



## Y Cylinder is a Robust Package

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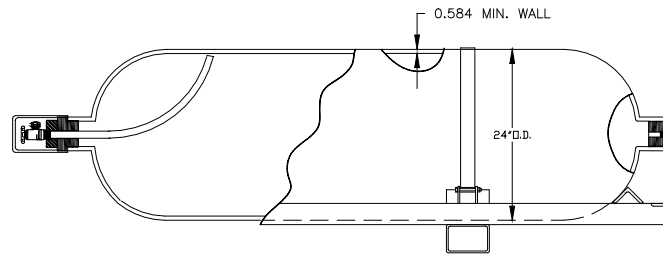
High pressure seamless bulk containers that can hold a 1,000 lbs of water were named as Y cylinders by Air Products, also known as a high-pressure tonner. Not a true tonner that has a 2000 lb water capacity. Y cylinders are very robust packages as demonstrated by incident history and testing.

Forty years ago, Y cylinders were made to DOT 3T specification using a 4145 alloy and primarily used for hydrogen chloride service. DOT 3AAX a 4130 alloy is a lower strength steel has become more common. DOT 3T steel alloy has a high tensile strength 155,000 psig making it lighter in weight than the DOT 3AAX with the same pressure rating. 49CFR173.302(a) DOT 3AX, 3AAX, and 3T cylinders are authorized for Division 2.1 and 2.2 materials and for carbon monoxide. DOT 3T cylinders are not authorized for hydrogen service because of embrittlement.



A horizontal carbon steel high pressure seamless cylinder 24" OD. Internal volume that can vary from 15.7 ft<sup>3</sup> (444.6 l) to 16.70 ft<sup>3</sup> (472.9 l). Nominally 454 liters that is defined as a bulk cylinder by CGA. It holds more than 10 times the volume of the typical 44 liter cylinder.

Hydrogen chloride as a liquefied compressed gas, the user must orient the Y Cylinder so that the goose neck tube is positioned upward inside the cylinder for vapor use or downward for liquid use. 40 years ago the Y cylinder was shipped without a cradle. The user had a roller that they placed the Y cylinder onto and could roll it to the right orientation. The valve outlet connection was oriented to the gooseneck position.



The 3AAX Y cylinder is the preferred cylinder for high purity electronic specialty gas use since it can be mechanically polished and cleaned prior to fabrication.

Y cylinders are now used for many other liquefied compressed gases for the Electronics Fabrication Industry, ammonia, chlorine, dichlorosilane, monochlorosilane, nitrous oxide, sulfur hexafluoride, etc. They might have a vapor valve on one end and a liquid valve on the other.

### **FIBA Fabrication (3AAX)**

Large diameter seamless high pressure carbon steel tubes are cut into the desired length. The interior is then ground to the bare metal and a good finish using an abrasive wheel to remove all manufacturing slag, contaminants, etc.

The ends of the tube are then preheated red hot. As the tube is spun, a robot arm starts to neck the end of the tube to form a concave head with a neck.



