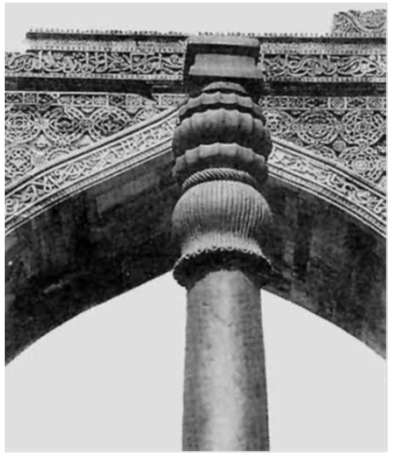
26/09/2019



Powder Metallurgy

By K.G.S.Prasad Rao
Consultant Metallurgist

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What is Powder Metallurgy ?

Definition of Powder Metallurgy

Study of properties and manufacturing techniques of metal powders for various applications

Eg : Metal powders: copper, Copper alloys, Steel , stainless steel, Graphite, Etc

To understand the concept we have to go through the broad classification of metal powders based on their Manufacturing technique.

IRON PILLAR IN DELHI

- IRON PILLAR IN DELHI HAS A LAND MARK IN THE HISTORY BETWEEN YEAR 35-414 AD- INDIAN METALLURGISTS HAVE CRAFTED 6.5 TONS OF STRUCTURE

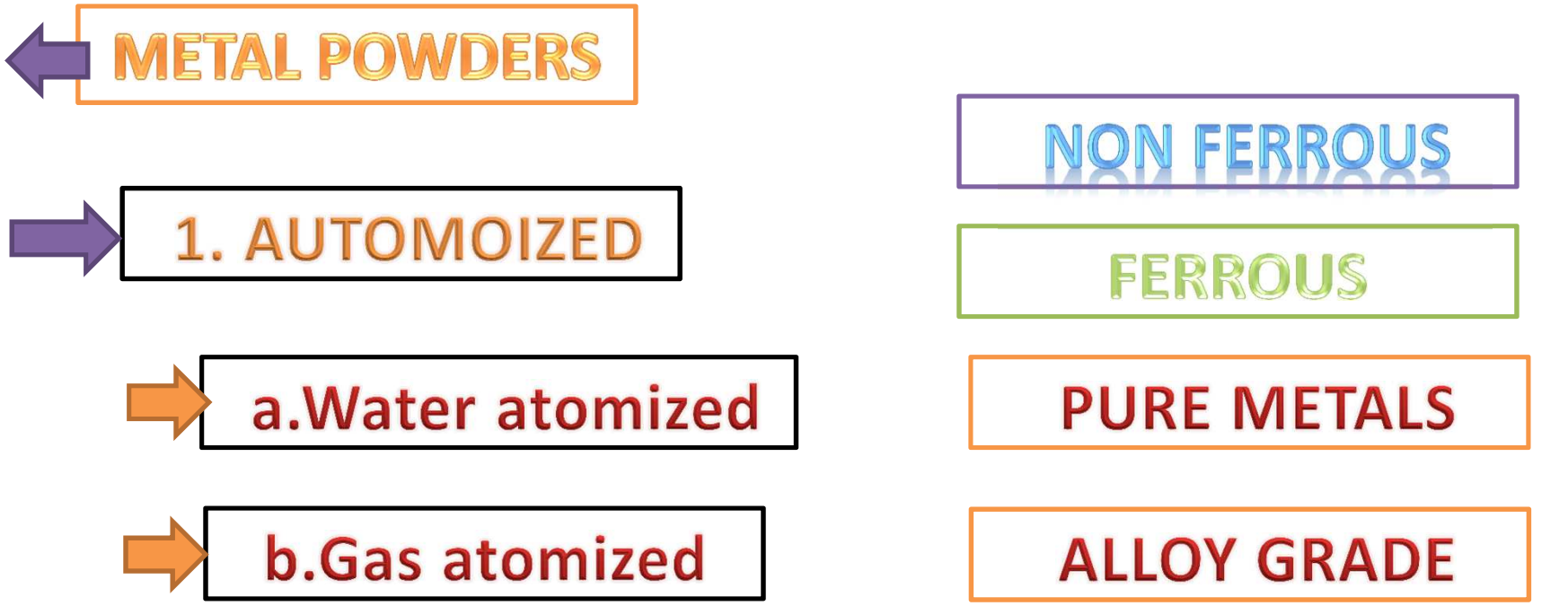
Total height – 7.2 Mtrs, 16 Inch diameter,
built during the period of king Chandragupta - 2

History of Powder Metallurgy

THE USAGE OF METAL POWDERS / POWDER METALLURGY IS RECORDED BACK IN 19TH CENTURY

- POWDER METALLURGY WAS BEING USED BY EGYPTIANS IN 3000BC - "Powder Metallurgy and Particulate Materials Processing" by Randall M. German.
- 20TH CENTURY – ELECTRICAL CONTACTS
- 1930 – CEMENTED CARBIDES AND POROUS BEARINGS
- SECOND WORLD WAR – CHRYSTLER(AMPLEX DIVISION), GMC (MORAINE PRODUCTS),US GRAPHITE, BROUND BROOK OIL LESS BEARING (ONLY COMPANY MFG SINTERED BEARING)

Classification of metal Powders



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Manufacturing powder by Automization

What is atomisation of metal powder ?

Atomisation is a process where the molten metal is rapidly cooled with fine particles of Cooling Media

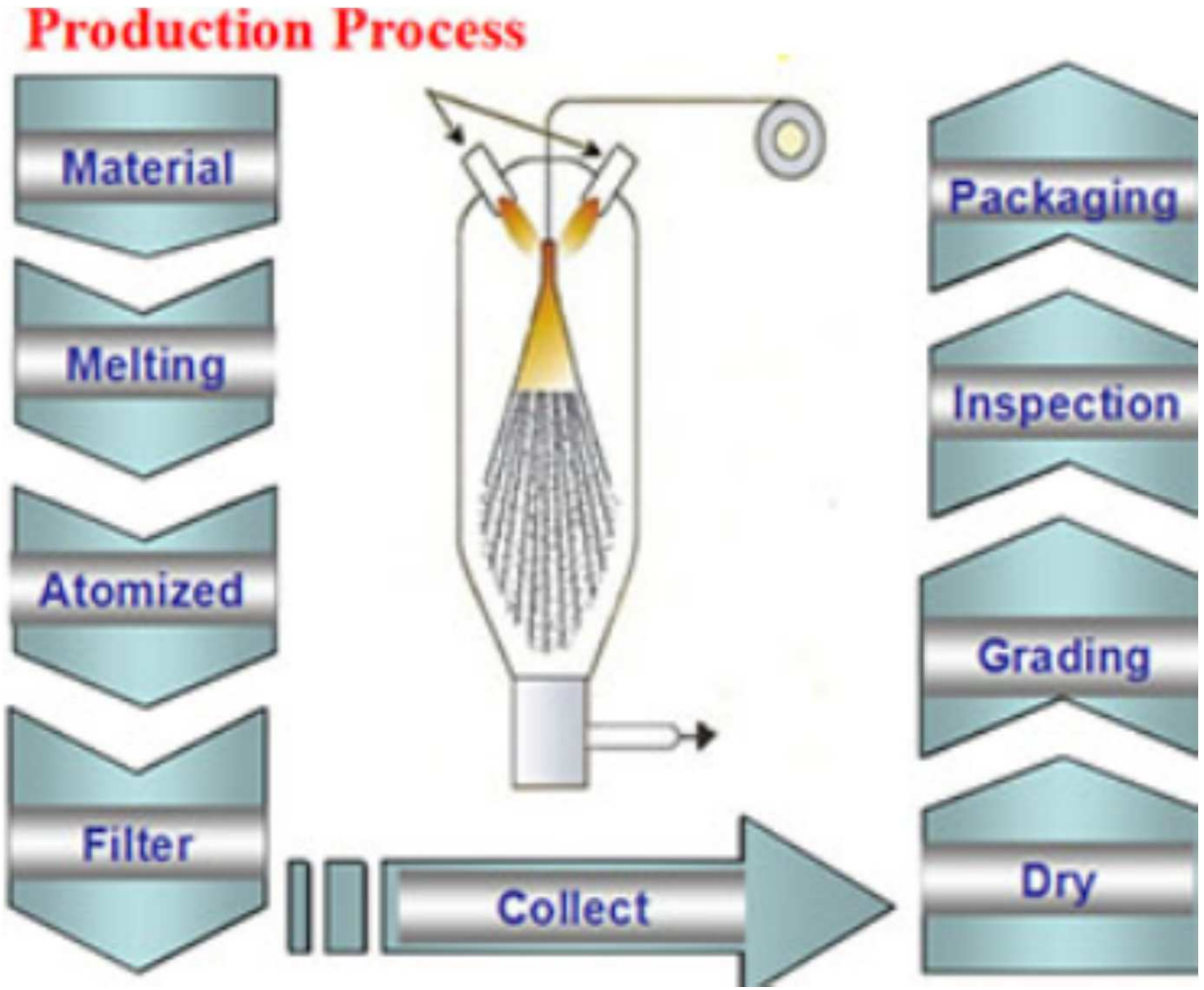
What are the types of Automisation ?

