

ALUMINUM L.P.G SEAMLESS CYLINDERS



Metal Mate Product Range

- Welded Steel Cylinder
- Seamless Aluminium Cylinder for LPG
- Composite cylinder for LPG and CNG
- Refurbish and retesting of cylinders



Metal Mate Product Range



ALUMINUM L.P.G SEAMLESS CYLINDERS

Steel Welded Cylinder

Automotive

Household



Composite type 4 cylinder)



Our Customers

International



OEM



After Market



Seamless AL Cylinder Design

“Plastic Collar”

From Impact Resistant (PP)

Firmly secured by the fork and the rubber

“Logo Sticker”

Durable decal sticker

High-impact Material

**High-impact grade of
Polypropylene (PP)**

*Adjusted to the body cylinder
by pressure force*



“True Seamless Aluminum Cylinder”

From A6061 T6

Seamless, Light and rust-free

“Paint free Surface Finish”

Smooth and shine surface

Glass grit shot blasting

Seamless Aluminium Manufacturing Process

AVi



Design of "Replaceable" Plastic Collar

Design for EN 1975 & DOT3AL Standard

We work on every details

"Plastic Collar"

Firmly secured by the fork and the rubber

"Comfortable Handles"

Large handles designed for comfort grip

"Starlock Ring"

Ring can only be removed (pull off) by designed tool.

"Endurance"

Strong structure for drop impacts: 50kg tested

"Cap Holder"

Cr 3+ Coating and Locking plastic collar to the spud

"Rubber"

For tightening and impact absorption

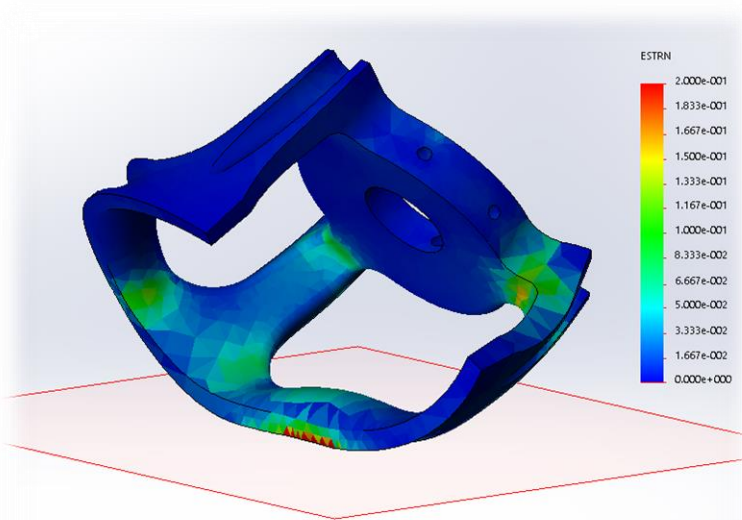
"Neck"

Cylinder neck grooved for locking

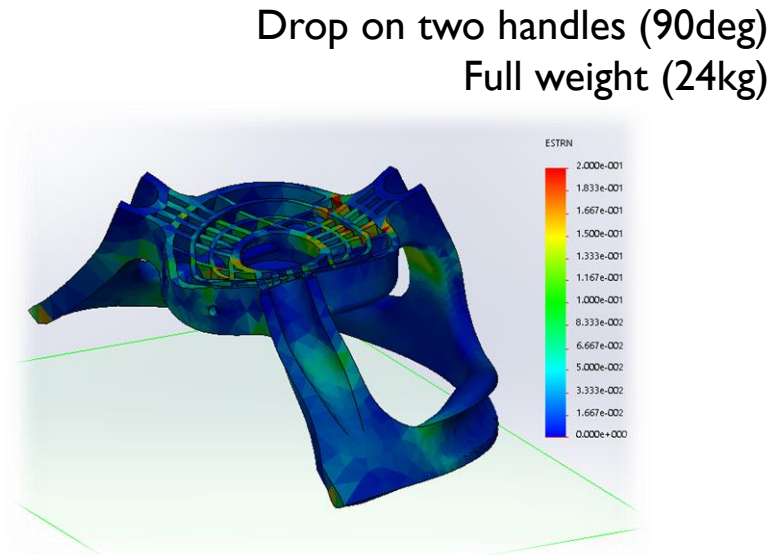


FEA – Drop Test Simulation

Warm colors indicate high “strain” (local deformation)
The latest results show that the plastic does not break and the deformed part does not hit valve.



Drop on one handle (45deg)
Full weight (24kg)



Drop on two handles (90deg)
Full weight (24kg)

These series of analysis helps us tremendously in reinforcing additional structure and removing wasteful weight before mold making process

Replaceable type Plastic Foot ring

Design Development
For Durability

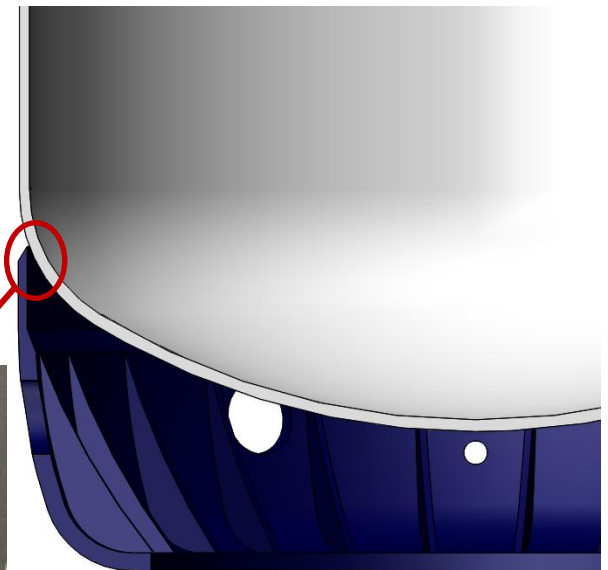


“High-impact Material”

High-impact grade of Polypropylene (PP) is selected for durability at lowest maintenance cost.

