm^3

$$Q = C_V \sqrt{\frac{\Delta P}{S.G.}}$$

Q = Flow (GPM)
ΔP = Pressure drop (PSIG)
S.G. = Specific gravity

Surface Finish

In a perfect world, tubing would transport fluids without any interactions between the inner wall and the fluid. Ideally, the biotechnology and pharmaceutical industries would like tubing to perform as follows:

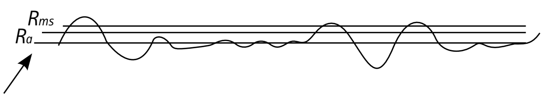
1. The tubing would not produce particles.
2. The tubing would not retain or entrap particles already present in the fluid.
3. The tubing would not allow for the formation of biofilm on its walls that would result in high TOC results due to organic by-products of bacterial growth.

By looking at these three critical requirements, we can begin to focus on surface parameters that might be effective measures of potential tubing performance.

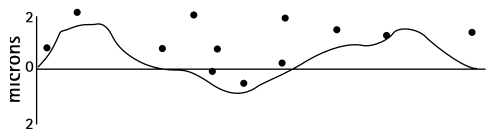
One of the most useful measurement techniques that has been developed is surface profilometry. This technique involves moving a sensitive stylus over the surface and measuring the changes in vertical height. The ability of the stylus to resolve the surface topography requires the stylus tip be smaller than the peaks and valleys it is trying to measure. With the introduction of polymer surfaces into the marketplace another measurement problem arose. Because polymers are much softer than metals, the stylus deforms the surface causing incorrect values. However, newer profilometry techniques have been developed in which lasers have replaced the stylus. This replacement allows for the resolution of extremely small features as well as eliminating the surface contact problem.

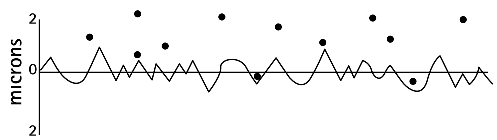
As surface profilometry developed as an analytical tool in surface measurement, specific surface topography measurements were defined. Most of these parameters were defined and developed because of their known relationship to specific performance requirements in the metal forming industry. Over the years, many of these parameters have been developed into industry standards. As the biopharmaceutical industry continues to explore the relationship between surface topography and tubing performance, it is only natural that they have turned to the standards that already exist and are well documented.

Two of the most common surface measurements are average surface roughness R_a and R_{ms}. Both measurements quantify the same feature. When a surface profilometer traces a surface, the instrument's computer generates a center line where the profile areas above and below this center line are equal.
The R_a and R_{ms} values are the averages of all the deviations of the traced line from the center line along some predetermined length. The R_a value is an arithmetic average and the R_{ms} value is a geometric average. For the most part, this is just a mathematical consideration. However, the R_{ms} value is always a little larger than the R_a value so you have to be careful when comparing average surface roughness values to ensure that both values are the same average. A drawing of the concept of average surface roughness is shown below.



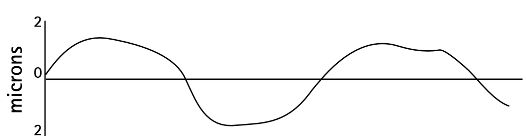
Originally, average surface roughness parameters were developed to quantify metal surfaces such as bearing and electrical contacts that were subjected to frictional wear. The R_a and R_{ms} values were critical variables of how well the product performed. The remaining question is whether R_a and R_{ms} values are meaningful parameters when discussing particle retention or biofilm adhesion properties. We can ask the question: Of the two surfaces shown below, which will be more likely to retain 0.3 µm particles?

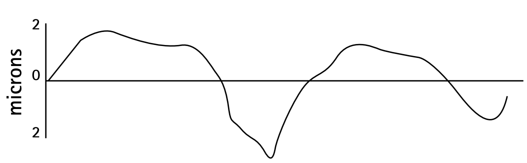




In the generation of the R_a and R_{ms} values, the first surface would have much larger R_a and R_{ms} values than the second. This is because the larger features on a surface are weighted more heavily than smaller features in calculating average surface roughness. But, would the first surface be more likely to entrap particles of the size shown in the drawing? Probably not. In fact, the first surface is probably the better of the two if judged on particle retention potential alone.

Another possible surface topography comparison is shown below. Here the R_a and R_{ms} values would be about the same, but the steepness of the peaks and valleys are much greater in the second surface. In cases such as this, the steeper valleys may retain more particles for a greater length of time and could act as possible biofilm initiation sites. In such cases, fluid flow rates may become significant variables from one application to another. An application with a flow rate of 1 liter/minute may be acutely affected by the second surface, while another application with a flow rate of 20 liters/minute will not suffer.





These examples were discussed because they show how a surface measurement such as average surface roughness may seem like an excellent measurement parameter but in reality may not correlate with the performance criteria that has been set. For the first example, a parameter that measures the average number of valleys that could entrap specific particle sizes might be a better standard. In the second example, a measurement of the average valley slopes might be a better standard. There are many possible parameters that can be measured from a profilometry trace. The important thing to remember from an evaluation standpoint, is there must be a correlation between the criteria you want your product to meet and the parameters you choose to evaluate.

Table 15 shows the average surface measurement of Cynergy tubing. Even though, based on these measurements, the Cynergy tubing surface equates to a 180 grit stainless steel surface (see Table 16), Cynergy tubing actually has smooth rounded slopes in contrast to the sharp jagged topography of polished stainless steel.

TABLE 15: TYPICAL CYNERGY TUBING SURFACE MEASUREMENTS

RMS (Micron)	RMS (Micro-inch)	RA (Micron)	RA (Micro-inch)	Grit Size
1	39	0.71	28	NA

Slight deviations from the norm do exist as these values are the average of many tests. Grit size does not apply since Cynergy tubing is not mechanically polished after manufacture.

TABLE 16: STAINLESS STEEL SURFACE MEASUREMENTS COMPARISON

RMS (Micron)	RMS (Micro-inch)	RA (Micron)	RA (Micro-inch)	Grit Size
2.03	80	1.80	71	80
1.47	58	1.32	52	120
1.20	47	1.06	42	150
0.86	34	0.76	30	180
0.43	17	0.38	15	240
0.36	14	0.30	12	320

Slight deviations from the norm do exist as these values are the average of many tests. Because of the many variables that create this data, deviations of ±5% would be considered well within good measurement parameters.

Product and Material Lot Traceability

Cynergy sanitary products made from Teflon PFA are coded with a lot number. This nondestructive, noncontaminating serial marking allows 100% traceability to a specific material lot, production date and production inspection record.

Extruded tubing has a nine-digit code that is laser marked onto the tube. See Figure 1.

Injection molded products have a unique two-digit code molded into the body. This code changes with every production lot. See Figures 2 an 3.