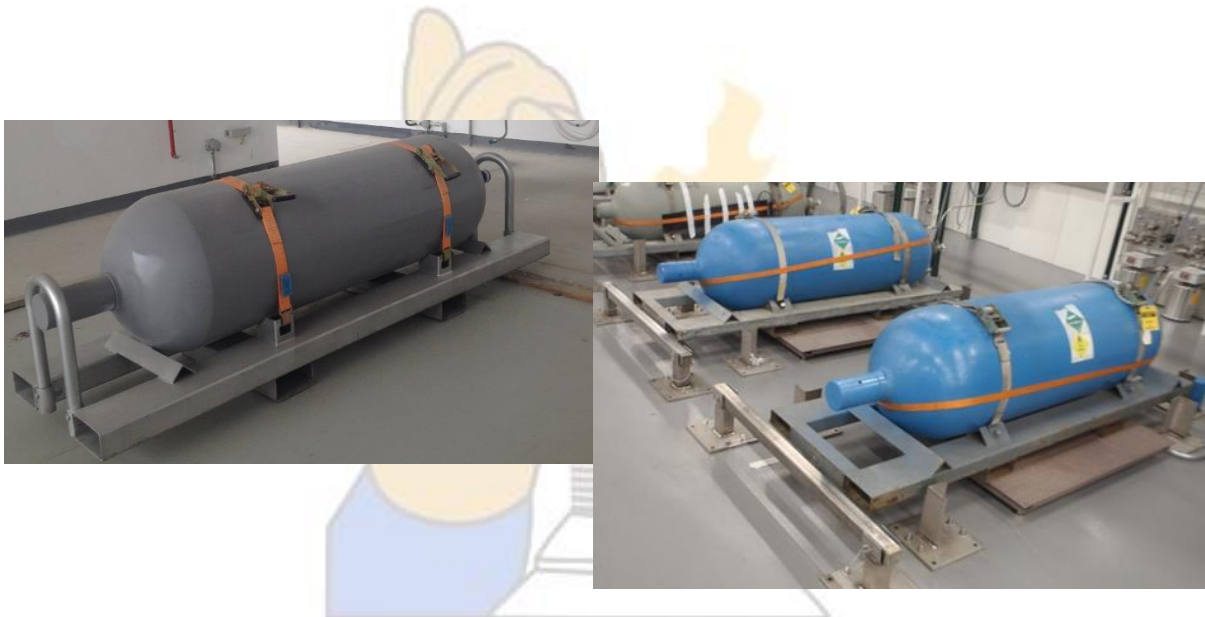
After both ends are formed, the tube is heat treated and quenched in a hot oil bath. Each end is then machined with a CNC to face and thread the neck.

The interior and exterior are then sandblasted. The interior is then heated using supersaturated steam flowed by a nitrogen purge. The tube is then sealed for assembly. The entire straight length of the tube is ultrasonically tested for any flaws, cracks, defects.

Each end is machined to 3 ¼" threaded opening which is plugged with a threaded Bullplug, sealed with a Viton O Ring and Teflon Backing Ring. Surface finish of the bull plug and tube are critical for a good seal, the bull plug is torqued onto the end until the metal surfaces mate (800-1,000 ft-lbs).



Most common configuration is a cylinder valve and PRD on one end and a PRD on the other. With PRD's becoming optional for many gases, the bullplugs are blank on one end. Some Y cylinders have a valve on both ends to allow the user to select liquid or vapor. The cylinder valves are protected by a metal cap.



This is a very robust package. A steel rollbar on the skid protects the cylinder valves from physical impact damage during transportation and handling. Testing in 2004 by Air Products, demonstrated that a Y container dropped during handling will not damage the valve. The metal skid prevents the cylinder cap from being impacted when it is dropped.

To determine if dropping a Y cylinder could cause it to leak. A height of 8 ½ ft was selected since I had authorized 3 high rack storage for them at Air Products.

### Background

Testing was conducted at Weldship Corp a Y cylinder and tube trailer company in PA on June 25, 2004.



Y-cylinder dropped from a height of 8 ½ ft will reach about 23 feet/sec (16 mph) when it strikes the ground

Y-cylinder will take about 0.75 seconds to hit the ground

The total Y-cylinder mass of around 2,393 lb (containing 980 lb of water), will impact the ground with over 5,000 lb of force (more than 2g)

The maximum tilt of the forklift skid will angle the Y skid so that it is 1 ½' higher at one end.

Chain was used to pull the Y cylinder off the forks as the forklift backed up

### Test Y Cylinder

Manufactured by CPI

Manual Tied Diaphragm 316 ss Ceodux Valve, 640 DISS

Was fill completely with water to 2393 lbs

New skid with straps that were load rated for 2333 lbs and 3300 lbs with a breaking strength of 10,000 lbs

Changed skid after Test #1

New American Cap used. Replaced after test #3, Cap Impact



### Test #1 Drop Flat Onto Skid

Forks were level

The front of the skid hit at a 45° angle causing minor damage to the front skid

At impact. the Y slid forward and bent the skid front cross angle

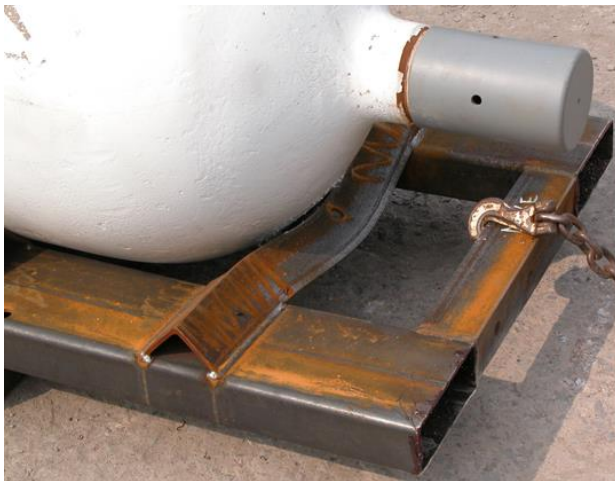
It then bounced backward and the Y slid back bending the skid rear cross angle

