

Honeywell Boron Trifluoride

A large, white, cylindrical industrial tank is shown from a low angle, looking up. The tank is oriented horizontally and has the words "BORON TRIFLUORIDE" printed on its side in a bold, green, sans-serif font. The tank is part of a larger industrial structure, with various pipes and mechanical components visible below it. A red and white striped safety barrier runs along the base of the tank. The background shows a clear blue sky with some light clouds.

BORON TRIFLUORIDE

Technical Information

Honeywell

Honeywell Performance Materials and Technologies Responsible Care[®] Commitment

At Honeywell Performance Materials and Technologies, we are committed to the safety of our employees, the quality of our products, and being responsible stewards for the protection of our environment, the communities in which we operate, and our customers. We are a member company of the American Chemistry Council, and Responsible Care[®] is the foundation of HS&E (health, safety, and environment) excellence in our business. Our Responsible Care[®] Management System is used to support our full commitment to comply with legal and other HS&E requirements to which we subscribe.

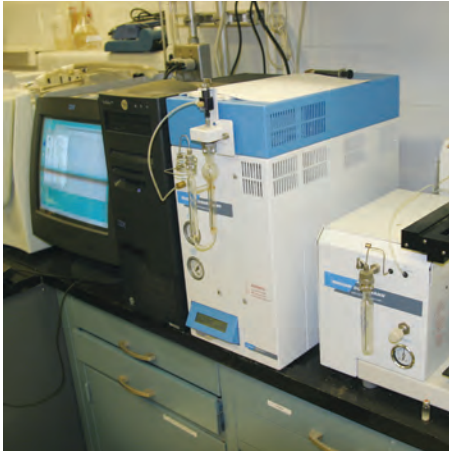
Global operational excellence and reliability is achieved through the integration of Responsible Care[®] principles into the way in which we operate and work with our commercial partners – from our contractors and other suppliers to our customers. Our management system is designed to ensure that we conduct thorough product risk assessments prior to commercialization and that we apply necessary resources and best practices in the development and handling of chemical products and materials. As we strive towards environmental excellence and the prevention of pollution, we protect individual and public safety by manufacturing, transporting, and storing our materials in a secure manner.

We continually improve our compliance processes and business practices using quantifiable goals to drive sustained safety and environmental excellence. We have made significant investments to enhance our data management systems to ensure the real-time availability of current information on the safe handling of our products and compliance and technical issues. We have seen marked improvement in our safety and environmental performance and we are committed to achieving and maintaining HS&E third party certification at the business and operational levels of the organization.

As a responsible corporate citizen, we continue to renew our commitment to the public through outreach activities, and proactively communicating with our surrounding communities.

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Our Vision

We will be one of the world's premiere companies, distinctive and successful in everything we do.

Our Commitment

We will become a Total Quality Company by continually improving all our work processes to satisfy our internal and external work customers.

Our Values

Customers

Our first priority is to satisfy customers.

Integrity

We are committed to the highest level of ethical conduct wherever we operate. We obey all laws, produce safe products, protect the environment, practice equal employment, and are socially responsible.

People

We help our fellow employees improve their skills, encourage them to take risks, treat them fairly, and recognize their accomplishments, stimulating them to approach their jobs with passion and commitment.

Teamwork

We build trust and worldwide teamwork with open, candid communications up and down and across our organization. We share technologies and best practices, and team with our suppliers and customers.

Speed

We focus on speed for competitive advantage. We simplify processes and compress cycle times.

Innovation

We accept change as the rule, not the exception, and drive it by encouraging creativity and striving for technical leadership.

Performance

We encourage high expectations, set ambitious goals, and meet our financial and other commitments. We strive to be the best in the world.

Honeywell Fluorine Products Product Stewardship Policy

Honeywell, in its quest to be one of the world's premiere companies, subscribes to the Chemical Manufacturer's Association's "Responsible Care" Program. Product Stewardship is an integral part of that program and enables us to make health, safety and environmental protection a key part of all product-related activities.

At Honeywell Fluorine Products, Product Stewardship encompasses all aspects of the product life cycle including design, manufacture, marketing, distribution, use, recycling and disposal of our products. It involves working closely with our worldwide customers, suppliers, employees, distributors, wholesalers, tollers and contractors to meet these goals.

Product Stewardship is not a one time effort designed only to comply with regulations, but a continuous, long-term process that is applied throughout all of our business operations.

Fluorine Products is committed to:

- Giving high priority to health, safety and environmental considerations in our business planning encompassing proper selection of raw materials through Materials Management, Customer Linked Commercialization for all new products, processes and waste materials and our Customer-Linked Manufacturing endeavors to improve existing operation processes.
- Guiding customers to the safe use, transportation and disposal of our products.
- Reporting promptly to customers, employees, government officials and the public of any new information on product-related issues.
- Providing technical assistance on various uses and applications for our products.
- Sharing pertinent information and experience with others who produce, handle, use, transport or dispose of our products.

Boron Trifluoride Overview

For more than 60 years, Honeywell has maintained its leadership position in Boron Trifluoride technology. As the sole manufacturer of BF₃ in North America, Honeywell Performance Materials and Technologies remains committed to providing our customers with a level of technical service second to none.

Boron Trifluoride (BF₃) is one of the strongest Lewis acids (or electron pair acceptors) known and, therefore, finds broad application as an acidic catalyst for organic synthesis reactions. As an electron pair acceptor, BF₃ readily reacts with chemicals containing Oxygen, Nitrogen, Sulfur, and other electron pair donors to form addition or coordination compounds.

Boron Trifluoride is a non-flammable compressed gas, packaged and shipped in cylinders under high pressure. It is often advantageous to use BF₃ in a complexed form so that BF₃ can be released under preferred conditions. BF₃ complexes are typically liquids or solids and therefore may be more easily managed than the high pressure gas. BF₃ complexes, in and of themselves, may function as catalysts and can provide unique catalytic effects or change the characteristics of the reaction products when compared to the products produced by the catalytic effect of BF₃ alone. When the coordinating organic specie is one of the reactants, addition of the complex is a convenient means of simultaneously introducing a reactant and BF₃ catalyst into the reaction. If you are interested in BF₃, please contact your Account Manager at 1-800-622-5002.





Because of its potency as a Lewis acid and its greater resistance to hydrolysis compared to other boron trihalides, Boron Trifluoride is widely used as a catalyst for organic synthesis reactions such as:

Polymerization

- olefins or diolefins
- vinyl ethers or esters
- heterocyclic unsaturated organics e.g., indene, coumarone, etc.
- unsaturated acids or esters
- terpenes or derivatives
- styrene or derivatives with isoprene, butadiene, 1, 3-Pentadiene, etc.

Alkylation

- aromatic hydrocarbons
- phenols with olefins
- phenols with alcohols

Isomerization

- paraffins
- unsaturated hydrocarbons

Synthesis

- acetals and ketals
- indoles
- alpha – methoxymercurials
- steroids and intermediates
- hydroxy fatty acids

Promoting Reactions of

- acetylenes with acids
- addition of olefins with organic acids or esters

Boron Trifluoride also aids in

- cyclization of natural and synthetic elastomers
- disproportionation of isoparaffins

It can be used as a reagent for

- desulfurizing solvents and intermediates
- desulfurizing cracked petroleum distilled
- separating xylene isomers
- absorbing water of nitration

Other uses of BF₃ include

- nucleonics
- brazing fluxes for metals and alloys
- manufacture of lube oil additives
- production of high purity boron isotope (¹⁰B)
- source of boron for manufacture of boranes and fluoroborates
- preparation of triphenyl and tetraphenyl borates
- p-type doping in semiconductor manufacture

Boron Trifluoride has the ability to form coordination compounds with

- inorganic chemicals, e.g.,
fluorides
anhydrous ammonia
water
sulfuric acid and its salts
phosphoric acid and its salts
hydrogen sulfide
sulfur dioxide
- organic chemicals, e.g.,
alcohols
ethers
aldehydes
ketones
amines
nitrites
carboxylic acids and esters
sulfonic acids and esters

Product Specifications

	Purified	Hi-Purity
Assay	Min. 99.0%	Min. 99.5%
	by wt.	by wt.