Figure 1: Laser Marking on Extruded Tubing

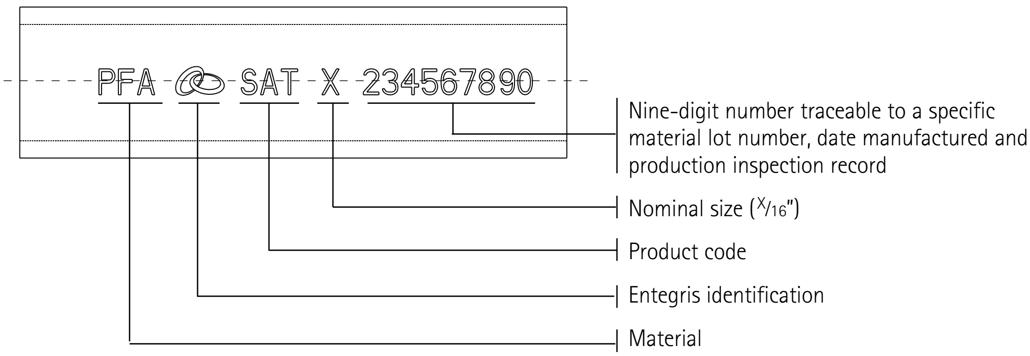


Figure 2: Marking on Fittings

Figure 3: Marking on Valves

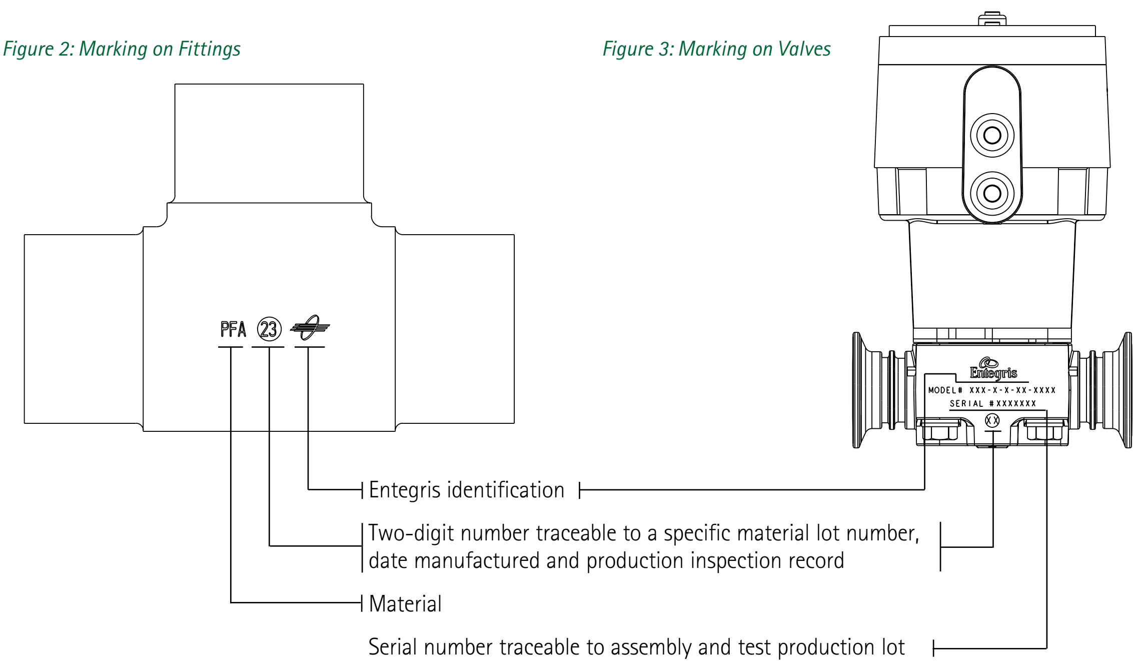
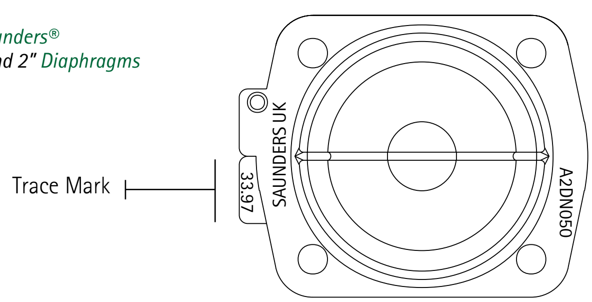


Figure 4: Marking on Saunders® PTFE/EPDM Backed 1" and 2" Diaphragms



Section 2: Product Performance


SPRING CLOSE
HIGH
TEMPERATURE

Section 3: Product Installation

Cynergy Valve Mounting Procedure

Entegris recommends that you support Cynergy valves independent of other piping components. To facilitate installation, a mounting kit is supplied with each Cynergy valve. The kit consists of a preformed stainless steel bracket and hardware. When properly installed, the bracket will orientate your Cynergy valve at the optimum angle for complete drainability. The bracket can be used with all horizontal and vertical runs.

The guidelines below provide direction for installation. Should you encounter unique circumstances not covered here, or have questions regarding your installation, contact your Entegris distributor or Entegris, Inc.

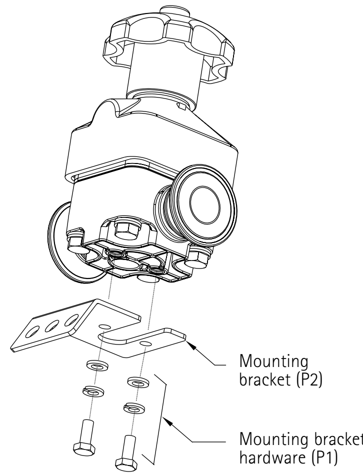


Figure 5

Horizontal Valve Mounting Guidelines

1. Using a 5⁄16″ hex wrench for 1⁄2″ valves, and a 7⁄16″ hex wrench for 1″ and 2″ valves, and hardware (P1) provided, attach the mounting bracket (P2) to your Cynergy valve (see Figure 5).

   Note: The mounting bracket (P2) is equipped with holes that allow you to secure it using 3⁄8″ threaded rod. Using the holes provided, the bracket may also be bolted or welded directly to framework, standoffs, walls or mounting plates.

2. Mount the valve bracket assembly to the preferred structure. To ensure complete drainability, the bracket flange must be on the horizontal plane (see Figure 6).
3. Visually verify the valve's horizontal position using the orientation indicators molded into the valve body (see Figure 7). Front to back orientation will be determined by the slope of the piping run.

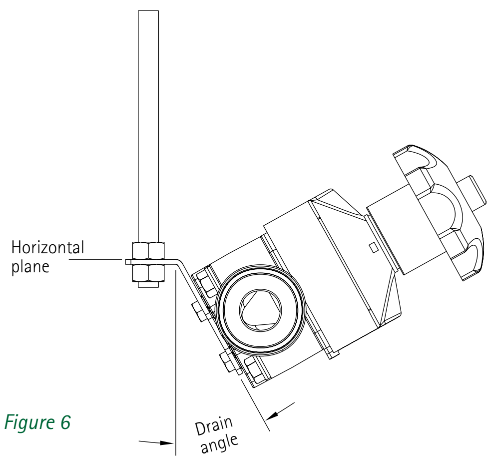


Figure 6

Vertical Valve Mounting Guidelines

Cynergy valves are fully drainable in a vertical orientation. Bracket flange orientation is not critical. Mount bracket to valve as indicated in the *Horizontal Valve Mounting Guidelines*.

Drain angles required for complete valve drainability are found on page 53.

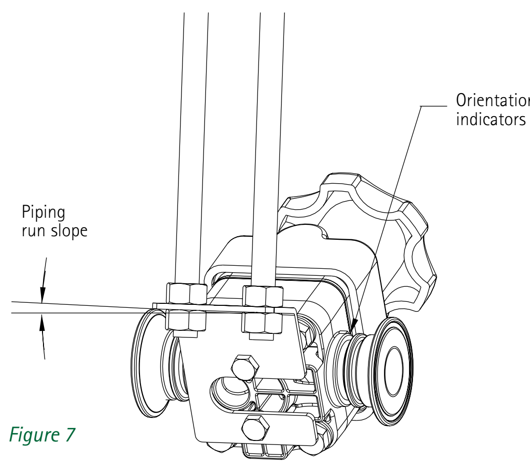
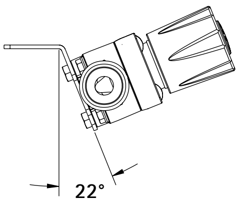


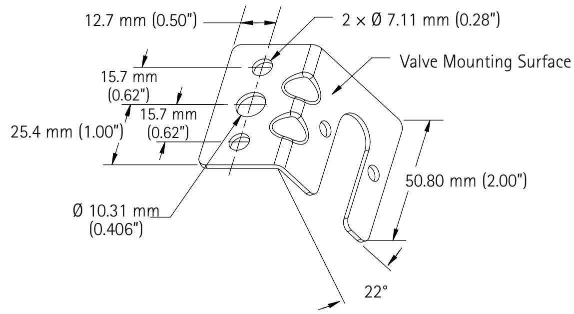
Figure 7

Mounting Bracket Dimensional Information

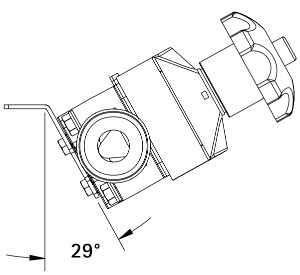
To facilitate installation, the mounting brackets are preformed to the correct drain angle to ensure complete drainability. A mounting bracket kit is included with each valve.