Water Atomised - Water is the rapidly cooling media

Gas Atomised - Argon / Nitrogen gas as a rapidly cooling media

Centrifugally Atomised - Can be either water or Gas but there is centrifugally Rotated electrode (suitable alloy) against a Tungsten arching electrode
Automisation is followed through

Powder Atomisation process



Water Automisation

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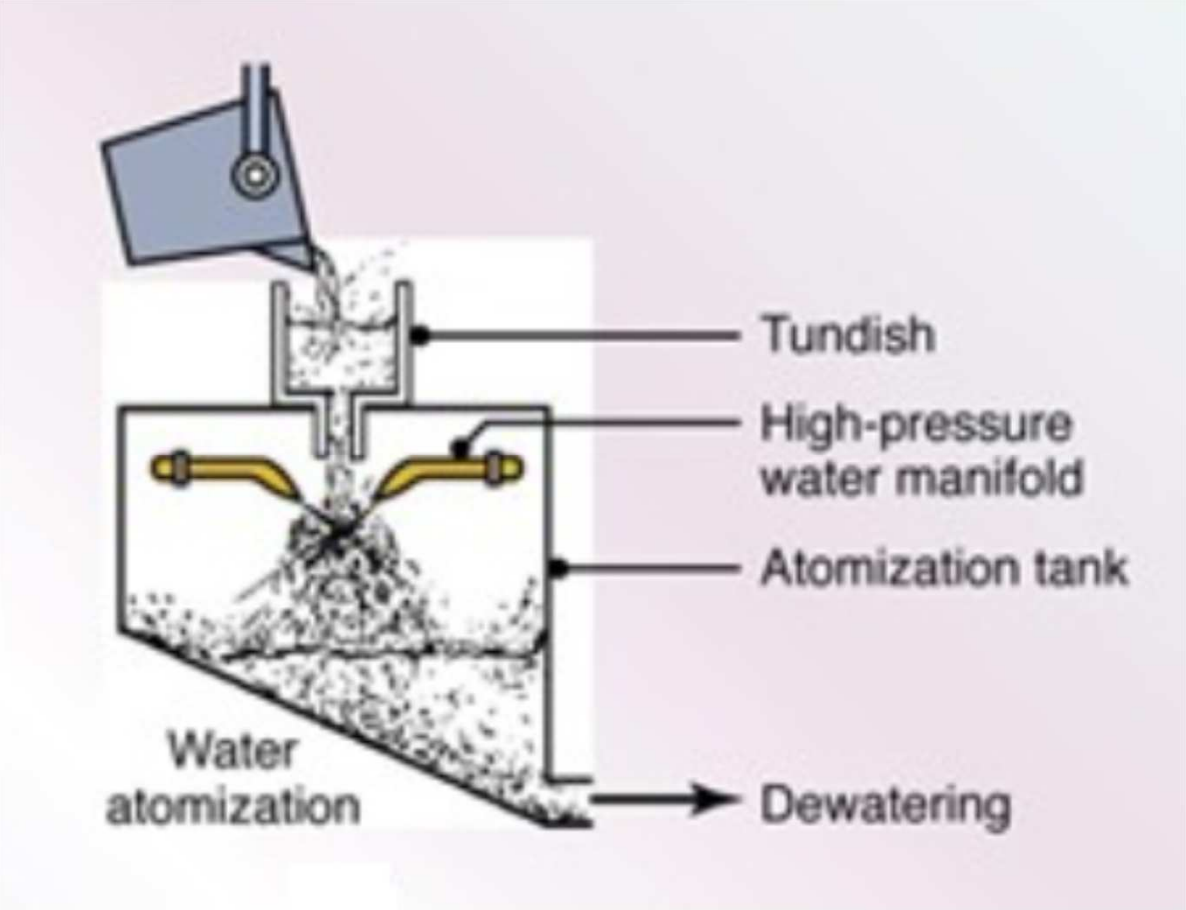
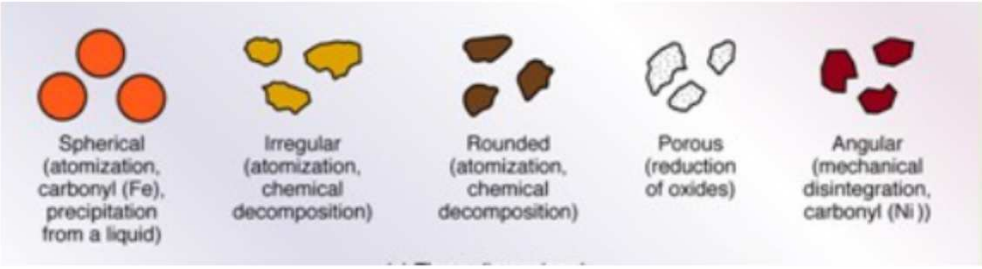
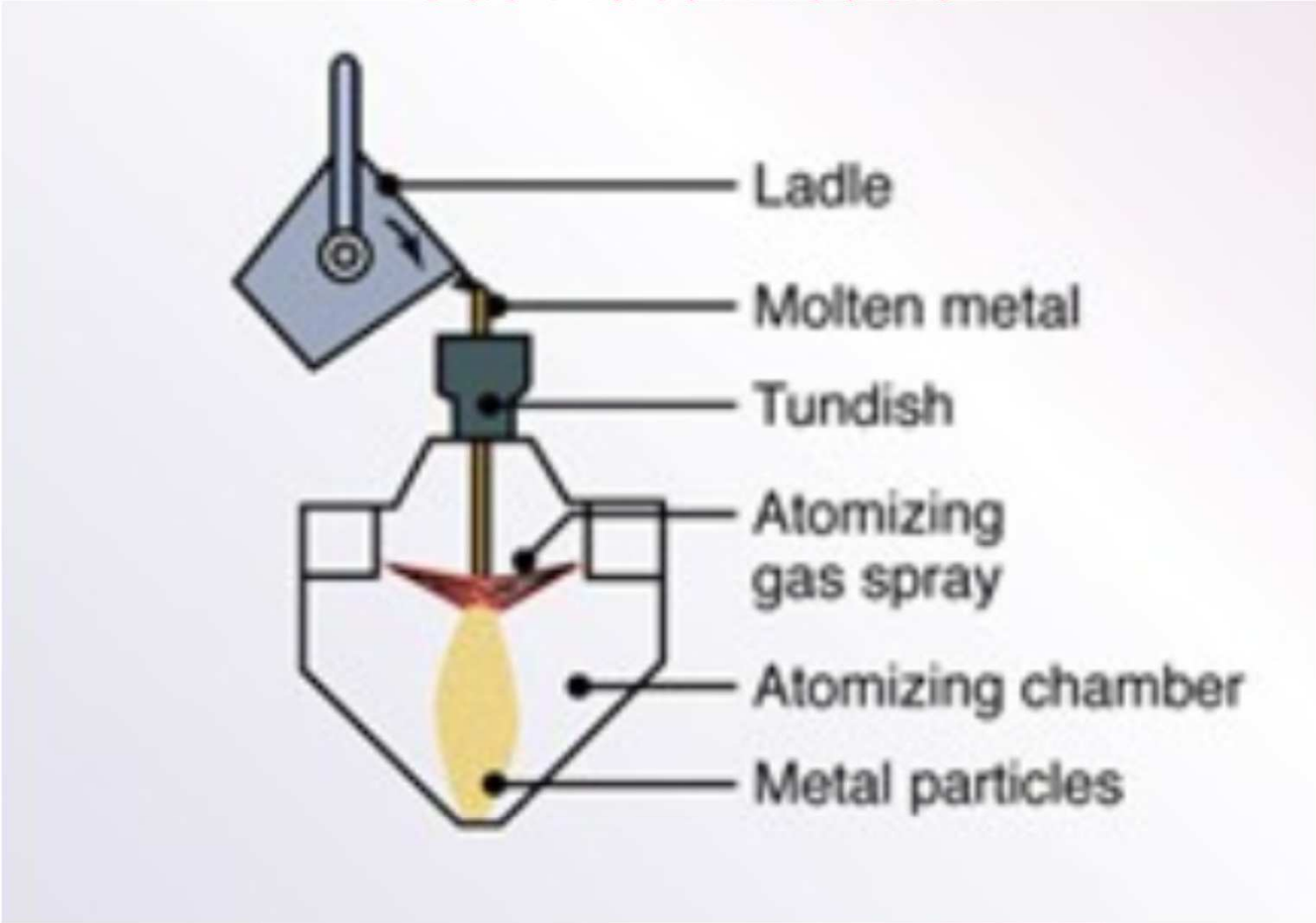