“UNDERSIZED” Design

Footring ID is smaller than cylinder OD (~6mm). After assembly, the footring is stretched nearly “yield limit” – providing >2000N (~200kg) holding force.

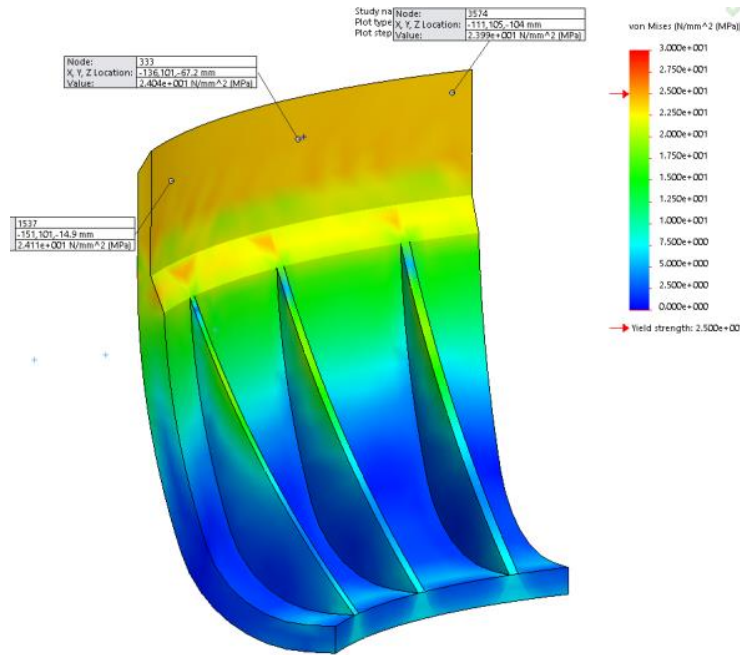


“Improved Adhesion (Knurling)”

Mechanically-improved surface furtherly enhances required forces to separate the footring from cylinder body.

Adhesion Against Pulling

FEA & Prototype Tests



“Pull tests”

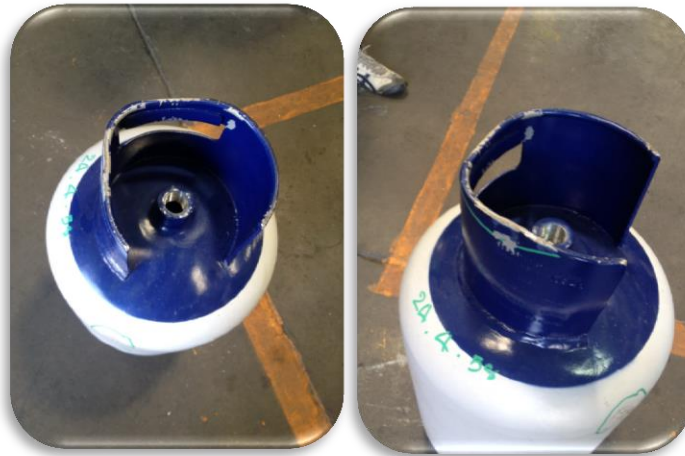
Without knurling, pull tests gave **50-70 kg reading**, depending on surface finishing. With knurling, we constantly achieved **120kg pull force** in recent tests.



“Stretching” in Assembly

The analysis expects residual stress of **24 MPa** holding cylinder bottom. Providing the material in holding area of **100mm²**, we expect **2400 N** holding force. Without knurling, design calculation expects **72kg pull force** (coefficient of friction: 0.3).

I - Stronger and Replaceable Collar



Drop test - Aluminum

[Video](#)



Drop test - Plastic Collar

	Aluminum Collar	Plastic Collar
Testing Standard	ISO 11119-3	ISO 11119-3 & ISO 11117
Size	27.25 L.	27.25 L.
Fill with water	11.5 kg.	11.5 kg.
Testing Height	1.2 meter	1.2 meter
Dropping position	5 positions	5 positions
Result	Dents, deforms and scratches	Scratches, no dents, no deforms

I - Stronger and replaceable Foot ring



Drop test - Aluminum



[Video](#)



Drop test – Plastic foot ring

	Aluminum Footring	Plastic Footring
Testing Standard	ISO 11119-3	ISO 11119-3 & ISO 11117
Size	27.25 L.	27.25 L.
Fill with water	11.5 kg.	11.5 kg.
Testing Height	1.2 meter	1.2 meter
Dropping position	5 positions	5 positions
Result	Dents, deforms and scratches	Scratches, no dents, no deforms