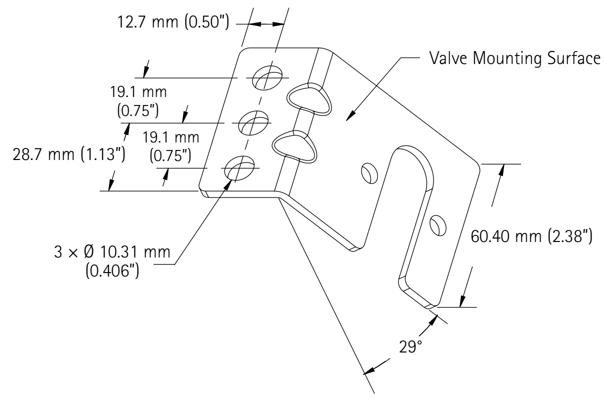
½" valve drain angle



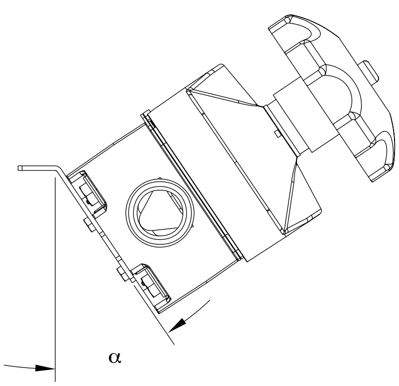
½" orifice valve mounting bracket with ½" port connection



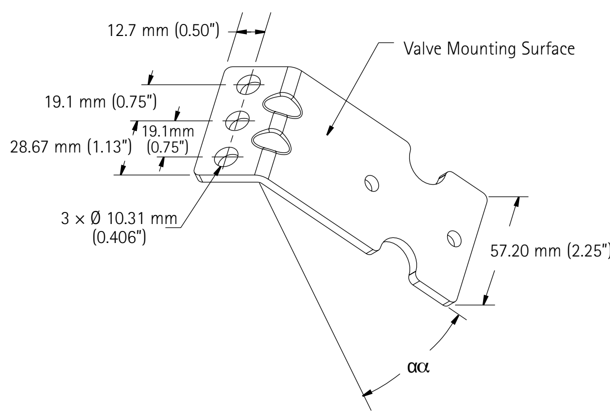
1" valve drain angle



1" orifice valve mounting bracket with 1" port connection



2" valve drain angle



2" orifice valve mounting bracket with 1½" or 2" port connection

Port Connection	Drain Angle α
1½"	34°
2"	23°

Other Guidelines

1. Cynergy valve mounting brackets are made from 304 stainless steel and can be subjected to standard metal working practices, i.e. cutting, drilling, filing and welding. Use these techniques to customize the brackets for your specific installation. Modify the brackets without the valve attached or valve damage may result.
2. If used in conjunction with Cynergy tube racks, independently support the tube racks as recommended in the *Cynergy Tube Rack Installation Guidelines*.

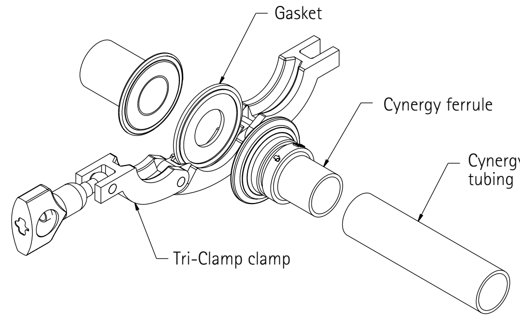


Figure 8

Cynergy Adapter Assembly

Assembly Instructions

1. Clean the Cynergy clamp fitting face with isopropyl alcohol (IPA) to remove surface contaminants and particles.
2. Select the recommended sanitary gasket and clamp specified in Table 17.
3. Place the appropriate gasket between the two sanitary flanges *(see Figure 8)*.
4. While holding the flanges together, place the clamp around them and secure the clamp. Tighten the clamp to the torque specification shown in Table 17.

Note: Laboratory testing of Cynergy clamp fittings shows performance reliability is dependent on the type of clamp and gasket used. Entegris strongly recommends the use of Tri-Clamp three-piece clamps for 1″, 1½″ and 2″ sizes, and Tri-Clamp two-piece clamps for ¼″, ½″ and ¾″ sizes. Entegris also recommends the use of sanitary gaskets by Tri-Clover® or Newman with Entegris' Cynergy clamp fittings.

Gasket Materials

Entegris recommends the use of sanitary EPDM gaskets by Tri-Clover or Newman with Entegris' Cynergy clamp fittings. In house testing has been performed on other high performance gasket materials with favorable results. Contact your Entegris distributor or Entegris, Inc. for a recommendation.

TABLE 17: GASKET AND CLAMP RECOMMENDATIONS

Cynergy Clamp Connection Size	Rubber Fab Tuf-Flex® PTFE/EPDM Gasket Number	Entegris Part Number for Tuf-Flex Gasket	Tri-Clover EPDM Gasket Part Number	Entegris EPDM Gasket Part Number	Tri-Clamp Clamp Number	Entegris Part Number for Tri-Clamp	Clamp-Torque N•m (in-lbs)
1/4"	–	–	0-42MP-E-1/4*	1333-022	13MHHS-3/4-S	01-008141	1.7 (15)
1/2"	A42MPGR-TF-050-E	01-1014718	42MP-E-1/2	01-008136	13MHHS-3/4-S	01-008141	1.7 (15)
3/4"	A42MPGR-TF-075-E	01-1014351	42MP-E-3/4	01-008137	13MHHS-3/4-S	01-008141	1.7 (15)
1"	A40MPGR-TF-100-E	01-034815	40MP-E-1	01-008138	13MHHS-11/2-S	01-008142	2.8 (25)
11/2"	A40MPGR-TF-150-E	01-034816	40MP-E-1 1/2	01-008139	13MHHS-11/2-S	01-008142	2.8 (25)
2"	A40MPGR-TF-200-E	01-034817	40MP-E-2	01-008140	13MHHS-2-S	01-008143	2.8 (25)

**Newman EPDM Gasket Part Number*

Section 3: Product Installation

Cynergy Clamp-to-Flaretek Adapter Assembly Procedure

Flaretek Adapter Connection

The flaring process provides a permanent expansion (flare) of the tubing end, allowing insertion of the Flaretek fitting body. Proper tube flaring and Flaretek fitting assembly results in a secure tubing connection.

Entegris recommends these procedures for flaring standard wall FluoroLine® PFA tubing only (0.062˝ wall thickness for 3⁄8˝, 1⁄2˝, 3⁄4˝ and 1˝ OD, 0.047˝ wall thickness for 1⁄4˝).

This flaring process is not recommended on Cynergy tubing.

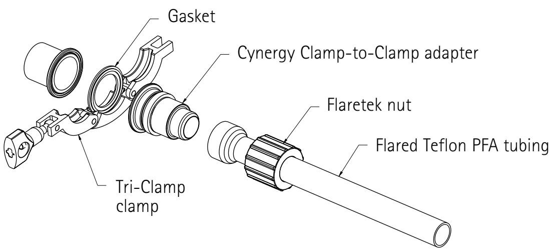
Note: The tubing cools rapidly so please read and understand all instructions before flaring your tubing.

Tubing Preparation

1. Cut the tubing end squarely (0.070˝ maximum squareness tolerance) using a Galtek® tubing cutter (Part Number 213-14, 213-16 or 213-30).
2. Insert the cut end of the tubing through the non-threaded end of the nut.

   Warning: If you do not put the nut on the tube now you will not be able to put it on after you complete the flare.

   Flaretek fittings are specifically designed, tested and characterized to work together with specific Flaretek fitting components manufactured by Entegris. Customer assumes the risk of connection integrity if Flaretek fittings, body and/or nut components are attached to components manufactured by third parties.



Cynergy Clamp-to-Flaretek adapter

Heat Flaring Instructions

1. If using an Entegris hot air gun (Part Number 213-79), set the hot air gun on "high." Hold the PFA tubing 1⁄4˝ to 1⁄2˝ above the heater and slowly rotate the tubing 360° for the approximate time specified in Table 18 or until a fine, clear line appears around the tubing (see Figure 9).