The skid bounced forward and the Y slid forward again

The front strap loosened slightly

No damage to the Y or straps

No leaks at 100 psig N<sub>2</sub>



### Test #2 Drop at an Angle

The forks were tilted to the maximum (10' rear & 8' front)

Front of skid hit at a 45° angle

Major damage to the front skid upon impact

Y did not slide as much as Test #1

The skid bounced backward and damaged the rear forklift channel

Straps stayed tight

No damage to the Y or straps

Y still had 100 psig N<sub>2</sub>, there were no leaks





### Test #3 Drop Upside Down Onto Cylinder Cap

The Y was hung upside down on the forks so that the impact would be on the cap.

The forks were tilted to the maximum (10' rear & 8 ½ ' front)

Was dropped without using the chain

The Y impacted onto the cylinder cap at a 45° angle

It bounced backward and then forward

Chipped out a hole in the concrete 1" deep and 4" diameter

Only minor damage to the Cap

The cap was easy to remove

Y still had 100 psig N<sup>2</sup>, there were no leaks





#### Test #4 Y Onto Y Cap On The Ground

An old empty HCl Y weighing 1325 lbs was dropped onto the Y with a cap on the ground.

Forks were level and the Y was pulled off

Skid front hit the ground first and pivoted backward hitting the cap

The dropped Y bounced on the rear skid and hit the cap again

Minor damage to the cap

Y still had 100 psig N<sub>2</sub>, there were no leaks



#### Test #5-1 & 2, Y Onto Valve, No Cylinder Cap

First dropped Y missed the valve by inches

Second dropped Y hit valve handle with skid front forklift channel. This damaged the valve causing a leak.

Impact made a dent in the channel

The front of the dropped skid hit ground after the valve impact

The skid pivoted backward and the center of the skid hit the valve again. It pivoted on the valve and hit the ground on the rear skid

The dropped Y bounced back and hit the valve again which caused the dropped Y to flip over



Y Hits Valve before  
the ground

Y Hits the ground

Y Pivots and Hits  
Valve Again



The impact broke off valve handle and hit the top of the valve bending it toward the bullplug. This pulled out the diaphragm nut causing a leak. Since the Y was still pressurized with Nitrogen, the water came out immediately from the leak check port and diaphragm nut  
Valve cracked at the threads but not through to the inner bore  
The PRD stopped the bending, preventing the valve from cracking fully

Y Cylinders have been involved in motor vehicle accidents without serious damage or leaks.





## Conclusions

The drop testing demonstrated how robust the Y cylinder package is.

The design of the Y cylinder and skid make it difficult to directly impact the cap or valve, the skid or cylinder shoulder gets in the way

Even with the forks greased and tilted, it was difficult to make the Y slide off. Had to back the forklift fast to jerk it off using momentum when no chain was used.

Even the lowest rated straps did not break and only one loosened slightly in the first test

Testing with an empty skid with backing the forklift slowly caused the skid to tilt as it dropped.

Backing it fast caused it to drop flat. In actual testing with the Y on the skid, it tilted in all cases, impacting at an angle.

No damage to the Y in any of the tests except scraping of the paint.

A gas supplier forwarded pictures of a NH<sub>3</sub> Y that was in a 40' trailer on a skid. The driver fell asleep and crashed through a guardrail into the side of a canal. The Y crashed through the bulkhead of the trailer through the cab and hit the concrete wall where it ricochets out of the trailer and down the canal embankment. It only suffered minor scratches, no leak.

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Even in the 2011 testing with full flame impingement from a silane Y PRD did not heat the adjacent Y filled with N<sub>2</sub> hot enough for it to rupture since the time was less than 3 minutes.



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