Cylinder options for UAVs

Many companies offer lightweight composite cylinders, these are normally type 3 or type 4. Type 3 use an aluminium liner with a carbon fibre wrap and type 4 use a plastic liner with carbon fibre wrap. Type 4 tend to be lighter. Type 5 may be available in the future, these have no liner.

The use of pressurised cylinders on drones for supplying the hydrogen is relatively new and at present there are no directly relevant certification standards relating to drones. However, the general pressure vessel design standards (EN12245, ISO11119-2 and ISO11119-3) are usually used. Only cylinders designed to these standards have been included in the tables below.
In addition, certification to the following standards is required to permit transportation of the full hydrogen cylinders:

- Europe TPED (π mark)
- USA DOT
- Canada TC, UN
- S. Korea KGS
- Germany TUV
- Japan JIS

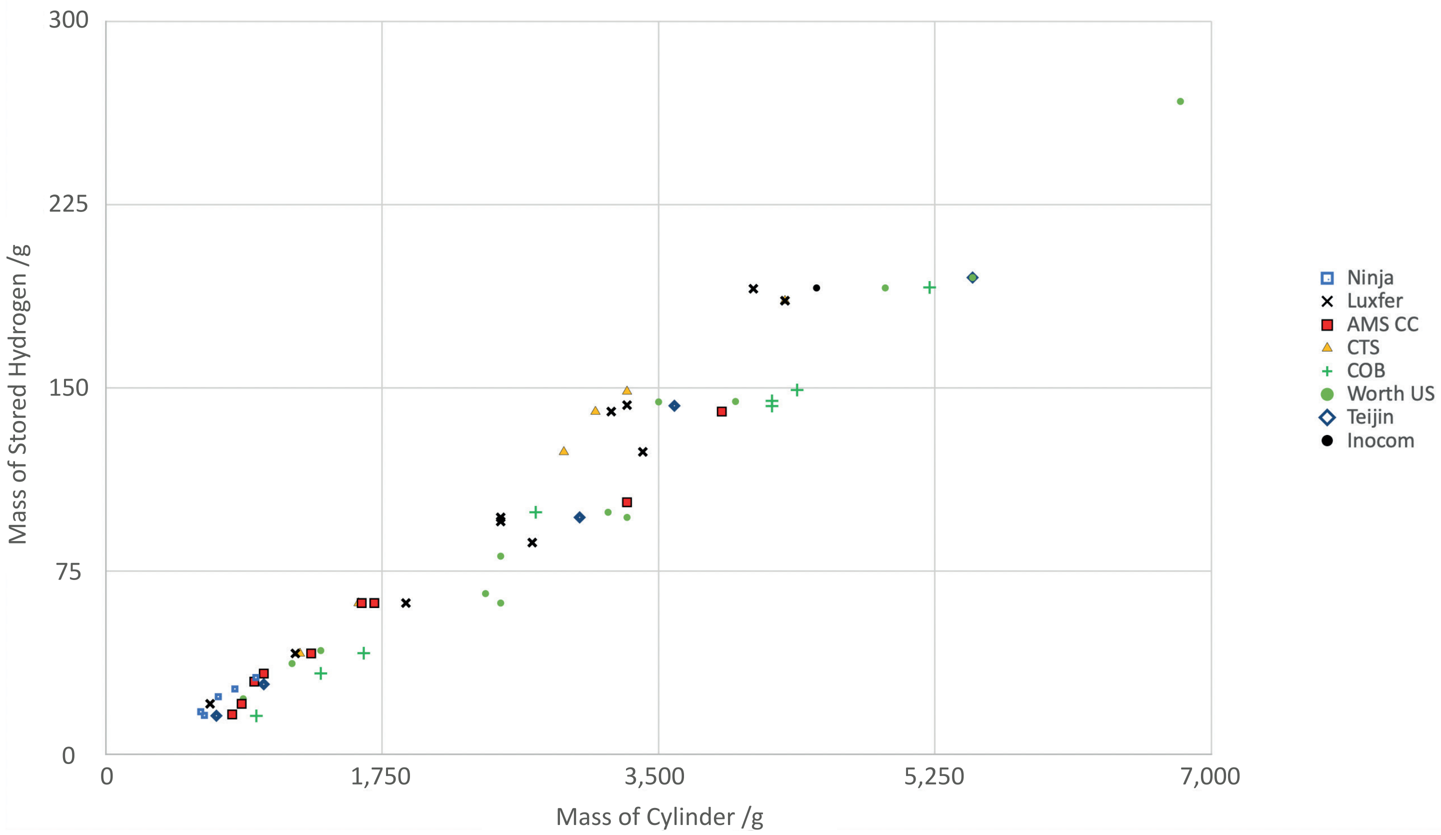
All of the cylinders in the tables below have or will be able to get TPED and/or DOT certification. However, many of the cylinders listed below still need to be taken through these pathways. Different regulations may apply in other countries. For example, in China the requirements permit lighter cylinders to be certified.