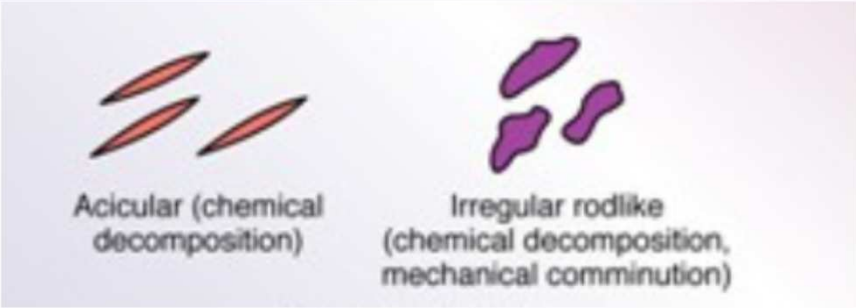


- **Factors of Influence**

↑	Water Pressure	Melting Temperature	Flowrate of the Melting
Grain Size	↓	↓	↑

Gas Automisation





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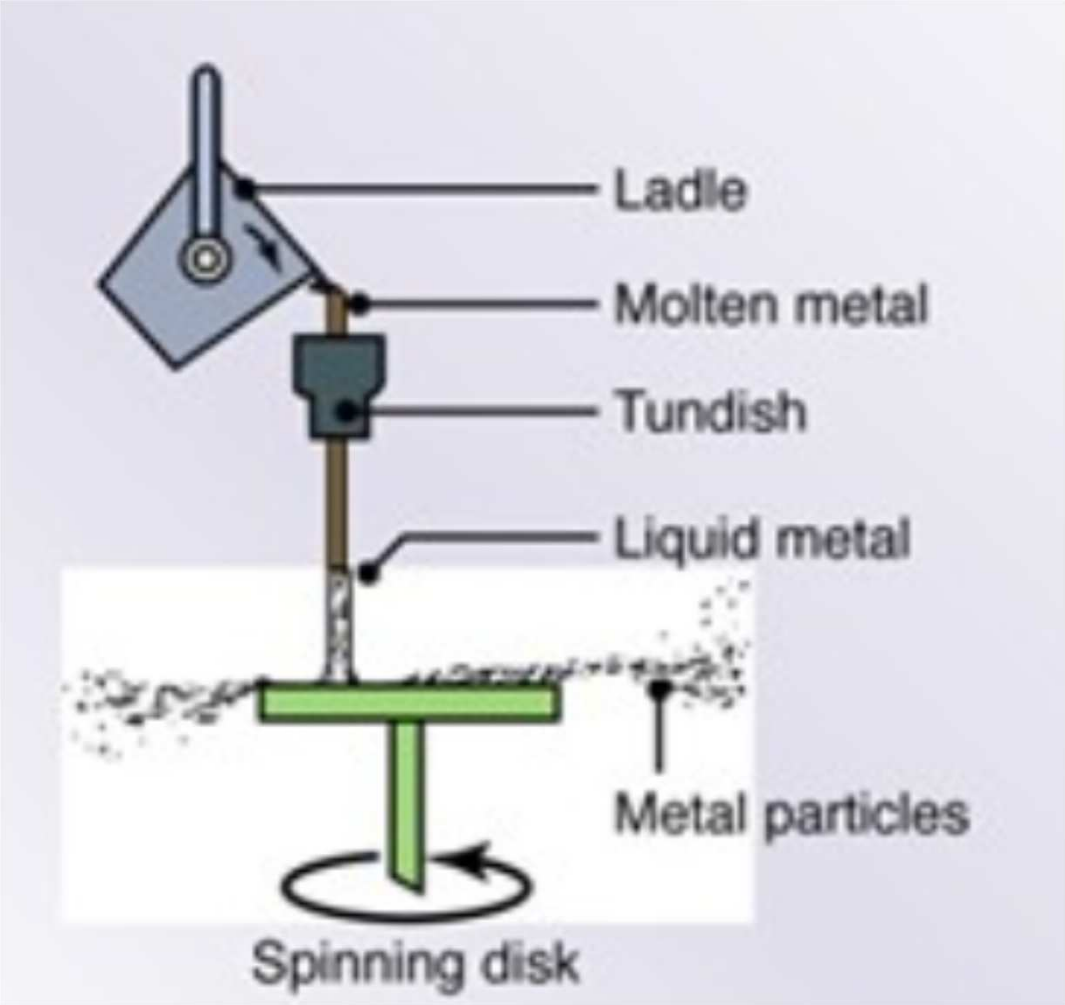
Centrifugal Atomisation-1



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Centrifugal Automisation-2

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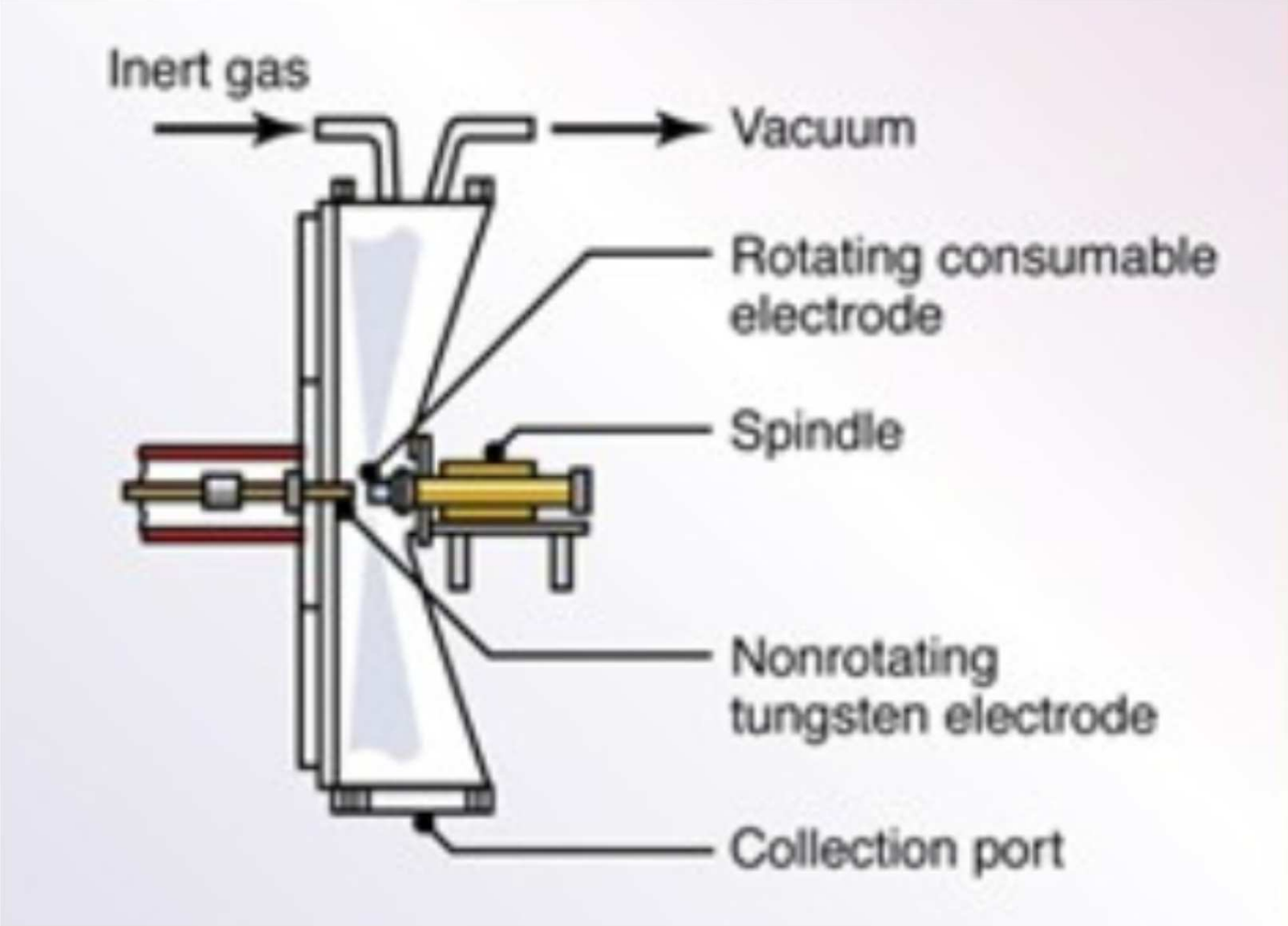
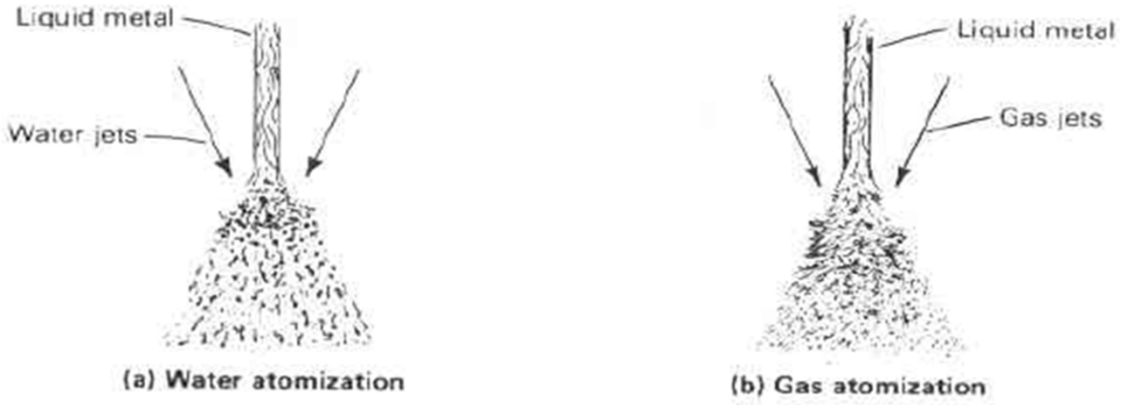