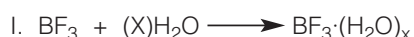
Maximum Limits of Impurities

Air	0.50%	0.40%
SO ₂	0.10%	0.002%
SO ₄	0.05%	0.001%
SiF ₄	0.03%	0.03%

Aqueous Chemistry of BF₃

The solubility of BF₃ in water at 0°C and a pressure of 1atm has been stated as 322% - 1 g. of water will absorb 3.22 g. of BF₃. This can be misleading as rather than water solubilizing BF₃, Boron Trifluoride will instantaneously react with water to produce several hydrates, depending on the amount of water present. The monohydrate (BF₃·H₂O), dihydrate (BF₃·2H₂O) and trihydrate (BF₃·3H₂O) have all been identified and isolated and have discrete chemical and physical properties. There are claims that the hemihydrate (BF₃·½ H₂O) also exists.

All these species exist as simple adducts and are liquids at room temperature. However, there is evidence that in dilute solution, the hydrates ionize to strong acids. As stated, the initial reaction is probably reaction I where X is ½, 1, 2, or 3, depending on the amount of water present.



There is evidence this highly acidic species exists in ionized form as in reaction II



It has also been demonstrated in the presence of excess water, reaction III may occur producing fluoroboric acid (HBF₄) and boric acid (H₃BO₃).



This last reaction can be demonstrated in the laboratory by absorbing BF₃ in water in a glass flask. Initially, a small amount of solid forms which re-dissolves. However, continued addition of BF₃ will result in precipitation of a white solid which can be isolated and identified as Boric Acid (H₃BO₃). The presence of fluoroborate ion (BF₄⁻) can be confirmed by selective ion electrode. The entire process can be carried out in glass with no visible etching of the glass – etching is a phenomenon normally associated with the presence of free hydrofluoric acid (HF). In fact, BF₃·(H₂O)_x hydrates can be stored indefinitely in glass containers without ever evidencing etching.

Under the above conditions, there is always an excess of boric acid present which acts as a fluoride scavenger. As long as there is free boric acid present, the existence of free fluoride ion is highly unlikely. However, if no free boric acid is present, fluoroboric acid may be hydrolyzed according to reactions IV and V that are reversible.



Conductometric titrations of aqueous fluoroboric acid solutions have shown that the hydrolysis of fluoroboric acid in concentrated solutions is very slow. The equilibrium in reversible reactions IV and V lies toward the left and can only be shifted to the right at temperatures above 90°C and a controlled pH of 2.0 – 2.5.

Several points can therefore be made:

- 1) The initial reaction of BF₃ with water forms BF₃ hydrate(s).
- 2) The BF₃ hydrate(s) may continue to react to form a mixture of hydrates, hydroxyfluoroborates, fluoroboric acid and boric acid.
- 3) There is no evidence that HF or free fluoride ion will be formed as long as free boric acid is present to act as a fluoride scavenger. As the reactions indicate, free boric acid will always be present in BF₃ – water solutions.





In a totally dry atmosphere, Boron Trifluoride is a colorless gas with a pungent odor. However, in the presence of even the smallest amount of moisture, BF₃ forms a cloud of dense, white smoke which has a sharply acidic odor. Even small leaks (as little as 1 ppm) are easily detected because of these properties. Other properties of Boron Trifluoride are shown in the chart at right.

Compressibility

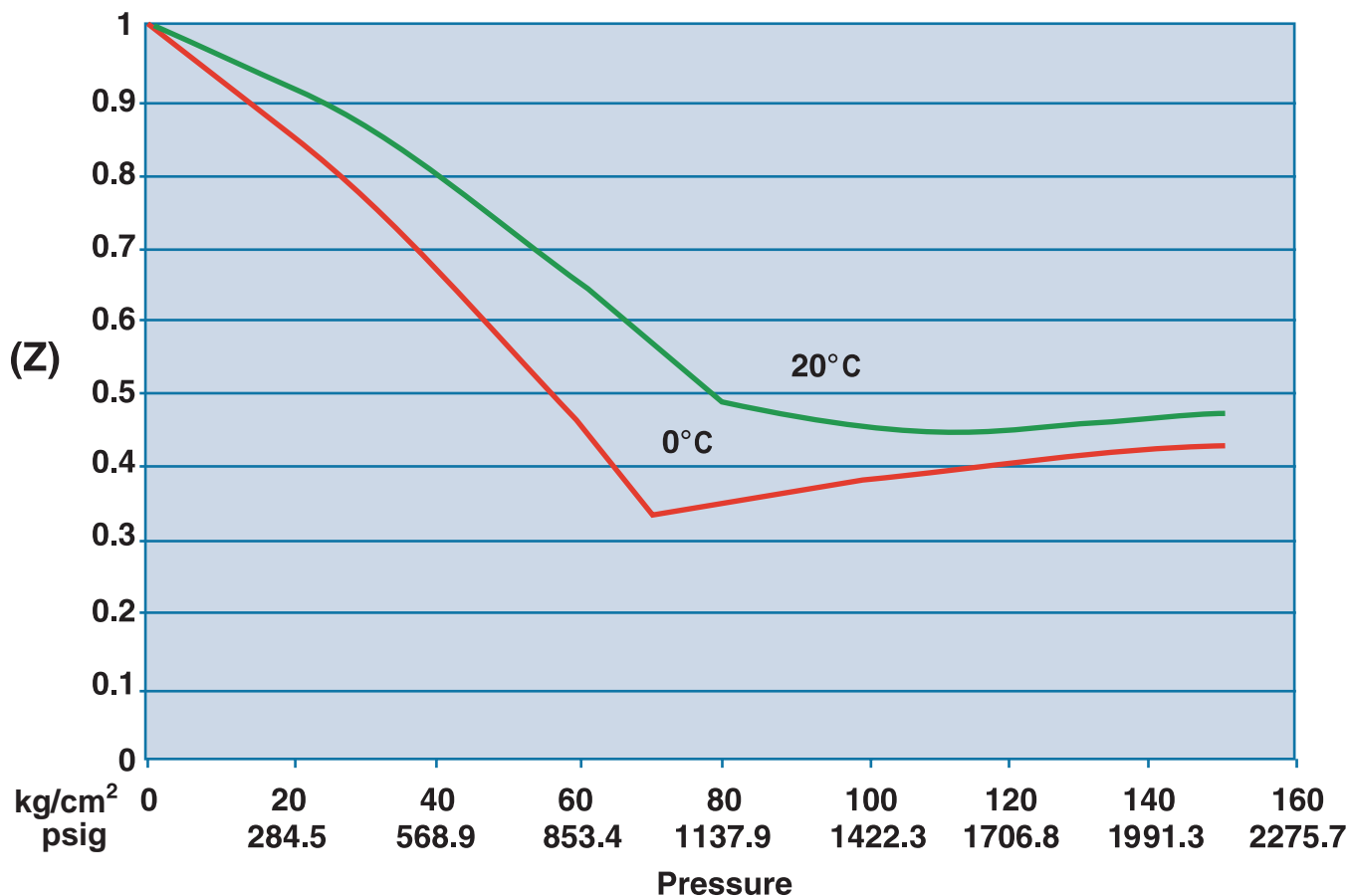
Like most compressed gases, Boron Trifluoride does not obey ideal gas laws. A Compressibility Factor (Z) must be applied to all calculations involving BF₃. The graph below shows the variation in the compressibility factor (Z) with pressure (P) at known temperatures. This can be useful in calculating the weight of BF₃ contained in a known volume from the equation:

$$PV = nZRT$$

For example, at a temperature of 20°C (293°k) and a pressure of 1340 psig (94.2 kg/cm²), the compressibility factor Z = ~0.5. A typical BF₃ cylinder of 2660 cu. in. (43.6 l) capacity would contain:

$$\frac{4.36 \times 94.2}{0.5 \times 0.083 \times 293} = 335 \text{ moles (50 lbs.) of BF}_3$$

Compressibility Factor (Z) Boron Trifluoride



Properties of Boron Trifluoride

Formula	BF ₃
Molecular Weight, g/mol	67.81
Melting Point °C @ 1 atm	-128.37
Boiling Point °C @ 1 atm	-100.4
Density:	
Gas at STP, g/l	3.077
Liquid at BP, g/ml	1.57
Liquid at MP, g/ml	1.68
Critical Temperature, °C	-12.25 +/- 0.03
Critical Pressure, kPa	4984
Critical Density, g/cm ³	0.591
Heat of Fusion, kJ/g-mol	4.238
Heat of vaporization, kJ/g-mol	18.560
Entropy @ 298.15°K kJ/(g-mol)(°C)	253.81
Heat of reaction in excess water, kJ/g-mol	102.55
Vapor Pressure:	
Liquid between 199.8° and 260.8°K	
Log (P _{atm}) = 5.1009 - 889.6/T°K	

Safety Precautions

All personnel involved with and responsible for handling Boron Trifluoride should be familiar with the appropriate safety and handling precautions. Such information is provided in the Material Safety Data Sheet (MSDS – Available by calling customer service 1-800-322-2766 or the business office 1-800-622-5002). The following summarizes some of the material found in the MSDS.

