

# **Large Diameter High Pressure Gas Cylinder Manufactured By Piercing and Drawing**

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**-In recent years due to the oil price fluctuation and air pollution caused by vehicles, specially in big cities, the need for a reliable substitute source of the energy increased dramatically and among the various sources of energies such as solar, wind, bio-fuels, H<sub>2</sub>, LPG, etc. the natural gas found its way to the top specifically because it is widely available and also in form of Bio-gas is renewable and clean and further development on bio-gas to bio-methane (upgraded biogas to pipeline quality standard), demonstrates that natural gas is a diverse, - renewable resource and not only a traditional fossil fuel.**

**- All these represents a new potential for the natural gas industries including the high pressure cylinder manufacturer as the natural gas should be stored in high pressure (20MPa and More) state (So called compressed natural gas or CNG).**

**-One of the major difficulties for using the CNG as fuel, was the limited range of the travelling on CNG which brought the necessity for bigger cylinders in order to store more natural gas and increase the travelling distance between two fillings.**

**There are generally three common manufacturing processes for producing the seamless cylinders based on the three different type of the raw material as per followings:**

- 1) Steel Plate (Deep Drawing)**
- 2) Seamless Tubes (Hot Spinning)**
- 3) Steel Billet (Piercing and drawing)**

**In next slides the three manufacturing processes are going to briefly introduced and then compare their limitations, advantages and disadvantages.**



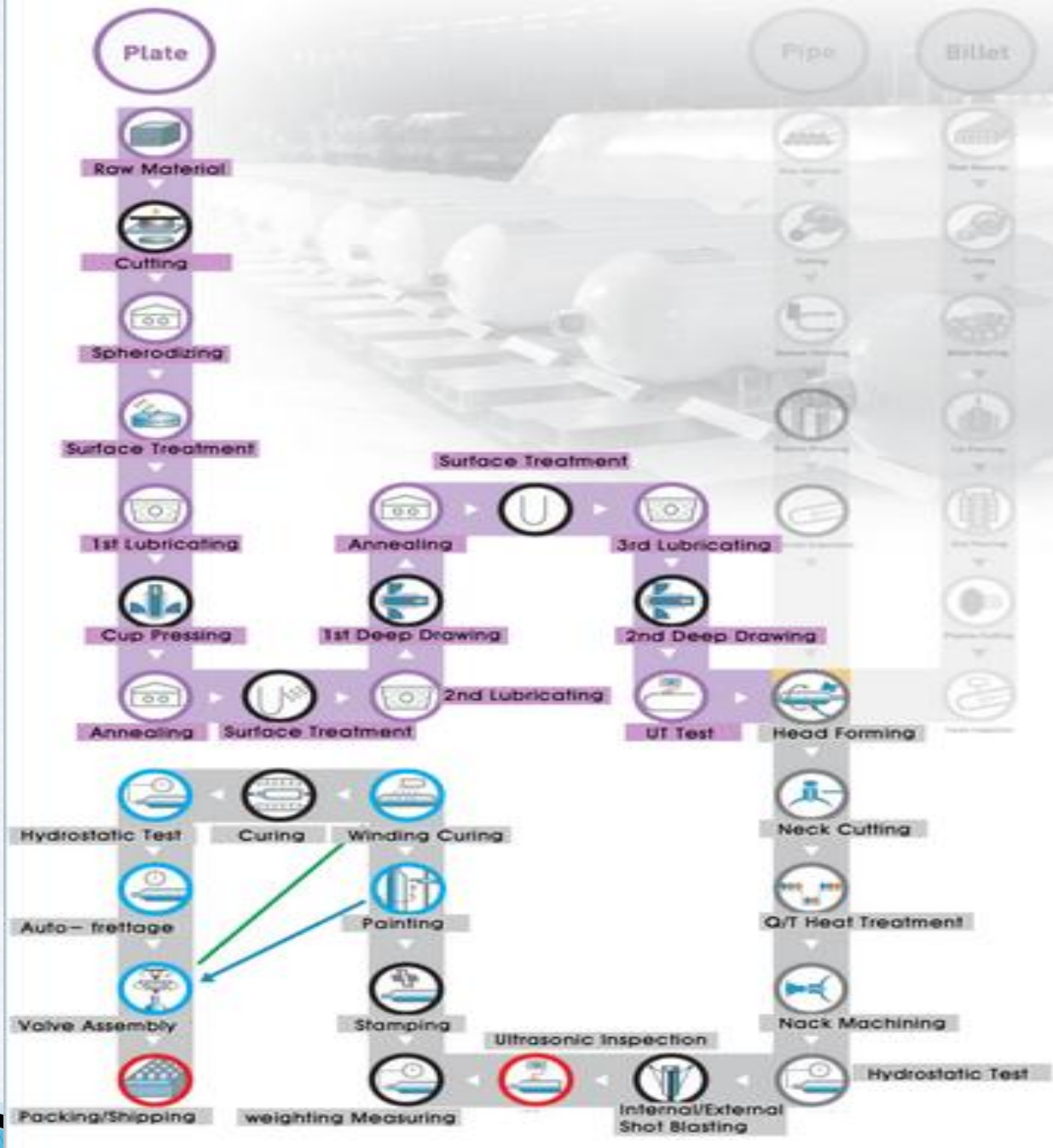
# Various Manufacturing Processes



Generally the high pressure Gas Cylinders are produced by either of the following processes (Different raw material):

- 1) **Plate Punching** (includes Annealing, lubricating, cold deep drawing, Annealing & Phosphating, Lubricating, cold deep drawing, etc.)
- 2) **Seamless Tubes Hot Forming/Spinning** (includes cutting to length, regional heating, base spinning, shaping, internal dressing, etc.)
- 3) **Billet Piercing** (includes Billet cutting, overall heating, cupping & hot piercing, wall thickness reduction by hot/cold drawing, etc.)