Below are tables showing the companies that we are aware of, that can supply lightweight certified cylinders. Others may be available. There are also several companies that will develop lighter cylinders to specific requirements if requested. Lighter cylinders may be available that are only certified for use in certain regions or for specific applications.

Careful analysis of the mass, power and energy requirements should be undertaken to establish the best solution for each application.

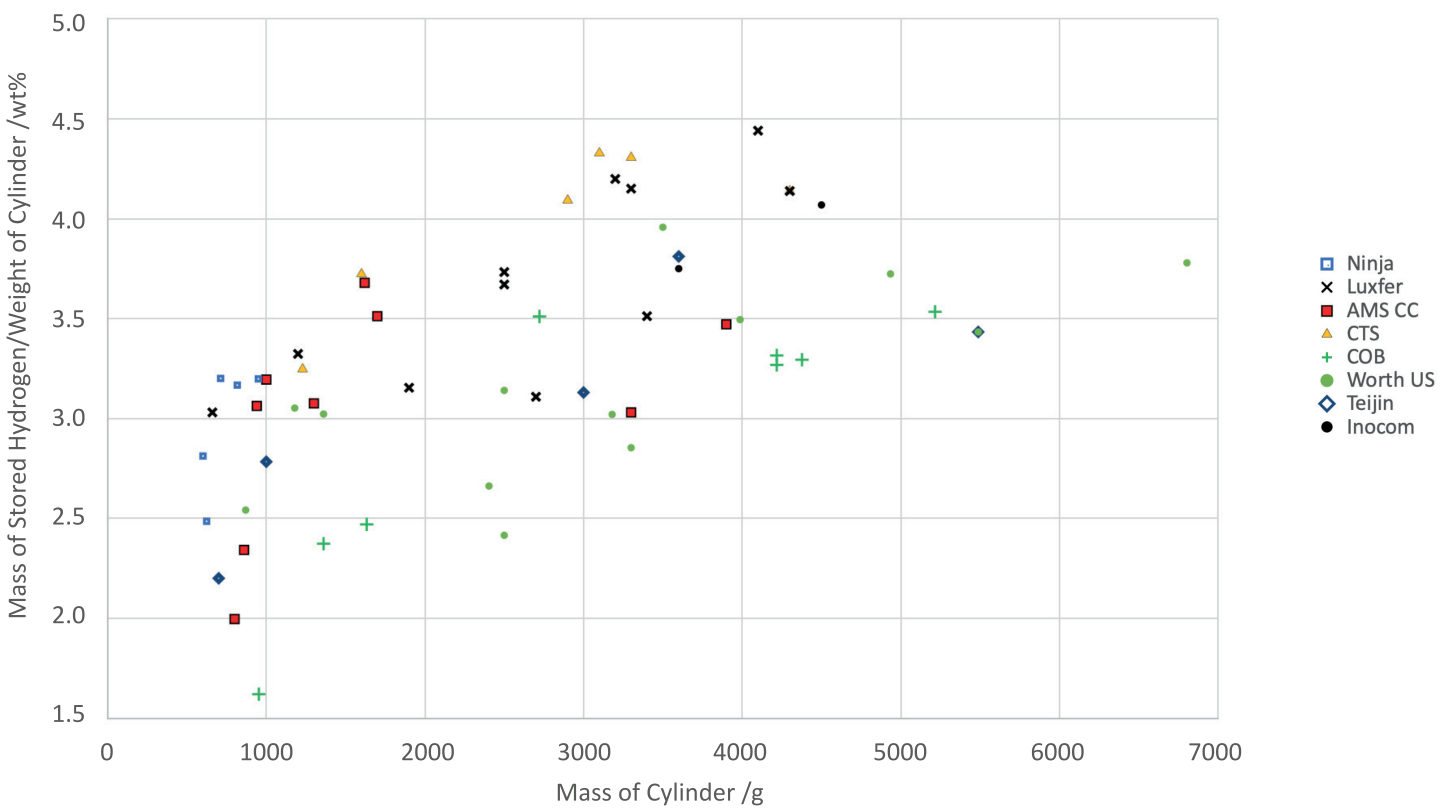
Graph 1

Mass of hydrogen stored in the cylinder versus mass of the cylinder.
(Fuel consumption calculations are shown at the end of this document).