Atomization Plant - YouTube (360p).mp4

Technology of Atomization - 1



As a natural science describes whenever a liquid metal is flown through a Orifice (Tundish) it flows in a straight line. The major disadvantage for atomization process. The solution is to make it conical by using an external source it is called **PRE FILMING** .

That is accomplished in following ways

- By suspending a dish on which flown down liquid metal falls and is rotated to disperse the liquid metal which is easily atomized ensure uniform cooling of the droplets.
- By using Vacuum in the centre of the fluid metal flow which creates a swirl and
- Creates an umbrella necessitates easy atomization on the droplets

Courtesy ASM Hand book vol 7

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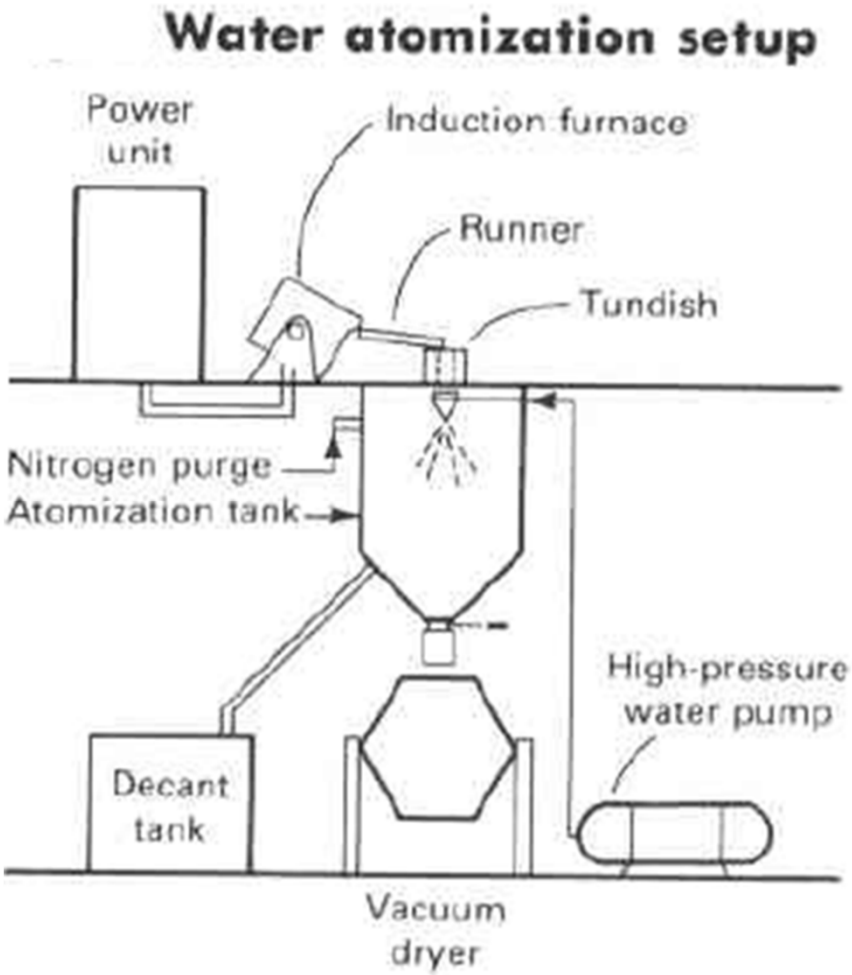
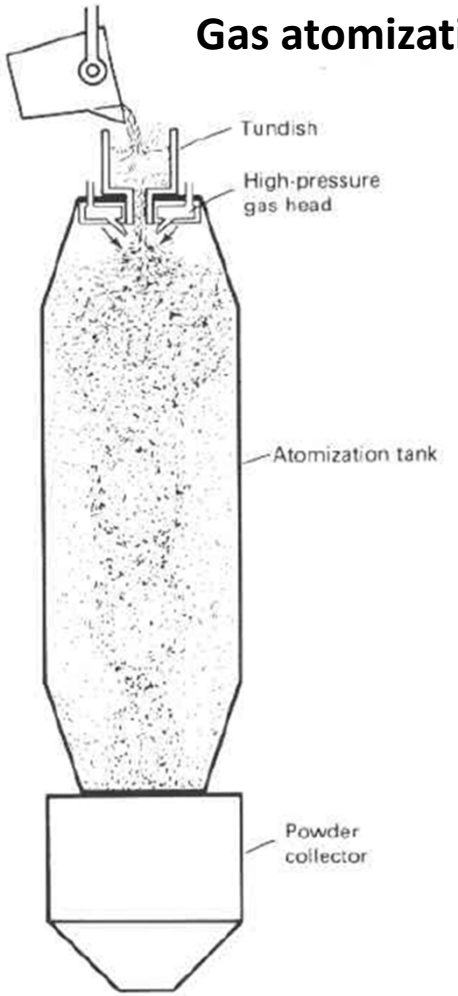
Technology of Atomization - 2