# 1) Plate Punching



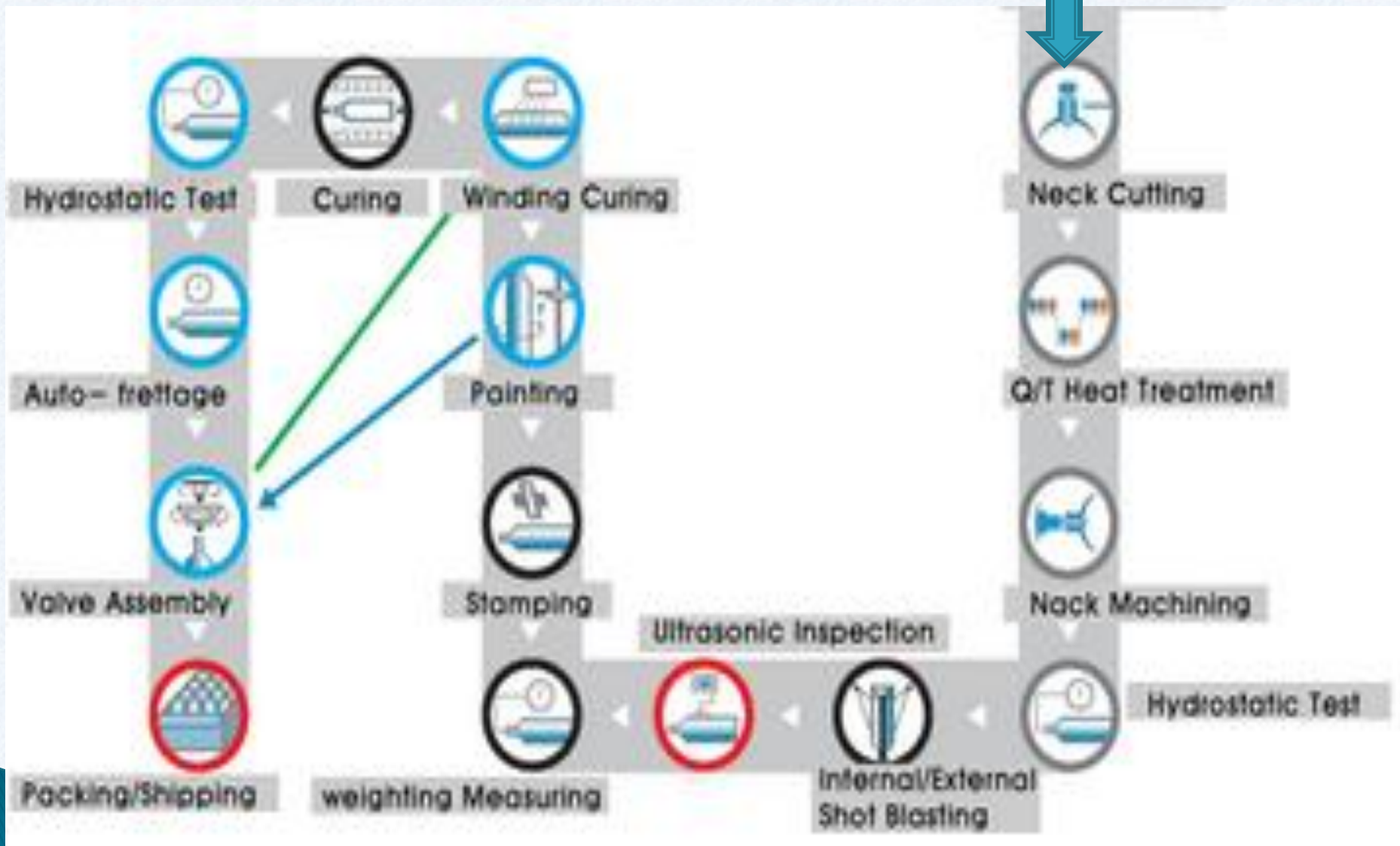


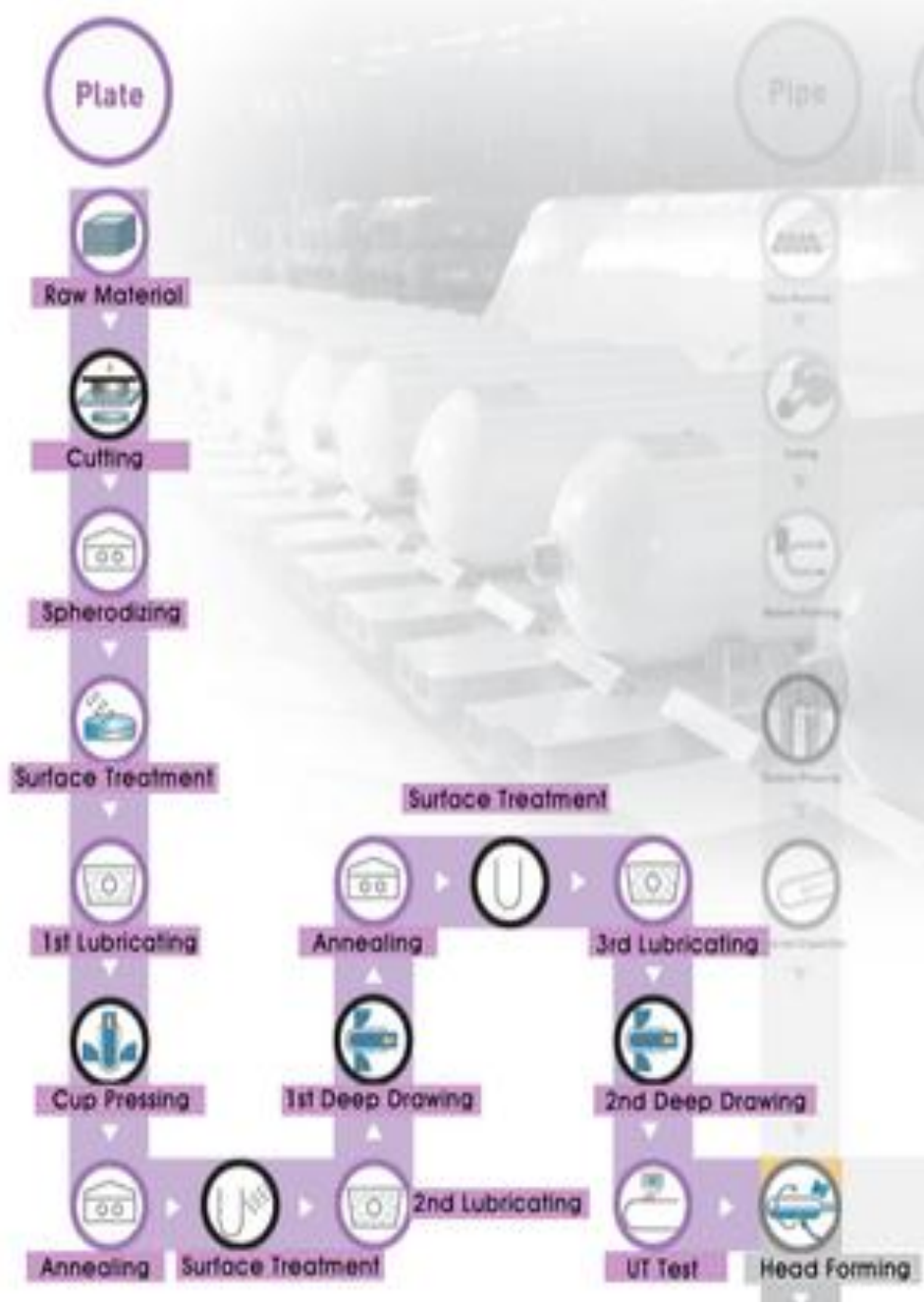






# Common Processes (After Neck Forming)





# 1. Plate Process Summary

## • Advantages:

- Uniform wall thickness
- The weight is lighter in comparison with other method
- Higher Capacity to Weight ratio
- If qualified (no wrinkle, ruffles, etc) it might have more uniform and smooth appearance

## • Disadvantages:

- Great risk of producing wrinkles/ruffles on shell side of the cylinder due to processing which may lead to further massive explosion (as many times happened in Italy)
- Numerous production machineries which needed higher preliminary investment
- Longer production time due to multi pass squeeze, annealing (phosphating treatment) and cold drawing
- Complicated production procedure
- Environmentally Polluted (due to several acid cleaning and annealing)
- Lower productivity thus more expensive
- Superior management and supervision is required (Hard to keep the quality uniform)



# Tube Process Summary



## ▶ Advantages:

- ▶ Relatively less preliminary investment and less work area required
- ▶ Higher productivity and cost efficiency (less equipment)
- ▶ Relatively uniform thickness on shell which resulted lower weight/volume ratio (depends original seamless tube as raw material)

## • Disadvantages:

- Higher cost of raw material (seamless tube)
- Some large diameter tube has made by hot-expansion which could affect the safety of high pressure cylinder during filling and usage.
- Due to Spinning process limitation, risk of lack of proper fusion at the middle of bottom, or having inclusions, cracks and other defects is high
- Lack of proper and reliable method for detecting the defects on base (Cracks, pores, inclusions, etc.)
- Base thickness can not be guaranteed for long term use, as thickness may decrease at touchdown part.
- The thickness in transition segment from shell to base generally is not increasing progressively (mostly equal) which can affect the larger expansion as well as leakage due to fatigue affect after couple of years in service
- The final product size of cylinders is limited to available seamless tube sizes in the market

# Billet Process Summary

## Advantages:

- ▶ Easy access to raw material (Billet)
- ▶ Better stress distribution over the base as no spinning process is involved (Forging to mould)
- ▶ Due to uniform and progressive thickness profile from shell to base, the stress level on most severe zone is adequate and significantly safer during service life
- ▶ Any specific and non standard size can be produced to meet specific requirement of the buyer and space limitations
- ▶ Higher productivity and efficiency than plate process