Boron Trifluoride is irritating to the skin, eyes, and mucous membranes and may cause thermal or chemical burns. The burns are not typical of HF exposure, but are caused by the formation of the strong acid, Fluoroboric Acid upon reaction of BF₃ with moisture on the skin. Breathing of BF₃ gas is highly suffocating and irritating to the respiratory system. Prolonged breathing of vapors may result in acute toxic effects.

The Permissible Exposure Limit (PEL) established by the US Occupational Safety and Health Administration (OSHA) is 1 ppm (3 mg/m³) ceiling. The American Congress of Governmental Industrial Hygienists (ACGIH) has also confirmed an air borne Threshold Limit Value (TLV) of 1 ppm ceiling. If the PEL/TLV is exceeded even briefly, proper respiratory protection should be provided.

The National Institute of Occupational Safety and Health (NIOSH) has established an Immediately Dangerous to Life and Health (IDLH) exposure level for BF₃ of 25 ppm. Exposure to >25 ppm requires the use of supplied air respiratory protection. While acid mist air purifying respirators have been found to be effective protection against exposures to nuisance levels of BF₃, air borne concentrations are extremely difficult to quantify (SEE: Section on Leak Detection). It is therefore recommended that a full face respirator with supplied air be utilized where the potential for inhalation of BF₃ vapor exists.





If BF_3 is inhaled, immediately move the victim to fresh air, provide oxygen, and apply artificial respiration if necessary. Get medical attention without delay.

Brief contact or exposure to a strong gas concentration of short duration can produce irritation or burning of the skin or eyes. In case of contact, immediately flush with water for at least 15 minutes and get immediate medical attention. For normal handling, chemical goggles and acid resistant gloves should be worn. Full acid resistant protective clothing should be worn when there is a possibility of skin contact.

As Boron Trifluoride is extremely hygroscopic, substances which contain water will attract BF_3 . For example, food, tobacco, and beverages will absorb and retain BF_3 so their usage should be prohibited in a BF_3 designated area.

Contact your Honeywell Account Manager at 1-800-622-5002 for more information on Boron Trifluoride safety and product handling seminars offered by Honeywell.

USDOT Shipping and Regulatory Information

Boron Trifluoride (UN1008) is classified by the U.S. Department of Transportation (DOT) as Hazard Class 2, Division 3 (2.3), Compressed Gas Poisonous by Inhalation in Hazard Zone B. All shipping containers must display the POISON – INHALATION HAZARD placard or label as well as the words “INHALATION HAZARD”. Honeywell has further determined that BF_3 meets the DOT definition for Class 8 CORROSIVE and has assigned that subsidiary hazard classification as well. The subsidiary CORROSIVE label is mandatory on all cylinder packages but not on bulk tube trailers.

BF_3 is shipped as a high pressure gas (1500-1800 psi) in three grades. Purified Grade in tube trailers, Hi-Purity Grade in tube trailers or cylinders, and Electronic Grade in cylinders. See the following sections for specific discussions on tube trailers and cylinders.

BF_3 is not listed as a hazardous air pollutant under the Clean Air Act Amendments (1990) and is not a priority pollutant under the Clean Water Act (1972, 1987). For air, general permitting provisions, such as opacity, may apply. For discharge of aqueous liquid waste streams, general pre-treatment standards, such as pH control, may apply.

Boron Trifluoride is identified as an extremely hazardous substance in the Superfund Amendments and Reauthorization Act (1986) with a reportable release quantity (RQ) of 500 pounds.

Boron Trifluoride is listed in Appendix A of the Occupational Safety and Health, Administration (OSHA) Rule 29 CFR 1910.119 (Process Safety Management of Highly Hazardous Chemicals, Explosives, and Blasting Agents) with a threshold quantity of 250 lbs. Locations having more than 250 lbs. of BF_3 on site at any one time must comply with the process management requirements of this rule.

BF_3 is further regulated under the U.S. Environmental Protection Agency (EPA) Accidental Release Prevention Requirements: Risk Management Program Requirements Under Clean Air Act Section 112(r)(7) with a threshold quantity of 5000 lbs. Locations having more than 5000 lbs. of BF_3 on site (e.g. a tube trailer) must conform to the requirements of this rule.

Locations must also familiarize themselves with any state or local regulations and LEPC implications of using BF_3 .

The National Advisory Committee on Acute Exposure Guideline Levels (AEGs) has established values for single, non-repetitive exposures, not exceeding 8 hours for BF_3 .

As of this printing, the values are in INTERIM status and are listed here:

Boron Trifluoride 7637-07-2 (interim)

	10 min	30 min	60 min	4 hr	8 hr
AEGL1 (mg/m3)	2.5	2.5	2.5	2.5	2.5
AEGL2 (mg/m3)	47	47	37	24	12
AEGL3 (mg/m3)	140	140	110	72	36

Please consult the most recent edition of the Honeywell Material Safety Data Sheet (MSDS) for Boron Trifluoride Compressed Gas for any updated values.

Recommended Equipment For Handling BF₃

BF₃ handling systems must be designed and built to withstand high pressure and corrosion. Typically these systems are designed for a Maximum Allowable Working Pressure (MAWP) of 3,000 psig. BF₃ is a Lewis acid gas and is extremely hygroscopic in nature. In the presence of even trace amounts of moisture, Boron Trifluoride forms acidic BF₃ hydrates which will rapidly corrode common metals. The solid metallic residues can be swept downstream and cause fouling and/or pluggage of pressure regulators and control valves. All BF₃ service lines must therefore be protected from moisture when not in use.

The following equipment and materials of construction are recommended for BF₃ handling systems:

Piping

Due to the possibility of moisture contamination, BF₃ feed systems are typically fabricated of schedule 80 type 316L stainless steel pipe to provide long term corrosion resistance.

Fittings

Pipe fittings should be of type 316L stainless steel construction. Butt weld fittings are preferred over screwed fittings. Socket weld and compression fittings are to be avoided. Where possible the number of joints should be minimized. Threaded connections can best be sealed using a white lead pipe joint compound over Teflon® tape.

Trailer Hookup Lines

Seamless type 316L stainless steel tubing with a 3/8" O.D. x 0.065" wall thickness and an electropolished I.D. is recommended. End fittings should be butt welded, preferably by the automatic orbital welding tungsten inert gas (TIG) process.

Gaskets

- for pressures less than 300 psig metal reinforced PTFE gaskets.
- for pressures greater than 300 psig nickel-graphite spiral wound gaskets.
- for CGA 330 connections, 1/16" thick Kel-F® (Neoflon® PCTFE) gaskets are preferred.

CAUTION: Natural or synthetic rubber gaskets are not suitable for BF₃ service.

Valves in BF₃ service must be properly designed from a corrosion, pressure and temperature cycling standpoint. Valves may be of stainless steel, aluminum silicon bronze or monel construction. Globe valves, have been specifically designed for this service and can provide leak tight shutoff and leak free service.





Control Valves

Due to the “auto refrigeration” effect exhibited by Boron Trifluoride, control valves must be designed for rapid temperature changes. Typically two globe type valves are used in series. Hastalloy® C-276 internal construction is preferred. Alloy 400 or stainless steel is acceptable.

Pressure Regulators

Pressure reduction equipment must be corrosion resistant, with a minimum 3/16” diameter orifice. Hastalloy® C and Kel-F® (Neoflon® PCTFE) construction of critical components is recommended.

Flow Measurement

A scale or load cell can effectively be used to monitor consumption of BF_3 into a process. Mass flowmeters are also commonly used.

Safety Devices

BF_3 containers are filled to nominal 1500 psig. Any equipment or piping not rated for 3000 psig pressure service must be properly protected from overpressurization. A typical pressure relief system consists of a reverse buckling rupture disc of Hastalloy® C-276 followed by a spring loaded relief valve which relieves to a suitable fume scrubbing system. A stainless steel pressure gauge with isolation valve should be installed between the rupture disc and relief valve to indicate disc failure. Dual relief systems are often employed to facilitate ease of maintenance.