Ref. Standard : ISO20703

Manufacturing

INTERNATIONAL
STANDARD

ISO
20703

First edition
2006-05-01

**Gas cylinders — Refillable welded
aluminium-alloy cylinders — Design,
construction and testing**

*Bouteilles à gaz — Bouteilles rechargeables soudées en alliage
d'aluminium — Conception, construction et essais*

Control Plan

Description	ISO 20703	DOT 3AL
Safety Margin (Burst Test)	2.0 min.	1.5 min.
Material	5052 / 5154 / 5083 A / 6082 / 6061A	6351 / 6061
Welding	Permitted	Not Permitted
Wall Thickness (minimum)	3.1 mm.	3.4 mm.
Design qualification tests	Mechanical testing, Burst testing and Cycling at 12,000 cycles to test pressure	Cycling : 10,000 cycles to test pressure. Burst testing to 2.5 times of service pressure-failure must initiate in sidewall.
Physical tests	One per batch = 200 cylinders (taken in longitudinal direction)	2 per lot = 200 cylinders (specimens 4D bar or gauge length 2 inches with width no over 1.5 inch taken in direction of extrusion approx. 180 degrees from each other . 24t x 6t when wall less than 3/16 inch thick.
Elongation	12% min, for gauge length see ISO 6892	10% for 24t x 6t; 14% for 4D or 2inch size specimen
Hardness test	Cylinders with seamless bodies,the hardness test per ISO 6506 or 6509	None
Flattening and bend test	Bend test on weld in accordance with ISO 7438	(1 per lot) Flattening to 9 times wall thickness or (2 per lot) an alternative bend test per ASTM E 290-77
Burst test	(1 per batch) 2.0 times test pressure extensive failure mode requirements.	No lot test requirement
Hydrostatic test	(each cyl.) Hydraulic test ,no. volumetric expansion test	(each cyl.) Volumetric expansion test to 5/3 times service pressure. Permanent expansion must be less than 10% of total expansion.

Seamless Aluminium Merits

- I. Light Weight
- II. Thermal conductivity
- III. Seamless Safety
- IV. Corrosion resistance
- V. “The Green Cylinder” 100% Recyclable
- VI. Best Value For Money

Weight comparison

	Composite Type 4	Seamless ALUMINIUM	Welded STEEL
			
Water Capacity (L.)	26.2	26.2	26.2
Tare weight (kg.)	6.6	6.4	13

Lower Transportation Cost

The most popular transportation to the target customers (restaurants and stalls) is by motorbike. One motorbike can deliver 1 - 3 tanks at a time(15 Kg/ tank)

Cylinder	Steel	Aluminium
Quantity	3	3
Size, (Kg.)	15	20
Net Weight, (Kg).	90	90
Gas Delivered, (Kg).	45	60
Save, (%)	-	33%
		

Thermal Conductance Comparison



Thermal Conductivity Coefficient

@ Room Temperature

○ Mild Steel	45-64 ^c	W/m.K
○ A6061 Aluminium	167 ^a -173 ^b	W/m.K
○ Glass-fiber Composite	0.167 ^d	W/m.K
• Fiber Glass	0.04 ^e	W/m.K
• Epoxy	0.35 ^e	W/m.K
○ HDPE	0.42-0.51 ^e	W/m.K
○ Copper	400 ^c	W/m.K

Remark ยิ่งค่าเยอะ ยิ่งนำความร้อนได้ดี

References

^a ASM Aerospace Specification Metals, Inc. (US-FL). (2015, March 18). *Aluminum 6061-T6; 6061-T651*. Retrieved from ASM Aerospace Specification Metals: <http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA606116>

^b AZoNetwork UK Ltd. (UK). (2015, March 18). *Aluminium Alloy 6061 - Composition, Properties, Temper and Applications of 6061 Aluminium*. Retrieved from AZoM Materials: <http://www.azom.com/article.aspx?ArticleID=3328>

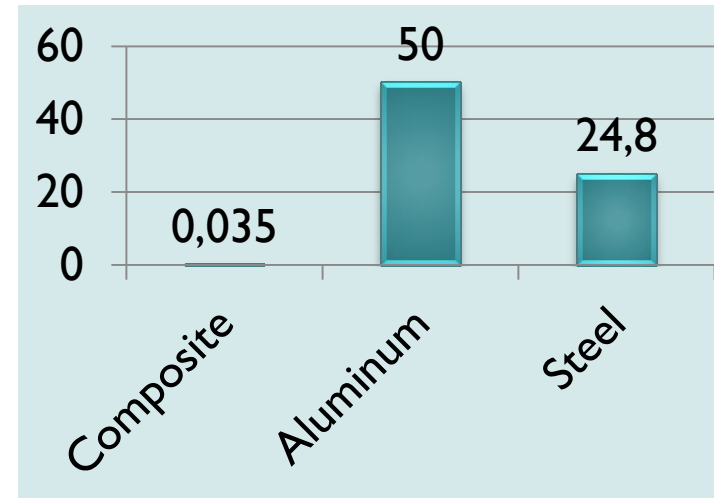
^c Engineering Edge, LLC (US-GA). (2015, March 18). *Thermal Properties of Metals, Conductivity, Thermal Expansion, Specific Heat*. Retrieved from Engineering Edge - Solution by Design: http://www.engineersedge.com/properties_of_metals.htm

^d Progelhof, R. C. (1976). Methods for Predicting the Thermal Conductivity of Composite Systems: A Review. *Polymer Engineering and Science*, 615.