Gas atomization set up



Courtesy ASM Hand book vol 7

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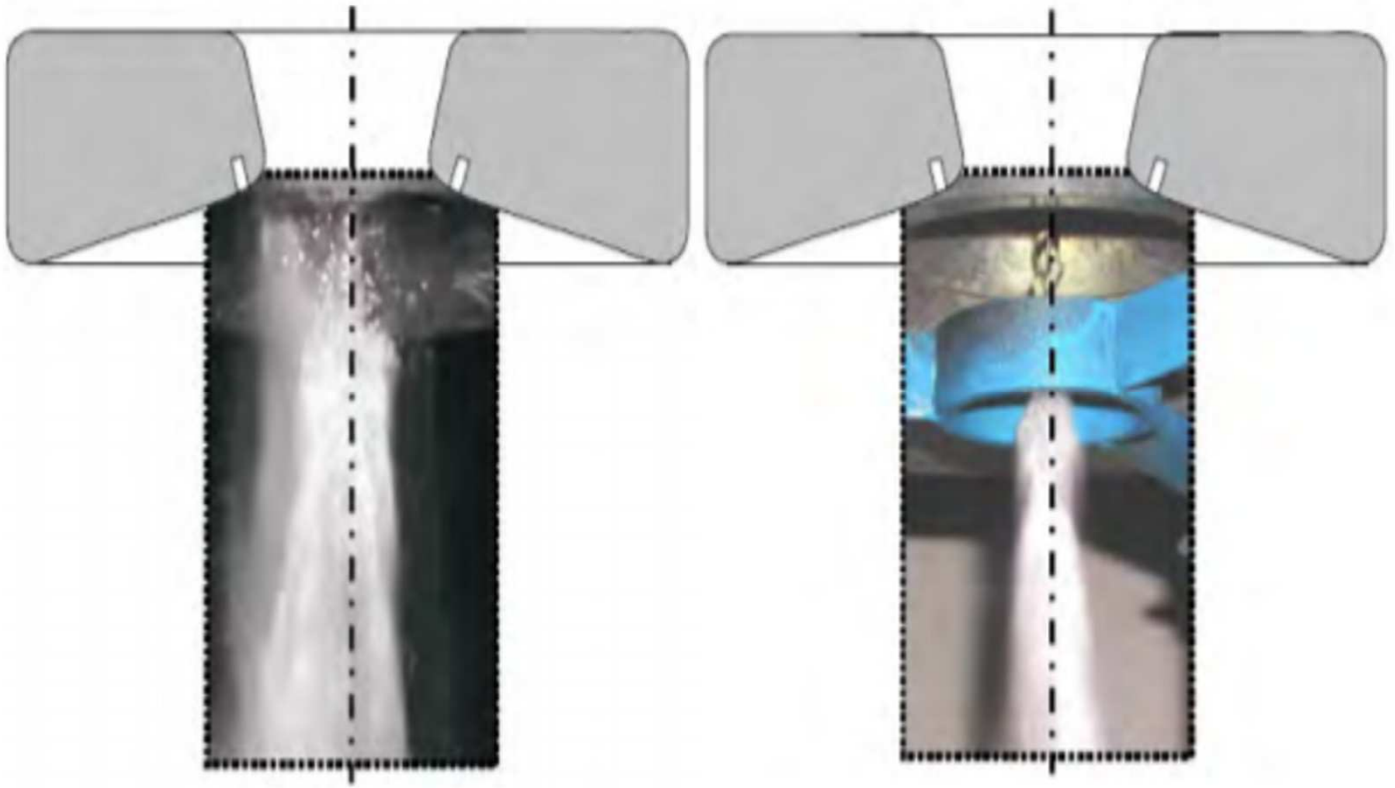
Technology of Atomization - 3



with prefilming

without prefilming

(From Czisch & Fritsching)

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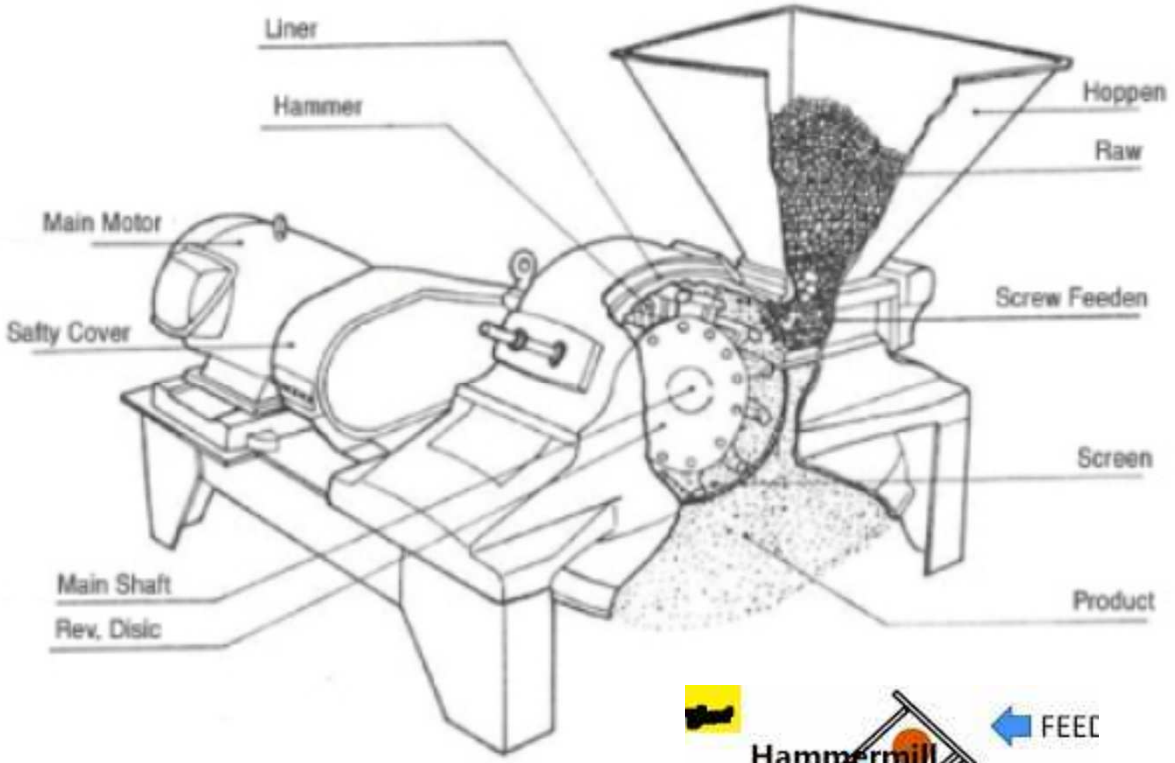
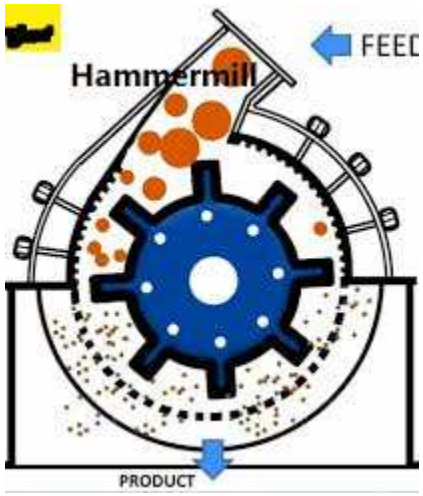
Mechanical crushing





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Electrolytic process

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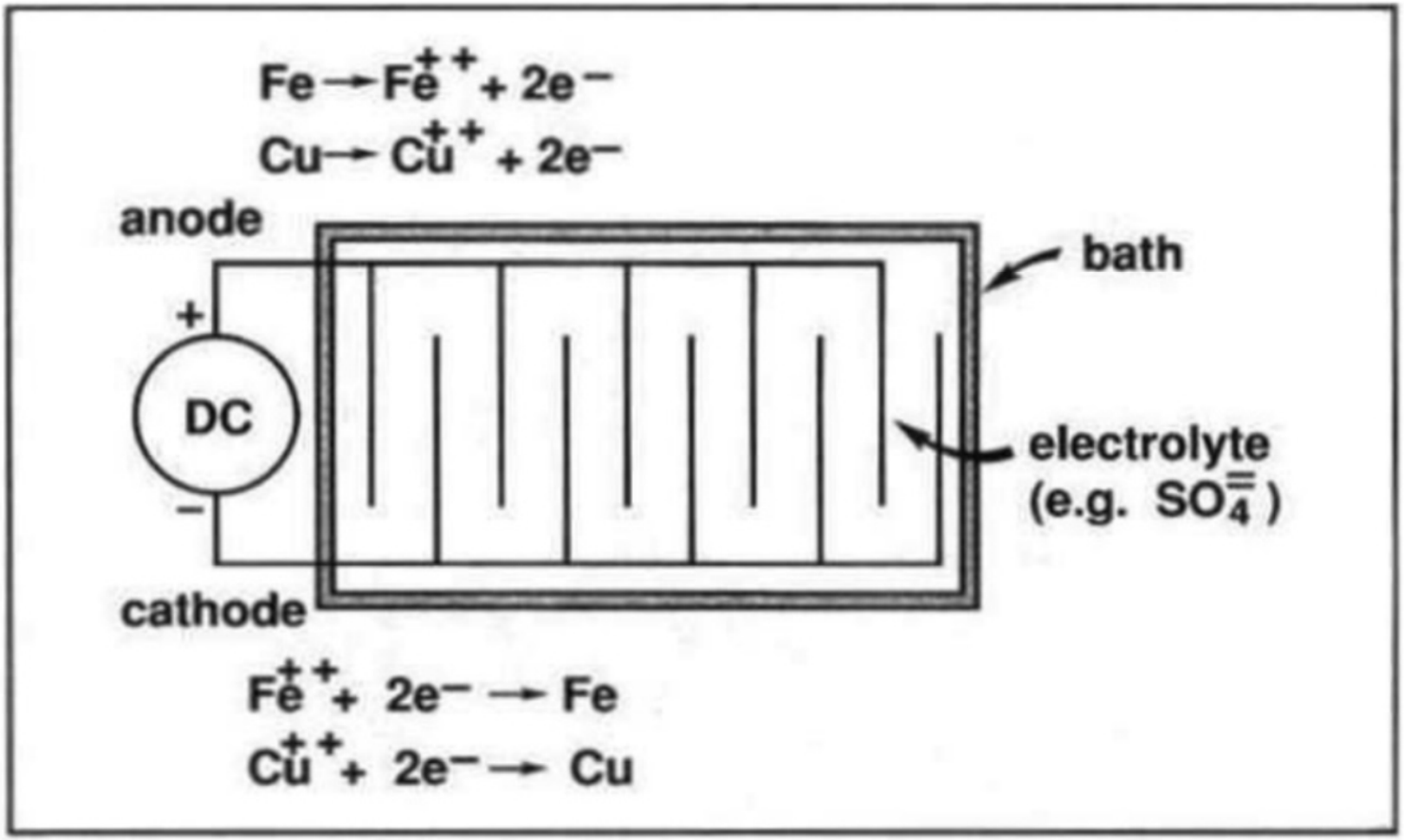

