



Welcome to the Composite Cylinder Public Meeting

Integration of Composite Cylinder
Special Permits into the DOT Code
of Federal Regulations 49 (CFR 49)

Map-21 Global Harmonization

See Disclaimer



Composite Cylinder Usage

- Composite Cylinders have been used in the United States under DOT Special Permits for over 25 years for the transportation of various compressed gases.
- Composite Cylinders are also authorized under DOT 49 CFR in §178.71 and in United Nation Model Regulations for over 10 years.



Composite Cylinder Standards Authorized Under Special Permits

- Special Permits - DOT-FRP 1
- Special Permits - DOT-FRP 2
- Special Permits - DOT-CFFC
- Special Permits - with Various Exceptions from CFFC, FRP-1 Standards
- Special Permits - Large Cylinders (Tubes)



Composite Cylinder Standards Authorized Under DOT 49 CFR and UN Regulations

- ISO 11119-1
- ISO 11119-2
- ISO 11119-3





Fiber Reinforced Plastic Fully Wrapped Composite Cylinder (FRP-1)

- Liner – Seamless Aluminum
- Shell – Glass Fiber
- Maximum water volume – 200 lbs. (90 l)
- Maximum service pressure – 5,000 psi
- Design service life – 15 years
- Safety factor (Min. burst/service pressure ratio) = 3.0





Fiber Reinforced Plastic Hopped Wrapped Composite Cylinder (FRP-2)

- Liner – Seamless Aluminum
- Shell – Glass Fiber
- Maximum water volume – 200 lbs. (90 l)
- Maximum service pressure – 5,000 psi
- Design service life – 15 years
- Safety factor (Min. burst/service pressure ratio) = 3.0





Fully Wrapped Carbon-fiber Reinforced Aluminum Lined Cylinder (CFFC)

- Liner – Seamless Aluminum
- Shell – Carbon fiber and glass fiber reinforced plastic
- Maximum water volume – 200 lbs. (90 l)
- Maximum service pressure – 5,000 psi
- Design service life – 15 years
- Safety factor (Min. burst/service pressure ratio) = 3.4





Hooped Wrapped Metallic Liner Composite Cylinder (ISO 11119-1)

- Liner – Seamless metallic (Steel or Aluminum)
- Shell – Carbon fiber or aramid fiber or glass fiber
- Maximum water volume – 1,000 lbs. (450 l)
- Maximum service pressure – 9,425 psi (650 bar)
- Design service life – Up to 38 years
- Safety factor (Min. burst/service pressure ratio) = 3





Fully Wrapped Metallic Liner Composite Cylinder (ISO 11119-2)

- Liner – Seamless metallic (Steel or Aluminum)
- Shell – Carbon fiber or aramid fiber or glass fiber
- Maximum water volume – 1,000 lbs. (450 l)
- Maximum service pressure – 9,425 psi (650 bar)
- Design service life – Up to 38 years
- Safety factor (Min. burst/service pressure ratio) = 3





Side by Side Design Qualification Evaluation of FRP-1 & CFFC Design Criteria with ISO 11119-2

- PHMSA Engineering made a comprehensive side-by-side Design Qualification Comparison of (FRP-1 & CFFC) Design Criteria and the ISO 11119-2.
- Copies are available.