^e *Thermal Conductivity of some common Materials and Gases*. (2015, March 18). Retrieved from The Engineering Toolbox: http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html

Heat Transfer Coefficient

- Heat Transfer Coefficient = $\frac{k}{t}$
 - k – Conductivity
 - t – Thickness



	LPG4 Composite Cylinder	Carbon Steel Cylinder	Aluminum Cylinder
Conductivity	0.167 (Composite) 0.45 (HDPE)	54.5 (avg.)	170 (avg.)
Sidewall Thickness	4mm (Composite) 2mm (HDPE)	2.2mm	3.4mm (DOT-3AL)
Heat Transfer Coefficient = $\frac{k}{t}$ (KW / m ² .K)	Composite: 0.042 (= $\frac{0.167}{4}$) HDPE: 0.225 (= $\frac{0.45}{2}$) TOTAL: 0.035 (= $\frac{1}{(\frac{1}{0.042} + \frac{1}{0.225})}$)	24.8 (= $\frac{54.5}{2.2}$)	50.0 (= $\frac{170}{3.4}$)

Thermal Conductance Experiment

Hypothesis	<p>Different type of cylinder has different thermal conductance that affect the efficiency of the gas usage observing by</p> <ul style="list-style-type: none">• The remaining gas left in the cylinder• The height of the flame during the test
Independent Variables	<p>The type each cylinder</p> <ul style="list-style-type: none">• Composite cylinder• Seamless Aluminum cylinder• Steel cylinder• room temperature - 40 degree celcius
Dependent variable	<ol style="list-style-type: none">1. The height of the flame during usage2. Amount of remain LPG in the cylinder
Controlled variable	<ol style="list-style-type: none">1. Amount of liquid LPG before the test2. Stove and accessories
Experimental results	<p>It was found that the performance of composite cylinder was inefficient due to the flame has drop drastically to 5 cm. after 6th hrs. The amount of gas left in the tank was 8.11 kg comparing to others. The aluminum seamless cylinder had a better performance than the steel cylinder . It was also gave a very good rate of usage at 0.8 kg./ hrs.</p>

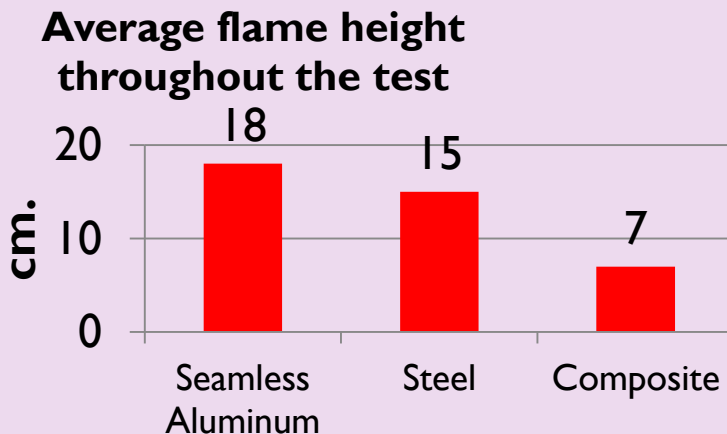
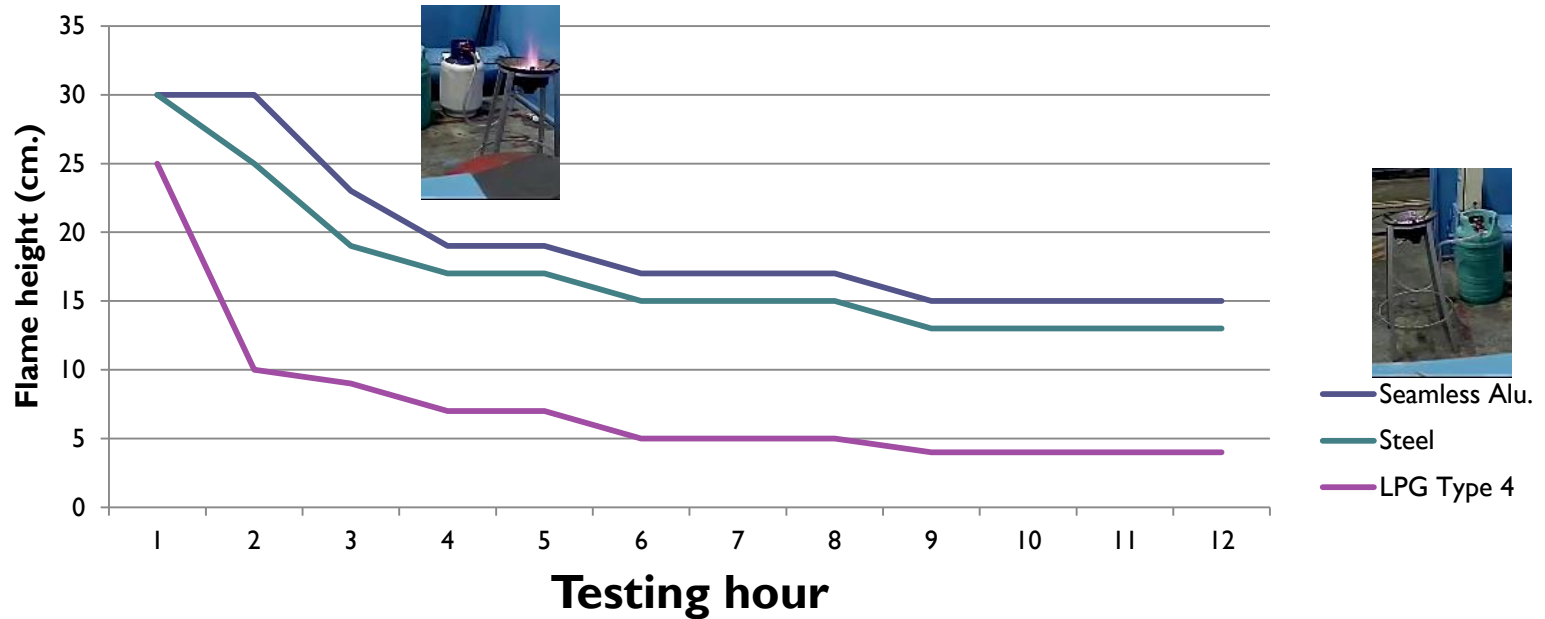
Weight before testing