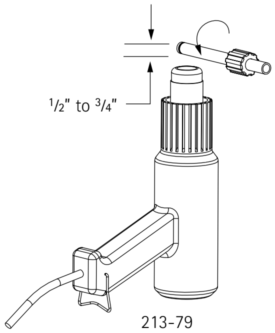


Figure 9

Note: It is very important to fully rotate the tubing over the heat source so all surface areas receive an equal amount of heat. Uniform heating is essential to making a good flare.

If using an Entegris infrared heating tool, turn on heating tool. Center 1⁄2˝ to 3⁄4˝ of the PFA tubing between the heat rings. While slowly rotating the PFA tubing back and forth between your forefinger and thumb, heat for the approximate time specified in Table 18 or until a fine, clear line appears around the tubing (see Figure 10).

Note: To flare 1˝ tubing with an Entegris infrared heating tool, a larger heat ring (Part Number 213-91 or 213-92) is needed.

Note: It is very important to rotate the tubing through the heat source so all surface areas receive an equal amount of heat. Uniform heating is essential to making a good flare.

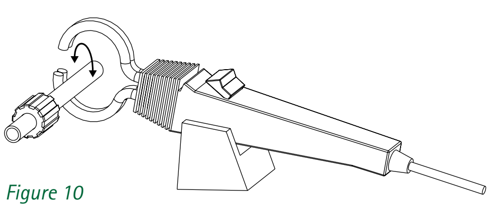


Figure 10

Section 3: Product Installation

2. Remove the PFA tubing from the heat source. Immediately push the flaring mandrel into the tubing until the end of the tubing reaches the tube stop (see Figure 11). Refer to Entegris' *Fluid Handling Products* catalog for available mandrel configurations.

   Note: Flaring ¼˝ tubing is the most challenging because of its small size. To get a firm grip on the small tube diameter, we recommend using the grip pad that is included in the mandrel kit (for additional grip pad, Part Number 213-73).

3. Firmly hold the tubing onto the mandrel for the time specified in Table 18.

4. Let the flared tubing continue to cool on the mandrel the time specified in Table 18.

5. The flaring process is now complete and the tubing may be removed from the mandrel.

Flaretek Fitting Assembly Instructions

1. Push the flared tubing end onto the Flaretek fitting body until the end of the fitting body contacts the flare shoulder of the tube (see Figure 12). The maximum gap between the tube end and fitting shoulder should be 0.08˝–0.015˝.
2. Tighten the nut onto the fitting body until hand tight.

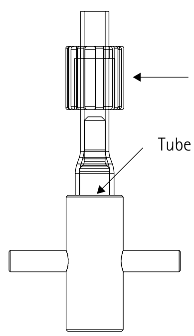


Figure 11

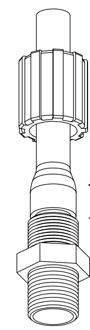


Figure 12

TABLE 18: HEATING AND COOLING GUIDE

Tubing and Fitting Size	1/4"	3/8"	1/2"	3/4"	1"
Heating time for PFA (sec.)					
Air gun	15	25	25	25	25
Infrared heater	40	50	50	50	60
Hold tubing on flare mandrel (sec.)	20	20	20	20	25
Minimum cooling time on mandrel (min.)	2	2	3	3	3

TABLE 19: TROUBLESHOOTING – FLARETEK TUBE FITTING ASSEMBLY

Problem	Possible Cause	Solution
After flaring the tubing, one side of the expanded portion of the tubing is wrinkled and shorter than its original length.	The tubing was not heated evenly. The wrinkled areas were overheated.	The wrinkles can be avoided by rotating and moving the tubing through the heat source with more uniformity. Cut off the flared tubing end and reflare.
The tubing kinks when pushing it onto the flaring mandrel.	The tubing was not heated properly before flaring.	1/2" to 3/4" of the tubing needs to be heated. Closely follow the recommended heating times in Table 18. Cut off the flared tubing end and reflare.
When the flared tubing is pushed onto the fitting body, the tubing is more than 0.150" away from the threaded area of the fitting body.	The tubing was not pushed onto the flaring mandrel all the way or the tubing was removed from the mandrel before it was cool.	Tubing may need longer heating time or longer cooling time on the flaring mandrel. Cut off the flared end and reflare.
The flared tubing will not fit onto the fitting body.	The tubing was removed from the mandrel before it was cool.	Reheat and reflare the undersized flared tubing end. Allow adequate cooling time prior to removing from the flare mandrel. *or* Cut off the flared tubing end and reflare. Be sure the tubing is cool before removing it from the mandrel.
Changes need to be made to a line after chemical has been run through the system. There is potential for vapor explosion in the line or hazard to the operator.		Heated flaring should only be attempted with tubing that has not been exposed to chemical. We recommend using the Entegris Room Temperature Flaring Tool (Part Number 213-112) if the tubing has been exposed to chemical.

Cynergy Clamp-to-FlareLock II Adapter Assembly Procedure

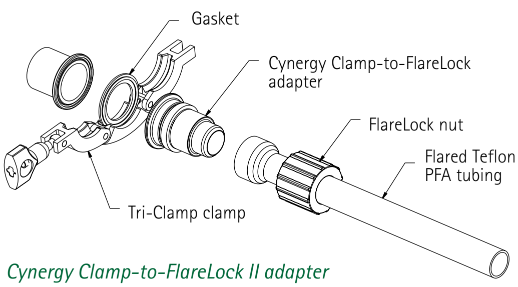
FlareLock II Adapter Connection

Grooving the tubing OD provides a groove in which the FlareLock II nut firmly connects. The flaring process provides a permanent expansion (flare) of the tubing end, allowing insertion of the Flaretek fitting body. Proper grooving, flaring and Flaretek fitting assembly result in a secure tubing connection.

Entegris recommends these procedures for use only with Entegris groove tools, heat sources and standard wall FluoroLine PFA tubing (0.062˝ wall thickness for: ⅜˝, ½˝, ¾˝ and 1˝ OD, 0.047˝ wall thickness for ¼˝).

This flaring process is not recommended on Cynergy Tubing.

Note: The tubing cools rapidly so please read and understand all instructions before flaring your tubing.



Cynergy Clamp-to-FlareLock II adapter

Tubing Preparation

1. Cut the tubing end squarely (0.070˝ maximum squareness tolerance) using a Galtek tubing cutter (Part Number 213-14, 213-16 or 213-30-1).

Grooving Instructions

1. Obtain the proper FlareLock II groove tool designed to groove the tubing outside diameter (OD).
2. Depress the blade thumb rest on the FlareLock II groove tool.
3. Insert tube into groove tool until it bottoms against the tube stop.
4. Release thumb rest.
5. While maintaining slight force between the tube end and groove tool, rotate groove tool in direction of arrow, four complete revolutions.
6. Depress thumb rest. Remove tube and inspect groove to be certain the depth is uniform and free from burrs.
7. Insert the grooved end of the tubing through the nonthreaded end of the nut.

WARNING: If you do not put the nut on the tube now you will not be able to put it on after you complete the flare.

Heat Flaring Instructions

1. If using a Entegris hot air gun, set the hot air gun on "high." Hold the PFA tubing ½˝ to ¾˝ above the heater and slowly rotate the tubing 360° for the approximate time specified in Table 20 or until a fine, clear line appears around the tubing (see Figure 13).

Note: It is very important to fully rotate the tubing over the heat source so all surface areas receive an equal amount of heat. Uniform heating is essential to making a good flare.

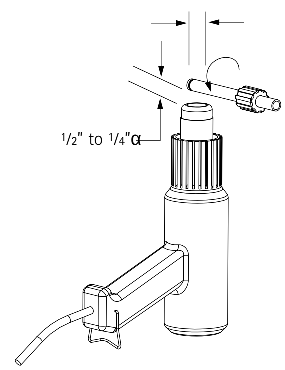


Figure 13

If using an Entegris infrared heating tool, turn on heating tool. Center ½″ to ¾″ of the PFA turning between the heat rings. While slowly rotating the PFA tubing back and forth between your forefinger and thumb, heat for the approximate time specified in Table 20 or until a fine, clear line appears around the tubing (see Figure 14).