YOUR HIGH PURITY IRON PARTNER _ IMP-INDIA - YouTube (360p).mp4

Roasting process for copper powder production

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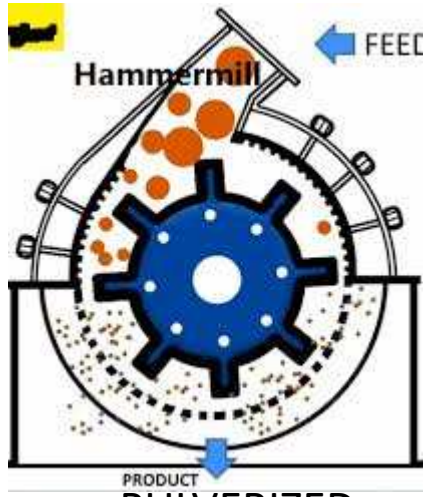
COPPER SCRAP

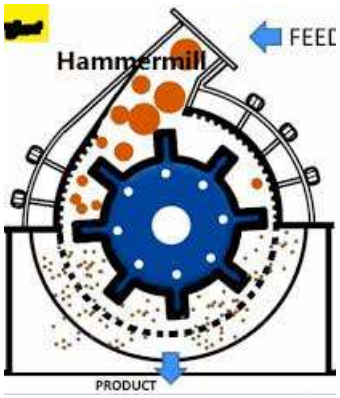
OXIDIZING



PULVERIZED

ROASTED

REDUCTION
SINTERED



PULVERIZED

SIEVING

Chemical Reduction

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- OXIDATION: This is a process of adding oxygen ions to a metal (this may in a NTP or conditions implied) Ionization process

Eg $Fe + O_2 = Fe_2O_5$, $Cu + O_2 = CuO$

- REDCUTION: Removal of oxygen ion from a metallic oxide is called reduction (in presence of reducing gas) De ionization process

Eg $Fe_2O_5 \xrightarrow[Hydrogen]{} Fe + H_2O$

$CuO \xrightarrow[Hydrogen]{} Cu + H_2O$

Making pure metals by REDUCTION - YouTube (360p).mp4

Copper Metal Powder

Properties:

- High electrical and thermal conductivities
- Ductility
- Corrosion resistance

Production Process:

- Atomization
- Electrolysis
- Solid state reduction
- Hydrometallurgy or chemical leaching

Copper Alloy Powder

- Brass (Copper – Zinc

- Bronze (Copper – Tin)

Chemical Reduction

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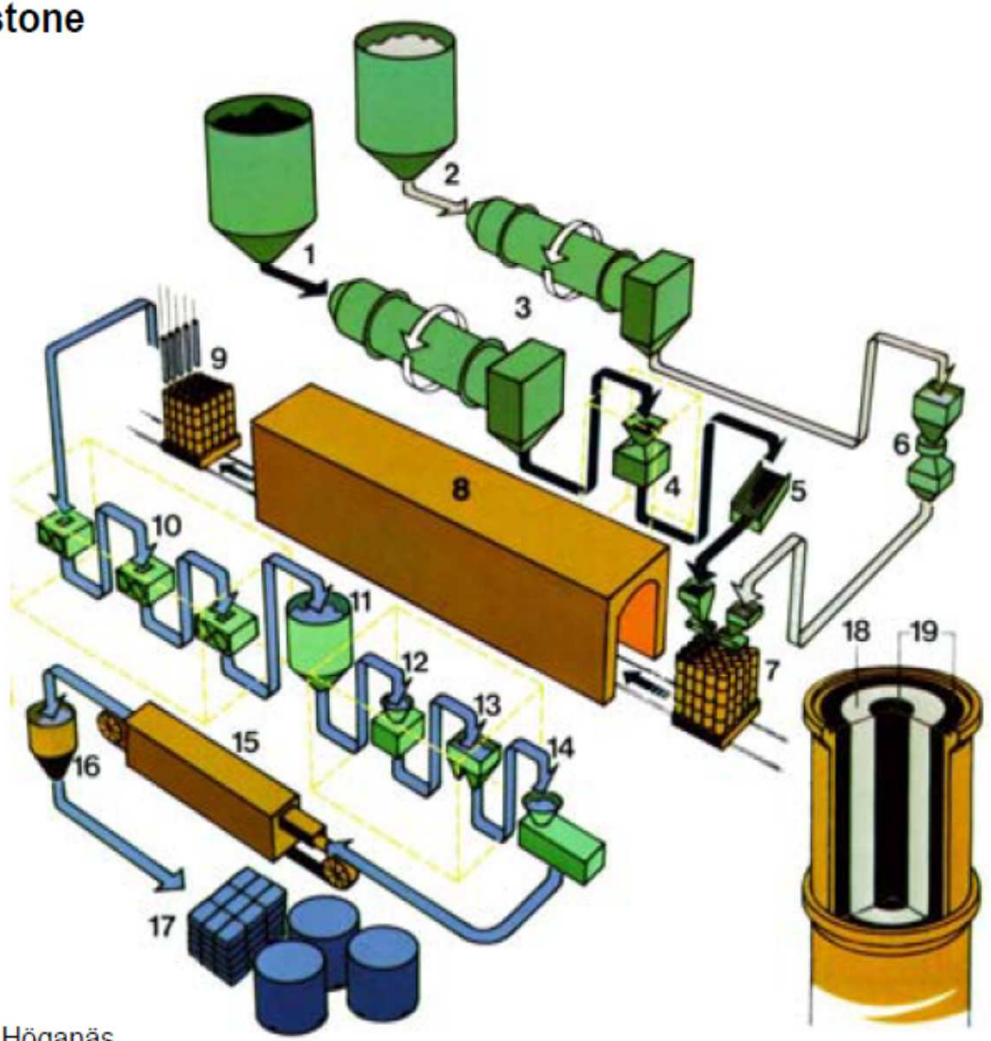
Powder Production: Chemical Reduction, Sponge Iron Powder

1 Reduction Mix of Coke Breeze and Limestone
2 Iron Ore
3 Drying
4 Crushing
5 Screening
6 Magnetic Separation
7 Charging in Ceramic Tubes
8 Reduction in Tunnel Kilns (1200°C)
9 Discharging
10 Coarse Crushing
11 Storage in Silos
12 Crushing
13 Magnetic Separation
14 Grinding and Screening
15 Annealing in Belt Furnace, approx. 800-900°C
16 Equalising
17 Automatic Packing
18 Iron Ore
19 Reduction Mix



source: Höganäs

Alloying of metal powders

Alloying Methods of Cu Powders

Completely Alloyed Powder

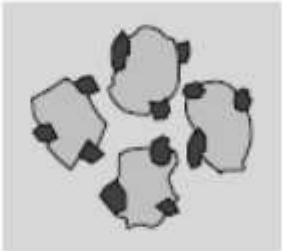
water-atomized powders, at which the molten material consists of the required alloying elements