Leak Detection

Under normal atmospheric conditions, Boron Trifluoride does not exist as such due to the instantaneous reaction of BF_3 with atmospheric moisture (see discussion on Aqueous Chemistry of BF_3). Therefore, no detectors have been developed specifically for BF_3 . The hydrate of BF_3 formed is a dense, white cloud visible at a level less than 1 ppm. Visual observation via closed circuit television is often used to monitor BF_3 processing areas for leaks.

HF specific point source monitors set at less than 10 ppm detection limits have been employed to detect the intermediate hydrolysis product resulting from a leak. This method cannot be used to quantify the amount or concentration of BF_3 only to indicate the existence of a leak.

Corrosion

Dry BF_3 Streams

Corrosion studies indicate that many materials show a high resistance to attack by BF_3 . Dry BF_3 can be safely handled at temperatures up to 200°C (392°F) in apparatus made of:

Stainless steel	Monel®
Carbon steel	Brass
Copper	Aluminum
Nickel	Noble metals
Borosilicate glass	PTFE

Wet BF_3 Vapor

See Tables 1, 2 and 3 on following pages for corrosion data.

System Maintenance and Inspection

Visually inspect all process lines and equipment on a routine, scheduled basis. Any defect or sign of corrosion should be corrected immediately. Before performing maintenance on any BF₃ process line, the section should be isolated, purged with an inert gas or dry air, and depressurized to ambient pressure. Lines and equipment may fume when exposed to the atmosphere even though an inert purge and depressurization were properly performed. Additional line flushing with a solvent or water or line evacuation may be necessary. Use of a flexible line, properly exhausted to a scrubber may be helpful in removing fumes from an initial line breaking.

Whenever possible, avoid the introduction of water into BF₃ piping systems. All lines must be properly dried prior to reintroduction of a BF₃ gas stream, because of the corrosion products that may form in the presence of water. Lines should be steamed until the condensate is clear followed immediately by a dry, inert gas purge. A hydrophilic solvent flush (e.g. acetone) may also be used, followed by a hot, dry inert gas purge to remove all of the solvent. Finally, a vacuum should be applied to the system to remove moisture from crevices which may be untouched by inert gas or solvent purge.

If scale or corrosion residues become a problem, the system may be steam cleaned provided the system is properly dried as described above. Routine steam cleaning of BF₃ process lines should be avoided. Rather, rely on proper dry, inert gas purges regularly before and after maintenance and between BF₃ supply changes to minimize corrosion and to avoid the formation of corrosion product scale.

Wet BF₃ Vapor Phase Corrosion

- 95% BF₃ + 5% H₂O
- Exposure Time: 168 Hours
- Corrosion Rate in mils/yr
(1 mil = 0.001")

Table 1

Material	21°C (70°F)	93°C (200°F)	149°C (300°F)	Macro Examination
A-285 Gr. Carbon Steel	0.35	3.8	7.2	Uniform Corrosion
S/S 304	0.15	8.5	16.2	Some Fine Pitting
S/S 316	0.06	0.4	6.9	Uniform Corrosion
S/S 347	0.15	5.9	12.7	Uniform Corrosion
Copper	1.5	28.6	96.3	Shallow Pitting
Monel® 400	0.22	11.1	30.5	Uniform Corrosion
Inconel® 600	0.12	3.9	7.4	Uniform Corrosion
Hastalloy® C-276	0.01	0.2	0.1	Uniform Corrosion
Alloy 20 Cb-3	0.28	6.9	4.8	Uniform Corrosion

Plastic Exposures

Material	Hardness	% Wt. Change	Visual
PTFE	+2	-0.03	No Change
Polypropylene	+3	+0.02	Discolored
Kynar®* PVDF	+3	-0.007	No Change
Atlac®* 382-05 (*)	0	-1.4	No Change (Loss of Gloss)
Material	Hardness	% Wt. Change	Visual
PTFE	+7	-0.02	No Change
Polypropylene	-2	+0.013	Discolored
Kynar® PVDF	+15	-1.0	No Change
Atlac® 382-05 (*)	0	-1.4	No Change (Loss of Gloss)
Material	Hardness	% Wt. Change	Visual
PTFE	+17	-0.01	No Change
Polypropylene	NR	NR	
Kynar® PVDF	+17	-7.4	Cracked Brittle
Atlac® 382-05 (*)	NR	NR	

*All edges sealed off with resin rich coat

NR–Not recommended at these temperatures

Wet BF₃ Vapor Phase Corrosion

- 98% BF₃ + 2% H₂O
- Exposure Time: 168 hours
- Corrosion Rate in mils/yr (1 mil – 0.001")

Table 2

Material	21°C (70°F)	93°C (200°F)	149°C (300°F)	Macro Examination
A-285 Gr. Carbon Steel	0.5	1.9	6.4	Uniform Corrosion
S/S 304	0.2	6.5	74.7	Severe Attack
S/S 316	0.15	1.3	10.2	Uniform Corrosion
S/S 347	0.2	3.1	12.1	Slight Pitting
Copper	1.0	24.7	29.8	Shallow Pitting
Monel® 400	0.3	9.8	23.9	Severe Attack
Inconel® 600	0.15	2.4	15.3	Uniform Corrosion
Hastalloy® C-276	0.02	0.1	0.2	Uniform Corrosion
Alloy 20 Cb-3	0.10	1.1	9.7	Uniform Corrosion

Plastic Exposures

Material	Hardness	% Wt. Change	Visual
PTFE	+7	-0.03	No Change
Polypropylene	0	+0.03	Discolored
Kynar® PVDF	+3	-0.003	No Change
Atlac® 382-05 (*)	0	-1.4	No Change
Material	Hardness	% Wt. Change	Visual
PTFE	+6	+0.002	No Change
Polypropylene	+1	+0.13	Discolored
Kynar® PVDF	+15	-1.0	No Change
Atlac® 382-05 (*)	-43	+3.4	Severe Attack, Charred
Material	Hardness	% Wt. Change	Visual
PTFE	+19	-0.01	No Change
Polypropylene	NR	NR	
Kynar® PVDF	-18	-31	Cracked Brittle
Atlac® 382-05 (*)	NR	NR	

*All edges sealed off with resin rich coat
NR–Not recommended at these temperatures

Wet BF₃ Scrubbler Simulation

- 10% BF₃ Aqueous solution @ 49°C (120°F)
- Exposure Time: 6 Hours
- Corrosion Rates in mils/yr (1 mil – 0.001")

Table 3

Material	Liquid	Vapor	Macro Examination
A-285 Gr. Carbon Steel	2511	135	Crevice & End Grain Attack
S/S 304	16	3.3	Uniform Corrosion
S/S 316	4.6	4.4	Uniform Corrosion
S/S 347	13.1	4.0	Uniform Corrosion
Copper	26.8	57.3	Pits in Vapor
Monel® 400	14.2	19.0	Uniform Corrosion
Inconel® 600	10.1	4.0	Fine Pitting
Hastalloy® C-276	3.6	2.2	Uniform Corrosion
Alloy 20 Cb-3	2.2	1.5	Uniform Corrosion

Plastic Exposures

Material	Hardness		% Wt. Change		Visual Examination
	Liquid	Vapor	Liquid	Vapor	
PTFE	+3	+3	-0.02	-0.03	No Visible Change
Polypropylene	0	-1	-0.02	-0.02	No Visible Change
Kynar® PVDF	+2	0	-0.01	-0.01	No Visible Change
Atlac® 382-05 (*)	0	0	+0.09	+0.12	No Visible Change

*All edges sealed off with resin rich coat

Recovery and Disposal

While Boron Trifluoride, Boron, and Fluoride are not identified as priority pollutants, local regulatory agencies and municipalities may have limits on discharge of these species. Users should check applicable environmental regulations prior to choosing the method of capture and disposal.