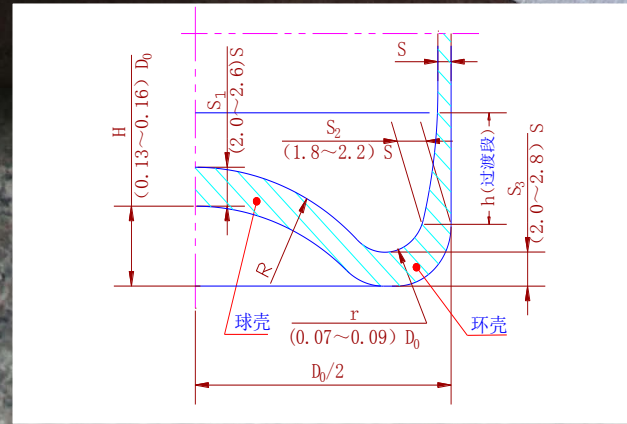
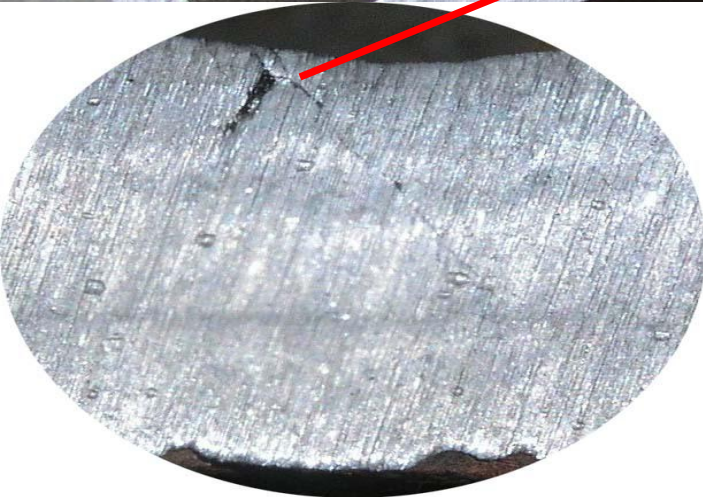
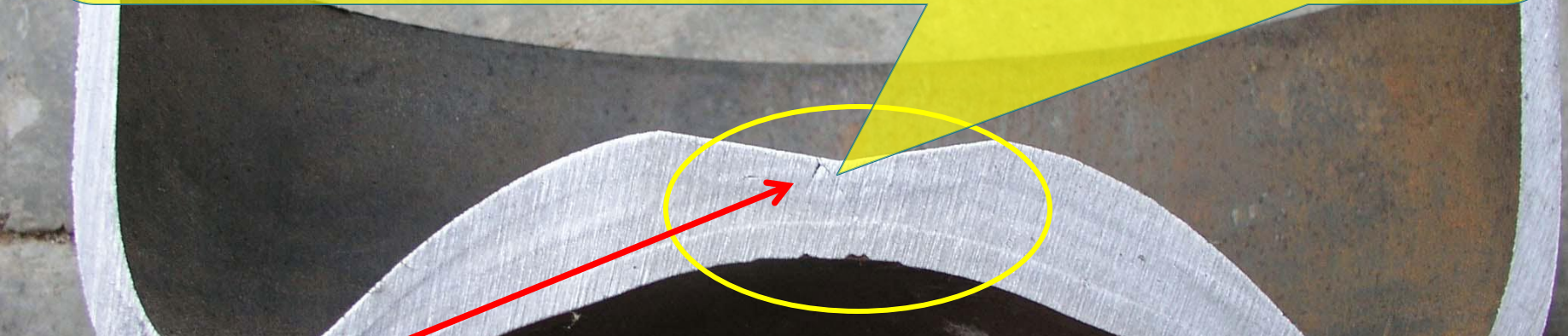
## Disadvantages:

- ▶ High preliminary investment and large production area required
- ▶ Surface quality specially in shell portion may have more beauty defects due to easy oxidation, scratches, grooves and other thermal processing defects on surface which make it not sound.
- ▶ Relatively higher Weight/Capacity (Kg/L) ratio
- ▶ Higher production and management control costs



# Tube (Bottom formed by Spinning)

**The Central Zone of Bottom:** Due to spinning process, likely lack of proper fusion at the central zone may lead to crack, lamination, folding, lap, etc. without any effective and reliable examination methods. (The function of internal dressing stage is to deal with such possible defects)





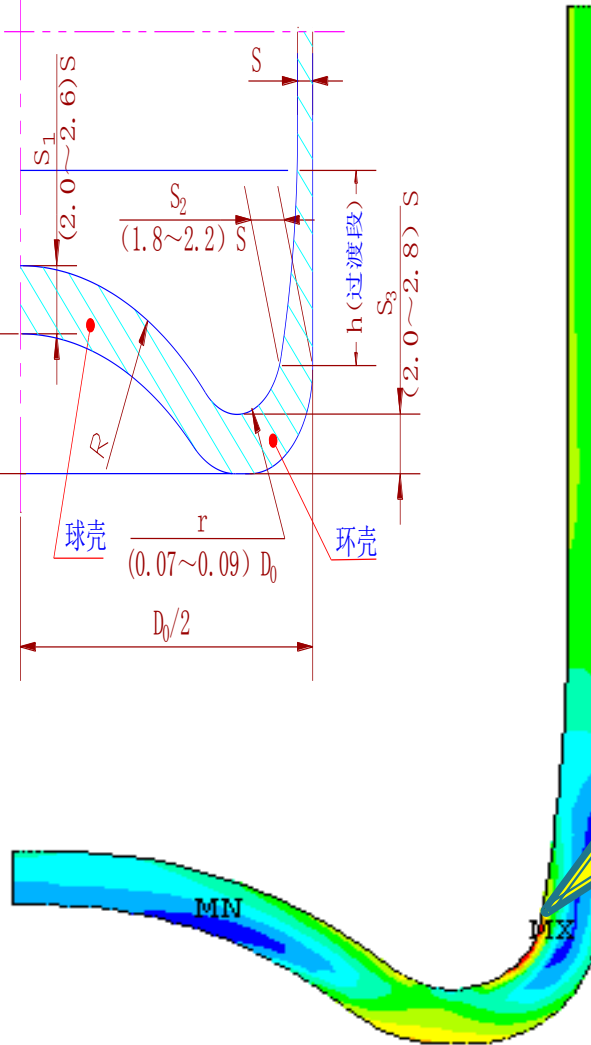
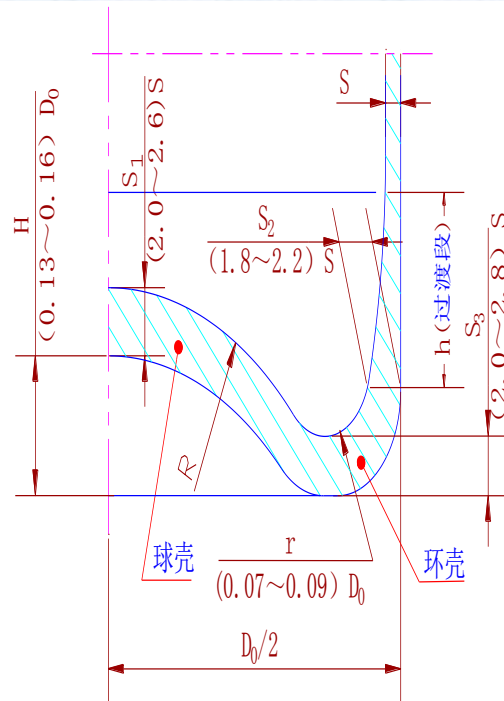
# **Billet (Bottom formed by Piercing/Cupping)**