Mixed Alloyed Powder

powder-mixes consisting of at least 2 pure alloying components

long sintering times and high sintering temperatures necessary for homogenizing

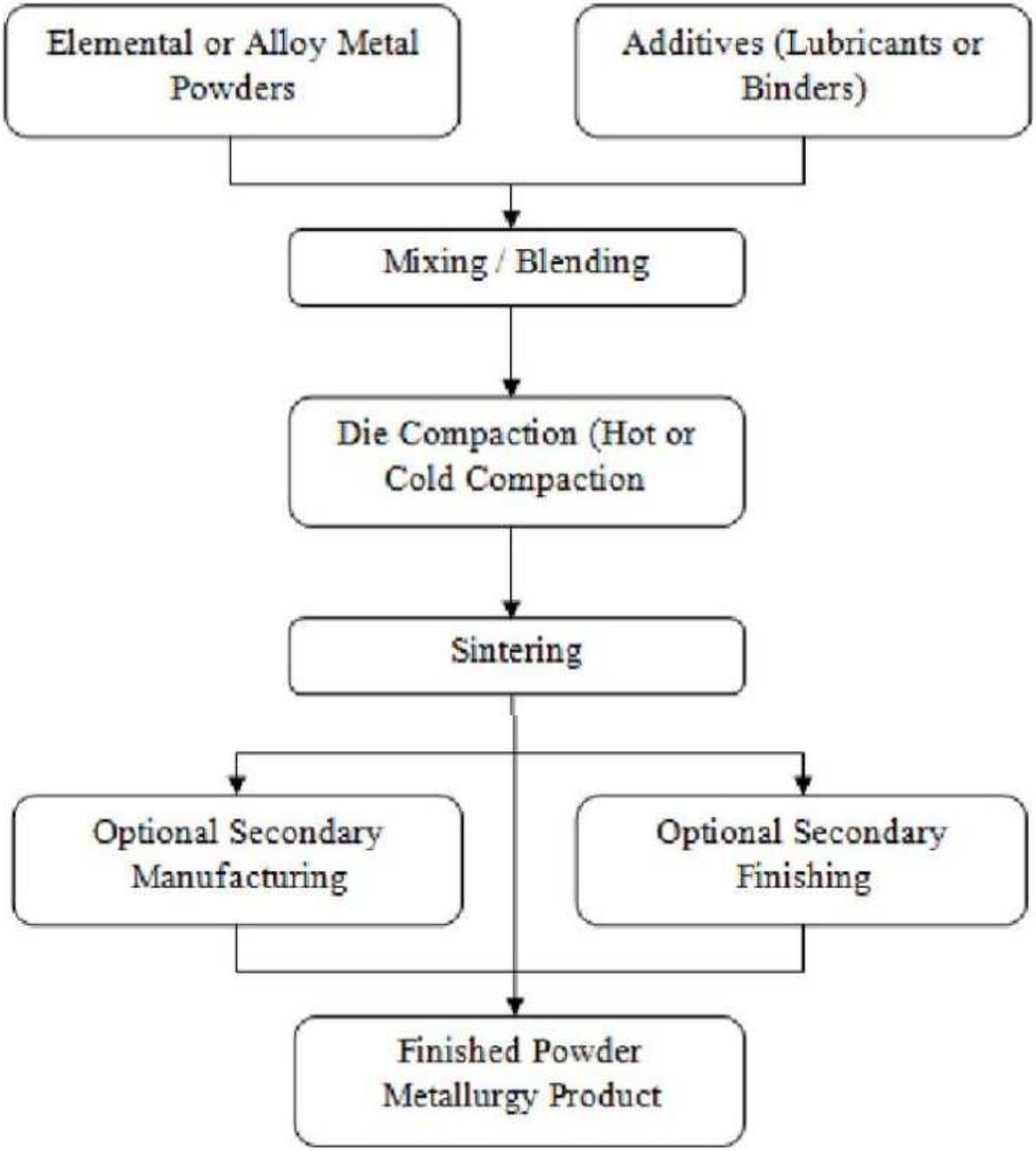
Partially Alloyed Powder



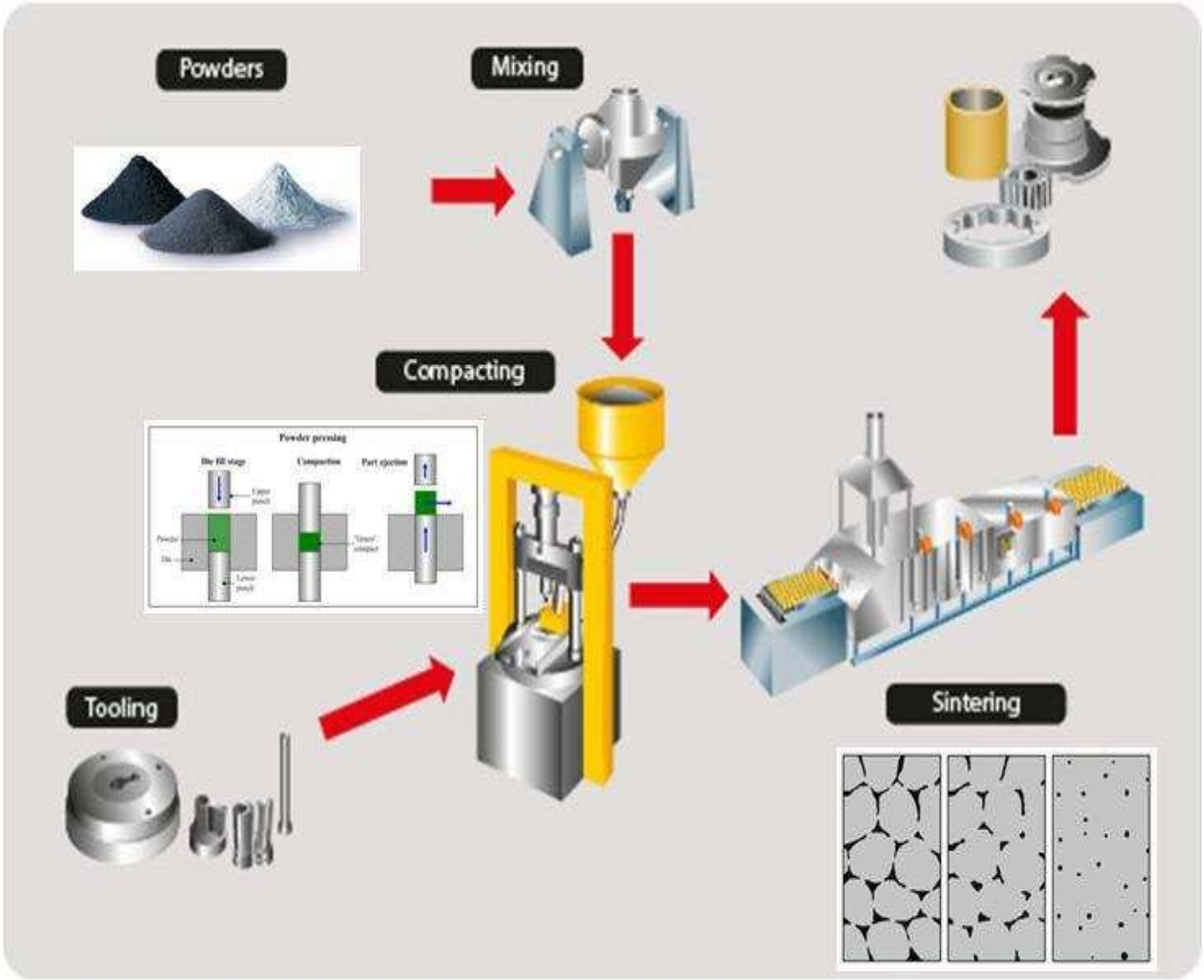
diffusion alloyed: annealing of mixed powders

adhesion alloyed: usage of alloying elements which can`t be bound on iron by a diffusion process

Flow chart for p/m part manufacturing



Powder Metallurgy



Powder testing - 1

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Characterization of Iron and Steel Powder

1. Metallurgical Properties

- Chemical Composition ⇒ Chemical Analysis
- Texture of Powder Particles ⇒ Polished Cross Sections
- Micro Hardness ⇒ Hardness Measurement

2. Geometrical Properties

- Particle Size Distribution ⇒ Sieve Analysis
- External Practical Shape ⇒ Scanning Electron Microscopy
- Internal Particle Structure (Porosity) ⇒ Metallographic Cut through the Powder Particle