The ability of Boron Trifluoride to complex with a great variety of organic solvents suggests BF_3 could be captured from a process in complex form. In practice this is very difficult due to the often complicated nature of the catalytic mechanism and the extremely strong mutual affinity of BF_3 and water. Any water present, liquid or vapor, will instantly react with BF_3 to form a complex mixture of BF_3 hydrates. In the proper molecular ratios of BF_3 to water, discrete compounds, $\text{BF}_3 \cdot \text{H}_2\text{O}$, $\text{BF}_3 \cdot 2\text{H}_2\text{O}$ or other hydrates will be formed. These hydrates may further hydrolyze to yield a mixture of fluoroborates, hydroxyfluoroborates, and boric acid. Even small amounts of BF_3 dissolved in water will lower the pH to an acidic level. An excess of water creates a strongly acidic solution of Fluoboric Acid plus Boric acid as indicated by the reaction:



Water, therefore, is an excellent scrubbing medium for capturing BF_3 for disposal. Depending on the application the process reactants may be quenched with water or stripped with an inert gas to a properly sized water scrubber. Scrubbers may be packed tower or venturi type with a one pass or recirculating water stream.

All entrance lines to the scrubber should have a barometric leg of properly calculated length to prevent water from being drawn back into the BF_3 containing system. The barometric leg should be sized to allow 2.31 linear feet for every 1 psi of operating pressure divided by the specific gravity of the scrubbing medium. A 1 foot safety allowance should be added. A water scrubber operating at normal atmospheric pressure would require a barometric leg of:

$$\frac{2.31 \times 14.7}{1.0} = 34 + 1 = 35 \text{ linear feet}$$

The acidic reaction products must be neutralized prior to ultimate disposal. Treatment with a sodium base such as sodium hydroxide will yield a neutral solution of Sodium Fluoroborate which is 40% soluble and may be discarded as a liquid. Treatment with Ammonium Hydroxide will also yield a very soluble salt solution. A potassium base will yield Potassium Fluoroborate which is less than 0.5% soluble and may be recovered as a solid for disposal. Treatment with calcium based alkalis (hydrated lime or calcium carbonate) favors hydrolysis of the Boron Trifluoride and precipitation of CaF_2 and $\text{Ca}(\text{BO}_2)_2 \cdot 6\text{H}_2\text{O}$, both of which may be recovered and disposed of as solids.

Some organic liquid process streams of low viscosity may be purged directly with anhydrous Ammonia which complexes with the BF_3 to form insoluble $\text{BF}_3 \cdot \text{NH}_3$. This solid may be filtered from the organic liquid stream for disposal.

Alternately, BF_3 vapor may be absorbed on a basic clay substrate which, when expended, may be landfilled.



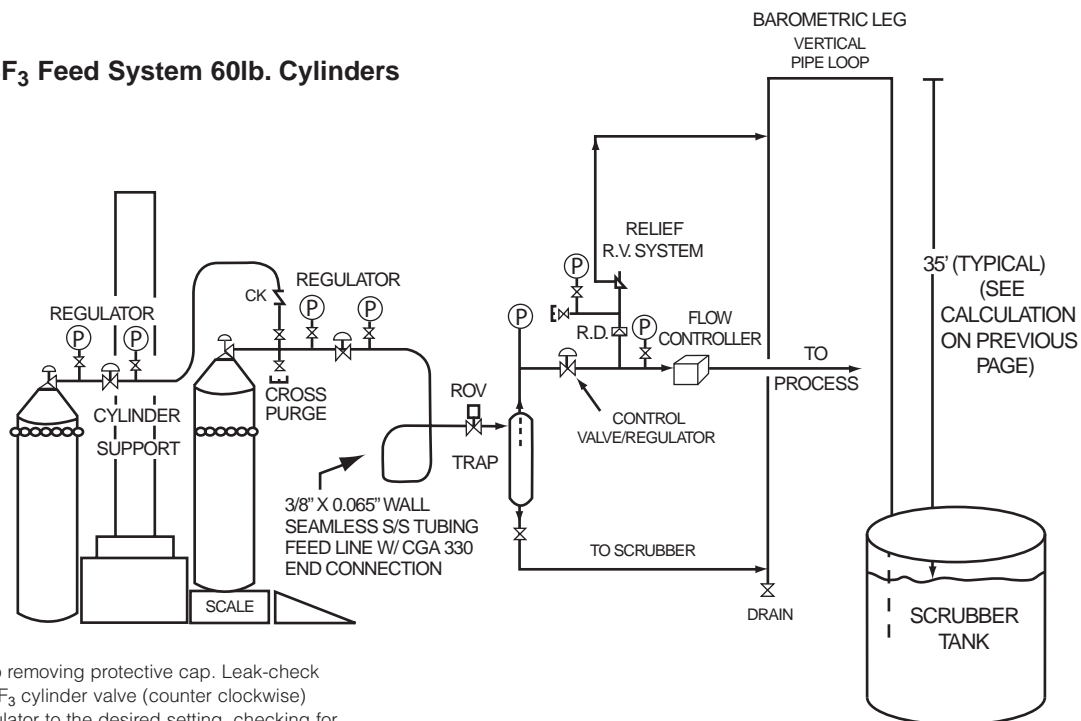


Control of Releases of BF₃ to the Atmosphere

It is well known that releases of BF₃ to the atmosphere create a dense, white cloud. This dense white cloud is comprised of aerosol sized droplets of BF₃ hydrates formed by the very rapid reaction of BF₃ with water vapor in moist air, or even air with very low humidity. It is estimated the rate of reaction between BF₃ and water is in the order of microseconds.

Although BF₃ is heavier than air, the thermal effect of the exothermic reaction between BF₃ and water vapor (24.51 kcal/g-mol) causes the cloud to initially become buoyant. Under ambient conditions, the aerosol sized BF₃ hydrate droplets may coalesce and eventually precipitate as droplets. Because of the very rapid reaction rate between BF₃ and water, water sprays are very effective in mitigating the cloud. Water sprays should be directed as close to the source of the leak as possible. Because of the acidic nature of BF₃ hydrates and their hydrolysis products (See further discussion under Aqueous Chemistry of BF₃), direct contact with the leak source should be avoided as corrosion and enlargement of the leak site may result. However, if large quantities of water are available, such as from a fire hose with a coarse fog nozzle, the coarse spray can be directed at the source to serve as both a diluent and coolant. As a reminder, all the possible species present – BF₃ hydrate(s), ionized BF₃ hydrate(s), hydroxyfluoroborate, and fluoroboric acid – are strong acids and must be directed to a containment or treatment facility to be ultimately disposed of in accordance with applicable environmental regulations. They also contained combined fluoride which could eventually affect human tissue if contacted in any significant quantity.

Typical BF₃ Feed System 60lb. Cylinders



Note: Properly support cylinders prior to removing protective cap. Leak-check system with Nitrogen prior to opening BF₃ cylinder valve (counter clockwise) checking for leaks. Carefully adjust regulator to the desired setting, checking for leaks. Feed gas from cylinder.

Note: Leave positive pressure (<20 psig) in cylinder to prevent moisture from being drawn back into the cylinder. Close BF₃ cylinder valve. Open nitrogen cylinder valve and purge system for several minutes to process or scrubber. Reduce pressure to zero. Close all valves, disconnect and cap off all openings.

In case of leakage from BF_3 cylinders, copious water sprays may be used or the cylinder may be inverted into a drum of water. The volume of water will act as a heat sink and control the exothermic reaction while providing a large excess of water for absorbing the BF_3 . It is also advisable to place a water hose in the drum to maintain a constant flow of water to assist absorption, keep the container cool, and reduce acidity and corrosion by dilution. The contaminated acidic water must be contained for ultimate treatment and disposal in accordance with applicable environmental regulations.

(NOTE: Some Emergency Response manuals incorrectly identify HF as the hazardous species present if BF_3 is released to the atmosphere. This cannot be confirmed by experience or by the facts published in literature.)

BF_3 in Cylinders

Cylinder users are advised to obtain Compressed Gas Association Publication number P-1 "Safe Handling of Compressed Gas in Containers". Copies are available from:

Compressed Gas Association, Inc.
4221 Walney Road, 5th Floor
Chantilly, VA 20151-2923

Honeywell offers High-Purify grade of Boron Trifluoride in returnable cylinders meeting U.S. Department of Transportation (DOT) specifications 3A and 3AA. When empty, these cylinders weigh approximately 129 lbs. (59 kg.) and 112 lbs. (51 kg.) respectively. Each cylinder is filled with 50 to 55 pounds (22.7 to 24.9 kg.) at a pressure of approximately 1400 psig (9500 kPa). Cylinders in BF_3 service must be requalified by hydrostatic test every five years. Cylinders must be supported and secured to a solid structure to prevent them from tipping over.