Cylinder type	Tare weight (kg.)	Weight before testing (kg.)	
		Total	LPG only
Steel cylinder	13.71	23.91	10.20
Composite cylinder	6.95	17.06	10.11
Aluminum cylinder	6.93	17.01	10.08



Thermal Conductivity Test

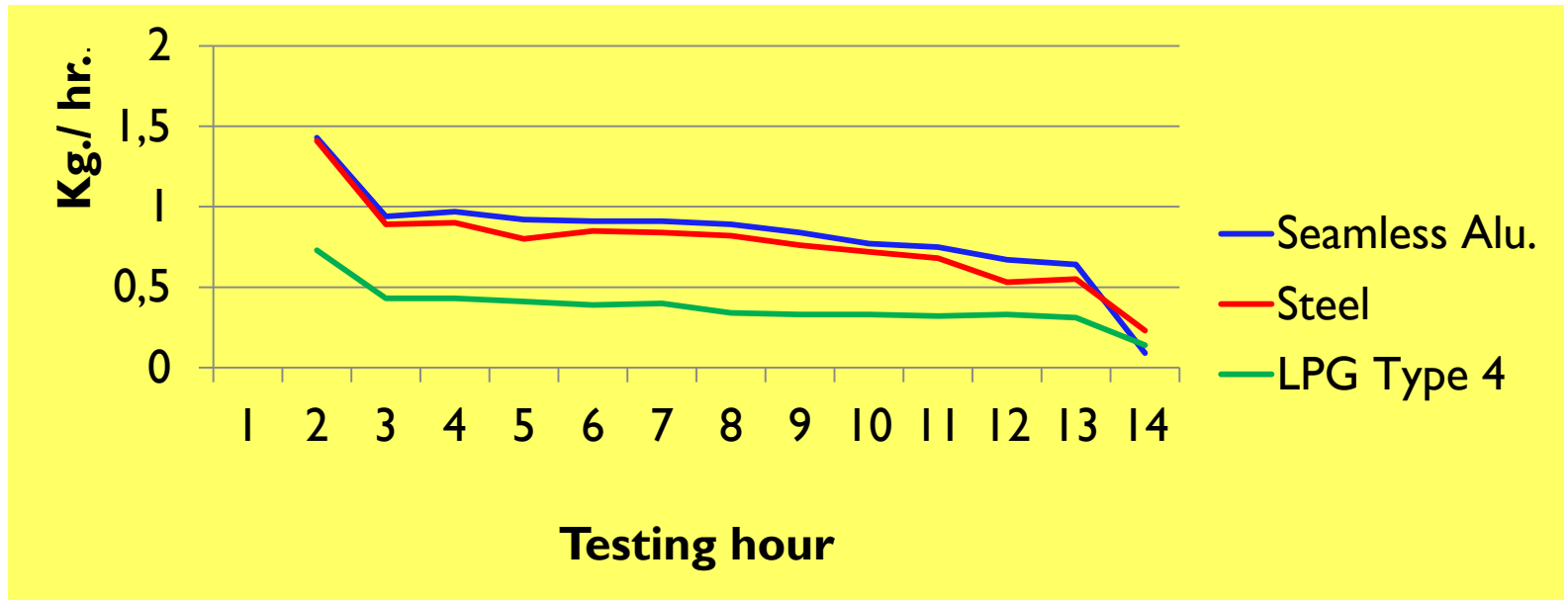
Thermal Conductance Flame height



Aluminum Seamless cylinder give a better flame comparing with :

- Steel 16.67 %
- Composite 61.11 %

Rate of gas usage per hour



Rate of gas usage per hour


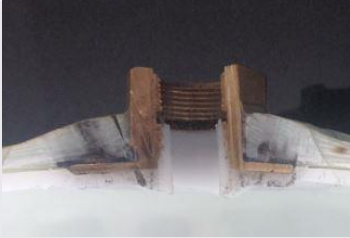

- Seamless Aluminum 0.81 kg./ hr.
- Steel 0.66 kg./ hr.
- Composite 0.35 kg./ hr.