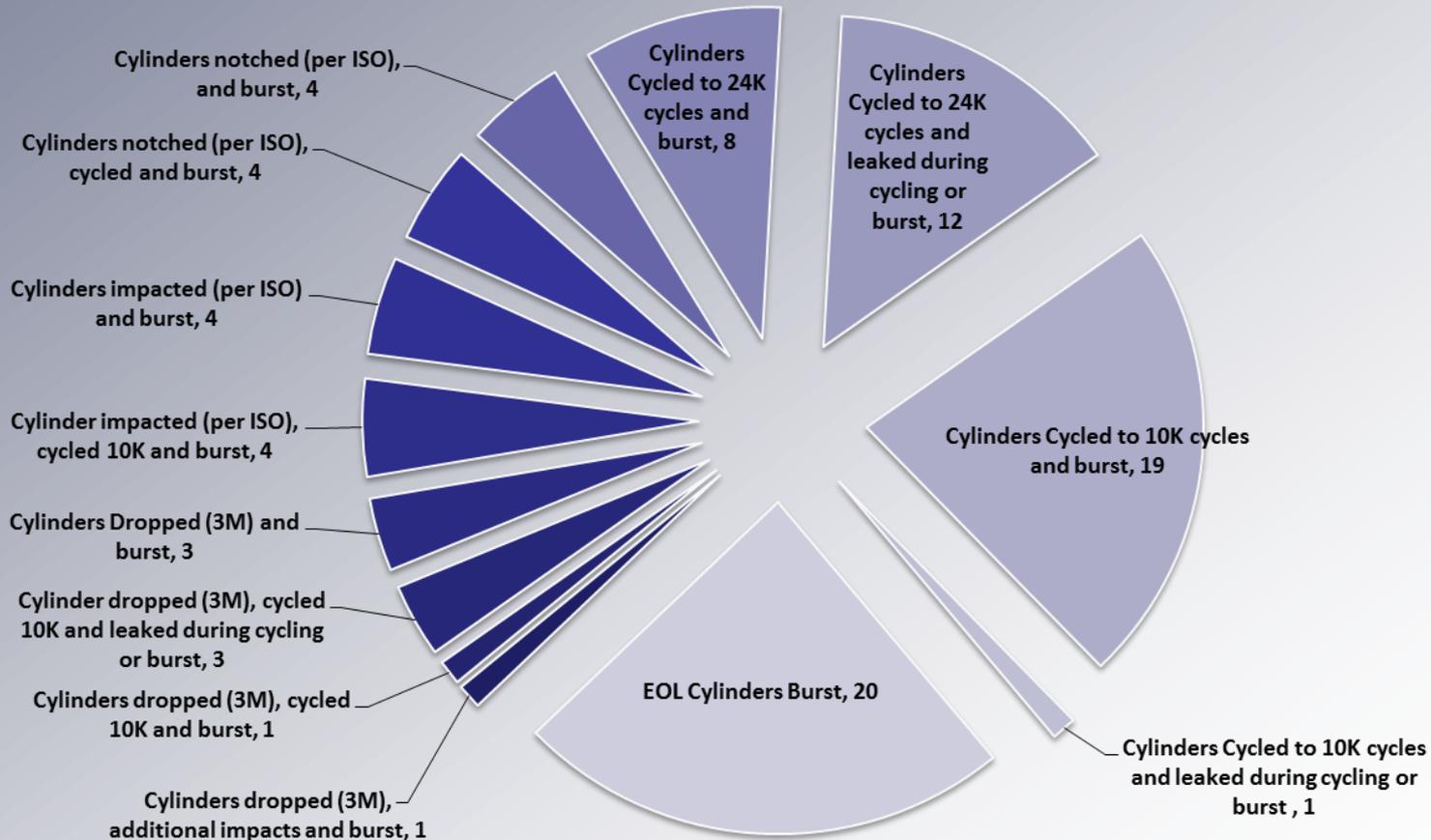


Performance Evaluation of DOT FRP-1 and CFFC Using ISO 11119-2 Criteria

- PHMSA also evaluated the performance of FRP-1 and CFFC cylinders Using ISO 11119-2 Criteria.
- 84 cylinders were randomly selected from a population of 50,000 FRP-1 and CFFC cylinders, which were approaching the end of their 15-year service life.
- Sample cylinders were subjected to ISO 11119-2 design qualification testing such as burst, pressure cycling, flaw tolerance and drop testing.



Performance Testing Types Which FRP-1 and CFFC Cylinders Were Subjected (84)





Testing Types and Criteria*

- ISO 11119-2
- None of the FRP-1, CFFC Cylinders used in this project were new.
- The testing consisted of:
 - Burst of used or end-of-life vessels
 - 10,000 pressure cycles then burst
 - Dropped and burst
 - Dropped and cycled
 - Notched and burst
 - Notched and cycled
 - Cycling pressure = Max. Developed Pressure for SCBA

*Test results and information only represent Navy Cylinders and their application.



Burst Pressures Results for Un-Cycled Cylinders

High	Low	Design	Average	STDev
16744	14972	13500	16078	738
18455	16988	13500	17911	606
20594	16805	15300	19036	1671
20075	18333	15300	19555	741



Burst Pressures Results for Cylinders Subjected to 10,000 Cycles (P = Max. Developed Pressure)

High	Low	Design	Average	STDev
16683	15399	13500	15919	597
16866	15094	13500	16139	644
20785	16225	15300	19380	1896
20625	19372	15300	20037	571



ISO Flaw Tolerance Test Notched Cylinder Criteria

Length, in	Depth, in	Width, in
1.200	0.132	0.04
1.350	0.149	0.04
1.125	0.124	0.04
1.025	0.113	0.04



ISO Flaw Tolerance Test Burst Pressure Results

Type	Burst Pressure, psi
FRP-1	14544
FRP-1	13597
CFFC	17111
CFFC	16011



ISO Drop Testing Rig





Drop Test Criteria Per Requirements of ISO 11119-2

- Cylinder (FRP-1/CFFC) filled with water to 50% capacity
- Dropped on 9 positions (boss, side, shoulder and base, twice each location)
- Dropped from 1.2 meters





Cycling Results After Drop Test as Required in ISO 11119-2

- Each Cylinder was subjected to 10,000 pressure cycles from 200 to 5200 psi (Max Developed pressure).
- All Cylinders passed the cycling tests with no leak and no burst.



Conclusion – Performance of DOT FRP-1&CFFC As Required in ISO 11119-2

- All FRP-1 & CFFC cylinders passed 10,000 pressure Cycling Test (200-5200 psi) and met the minimum burst pressure requirement.
- All FRP-1 & CFFC cylinders passed 1000 pressure cycles and met the minimum burst pressure requirement.
- All FRP-1 & CFFC cylinders passed post drop cycling and minimum burst pressure requirement.



Public Concerns for Switching to ISO 11119-2 from FRP-1, CFFC

- Representative Criteria for Fatigue Performance (Max. Developed Service Pressure)
- Representative Criteria for Drop Testing
- Addition of Damage (Flaw) Tolerance Testing
- Fear of Unknowns



Benefits for Switching to ISO 11119-2 from FRP-1, CFFC

- Consistent Regulation and Enforcement practice
- Keeping up with global competition
- Periodic revision of the Standard by global experts
- Options for making larger Cylinders (5 times)
- Options for making higher pressure Cylinders
- Options for having various performance designs (e.g. 15, 20, 30 years)
- Potential for a longer service life (e.g. 38 years or indefinite)
- Meeting requirements of MAP-21 & Global Harmonization



DISCLAIMER

The information in this presentation is based on test data from cylinders in special limited-use application. It is in no way to be construed as a conclusion or recommendation to use composite cylinders beyond their current service life limit of 15 years.”