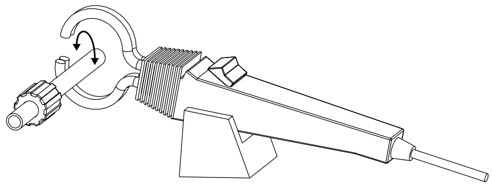


Figure 14

Note: To flare 1″ tubing with an Entegris infrared heating tool, a larger heat ring (Part Number 213-91 or 213-92) is needed.

Note: It is very important to rotate the tubing through the heat source so all surface areas receive an equal amount of heat. Uniform heating is essential to making a good flare.

2. Remove the PFA tubing from the heat source. Immediately push the flaring mandrel into the tubing until the end of the tubing reaches the tube stop (see Figure 15). Refer to Entegris' *Fluid Handling Products* catalog for available mandrel configurations.

   Note: Flaring ¼″ tubing is the most challenging because of its small size. To get a firm grip on the small tube diameter, we recommend using the grip pad that is included in the mandrel kit (for additional grip pad, Part Number 213-73).

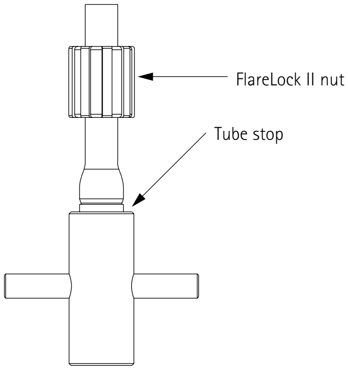


Figure 15

3. Firmly hold the tubing onto the mandrel for the time specified in the following table.

   Note: To ensure the FlareLock II fitting functions properly, it is crucial that the tubing is held firmly against the tube stop for the time specified in Table 20.
4. Let the flared tubing continue to cool on the mandrel the time specified in Table 20.
5. The flaring process is now complete and the tubing may be removed from the mandrel.

FlareLock II Fitting Assembly Instructions

1. Push the flared tubing end onto the Flaretek fitting body until the end of the fitting body contacts the flare shoulder of the tube (see Figure 16). The gap between the tube end and fitting shoulder should be 0.08″ to 0.15″.
2. Tighten the nut onto the fitting body until hand tight.

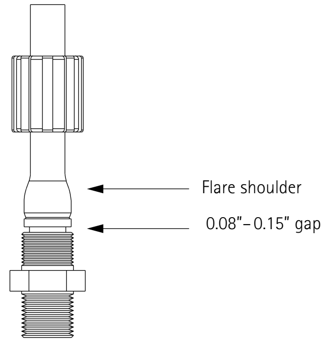


Figure 16

Section 3: Product Installation

TABLE 20: HEATING AND COOLING GUIDE

Tubing and Fitting Size	1/4"	3/8"	1/2"	3/4"	1"
Heating time for PFA (sec.)					
Air gun	15	25	25	25	25
Infrared heater	40	50	50	50	60
Hold tubing on flare mandrel (sec.)	20	20	20	20	25
Minimum cooling time on mandrel (min.)	2	2	3	3	3

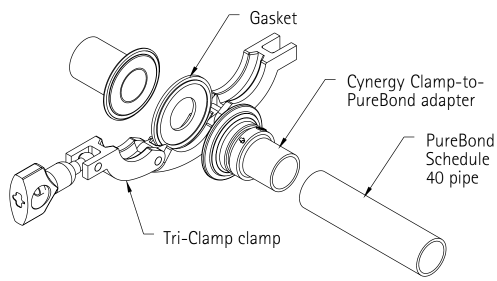
TABLE 21: TROUBLESHOOTING – FLARELOCK II TUBE FITTING ASSEMBLY

Problem	Possible Cause	Solution
After flaring the tubing, one side of the expanded portion of the tubing is wrinkled and shorter than its original length.	The tubing was not heated evenly. The wrinkled areas were overheated.	The wrinkles can be avoided by rotating and moving the tubing through the heat source with more uniformity. Cut off the flared tubing end and repeat assembly instructions beginning with tube preparation.
The tubing kinks when pushing it onto the flaring mandrel.	The tubing was not heated properly before flaring.	1/2" to 3/4" of the tubing needs to be heated. Closely follow the recommended heating times in Table 20. Cut off the flared tubing end and repeat assembly instructions beginning with tube preparation.
When the flared tubing is pushed onto the fitting body, the tubing is more than .150" away from the threaded area of the fitting body.	The tubing was not pushed onto the flaring mandrel all the way or the tubing was removed from the mandrel before it was cool.	Tubing may need longer heating time or longer cooling time on the flaring mandrel. Cut off the flared tubing end and repeat assembly instructions beginning with tube preparation.
The flared tubing will not fit onto the fitting body.	The tubing was removed from the mandrel before it was cool.	Reheat and reflare the undersized tubing end. Allow adequate cooling time prior to removing from the flare mandrel. *or* Cut off the flared tubing end and repeat assembly instructions beginning with tube preparation. Be sure the tubing is cool before removing it from the mandrel.

Cynergy Clamp-to-PureBond Adapter Assembly Procedure

PureBond Weld Procedure

The PureBond weld process should only be performed by an individual who has been trained in the patented weld process. PureBond weld tools are available for use in the PureBond process. Please consult your local Entegris distributor or Entegris, Inc. for details on PureBond weld tools and procedures.



Cynergy Clamp-to-PureBond adapter

Cynergy Beadless Welding Procedure

The automated Weld-in-Place Equipment enables trained individuals to construct Cynergy fluid handling systems on site. An all Teflon PFA installation can be welded in place, allowing for a system that is fully drainable and CIP/SIP capable. The equipment provides continuous monitoring of the weld process and collects data required for validation. The equipment is available for lease or sale. Please contact your Entegris distributor or Entegris, Inc. for additional information.

CE Approved

CE
CE Directives 73/23/EEC, 89/336/EEC
Standards EN60335-2-45, EN55011, EN61000-6-2

Cynergy PVDF Tube Adapter Assembly Procedure

Tubing Preparation

Note: Reference Table 22 for tube size and nut torque information. If using PFA tubing, refer to page 55 of this guide for PFA tube flaring instructions.

1. Cut the silicone tubing end squarely (0.070˝ maximum squareness tolerance). A Galtek tubing cutter may be used (Part Number 213-14, 213-16 or 213-30).
2. Insert the cut end of the tubing through the non-threaded end of the Flaretek nut.

Silicone Tubing Assembly Instructions

1. Push the silicone tubing end onto the nose of the Cynergy PVDF tube adapter until the end of the tube contacts the shoulder of the adapter body (see Figure 17).

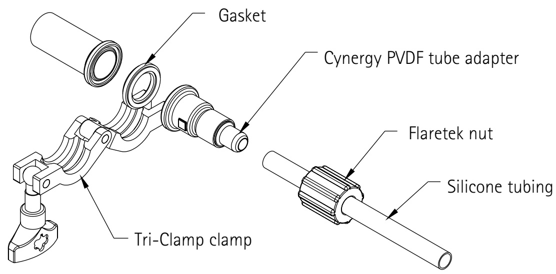


Figure 17

Section 3: Product Installation

TABLE 22: RECOMMENDED SILICONE TUBING ASSEMBLY

Cynergy PVDF Tube Adapter Size	Silicone Tubing O.D.	Silicone Tubing I.D.	Silicone Tubing Wall	Minimum Flaretek Nut Torque In•lbs (N•m)
1/4"	0.250"	0.125"	0.062"	5 (.6)
3/8"	0.375"	0.250"	0.062"	8 (.9)
1/2"	0.500"	0.375"	0.062"	11 (1.2)
3/4"	0.750"	0.625"	0.062"	14 (1.6)

Note: Adapters are not compatible with thin walled (.032") or reinforced silicone tubing.