## **The Central Part of Cylinder Bottom**

**Billet Piercing form the bottom with uniform thickness and shape according to the mold profile with no defect and discontinuity.**



# Finite Element Stress Distribution



Maximum Stress at transition zone , which requires the thickness to be progressively increased to min. 2 times the wall thickness



# Tube (Bottom formed by Spinning)

**The Transition Segments:** Acc. To ISO and IS standards, for obtaining proper stress distribution, the thickness of cylinder shall increase progressively (Min. 2 times) in the transition region between cylindrical wall and base, however due to limitations of spinning process (size and shape restrictions), it is very difficult to achieve the required thickness which definitely shorten the service life due to fatigue.





# Billet (Bottom formed by Piercing/Cupping)

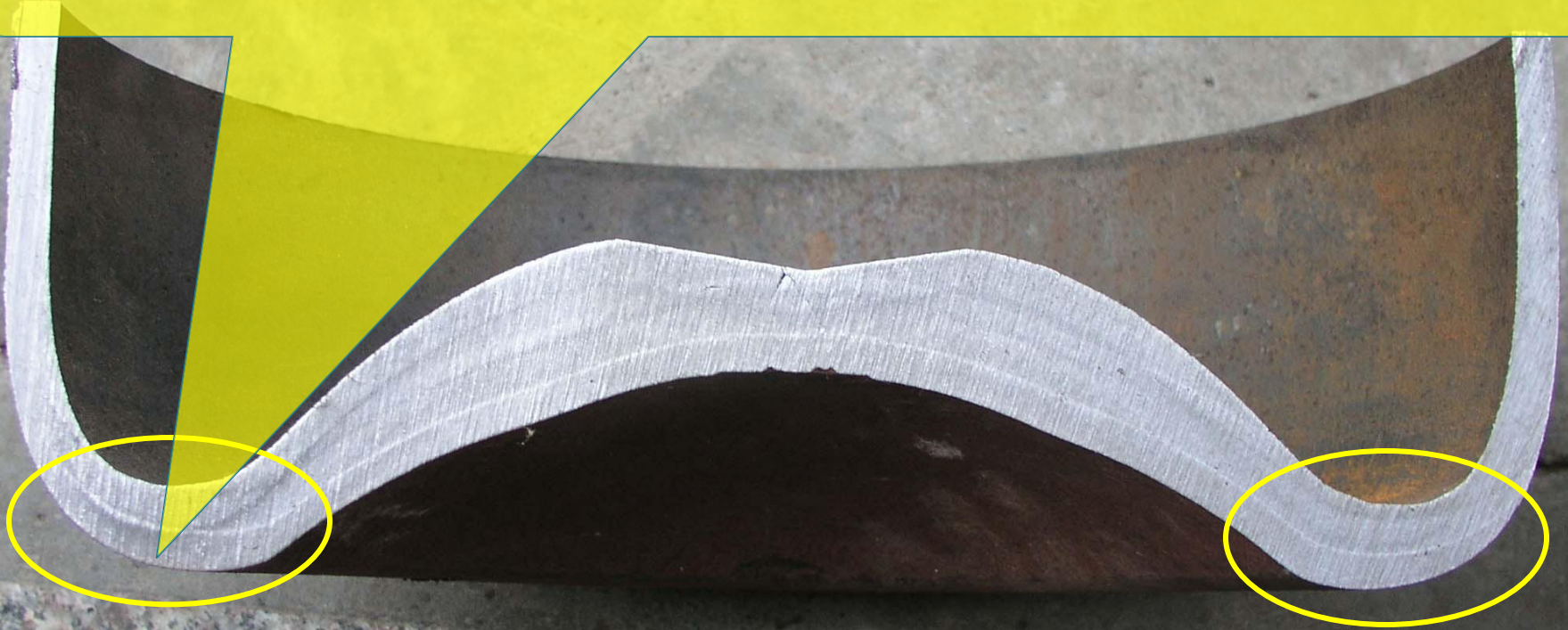
**The Transition Segment:** The required shape and thickness gradient on most severe and critical segment (Highest stress level) of the base can easily obtained by Mould design and profile, providing a satisfactory stress distribution and higher fatigue cycles (Service life)





# Tube (Bottom formed by Spinning)

**The Touchdown Part:** The shape and size of the cylinder's touchdown part restricted by the spinning processes, that made the corrosion allowance thickness with deficiency (thinner than 2 times the wall thickness) and would affect the service life because of corrosion during usage.