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Seamless Aluminum has a higher rate comparing with :-

- Steel 18 %
- Composite 57 %

“Seamless” Safety

Type	Structure	
Welded Steel	<p>4 Welding <i>Leakage cylinder at the refurbishing plant approx. 0.05% *</i></p>	
Composite	<p>Possibility of leak at the joint at the plastic to brass spud</p>	
Seamless Aluminium	<p>Completely Seamless Zero Chance to Leak</p>	

Material Recyclability



- Aluminum is a material that can recycle effectively because :
 - Recycling A6061 AL required only 5% of the energy used to produce new Aluminum.
 - The energy required to recycle AL is much lower than steel due to its lower melting point.
 - Unlike plastic, Aluminum can be recycle infinitely without downgrading in material property.
 - Pressure envelop of composite cylinder which make from glass fiber and epoxy cannot be recycled

Corrosion resistance

Material	Salt Spray Testing 120 hrs.	Salt Spray Testing 240 hrs.
STEEL	 <p data-bbox="832 819 1035 858">No blister</p>	 <p data-bbox="1296 822 1818 919">Some blister, many rust on scratch surface</p>
ALUMINUM	 <p data-bbox="832 1353 1035 1392">No blister</p>	 <p data-bbox="1456 1353 1659 1392">No blister</p>

Cost of owner & Value for Money Comparison

- Formula

$$\text{Cost of Owner} = \frac{(\text{Purchasing Price} + \text{Testing} + \text{Maintenance}) - \text{Scrap Value}}{\text{Service Lifetime}}$$

- Assumption

	Steel	Composite	Aluminum
Size (kg.)	12.5	12.5	12.5
Lifetime (yrs.)	25	20	30
<i>*** Usage Life of the cylinder is not mentioned, MTM estimated an average usage life only for this analysis</i>			
Retest (yrs.)	5	5	5
Jacket Change (yrs.)		5	
Collar/Footing Change (yrs.)	10		10

Lifetime Cost Steel cylinder

Steel	Size	Testing fee	Maintenance Fee	Scrap
Size	24 ltr			
Service Lifetime	25			
Buy Price	\$26.75			
Retest cycle (yrs.)		5		
Retest frequency		4		
- Hydrostatic Test	-	\$0.34		
- Expansion Test	-	\$0.53		
Collar & Footring Replacement cycle (yrs.)			10	
Collar & Footring Replacement frequency			2	
- Collar & Footring Change	-		\$6.03	
- Painting	-		\$2.27	
Scrap Value (per kg.)				\$0.25
Scrap weight (kg.)				12
Total Cost	\$26.75	\$3.48	\$16.61	\$2.99
Cost per Year				\$1.75

Calculation

$$= \frac{[26.75 + (3.48) + (16.61)] - 2.99}{25}$$

Cost of Steel cylinder = 1.75 US\$/year

25

Remark

1. Steel Scrap Price - \$0.25/ kg.
2. Weight - 12 kg.
3. Service Lifetime = 25 yrs



Lifetime Cost - Seamless Aluminum

Aluminum	Size	Testing fee	Maintenance Fee	Scrap
Size	24 ltr			
Service Lifetime	30			
Buy Price	\$41.99			
Retest cycle (yrs.)		5		
Retest frequency		5		
- Hydrostatic Test	-	<u>\$0.34</u>		
- Expansion Test	-	<u>\$0.53</u>		
Collar & Footring Replacement cycle (yrs.)			10	
Collar & Footring Replacement frequency			2	
- Collar & Footring Change	-		<u>\$3.42</u>	
- Painting	-		<u>\$2.27</u>	
Total Maintenance Fee	-		-	
Scrap Value (per kg.)				\$1.71
Scrap weight (kg.)				\$6.50
Scrap Value - Plastic CR/ FR (per kg.)				\$0.28
Total Cost	\$41.99	\$4.35	\$6.84	\$12.49
Cost per Year				<u>\$1.36</u>

Calculation = $\frac{[41.99 + 4.35 + 6.84 - 12.49]}{30}$

Cost aluminum cylinder = **1.36 US\$/year**

Remark

1. Aluminum Scrap Price - \$1.71/ kg.
2. Weight - 12 kg.
3. Service Lifetime = 30 yrs



Lifetime Cost Composite

Composite	Size	Testing fee	Jacket & Retest	Scrap
Size	24 ltr			
Service Lifetime	20			
Buy Price	<u>\$41.99</u>			
Retest cycle (yrs.)		5		
Retest frequency		3		
- Hydrostatic Test	-	<u>\$0.34</u>	-	
- Expansion Test	-	<u>\$0.53</u>	-	
Jacket & Retest (yrs.)	-	-	5	
Jacket & Retest frequency	-	-	3	
Jacket & Retest Fee	-	-	<u>\$8.55</u>	
Scrap Value (per kg.)				\$0.28
Scrap weight (kg.)				\$2.00
Scrap Value - Plastic CR/ FR (per kg.)				
Scrap weight (kg.)				
Total Cost	\$41.99	\$2.61	\$25.66	\$1.12
Cost per Year				\$3.46