The valve cap should always be in place when the cylinder is not in use or when the cylinder is being moved. Full cylinders should be stored separately from empty cylinders in areas clearly marked for those purposes.

Use of BF_3 Cylinders

Each cylinder is equipped with a packed needle type cylinder valve of aluminum silicon bronze construction. This valve is designed to be operated fully open or fully closed. Throttling of this valve may cause erosion of the stem and seat such that the valve may not provide a complete seal when closed. To operate this valve, use a 3/8" square wrench and turn the stem counterclockwise 1-1/2 turns to the full open position. A turning torque of 25 foot-pounds is sufficient to effect full closure. Avoid overtightening the valve stem as excessive force may damage the seat. Pipe wrenches or vise grips must not be used on the valve stem to avoid rounding the wrench flats. The cylinder valve has a 0.825" - 14 National Gas Thread Outlet connection with a left-handed external thread (designated as CGA 330). A full face Kel-F® (Neoflon®) gasket is provided in the outlet cap to provide a seal. The outlet cap should be in place whenever the cylinder is not connected to the process, to minimize the accumulation of moisture in the valve outlet and subsequent formation of corrosion scale in the valve

WARNING:

- Do not drop cylinder
- Do not allow cylinders to slam together
- Do not apply heat to cylinders
- Do not cool cylinders below -29°C (-20°F)
- Do not add BF_3 or other gases to cylinders
- Do not tamper with valve or valve safety device
- Do not store cylinders near a source of heat (e.g., radiators)
- Store away from corrosives





discharge port. Cylinders should be connected to the process using a stainless steel flexible tubing pigtail with a welded CGA 330 female fitting to mate with the cylinder valve outlet. The process and connection may be of any appropriate high pressure fitting. Flexible hoses should not be used in BF_3 service, CGA fittings should be sealed using a Kel-F® (Neoflon®) or PTFE gasket.

The process line should provide a means of regulating and measuring both pressure and flow. It should include a pressure relief line incorporating a safety device such as a rupture disc and relief valve to protect the low pressure side in the event of failure of the pressure reducing system. All vents should discharge through a properly sized barometric leg to an appropriately sized scrubber. A tangential trap is also recommended to remove any entrained solids from the gas stream. Remotely operable valves should be installed in a system to allow immediate stoppage of gas flow in the event of an emergency.

Do not apply heat to the outside of the cylinder or otherwise attempt to completely empty the cylinder. A nominal positive pressure (<20 psig) should be left in the cylinder.

Since line breaking and cylinder replacement can allow moisture to enter the system, provisions should be made to purge the process line to the process or to a scrubber, with an inert gas to prevent corrosion and build-up of corrosion scale.

Each cylinder valve is equipped with a combination safety relief device. The safety consists of a frangible disc which ruptures at 2,700 - 3,000 psig (23,167 kPa) backed by a fusible metal plug which melts at $>212^\circ\text{F}$ ($>100^\circ\text{C}$). The purpose of this device is to allow the contents of the cylinder to be released under fire conditions which could otherwise result in catastrophic rupture of the cylinder. The safety device as installed is in constant contact with the cylinder contents. Do not strike or otherwise disturb the safety device as doing so could cause product leakage or premature failure of the safety device.

Individual cylinders should be weighed before and after use to determine the amount of gas used. The cylinders may be manifolded or used individually.

Honeywell can also provide 50 to 55 lb. net cylinders in pre-manifolded racks. Twelve or 16 cylinders are secured in a rack with all cylinder valve outlets interconnected. Manifolding allows access to the contents of the cylinders, either individually or in any combination while only requiring one field connection. This minimizes individual cylinder handling and, especially, the need to disconnect and change cylinders between usage. Reducing the number of field make-and-break connections minimizes the potential for moisture to enter the charging system. The field connection can also be to a Remotely Operable Valve (ROV) which serves as an Emergency Shutdown Device (SEE: Discussion of ROV operation in the Tube Trailer Section).

The 4 way double access skid mounting allows easy transport via forklift. The skid can also be conveniently placed on a scale to accurately and continuously measure the amount of BF_3 being introduced into the process.

Contact your Honeywell Account Manager at 1-800-622-5002 to discuss the Manifolded Rack option.

BF₃ in Tube Trailers

Boron Trifluoride is shipped as a compressed gas at ~ 1800 psig in tube trailers having the capacities and dimensions shown in the chart below. The tubes are manufactured to DOT Specification 3AAX2400 and must be requalified every 5 years.

Tube Trailer Storage

To utilize tube trailers effectively, a properly equipped location must be provided. The tube trailer should be placed on a paved, level surface. Access must be sufficient to allow maneuvering of the tube trailer by the tractor. The area should be covered to avoid exposure of the tube trailer to direct sunlight and potential overpressurization. The structure may be open on the sides to allow ventilation. A roof with a minimum clearance of 14 feet can provide adequate sunlight protection. A manually operable water curtain or fire monitor system should be installed to be activated for mitigation in the event of a BF₃ leak.

The trailer must be prevented from movement once it is detached from the tractor. Concrete wheel stops and chocks should be used. The fifth wheel plate should be supported by portable jack stands for additional stability.

The tube trailer pad should be located as near as possible to the process area to minimize the length of feed piping as well as to facilitate visual monitoring. The area should be dry and free of explosives, corrosives or flammable materials.

Use of BF₃ Tube Trailers

Although tube trailers vary in dimensions and payload, unloading BF₃ from the tubes involve similar equipment and procedures. Each tube is equipped with a packed needle type cylinder valve at the rear or cabinet end of the tube trailer. This valve is designed to be operated fully open or fully closed. Throttling of this valve will cause erosion of the stem and seat such that the valve may not provide a complete seal when closed. To operate this valve use a 3/8" square wrench and turn the stem counterclock-wise 1-1/2 turns to the full open position. A turning torque of 25 foot-pounds is sufficient to effect full closure. Avoid overtightening the valve stem as excessive force may damage the seat. Pipe wrenches or vise grips must not be used on the valve stem to avoid damaging the wrench flats.

Depending on the capacity of the tube, one or more combination safety devices are provided at either end of the tube. The safety devices consist of a frangible disc which ruptures at 2700-3000 psig (18,600 - 20,700 kPa) backed by a fusible metal plug which melts at >212°F (>100°C). These devices allow the contents of the cylinder to

Capacities & Dimensions of BF₃ Tube Trailers

Net Weight of Gas	Number of Tubes	(L x W x H)
9,000 - 13,000 lbs.	30 or 32	24' 6" x 8' x 8'
12,500 - 15,500 lbs	8	24' 6" x 8' x 8'
16,000 - 21,000 lbs	6 or 7	40' x 8' x 8'
18,000 - 21,500 lbs	6	44' x 8' x 8'