# Billet (Bottom formed by Piercing/Cupping)

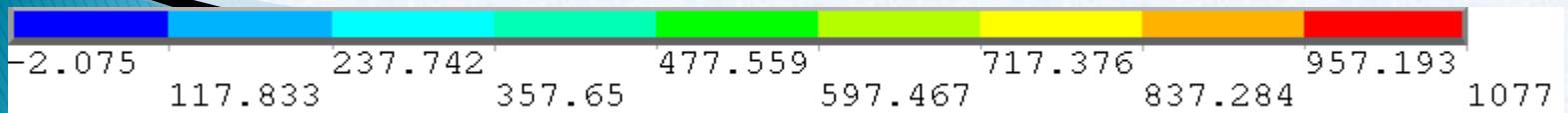
**The Touchdown Part:** The shell's shape and size of the billet extruded cylinder as usual is a function of mould profile therefore can entirely meet the requirements of design and guaranty the safe usage during its designated service life.



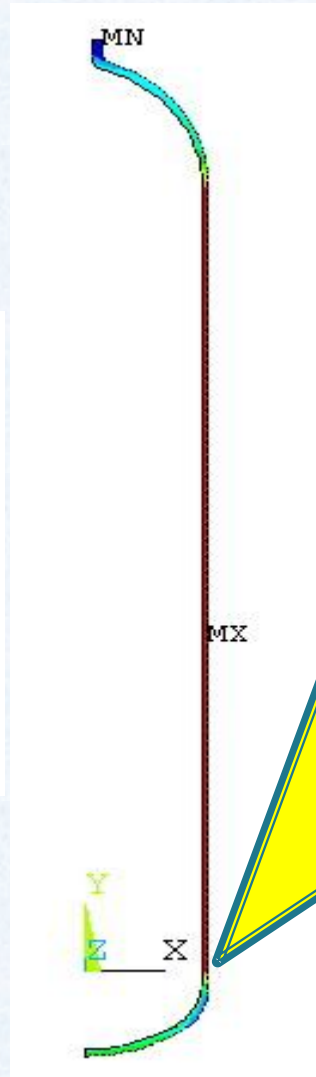
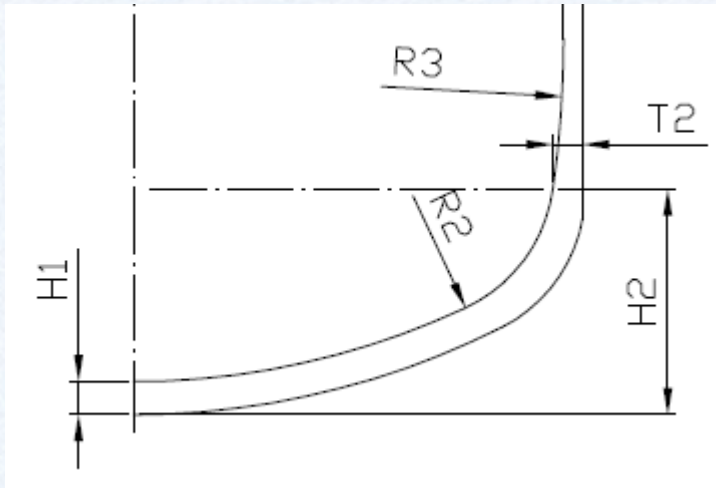


# Finite Element Stress Analysis (Tube)

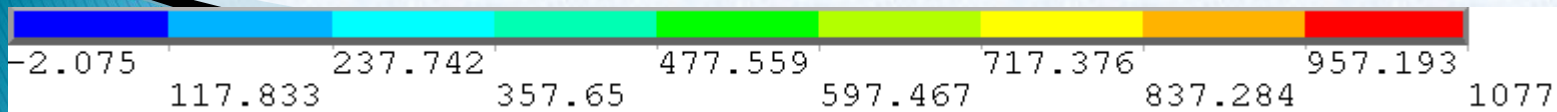
Due to even wall thickness at the connection point, relatively higher stress is resulted at the transition point of the body (Shell) to the base