Graph 2

Weight percent of hydrogen stored from various suppliers. Generally, the larger cylinders can store a higher proportion of their weight + hydrogen weight.



Cylinders availability

Intelligent Energy holds a stock of the most popular cylinders as indicted in the tables below. Other cylinders are available directly from manufacturers. Note: the figures below are based on the suppliers published data and not actual measurement.

Sample list of cylinders

Ninja (US) produces components for paintball applications. The largest cylinder they produce is 1.48L and all have a 5/8 UNF thread.
www.ninjapaintball.com

Cylinder Name	Design Standard	Certification	Type	Volume (L)	Dia (mm)	Length (mm)	Mass (g)	Pressure (bar)	Mass of hydrogen (g)	wt% H2	Electrical Energy (Wh)	Thread
SL45	n/a	DOT	3	0.8	n/a	n/a	624	310	15.9	2.5	265	5/8 × 18 UNF
SL50	n/a	DOT	3	0.8	n/a	n/a	601	310	17.4	2.8	290	5/8 × 18 UNF
SL68	n/a	DOT	3	1.1	n/a	n/a	712	310	23.5	3.2	392	5/8 × 18 UNF
SL77	n/a	DOT	3	1.3	n/a	n/a	817	310	26.7	3.2	445	5/8 × 18 UNF
SL90	n/a	DOT	3	1.5	n/a	n/a	950	310	31.4	3.2	523	5/8 × 18 UNF

Luxfer (UK/US) – All cylinders can be certified for the US and/or Europe. www.luxfercylinders.com/products

Cylinder Name	Design Standard	Certification	Type	Volume (L)	Dia (mm)	Length (mm)	Mass (g)	Pressure (bar)	Mass of hydrogen (g)	wt% H2	Electrical Energy (Wh)	Thread
M10H/F	EN12245	TPED, DOT on request	3	1.0	87	281	660	300	20.6	3.0	343	M18 x 1.5
L19G	EN12245	TPED, DOT on request	3	2.0	102	372	1200	300	41.3	3.3	687	M18 x 1.5
L29C	EN12245	TPED, DOT on request	3	3.0	114	443	1900	300	61.9	3.2	1030	M18 x 1.5
L64G	ISO 11119-2 & EN12245	TPED, DOT on request	3	3.8	123	492	2500	379	95.3	3.7	1586	M18 x 1.5
L43F	EN12245	TPED, DOT on request	3	4.2	117	580	2700	300	86.6	3.1	1443	M18 x 1.5
L46E (Stock)	ISO 11119-2 & EN12245	TPED, DOT	3	4.7	138	466	2500	300	97.0	3.7	1614	M18 x 1.5
L66Q	ISO 11119-2 & EN12245	TPED, DOT on request	3	5.7	160	484	3300	379	142.9	4.2	2379	M18 x 1.5
L58F	EN12245	TPED, DOT on request	3	6.0	156	470	3400	300	123.8	3.5	2061	M18 x 1.5
L66N	ISO 11119-2 & EN12245	TPED, DOT on request	3	6.8	156	520	3200	300	140.3	4.2	2336	M18 x 1.5
L88E	ISO 11119-2 & EN12245	TPED, DOT on request	3	7.6	169	511	4100	379	190.5	4.4	3173	M18 x 1.5
L88C (Stock)	ISO 11119-2 & EN12245	TPED, DOT	3	9.0	173	543	4300	300	185.7	4.1	3091	M18 x 1.5

AMS Composite Cylinders (UK/Taiwan). Certified for use under PED (CE)/TPED (π) for Europe and DOT/TC for US. Global cylinders.
www.ams-composites.com