Cynergy Tube Rack Assembly Procedures

Cynergy System Components

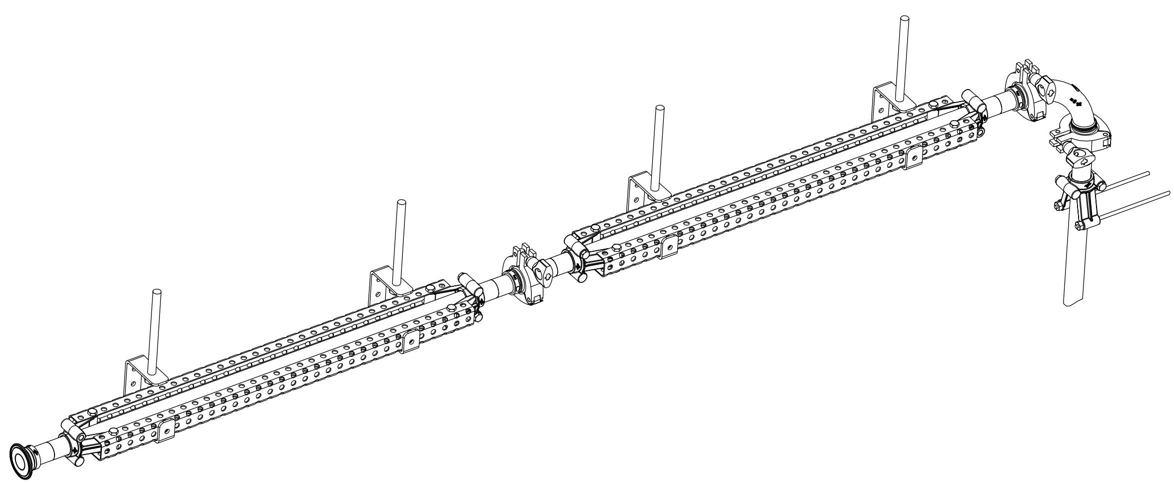
The Cynergy system comprises several specialized components including Cynergy tube racks, tube clamps and hangers. All hardware is provided for use with the Cynergy tube clamps. Depending on the installation specifics, additional hardware may be required. Cynergy tube racks are available for ¾″, 1″, 1½″ and 2″ Cynergy tubing. Reference pages 66-68 if you are installing ¼″ or ½″ Cynergy tubing.

Cynergy Support System

Because Cynergy tubing differs from stainless steel tubing it requires unique installation and support requirements. The fluoropolymer resin used in Cynergy tubing has a greater coefficient of thermal expansion than stainless steel tubing. Consequently, a greater change in length results when exposed to the same thermal variation. The tubing also becomes pliable during elevated temperature conditions. Due to these unique characteristics, Entegris recommends using Cynergy tube racks with Cynergy tubing.

Cynergy tube racks confine the thermal expansion and contraction eliminating potentially undesirable loads onto other system components, so flexible sections or expansion joints are not needed. When properly installed, Cynergy tube racks eliminate low spots in the tubing system that occur during elevated thermal conditions – including steam – ensuring complete drainability and compliance with cGMP requirements.

The guidelines below provide direction for most installations. Should you encounter circumstances not covered, or if you have questions about an installation, please contact your Entegris distributor or Entegris, Inc.



3/4", 1", 1½" and 2" Cynergy System Components

Part Numbers

Nominal Tube Size	Cynergy Tubing Part Number	Tube Rack Part Number	Tube Clamp Kit Part Number	Hanger Part Number
3/4"	SAT12–*	TR12-X	TC12-H	HG12
1"	SAT16–*	TR16-X	TC16-H	HG16
1 1/2"	SAT24–*	TR24-X	TC24-H	HG24
2"	SAT32–*	TR32-X	TC32-H	HG32

Replace "*" with "**X**" for 10 foot length, or "**VIII**" for 8 foot length.

Horizontal Installation Instructions

Entegris requires the use of Cynergy tube racks for any horizontal run that will be exposed to elevated temperatures – including cyclic steam – and where complete drainability is specified. When exposed to elevated temperatures the tubing grows in length. This results in the tubing snaking within the rack. During cooldown, the tubing straightens to its original length. Cynergy tube clamps secure the tubing during this thermal cycling. Cynergy tube racks are available in 10 feet lengths for 3⁄4˝, 1˝, 1½˝ and 2˝ Cynergy tubing. Multiple racks can be welded together to achieve a desired length.

1. Determine the system layout. This should include the desired tube length from fitting shoulder to fitting shoulder of all system tubing. These dimensions will be used to determine the tube rack lengths.

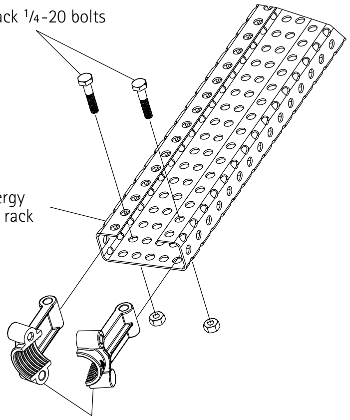


Figure 18

2. Determine which sections need continuous support. Horizontal runs that will be exposed to elevated temperatures (150°F or greater) or steam and require complete drainability should be supported with Cynergy tube racks. Shorter lengths may be left unsupported and remain drainable depending on several factors. Refer to page 67 for recommended spacing distances for unsupported lengths.
3. Calculate the tube rack length required for each tubing section by subtracting 6.25 inches from the tube length as measured from fitting shoulder to fitting shoulder (see Figure 19).

Example: Tube length (from fittings shoulder to fitting shoulder) = 8′8˝ or 104˝
Tube Rack Length = 104˝– 6.25˝ = 97.75˝ or 8′1¾˝

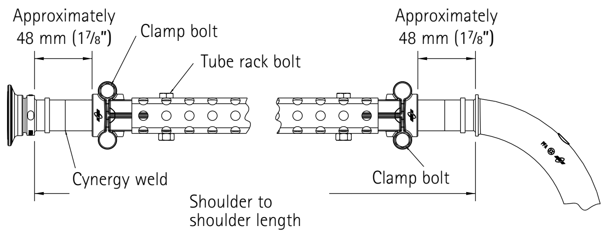


Figure 19

4. Cut the Cynergy tube rack to the required length. The supports should be cut between sets of holes and not directly through any hole.

   Note: If the cut line falls through a row of holes, cut the tube rack slightly shorter between two rows of holes.

   Example: Cutting a tube rack at 8´1¾˝ will cause the cut to take place through a row of holes. Cut the rack at 8´1½˝ so the holes are not cut.

5. File the cut end to remove any burrs.

   Note: Failure to remove burrs may result in damage to the Cynergy tubing during operation.

6. The cut Cynergy tube racks can be used to rough-in hanger locations. Any type of stand-off, mounting bracket or channeling should be installed or fabricated at this time. Horizontal runs should be installed at a minimum 2% (1°) slope to ensure drainability. To provide the required support, Cynergy hangers are to be installed at a maximum of 8 foot intervals. The hangers are designed to use standard 3⁄8˝ threaded rod to attach them to the building structure. They may also be attached directly to walls or ceilings via the mounting holes. In most cases, the hangers do not need to be fixed to the Cynergy tube rack. Should this be necessary, Entegris recommends spot welding the hanger to the tube rack or using a carriage bolt through the tube rack and hanger with the bolt head on the inside of the tube rack. After installing the hanger system, remove the Cynergy tube racks and proceed to Step 7.
7. Slide one tube clamp set into one end of the tube rack. Secure the clamp halves to the rack through the second set of holes from the end of the rack using two 1⁄4-20 bolts and corresponding nuts (see Figure 18). Reference Table 23 for correct bolt size. **Do not tighten the nuts.**
8. Attach the second tube clamp set to the other end of the tube rack repeating Step 7.
9. With the clamp halves separated, lay the corresponding tubing length into the rack and center it from end to end.
10. Close the clamp halves together and secure the halves using the remaining 1⁄4-20 bolts. Refer to Table 23 for correct clamp size. The clamp halves should be approximately 17⁄8˝ from the fitting collar (see Figure 19). Do not clamp over the Cynergy weld. Tighten the bolts with a 7⁄16˝ hex wrench to eliminate any gap between the two halves.
11. Secure the clamp to the rack by tightening the tube rack bolts with a 17⁄16˝ hex wrench.
12. The entire assembly may now be placed into the previously installed Cynergy hangers.
13. After hanging the tubing and support assemblies, connect the Cynergy adapter flanges using the recommended gasket and clamp. Refer to Cynergy Clamp Ferrule Fitting Assembly Procedures provided with the Cynergy adapters for recommended clamp and gasket part numbers as well as detailed assembly instructions.