# Finite Element Stress Analysis (Billet)

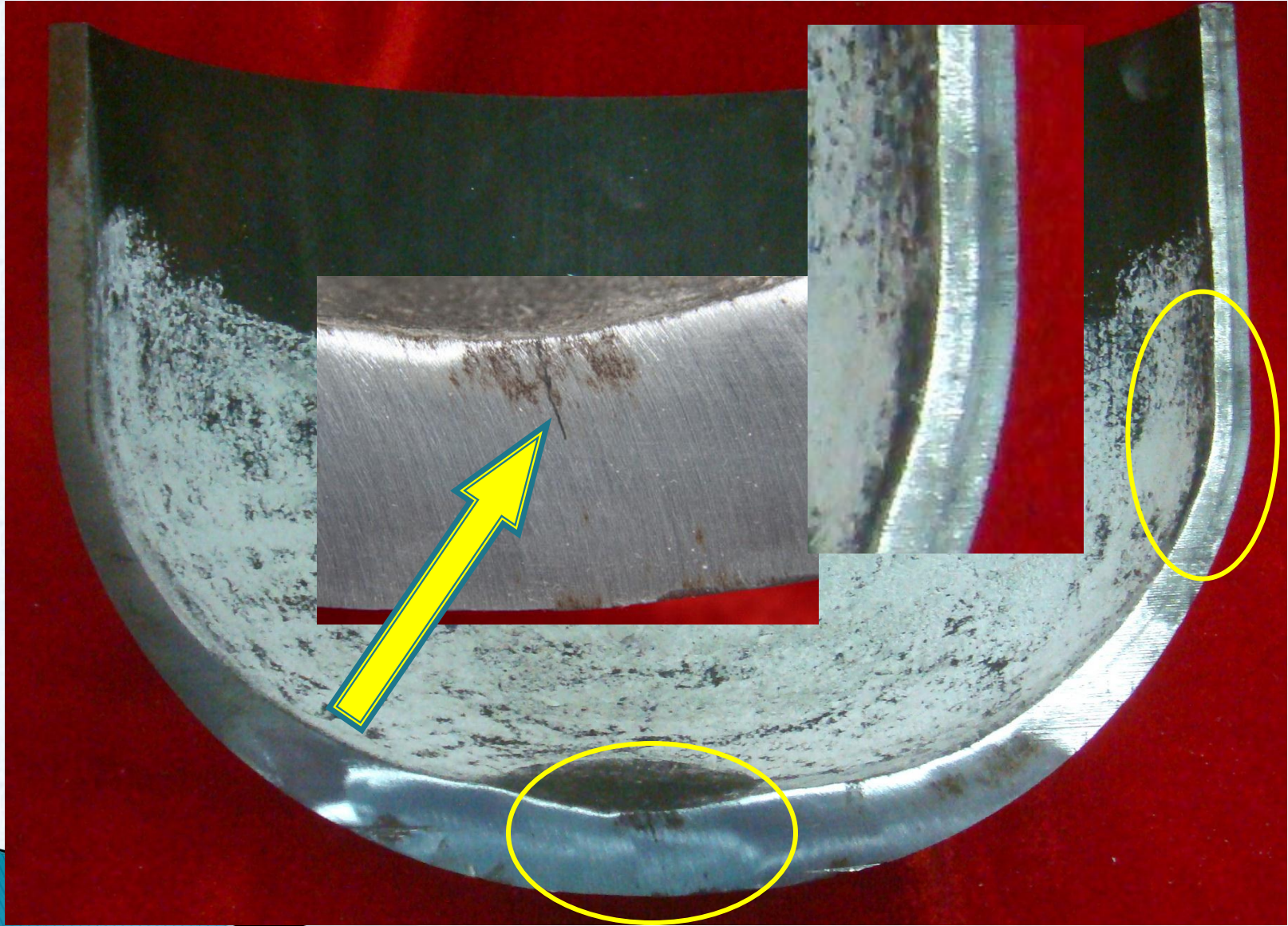


Since the profile of the bottom is resulted from forging the material into the designated mould, the thickness can be increased as your mould design before reaching to the bottom, as a result more appropriate stress distribution will be achieved which is impossible to have in tube cylinders formed by spinning process