Calculation

$$= \frac{[41.99 + 2.61 + 25.66 - 1.12]}{20}$$

Cost composite cylinder = 3.46 US\$/year

Remark

1. Plastic Scrap Price - \$0.28/ kg.
2. Weight - 12 kg.
3. Service Lifetime = 20 yrs



Lifetime Cost Comparison

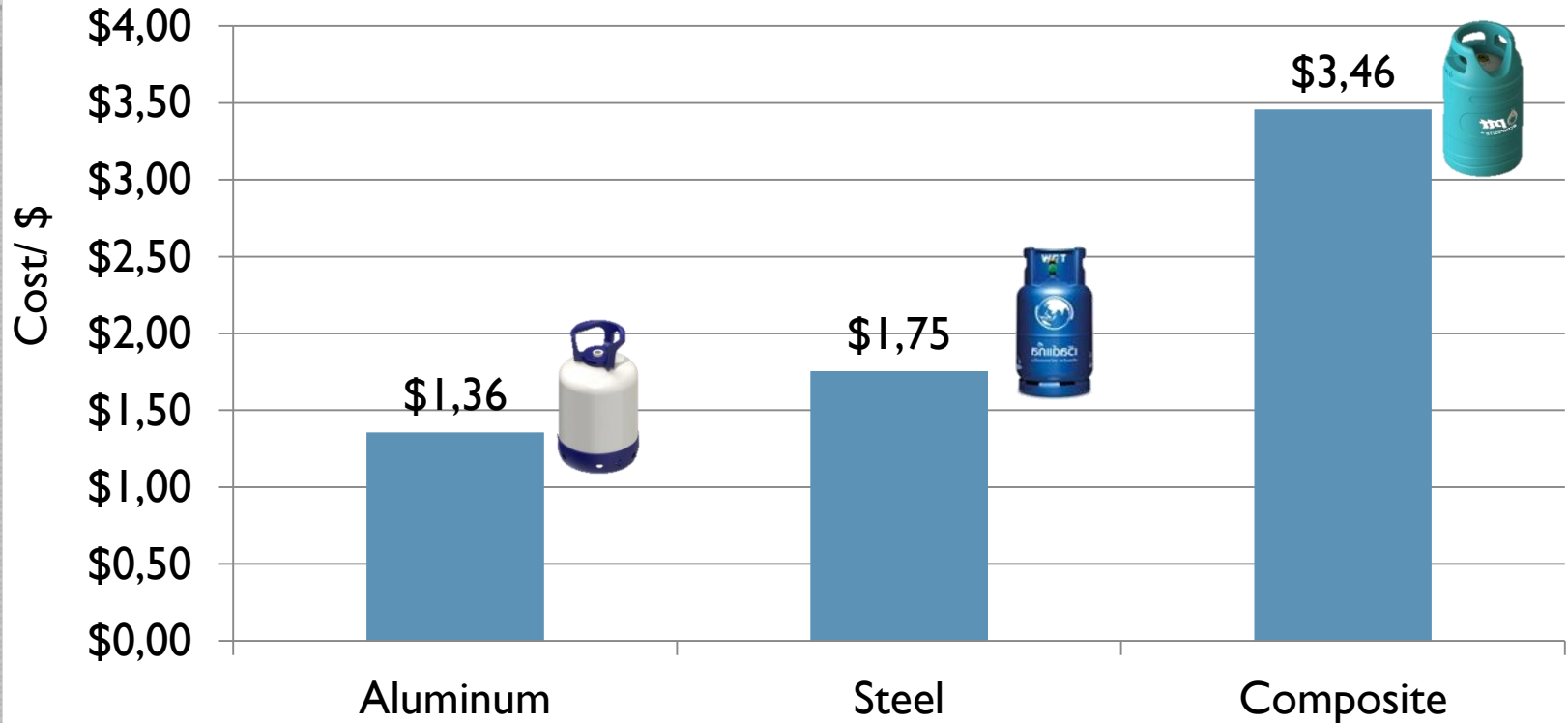
	Steel	Composite	Aluminum
Size	24 ltr	24 ltr	24 ltr
Service Lifetime	25	20	30
Buy Price	<u>\$26.75</u>	<u>\$41.99</u>	<u>\$41.99</u>
Retest cycle (yrs.)	5	5	5
Retest frequency	4	3	5
- Hydrostatic Test	<u>\$0.34</u>	<u>\$0.34</u>	<u>\$0.34</u>
- Expansion Test	<u>\$0.53</u>	<u>\$0.53</u>	<u>\$0.53</u>
Total testing fee	<u>\$3.48</u>	<u>\$2.61</u>	<u>\$4.35</u>
Jacket & Retest (yrs.)		5	
Jacket & Retest frequency		3	
Jacket & Retest Fee		\$8.55	
Total Jacket & Retest		<u>\$25.66</u>	
Collar & Footring Replacement cycle (yrs.)	10		10
Collar & Footring Replacement frequency	2		2
- Collar & Footring Change	<u>\$6.03</u>	-	<u>\$3.42</u>
- Painting	<u>\$2.27</u>	-	-
Total Maintenance Fee	<u>\$16.61</u>	-	<u>\$6.84</u>
Scrap Value (per kg.)	\$0.25	\$0.28	\$1.71
Scrap weight (kg.)	12	2	6.5
Scrap Value - Plastic CR/ FR (per kg.)			\$0.28
Scrap weight (kg.)			4.89
Total Scrap	<u>\$2.99</u>	<u>\$1.12</u>	<u>\$12.49</u>
Total Cost	<u>\$43.86</u>	<u>\$69.14</u>	<u>\$40.70</u>
Cost per Year	<u>\$1.75</u>	<u>\$3.46</u>	<u>\$1.36</u>