    Note: Entegris strongly recommends the use of Tri-Clamp three-piece clamps for 1˝, 11⁄2˝ and 2˝ sizes, and Tri-Clamp two-piece clamp for 3⁄4˝ sizes. Entegris also recommends the use of sanitary gaskets by Tri-Clover or Newman with Entegris' Cynergy clamp fittings. Please contact your Entegris distributor or Entegris, Inc. for gasket material recommendation.

TABLE 23: BOLT SIZE

Nominal Tube Size	Tube Clamp Kit Part Number	Tube Rack Bolt Size	Clamp Bolt Size
3/4"	TC12-H	1/4-20 × 1 1/4"	1/4-20 × 1 1/4"
1"	TC16-H	1/4-20 × 1 1/4"	1/4-20 × 1 1/4"
1 1/2"	TC24-H	1/4-20 × 2"	1/4-20 × 1 1/2"
2"	TC32-H	1/4-20 × 2 3/4"	1/4-20 × 1 3/4"

Vertical Installation Instructions

Vertical runs may be installed with or without Cynergy tube racks. If installing using the Cynergy tube racks, follow the Horizontal Installation Instructions. If installing without using the Cynergy tube racks proceed with the following instructions.

With vertical runs, the tubing must be fixed at the end points and where the tubing transitions into another component such as a tee, elbow, reducer or valve. The tubing ends should be fixed using Cynergy tube clamps. The remainder of the vertical run does not need to be fully supported, however, Entegris recommends guides be used every 5 feet to align tubing. The use of a nonmetallic tubing guide, split ring hanger, eyelet or plastic pipe is recommended. So it does not tighten on the tubing or restrict axial movement, the guide's inside diameter should be 0.125″–0.250″ larger than the tubing's outside diameter. The tubing may also be fully enclosed in plastic pipe with access to the ends of the tube. To install the tubing section from the plastic pipe, the pipe needs to have an inside diameter 2.5 times larger than the outside diameter of the Cynergy tubing.

1. Determine the tubing layout. This should include the desired tube length from fitting shoulder to fitting shoulder.
2. Using two ¼″-20 bolts as called out in Table 23, install one set of Cynergy tube clamps at each end of the tubing section at a location 1⅞″ inches from the Cynergy fitting shoulder (see Figure 20). Do not clamp over the Cynergy weld.

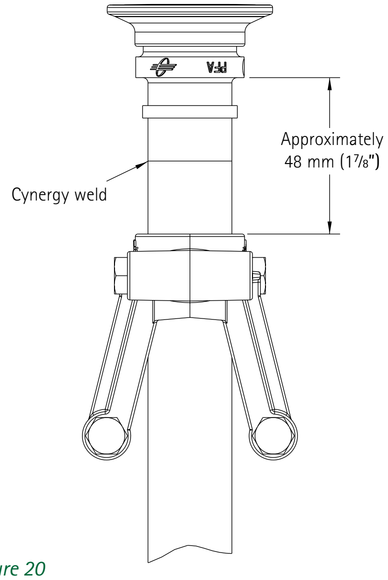


Figure 20

3. Attach the Cynergy clamps to a wall, stand-off or mounting plate.
4. Tubing guides or plastic pipe may be used to align the tubing between clamps. Entegris recommends a guide every 5 feet.
5. After hanging the tubing and support assemblies, connect the Cynergy adapter flange faces using the recommended gasket and clamp. Refer to Entegris Cynergy Clamp Ferrule Fitting Assembly Procedures provided with the Cynergy adapters for recommended clamp and gasket part numbers as well as detailed assembly instructions.

   Note: Entegris strongly recommends the use of Tri-Clamp three-piece clamps for 1″, 1½″ and 2″ sizes; and Tri-Clamp two-piece clamp for ¾″ sizes. Entegris also recommends the use of sanitary gaskets by Tri-Clover or Newman with Entegris' Cynergy clamp fittings. Please contact your Entegris distributor or Entegris, Inc. for gasket material recommendation.

Component Installation

Piping components such as adapters, tees, reducers and elbows should not be contained within the Cynergy tube rack. These components do not need to be fully supported. Only the tubing leading up to the component needs to be fully supported.

In-line valves should be supported independently of the Cynergy tube racks. Separate supports are required to support this weight.

Other Guidelines

Fabrication

Cynergy tube racks are made from 304 stainless steel and are compatible with standard metal working practices; i.e. cutting, drilling, filing and welding. Use of these techniques will allow you to customize the racks for your specific installation. Any type of modifications to the racks should be accomplished without the tubing in the rack structure. Failure to remove the tubing may result in tubing damage.

Connecting Tube Racks

To achieve the desired length, tube racks can be joined by welding two racks together. The weld bead should run along the outside of the tube rack.

Note: No internal weld beads, steps or burrs should be present. They may cause tubing damage.

Installation Verification and Inspection

1. Verify that all hardware is secure.
2. Verify slope of Cynergy tube racks to ensure drainability. Cynergy tube racks should be installed at a 2% slope minimum.
3. After the initial thermal cycle, check for tubing movement that may have occurred at the Cynergy clamps. Tighten clamp bolts if movement has occurred.
4. Inspect the tubing for excessive wear; especially in regions where welds, cuts or bolt heads are present in the Cynergy tube racks. In the instance of excessive wear, replace the tubing or contact your Entegris distributor or Entegris, Inc.

Disassembly Instructions

1. Disconnect the flange clamp connection.
2. Remove the Cynergy tube clamps from the tubing and allow the halves to spread apart.
3. Remove the tubing from the tube rack.

When reinstalling, place the tubing back into its respective rack and secure the clamps to the tubing two inches from the shoulder on the ferrule ends.

System Installation Recommendations

Thermal Expansion

Thermal expansion and contraction of PureBond Schedule 40 pipe and Cynergy tubing should be considered during the design and installation stages of a piping system. If the working temperature is higher than the installation temperature the tubing/pipe becomes longer. If the working temperature is lower than the installation temperature the tubing/pipe will become shorter. Consequently, the installation temperature as well as the maximum and minimum working temperatures must be considered when designing a system.

Calculating the Amount of Thermal Expansion (Formula 1)

To determine the amount of length change, a formula is used that takes into account the coefficient of linear thermal expansion of the tubing/pipe material. The formula is:

$\Delta L = L \bullet \Delta T \bullet C$

Where:

ΔL = change in tube length mm (inches)

L = original length of the tube mm (inches)

ΔT = change in temperature °C (°F)

C = thermal expansion coefficient

For Teflon PFA, C=

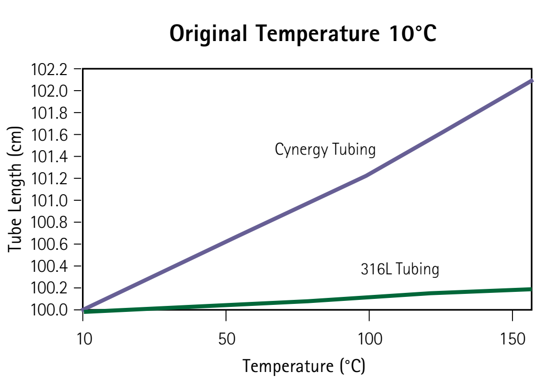
14×10^{-5} mm/mm/°C when T is 21°–100°C
(7.6×10^{-5} in/in/°F when T is 70°–212°F)

17×10^{-5} mm/mm/°C when T is 100°–149°C
(9.2×10^{-5} in/in/°F when T is 212°–300°F)

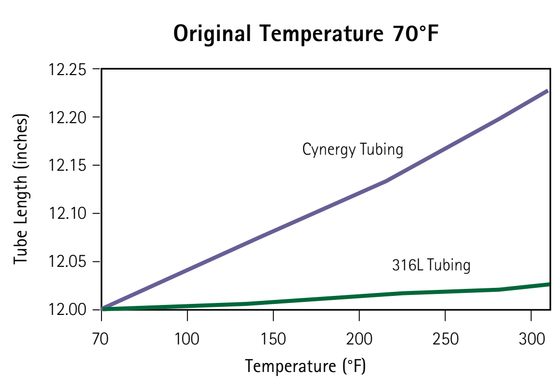
21×10^{-5} mm/mm/°C when T is 149°–208°C
(11.5×10^{-5} in/in/°F when T is 300°–408°F)

The following graphs provide an easy means for determining the amount of thermal expansion expected per unit length of tubing. To determine the total amount of length change due to thermal expansion, multiply the total system length by the change, at a given temperature, using the following graphs.