Cylinder Name	Design Standard	Certification	Type	Volume (L)	Dia (mm)	Length (mm)	Mass (g)	Pressure (bar)	Mass of hydrogen (g)	wt% H2	Electrical Energy (Wh)	Thread
MC0.8	ISO 11119-2	TPED, DOT	3	0.8	109	185	800	300	16.3	2.0	271	M18 x 1.5
MC1	ISO 11119-2	TPED, DOT	3	1.0	99	235	860	300	20.6	2.3	343	M18 x 1.5
CF88UL (Stock)	ISO 11119-2	TPED, DOT	3	1.4	112	252	940	300	29.7	3.1	495	M18 x 1.5
CF98UL	ISO 11119-2	TPED, DOT	3	1.6	112	273	1000	300	33.0	3.2	550	M18 x 1.5
MC2L (Stock)	ISO 11119-2	TPED, DOT	3	2.0	101	386	1300	300	41.3	3.1	687	M18 x 1.5
MC3	ISO 11119-2	TPED, DOT	3	3.0	115	425	1700	300	61.9	3.5	1030	M18 x 1.5
3 CF	ISO 11119-2	TPED, DOT	3	3.0	115	425	1620	300	61.9	3.7	1030	M18 x 1.5
MC5	ISO 11119-2	TPED, DOT	3	5.0	158	405	3300	300	103.1	3.0	1717	M18 x 1.5
MC6.8	ISO 11119-2	TPED, DOT	3	6.8	160	524	3900	300	140.3	3.5	2336	M18 x 1.5

Composite Technical Systems (Italy). Manufactures type 4 cylinders. www.ctscyl.com/prodotti/h2/?lang=en

Cylinder Name	Design Standard	Certification	Type	Volume (L)	Dia (mm)	Length (mm)	Mass (g)	Pressure (bar)	Mass of hydrogen (g)	wt% H2	Electrical Energy (Wh)	Thread
H2CY2.0	EN12245	TPED	4	2.0	113	369	1229	300	41.3	3.2	687	M18 x 1.5
H2CY3.0	EN12245	TPED	4	3.0	119	440	1600	300	61.9	3.7	1030	M18 x 1.5
H2CT6.0	EN12245	TPED	4	6.0	161	481	2900	300	123.8	4.1	2061	M18 x 1.5
H2CY6.8	EN12245	TPED	4	6.8	161	520	3100	300	140.3	4.3	2336	M18 x 1.5
6.8 Plus	EN12245	TPED	4	7.2	161	545	3300	300	148.5	4.3	2473	M18 x 1.5
H2CY9.0 (Stock)	EN12245	TPED	4	9.0	182	545	4300	300	185.7	4.1	3091	M18 x 1.5
n/a	EN12245	Pending	4	13.0	225	545	5500	300	268.2	4.6	4465	M18 x 1.5

Cobham (UK/US). www.cobham.com/mission-systems/composite-pressure-solutions.aspx

Cylinder Name	Design Standard	Certification	Type	Volume (L)	Dia (mm)	Length (mm)	Mass (g)	Pressure (bar)	Mass of hydrogen (g)	wt% H2	Electrical Energy (Wh)	Thread
6319	n/a	DOT, TC	3	0.7	98	213	953	310	15.7	1.6	261	M18 x 1.5
6211A	n/a	DOT, TC	3	1.6	87	410	1361	310	33.1	2.4	551	M18 x 1.5
6250	n/a	DOT, TC	3	2.0	87	508	1633	310	41.4	2.5	689	M18 x 1.5
6223A	n/a	DOT, TC	3	4.7	133	503	2722	310	99.0	3.5	1649	M18 x 1.5
6148	n/a	DOT, TC	3	6.7	167	479	4218	310	142.5	3.3	2373	M18 x 1.5
6256	n/a	DOT, TC	3	6.8	173	457	4218	310	144.6	3.3	2408	M18 x 1.5
6244	n/a	DOT, TC	3	7.0	167	497	4377	310	149.1	3.3	2483	M18 x 1.5
6109	n/a	DOT, TC	3	9.0	177	551	5216	310	191.1	3.5	3182	M18 x 1.5

Worthington, wide range, manufacture in Europe and the US. Thread options should be conformed with Worthington prior to order.
www.worthingtonindustries.com

Cylinder Name	Design Standard	Certification	Type	Volume (L)	Dia (mm)	Length (mm)	Mass (g)	Pressure (bar)	Mass of hydrogen (g)	wt% H2	Electrical Energy (Wh)	Thread
572	n/a	DOT	3	1.1	n/a	n/a	870	300	22.7	2.5	378	
1001	n/a	DOT	3	1.6	105	305	1179	345	37.1	3.1	618	M18 x 1.5
996UW	n/a	DOT	3	2.0	116	312	1361	310	42.4	3.0	706	M18 x 1.5
724T	n/a	TUV	3	3.0	137	350	2500	300	61.9	2.4	1030	
769MUW	n/a	DOT	3	3.1	122	437	2404	310	65.7	2.7	1095	M18 x 1.5
870	n/a	DOT	3	3.9	n/a	n/a	2500	300	81.1	3.1	1350	
639D	n/a	DOT	3	4.7	140	488	3180	310	99.0	3.0	1649	7/8-14UNF
639M	n/a	DOT	3	4.7	140	488	3300	300	97.0	2.9	1614	M18 x 1.5
845	n/a	DOT	3	6.8	163	521	3500	310	144.2	4.0	2401	M18 x 1.5
914	n/a	DOT	3	7.0	158	556	3987	300	144.4	3.5	2404	M18 x 1.5
1010	n/a	DOT	3	9.0	183	541	4935	310	190.9	3.7	3178	
ALT604	ISO11119-2	TPED, DOT	3	9.2	183	533	5488	310	195.1	3.4	3249	7/8-14UNF
882	n/a	DOT	3	12.6	163	882	6804	310	267.2	3.8	4450	7/8-14UNF