Following points shows the reasons Seamless AL cylinder has lowest cost of owner

1. Aluminum has highest Scrap cost compare to Steel and composite. (AL scrap is 57% of the new AL price)
2. Cost of changing plastic CR and FR for AL cylinder are lower. No hot work required. (only 56% of the cost of re-welding CR and FR for steel Cylinder.)
3. Longer life time due to better corrosion resistance (compared to steel) and no limit life at 20 years (compared to composite)
4. Seamless AL has lower cost of leak testing because it has no weld joint compare to welded cylinder and no need to change plastic jacket every time you do leak testing
5. No repainting required due to the special surface treatment



Cost of owner

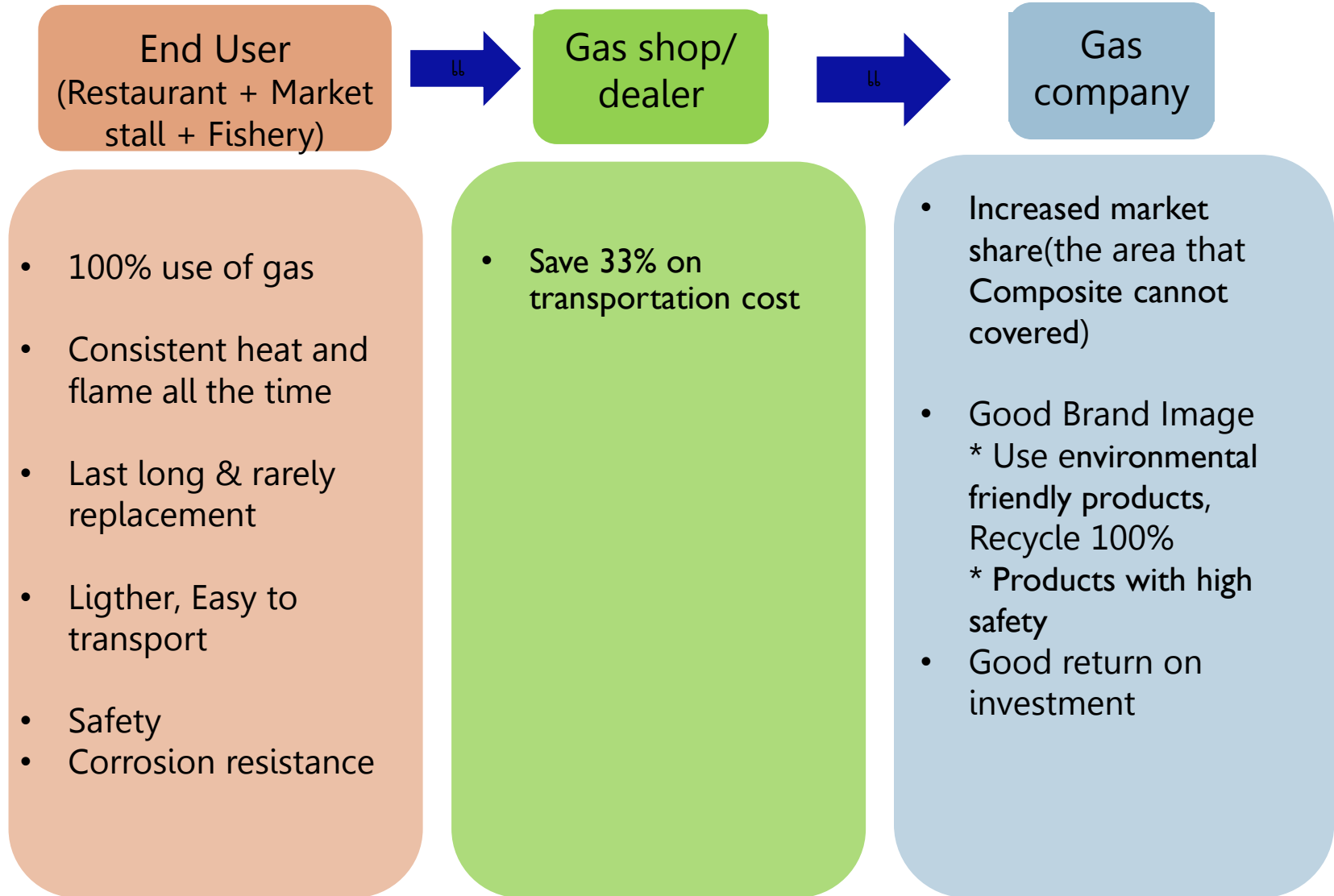


Cost comparison with steel cylinder

- Seamless aluminum with Plastic CR & FR
- Composite

cheaper 23 %
more expensive 97%

Value to Supply Chain



Bonfire Test

Bonfire Test Aluminum cylinder

	Aluminum Seamless Cylinder
Testing Standard	ISO 11119-3
Size	27.25 L.
Fill with LPG	80% of water capacity
Start to blow at	4.58 min.
Fire Temp.	574 °C
Result	Not Explode

Start to blow out at 4.58 min.