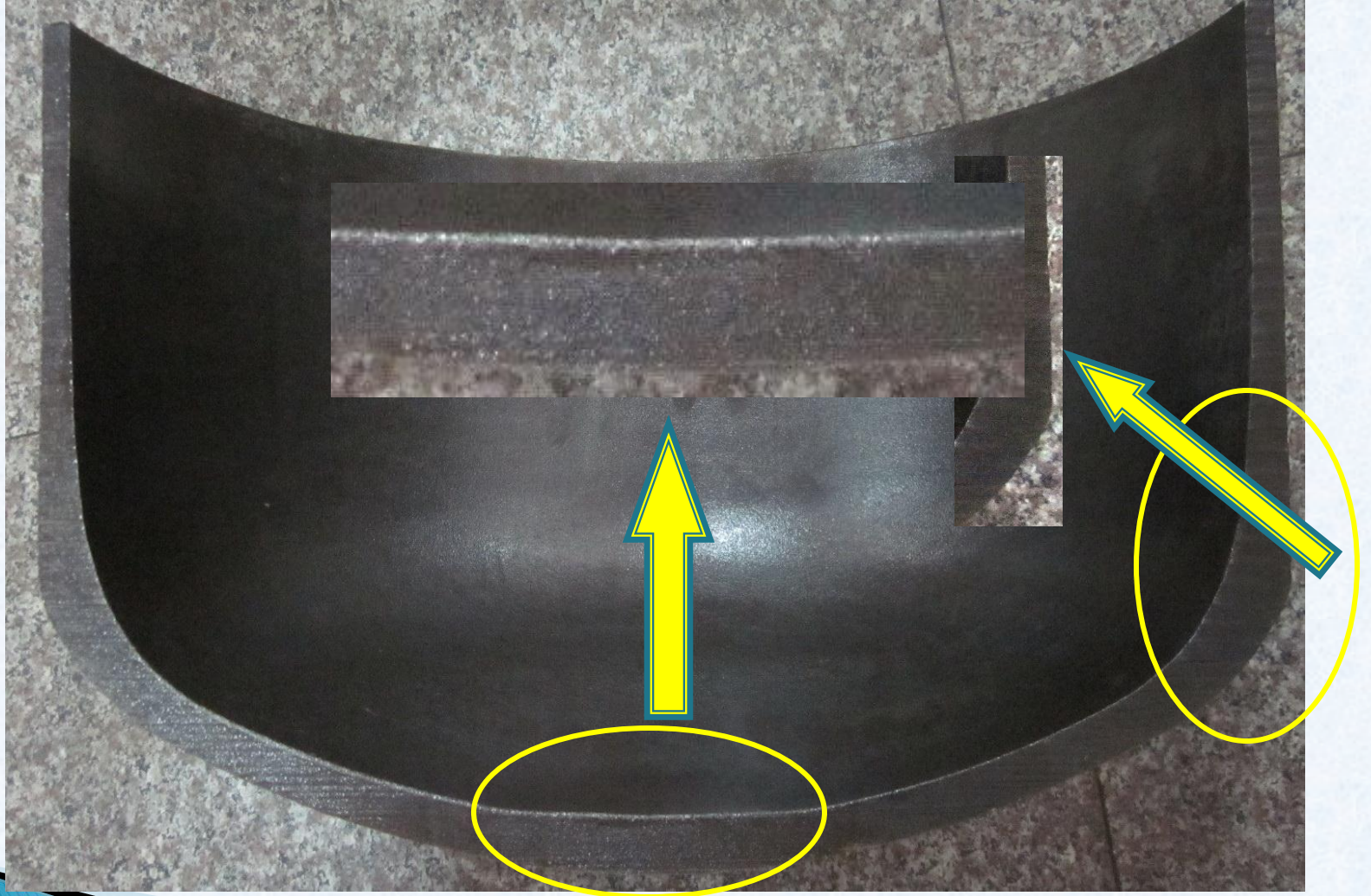


# Finite Element Stress Analysis (Tube)





# Finite Element Stress Analysis (Billet)



**-In general the tube based cylinders are less safe and reliable for producing the seamless cylinders, specially for larger diameter cylinders (as it had seen that in some cases, the larger diameter seamless tubes were manufactured by hot expansion process, which would be very dangerous for storing high pressure gases and caused many explosions, as reported), and this is why in United States the tube cylinders are unlikely to be used neither for NGVs nor industrial gases and even in Europe nowadays the major cylinder manufacturers (e.g: Faber) are concentrating on other two manufacturing processes.**



**-As the Plate deep drawing process, is not appropriate for mass production of Seamless cylinders (lower productivity thus more expensive) and also is not an environment friendly process, the development of Billet piercing process which was commonly used for diameter up to 279 mm, became important.**

**-In billet piercing method, as the bottom of the cylinder will be formed through forging the hot billet into the mould, the bottom profile (which is the major factor for ensuring the safety of the cylinders during the service life), can be precisely designed.**

**-In order to produce large diameter cylinder through billets piercing process, heavy duty vertical press machine (for cup making by forging the billet into mould) and horizontal press machine (for further drawing) are required.**

**-The larger the diameter, the heavier duty equipment are required and eventually controlling the quality and operating the equipment getting more difficult, specially for controlling the wall thickness which is the technical bottleneck for producing large diameter cylinders safely.**



**-Zhejiang Jindun Pressure Vessel Co. Ltd. Through comprehensive research, successfully develops the billet process and became the first and only CNG cylinder manufacturer in the world with capability of producing cylinders larger than 356 mm (406, 420mm) in diameter by implementing the following techniques:**

- 1- Vertical heavy duty press (over 3600 tons)**
- 2- Fast assembly and disassembly of Hot Billets**
- 3- Wall thickness control in Vertical press forming/forging**
- 4- Wall thickness control in horizontal press forming/drawing**
- 5- Precise heat treatment process (Q+T) through providing Even Temperature distribution and cooling (Q)**

**JINDUN**

Φ356 / 150.8L / 138.3KG  
Length: 1820MM

**JINDUN**

Φ356 / 100.8L / 101.2KG  
Length: 1270MM





Φ 229





Φ 356  
150L



## Size (Diameter & Water Capacity)

<b>Industrial Cylinders (Tube)</b>	<b>Φ100, Φ102, Φ108, Φ140, Φ152, Φ159, Φ168, Φ178</b>	<b>2L-20L</b>
<b>Industrial Cylinders (Billet)</b>	<b>Φ204, Φ219, Φ229, Φ232, Φ267, Φ279, Φ325</b>	<b>10L-120L</b>
<b>CNG Cylinders (Billet)</b>	<b>Φ229, Φ232, Φ267, Φ279, Φ325, Φ340, Φ356, Φ406, Φ420</b>	<b>20L-200L (Φ356:150L) (Φ420:200L)</b>

## Obtained Manufacturing Standards:

- ISO 11439 (CNG)
- NZS 5454 (CNG)
- GB 17258 (CNG)
- DOT-3AA/TC-3AAM
- ISO 9809-1/-2 /-3
- EN 1964-1/-2
- IS 7285-2
- JIS 8241
- GB 5099



## Obtained Management & Product Certificates:

- **ISO/TS 16949**
- **ISO 9001; ISO 14001; ISO 18001**
- **B1 & B3 (China)**
- **DOT-3AA (USA)**
- **TC-3AAM (Canada)**
- **IS 7285-2 (India)**
- **Classification Society: CCS, DNV, LR, GL, BV, ABS, RINA**
- **ISO 9809-1 / EN 1964-1:TPED Certificate**
- **KGS AC212**



# **Thank You For Your Kind Attention!**

**Ma Xia Kang  
President  
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