Teijin Engineering import cylinders to Japan, mainly Worthington. www.teijin-eng.co.jp/en/products/environment_energy/ultressa/

Cylinder Name	Design Standard	Certification	Type	Volume (L)	Dia (mm)	Length (mm)	Mass (g)	Pressure (bar)	Mass of hydrogen (g)	wt% H2	Electrical Energy (Wh)	Thread
ALT764J	n/a	JIS	3	1.1	n/a	n/a	700	197	15.7	2.2	262	7/8-14UNF
ALT765J	n/a	JIS	3	2.0	n/a	n/a	1000	197	28.6	2.8	477	7/8-14UNF
ALT639J	n/a	JIS	3	4.7	139	485	3000	300	97.0	3.1	1614	7/8-14UNF
ALT841J	n/a	JIS	3	6.8	160	521	3600	306	142.6	3.8	2375	7/8-14UNF
ALT604H	n/a	JIS	3	9.2	183	533	5488	310	195.1	3.4	3249	7/8-14UNF

Inocom (South Korea) https://inocom21.tradekorea.com/main.do

Cylinder Name	Design Standard	Certification	Type	Volume (L)	Dia (mm)	Length (mm)	Mass (g)	Pressure (bar)	Mass of hydrogen (g)	wt% H2	Electrical Energy (Wh)	Thread
P110C33/34	ISO11119-2, DOT, TC	DOT, TC	3	1.1	110	231	1000	310	23.3	2.3	388	M18 x 1.5
P164C31-1/2W	DOT, TC	DOT, TC	3	1.6	110	309	1250	310	34.8	2.7	579	5/8-18UNF
P200C33-1/2/3W	ISO11119-2, KGS	KGS	3	2.0	109	360	1500	300	41.3	2.7	687	M18 x 1.5
P470C33-1/2/3W	EN122245, DOT, TC	DOT, TC	3	4.7	142	465	3000	300	97.0	3.1	1614	M18 x 1.5
P680C32-1W	DOT, TC	DOT, TC	3	6.8	161	526	3600	300	140.3	3.8	2336	M18 x 1.5
P900C32-1W	DOT, KGS	DOT, KGS	3	9.0	179	538	4500	310	190.9	4.1	3178	7/8-14UNF

Sinoma UAV Cylinders China. http://www.sinoma-cd.com/en/

Cylinder Name	Design Standard	Certification	Type	Volume (L)	Dia (mm)	Length (mm)	Mass (g)	Pressure (bar)	Mass of hydrogen (g)	wt% H2	Electrical Energy (Wh)	Thread
CHG3-C-158-7-30T	IOS11119-2	TPED on request	3	7.0	158	530	3600	300	144.4	3.9	2404	M18 x 1.5
CHG3-C-178-10-30T	IOS11119-2	TPED on request	3	10.0	178	580	4800	300	206.3	4.1	3435	M18 x 1.5

Fuel consumption calculation

- The mass of hydrogen stored in a cylinder is proportional to the pressure.
- The approximate figures at 300bar are: 20.7g/L at 25°C and 21.2g/L at 15°C.
- The efficiency of the fuel cell system varies with load, so the fuel consumption also varies.

$$\text{The fuel consumption (g/h)} = \frac{(\text{Power } W)}{(\text{Energy content of hydrogen } (\frac{\text{Wh}}{\text{g}}) \times \text{Efficiency})}$$

Where: Power is the average power consumed by the UAV in W
Energy content of hydrogen (LHV) is 33.3Wh/g
Efficiency (lhv) of the 650W system is between 0.53 at 650W and 0.56 at 500W
Efficiency (lhv) of the 800W system is between 0.53 at 800W and 0.56 at 700W

Example: If the UAV draws average power of 500W then the fuel consumption will be:

$$\text{Fuel consumption (g/h)} = \frac{500}{33.3 \times 0.56} = 26.8\text{g/h}$$

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