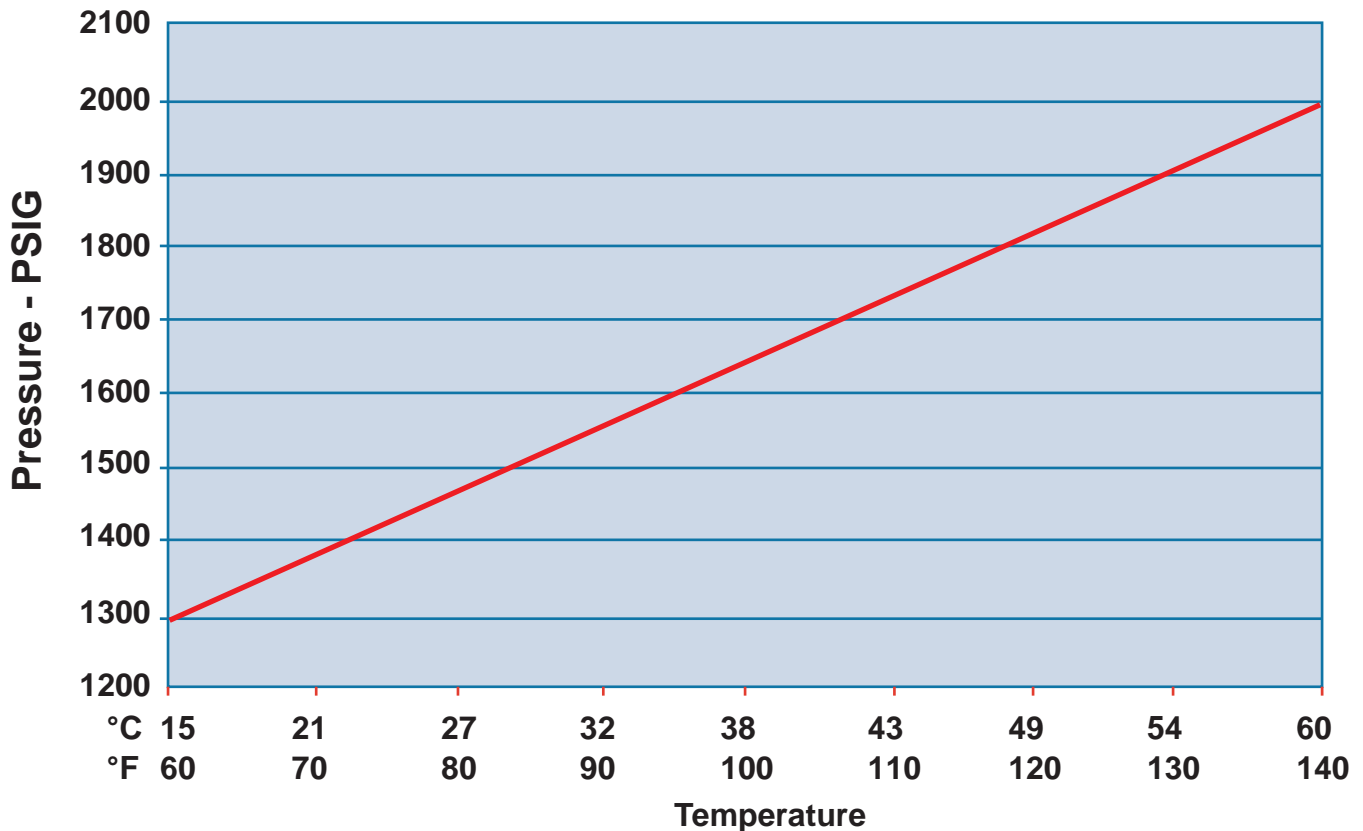
be released under fire conditions which could otherwise result in catastrophic rupture of the cylinder. The safety devices as installed are in constant contact with the cylinder contents. Do not strike or otherwise disturb the safety devices as this could cause product leakage or premature failure of the safety device.

The tube cylinder valves are manifolded together inside the cabinet at the rear of the trailer. The tube manifold is fabricated using mostly welded connections, however excessive torque on any of the manifold or cylinder valves or extreme temperature cycling can cause weld failure. In the event of weld failure on the tube trailer manifold, the tube trailer must be returned to Honeywell for repair. No field welding is permitted unless it is done under the supervision of a Honeywell representative.

The manifold master valves (or wing valves) are globe type and specially constructed for high pressure positive shut-off. These globe valves should be used only in the fully open or fully closed position. The valves require 1-1/4 turn to full open or close. Over-tightening may damage the seat and could result in leak through. The wing valves should be operated by hand only. Do not use wrenches or other mechanical devices to operate these valves.

The manifold terminates at both sides of the manifold cabinet to allow the user to connect to either side, depending on process orientation to the constructively placed trailer. The outlet of the manifold consists of a CGA 330 (left handed) male connection with a protective end cap that should be removed only when ready to connect the trailer to the process, in order to prevent atmospheric moisture from entering the

Variation of Pressure with Temperature Boron Trifluoride



manifold. Use two wrenches when removing the end cap and attaching the process feed line to minimize excessive torque on the tube trailer manifold.

Alternately, the process line should be connected to a Remotely Operable Valve located within the manifold cabinet this valve is pneumatically operated (air-to-open, spring-to-close) and can be activated from a remote location. The valve begins to open at 60 psig and is fully open at 90 psig of operating air. This remotely operable valve allows instantaneous stoppage of the gas flow at the source in the event of an emergency. This valve is installed for use as an emergency shut-off device only and should not be used to control flow. Customers are encouraged to tie in this valve to similarly configured systems within their own process lines. The Remotely Operable Valve terminates in a male CGA 330 connection which has a protective end cap installed.

Tube trailers should be connected to the process using hard pipe or a stainless steel flexible tubing pigtail with a welded CGA 330 female fitting to mate with the manifold or ROV outlet. The process end connection may be of any appropriate high pressure fitting. Flexible hoses should not be used in BF_3 service. CGA fittings should be sealed using a new Kel-F® (Neoflon®) gasket.

The process line should be equipped with a means of regulating and measuring both pressure and flow. It should include a pressure relief line incorporating a safety device such as a rupture disc and relief valve to protect the low pressure side in the event of failure of the pressure reducing system. All vents should discharge through a barometric leg to an appropriately sized scrubber. A tangential trap is also recommended to remove any entrained solids which may be present in the gas stream. Remotely operable valves should be installed in the system to allow immediate stoppage of gas flow in the event of an emergency.

An inert gas purge provision should be provided on the tube trailer manifold side opposite of the process connection side. This allows the manifold to be purged free of moisture or entrained solids prior to introducing BF_3 to the process and to purge the manifold free of BF_3 prior to disconnecting the trailer for removal. Purge gases should be exhausted to process or to an adequately sized scrubber. It is preferable to use cylinder inert gas rather than tying in to a plant wide system to prevent cross contamination of the gas streams. Alternately, applying a vacuum to the manifold piping can also be effective in removing entrained moisture.

Each tube of gas should be used individually. Do not attempt to equalize pressure between tubes. The rapid movement of gas through the cylinder valve results in a refrigeration effect icing the valve. This sudden reduction in temperature may make the fluoropolymer packing in the valves contract, resulting in leakage of BF_3 through the valve stem. Overtightening of the packing nut to mitigate a packing leak could result in the valve body or packing nut being cracked by the expanding packing as the valve warms to ambient temperature. Do not attempt to tighten the packing nuts on the valves beyond the following values:

Tube Cylinder Valve	50 foot-pounds
Manifold Wing Valves	120 foot-pounds





Rapid depressurization of gas through the manifold can similarly cause refrigeration which in turn causes ice to form on the manifold. This is an external phenomenon and does not restrict the flow of gas in any way. Do not attempt to steam or otherwise thaw ice from the manifold piping. Graphs have been prepared for each trailer showing the pressure-temperature weight relationship for BF₃ tube trailers. These charts are available upon request.

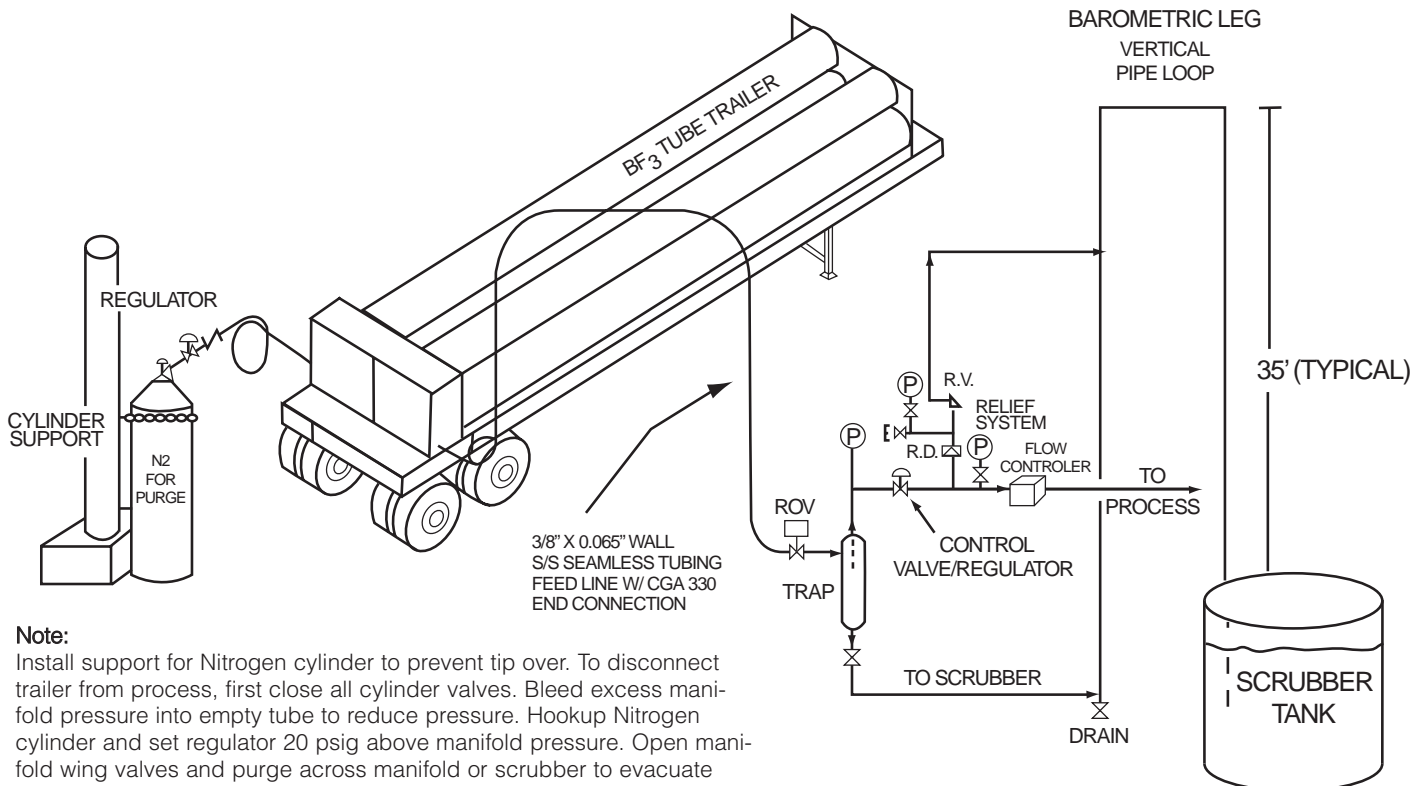
All tubes on tube trailers are filled simultaneously to ensure equal pressure in all tubes. The weight of BF₃ in one tube can be estimated by dividing the weight obtained above by the total number of active tubes on the trailer.