**GRAPH 3: EXPANSION COMPARISON
1 METER (100 CM) TUBE**

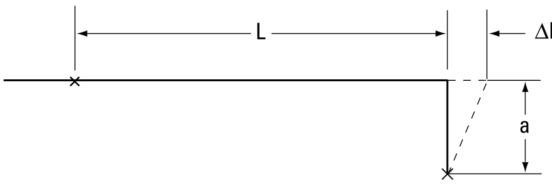


**GRAPH 4: EXPANSION COMPARISON
1′(12″) TUBE**



Accommodations for Thermal Expansion (Formula 2)

Changes in pipe lengths during working conditions can be accommodated using fixed brackets and flexible sections. Flexible sections occur wherever a change in direction takes place. The figure below shows how a flexible section accommodates the length change.



The length of flexible section can be calculated using the following formula:

$a = k(\Delta L \bullet D)^{1/2}$

Where:

a = length of flexible section (inches)

k = constant ($k = 25$ for Teflon PFA)

ΔL = change in tubing length (inches)

D = tubing outside diameter (inches)

Example 1:

A 10 foot length of 1″ outside diameter tubing is installed at 70°F and will have a working temperature of 200°F. Determine the change in length from installation to working conditions, and the amount of flexible section required to accommodate this change in length.

Using formula 1:

$L = 10$ ft $= 120$ inches

$\Delta T = 200° - 70° = 130°F$

$C = 7.6 \times 10^{-5}$ in/in/°F

$\Delta L = 120 \bullet 130 \bullet 7.6 \times 10^{-5} = 1.19$ inches

Using formula 2:

$k = 25$

$\Delta L = 1.19$ inches

$D = 1$ inch

$a = 25(1.19 \bullet 1)^{1/2} = 27.2$ inches

Tubing Support

To provide trouble-free service, long lengths of Teflon PFA tubing/pipe must be supported. Supporting the pipe minimizes the stress and strain within the pipe wall as well as accommodates drainability. Pipe support distances are dependent on the tubing size (ID and OD), the specific gravity of the fluid being transported through the pipe, the average temperature of the tubing and the acceptable amount of vertical tubing deflection between supports. The formula used to determine the spacing between pipe supports is shown below:

$$L = \left(\frac{384 Y_{max} \bullet E \bullet I}{5w}\right)^{1/4}$$

Where:

L = length between pipe supports (inches)

Y_{max} = maximum tube deflection between supports (inches)

E = modulus of elasticity (lbs/in^2)

I = tubing moment of inertia (in^4)

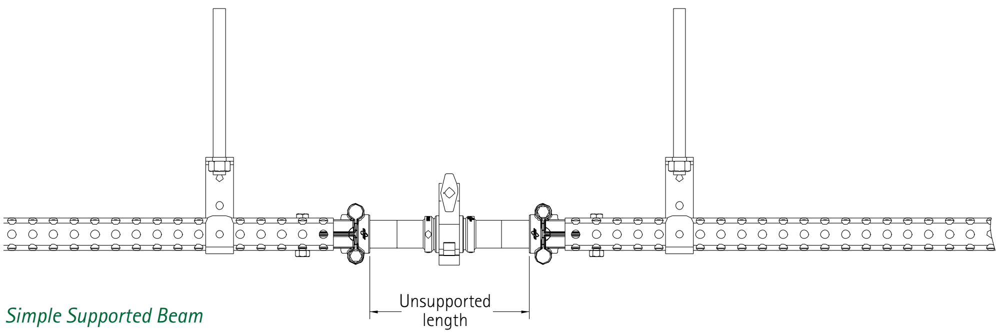
w = weight of tubing and fluid in the tubing (lbs/in)

TABLE 24: RECOMMENDED SPACING DISTANCE FOR UNSUPPORTED LENGTHS

Simple Supported Beam (1/8" Maximum Tube Deflection)

Nominal Tube Size	Cynergy Tubing Part Number	73°F H_2O Fluid	180°F H_2O Fluid	300°F Steam
1/4"	SAT4	0"	0"	7"
1/2"	SAT8–*	17"	14"	8"
3/4"	SAT12–*	24"	18"	12"
1"	SAT16–*	26"	20"	14"
1 1/2"	SAT24–*	35"	30"	24"
2"	SAT32–*	43"	36"	30"

Replace "*" with "**X**" for 10 foot length, or "**VIII**" for 8 foot length.



Simple Supported Beam

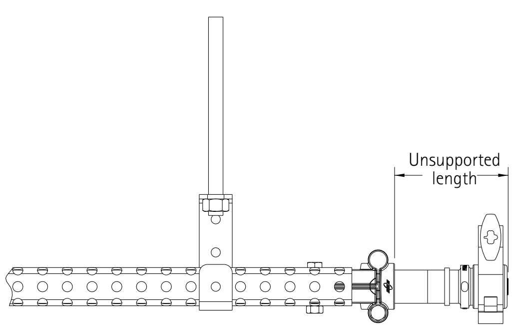
TABLE 25: RECOMMENDED SPACING DISTANCE FOR UNSUPPORTED LENGTHS

Simple Supported Beam (1/8" Maximum Tube Deflection)

Cantilever Beam (1/8" Maximum Tube Deflection)

Nominal Tube Size	Cynergy Tubing Part Number	73°F H_2O Fluid	180°F H_2O Fluid	300°F Steam
1/4"	SAT4	0"	0"	0"
1/2"	SAT8–*	4"	2"	0"
3/4"	SAT12–*	5"	2"	0"
1"	SAT16–*	8"	4"	2"
1 1/2"	SAT24–*	10"	6"	3"
2"	SAT32–*	13"	7"	4"

Replace "*" with "**X**" for 10 foot length, or "**VIII**" for 8 foot length.



Cantilever Beam

Adding components to the run will require additional support. Specific gravity of a fluid greater than 1.0 will affect the unsupported length recommendation. In these cases, the recommended spacing distance in Table 24 or Table 25 should be multiplied by the factor indicated in Table 26.

TABLE 26: SPECIFIC GRAVITY FACTORS

Specific Gravity	Factor
1.00	1.00
1.25	0.94
1.50	0.89
1.75	0.86
2.00	0.82
2.25	0.79
2.50	0.76
2.75	0.74
3.00	0.72

Support Selection

The pipe supports specified should not be the type that clamp the pipe tightly and restrict movement. The hangers should allow the tubing to slide through it during normal thermal cycling. Although in a flexible section situation, the pipe hanger must be secured to the pipe and restrict movement at that point. Thermal expansion and contraction of the system can result in abrasions to the tubing where it comes into contact with other surfaces. It is recommended that all surfaces in contact with the tubing be smooth and free of sharp corners.

In applications where complete drainability is needed, continuous tubing support is recommended. Common extruded shapes such as channel, conduit and angle work well as continuous supports. To accommodate drainability, the tubing can be laid in the extruded shape and sloped according to industry standards. The type of continuous support chosen will dictate the type of hangers required.

Accessory Supports

Accessory items that may be plumbed into the system (valves, filter housings, gauges) must have their own independent supports. Failure to do so may result in excessive stress on the system pipe and potential failure.

The support guidelines listed above are just that, guidelines. Each individual pipe system may encounter unique support issues not covered above. Should you encounter such a situation, please contact your Entegris distributor or Entegris, Inc. to discuss your specific application.

Riser Support

Vertical sections of pipe, referred to as Risers, must be supported at the top and base. Support brackets should be at a maximum of 1.5 meter (5 foot) vertical intervals.

For More Information

Please call your Regional Customer Service Center today to learn what Entegris can do for you. Visit *www.entegris.com* and select the "Customer Service" link for the center nearest you.

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