This technique can also be utilized to estimate the heel weight in an "empty" trailer by opening all tube valves to equalize pressure in the manifold, then completing steps 1-5 as follows:

For a full trailer:

1. Open the first tube to fully pressurize the manifold.
2. Record the pressure at the manifold. Record the ambient temperature of the tube trailer.
3. Confirm that the chart used corresponds to the tube trailer in use and locate the temperature on the Y axis.
4. Draw a horizontal line from this point to the appropriate pressure curve.
5. Draw a vertical line from this intersection to the weight (X) axis and read the weight in pounds.

NOTE: Do not attempt to equalize pressure if there is more than 500 psig on any one or more tubes.



Note:
Install support for Nitrogen cylinder to prevent tip over. To disconnect trailer from process, first close all cylinder valves. Bleed excess manifold pressure into empty tube to reduce pressure. Hookup Nitrogen cylinder and set regulator 20 psig above manifold pressure. Open manifold wing valves and purge across manifold or scrubber to evacuate BF₃. Gradually reduce Nitrogen pressure to zero. Isolate manifold by closing wing valves and disconnect feed and Nitrogen lines. Cap off feed line and trailer manifold.

Return of Empty Tube Trailers

Tube trailers should never be completely emptied (to 0 psig). Pressure in the tube trailer tubes and manifold should be kept above the customer's process pressure but never less than 50 psig to prevent back-flow into the trailer.

DOT regulations prohibit shipment of any compressed gas in tube trailers if there is any product in the manifold tubing (as indicated by positive pressure on the manifold pressure gauge). In order to comply with these regulations, the following procedure must be completed by the customer prior to removal of the trailer.

1. Close all tube cylinder valves.
2. Bleed BF_3 manifold pressure to process as low as possible. Do NOT bleed manifold directly into water as water will be drawn back into the manifold.
3. Turn on inert purge stream to the manifold. NOTE: Insure inert gas pressure is greater than the residual pressure indicated on the manifold pressure gauge.
4. Slowly purge all lines that will be open to the atmosphere to process or to a scrubber.
5. Slowly reduce inert gas pressure to 20 psig and continue to purge for at least five (5) minutes.
6. Cease inert gas purge and allow the manifold pressure to reduce to 0 psig.
7. Disconnect the purge point on the manifold and immediately cap the manifold outlet.
8. Disconnect the process feed piping from the trailer and immediately cap manifold outlet.
9. Close all wing valves on the manifold except the wing valve under the manifold pressure gauge. (This valve must be left open at all times during transit.)





Consequences of Release of BF_3 to the Atmosphere

The information in this section is only intended to support the understanding of the chemical reactions that occur during the release of Boron Trifluoride (BF_3) to the atmosphere. This document is NOT meant to take the place of the Material Safety Data Sheet (MSDS). All personnel involved with and responsible for handling BF_3 based products should be familiar with the appropriate safety and handling precautions. Such information is provided in the MSDS.

Proper management of emissions of BF_3 is a matter of concern to anyone involved in handling these products. It is, therefore, desirable to have an understanding of possible reactions, potential byproducts and the consequences to be expected if BF_3 is released to the atmosphere.

BF_3 is classified as a hazardous material due to its chemical properties, its low PEL/TLV (1 ppm), and the fact that it is shipped as a gas under high pressure (1800 psig). A discussion of the properties and characteristics of BF_3 and how it acts if allowed to contact moist air and water will guide personnel in setting up procedures to handle accidental releases.

It is well known that BF_3 forms a white cloud when exposed to water vapor, moist air, or even air with very low humidity. This dense white cloud may be comprised of aerosol-sized droplets of BF_3 hydrates under a certain set of meteorological conditions. Experience has shown that BF_3 is absorbed by water very rapidly. It is estimated that the rate of reaction between BF_3 and water may be of the order of microseconds.

It is necessary to point out that all of the possible species present - BF_3 hydrate(s), ionized BF_3 hydrate(s), hydroxy fluoroborate, and fluoroboric acid - are strong acids and must be treated as such when considering the environmental consequences of a BF_3 emission. They all contain combined fluoride which will eventually affect human tissue if contacted in any significant quantity.

Honeywell's suggested procedure for handling potential BF_3 leaks and emissions states that water should not be sprayed directly onto a leak point since corrosion and enlargement of the leak site may result. This is especially true if limited water is used since the hydration reaction is very exothermic and the hydration products are strongly acidic. However, if large quantities of water are available, such as from a fire hose with a fog nozzle, the fog spray may be directed onto the leak spot to both absorb the BF_3 and cool the vessel. It is important that copious amounts of water be used to ensure complete absorption of the BF_3 . The water off-flow will be acidic and should be directed to a containment or treatment facility.

In case of leakage from BF_3 cylinders, copious water spray may be used or the leaking cylinder may be immersed in a drum of water. The volume of water in the drum will act as a heat sink and keep temperatures low while providing a large excess of water for absorbing the BF_3 . It is also advisable to place a running water hose in the drum so as to have a constant flow of fresh water to assist in BF_3 absorption. This will serve to cool the cylinder, keep the acidity low by dilution, and therefore reduce corrosion. The contaminated water should flow to a containment or treatment facility.

NOTES:

Sustainable Opportunity Policy: Honeywell's Commitment to Health, Safety and the Environment

By integrating health, safety and environment into all aspects of our business, we protect our people and the environment, achieve sustainable growth and accelerated productivity, drive compliance with all applicable regulations and develop the technologies that expand the sustainable capacity of our world. Our health, safety and environment management systems reflect our values and help us meet our business objectives.

- We protect the safety and health of our employees, and minimize the environmental footprint of our operations through prevention of illness, injury and pollution.
- We actively promote and develop opportunities for expanding sustainable capacity by increasing fuel efficiency, improving security and safety, and reducing emissions of harmful pollutants.
- We are committed to compliance with all of our health, safety, environmental and legal requirements everywhere we operate.
- Health, safety and environment is an integral aspect of our design of products, processes and services, and of the lifecycle management of our products.
- Our management systems apply a global standard that provides protection of both human health and the environment during normal and emergency situations.
- We identify, control and endeavor to reduce emissions, waste and inefficient use of resources and energy.
- We are open with stakeholders and work within our communities to advance laws, regulation and practices that safeguard the public.
- We abide by the company's own strict standards in cases where local laws are less stringent.
- Our senior leadership and individual employees are accountable for their role in meeting our commitments.
- We measure and periodically review our progress and strive for continuous improvement.

These are our commitments to health, safety, and the environment, and to creating Sustainable Opportunity everywhere we operate.

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