3. Mechanical Properties

- Flow Rate ⇒ Hall-Flowmeter (Standardized Cone)
- Bulk Density ⇒ Filling a Bowl with a Standardized Cone
- Compressibility ⇒ Pressing Standardized Stopper, results presented as a curve
- Green Strength ⇒ Fatigue Strength of a Pressed Square Test Bar
- Spring-Back ⇒ Elastic Extension of a Pressed Stopper, d=25 mm

Powder testing - 2

Demo Video for Hall Flow Meter , Hall Flowability Tester , Hall Flow Equipment - YouTube (360p).mp4

Method for Determination of Compressibility of Metal Powders - YouTube (360p).mp4

Method for Determination of Sieve Analysis of Metal Powders - YouTube (360p).mp4

Average Particle Size Analyzer Fisher Sub Sieve Sizer Size Analysis Test Particle Size D50?HMK22 - YouTube (360p).mp4

Method for Determination of Green Strength of Unsintered Compacted Powder Metallurgy Materials - YouTube (360p).mp4

Over view of Copper metal powder applications

Abrasive Wheels	
Bonding	Copper
Agriculture	
Fungicides	Copper
Lawn and Garden Equipment	Bronze
Soil Conditioning	Copper
Aerospace	
Brake Linings	Copper
Counterweights	Copper-tungsten
Filters	Bronze
Automotive	
Brake Bands, Liners	Copper, brass, copper-lead, copper-lead-tin
Bushings	Bronze
Instruments	Nickel silver
Building and Construction	
Conductive and Non-sparking Floors	Copper
Decorative Plastics	Copper, bronze, brass
Domestic Water Filters	Brass
Lock Components	Brass
Pipe Joint Compounds	Copper
Chemical	
Catalysts	Copper
Filters	Bronze
Valve and Pump Parts	Copper-nickel
Coatings	
Anti-fouling Paints	Copper
Conductive Paints and Plastics	Copper, brass
Decorative Paints	Copper, brass, bronze
Lacquers	Brass, bronze
Mechanical (Peen) Plating	Copper, brass
Spray Coating	Copper, brass
Vacuum Metallizing	Copper
Coins, Medals, Medallions	Copper-nickel, brass
Electrical and Electronic	
Brushes	Copper
Brush Holders	Nickel silver
Contacts	Copper
Heat Sinks	Copper, dispersion-strengthened copper
Printed Circuits	Copper
Semi-conductor Stud Bases	Copper, dispersion-strengthened copper
Telephone Components	Brass, bronze
Hardware	
Lock Components	Brass, bronze
Industrial, General	
Balancing Weights	Copper-tungsten
Bearings and Bushings	Bronze, copper-lead, copper-lead-tin
Filters, Liquid and Gas	Bronze
Flame Arrestors	Bronze
Instruments, Control	Nickel silver
Joining	
Brazing Compounds	Copper,bronze,brass
Resistance Welding Electrodes	Copper, dispersion-strengthened copper
Lubricants	
Anti-galling Pipe Joint Compounds	Copper
Copper Lubricants	Copper
Plastic-Filled Metal	Copper, bronze
Machining	
Electrical Discharge Machining (EDM)	Copper
Electrochemical Machining (ECM)	Copper
Office Equipment	
Business Machines	Brass
Ordnance	
Armor-piercing Cores	Copper
Fuze Parts	Brass
Projectile Rotating Bands	Copper, brass
Personal Products	
Cordless Electric Toothbrush and Razor	Copper
Fingernail Lacquer	Copper
Photographic Equipment	Bronze, brass, nickel silver
Poker Chips	Brass, bronze, copper-nickel
Printing Inks	
Metallic Inks for Offset, Letterpress, Gravure	Copper, brass
Radio and Television	
Printed Circuits	Copper
Railroads	
Brake Linings	Bronze, copper-lead, copper-lead-tin
Friction Strips on Pantographs	Copper
Self-lubricating Parts	
Oil-filled	Bronze
Plastic-filled	Copper
Ships	
Anti-fouling Paint	Copper

Metal powders – sintered components

Iron Powders for Sintered Components

TYPICAL DATA - Sintered properties at P=600 MPa, T=1120°C, t=30 min, Atm=90/10N_2/H_2, dT/dt=0.8°C/s)

Powder properties	Sponge iron powder grades			Atomised iron powder grades		
	NC100.24	SC100.26	MH80.23	AHC100.29	ASC100.29	ABC100.30
AD, g/cm³	2.43	2.68	2.30	2.99	2.99	3.02
Flow, s/50 g	31	29	34	24	24	24
Powder chemistry						
Mo, %						
Ni, %						
Cu, %						
Cr, %						
P, %						
Green properties with 0.8% lubricant						
GD 600 MPa, g/cm³	7.00	7.11	6.75	7.15	7.20	7.26
GD 4.2 t/cm², g/cm³	6.6	6.7	6.3			
GS 600 MPa, N/mm²	21	15	29	13	14	13
Sintered properties						
% C, as sintered	0.80	0.80	0.80	0.80	0.80	0.80
% Cu	2.00	2.00	2.00	2.00	2.00	2.00
SD, g/cm³	6.80	6.90	6.67	6.96	7.02	7.02
DC g-s, %	0.12	0.17	-0.05	0.10	0.10	0.11
HV10	170	180	155	180	185	185
YS, MPa	410	395	360	450	460	470
TS, MPa	530	520	440	570	585	590
A, %	2.00	2.50	1.90	1.80	2.00	2.40
IE, J	12	13		12	14	14
Applications	- Low to medium density parts - Self-lubricating bearings, especially MH80.23 and NC100.24 - Parts with complicated geometry where high green strength is essential in order to avoid green cracks - Shock absorber parts			- Medium to high density parts - Soft magnetic applications, especially ABC100.30 - Clutch and pulleys		

Höganäs AB (publ.), June 2013 0523HOG

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Metal powders- MIM

Höganäs

POWDERS FOR POWDER METALLURGY

Number PD-5259
Issue 1-21.12.2015

AMPERSINT® 0711.01 FeCrNiCuNb 17-4PH

Chemical Characteristics
(Mass fraction in % [cg/g]; ppm [µg/g])

C		<=	0.07	%
Si		<=	1.00	%
Mn		<=	1.00	%
P		<=	0.040	%
S		<=	0.030	%
Cr	15.0	-	17.5	%
Ni	3.00	-	5.00	%
Cu	3.00	-	5.00	%
Nb+Ta	0.15	-	0.45	%
Fe	balance			

Physical Characteristics

Particle Size Distribution

38/5 µm			
+ 38 µm	max.	7	%[1]
- 5 µm	max.	3	%[2]
45/15 µm			
+ 45 µm	max.	7	%[1]
- 15 µm	max.	3	%[2]
53/10 µm			
+ 53 µm	max.	5	%[1]
- 10 µm	max.	3	%[2]
-22 µm			
D90 %	max.	22	µm[2]

1) ROTAP Screening per ASTM B 214, 2) MICROTRAC by Laser Light Diffraction per ASTM C 1070.

Properties of water / gas atomoized copper powders

Copper, %	Chemical properties, %		Physical properties						
	Hydrogen loss	Acid insolubles	Hall flow rate, s/50 g	Apparent density, g/cm^3	Tyler sieve analysis, %				
					+100	−100+150	−150+200	−200+325	−325
99.65(a)	0.28	...	...	2.65	Trace	0.31	8.1	28.2	63.4
99.61(a)	0.24	...	...	2.45	0.2	27.3	48.5	21.6	2.4
99.43(a)	0.31	...	...	2.70	tr	0.9	3.2	14.2	81.7
>99.1(b)	<0.35	<0.2	~50	2.4	<8	17-22	18-30	22-26	18-38
99.1	0.77	...	No flow	4.8	Trace	3	...	...	...
99.2	<0.7	...	9-13	4.9-5.5	7-14	←20-30→	←20-30→	15-30	30-50

(a) Water atomized plus reduced. (b) Contains magnesium

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Metal powders- Additive Manufacturing

AMPERPRINT® 0634

FeCrMoSiVCMn (1.2344)

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Short product information	
Product designation	***AMPERPRINT***® 0634.074
Atomization	Vacuum Induction Melting (VIM) Atomized with Argon

- Selective laser melting

Table 6 Properties of commercial grades of water- and gas-atomized copper powders

Copper, %	Chemical properties, %		Physical properties						
	Hydrogen loss	Acid insolubles	Hall flow rate, s/50 g	Apparent density, g/cm³	Tyler sieve analysis, %				
					+100	−100+150	−150+200	−200+325	−325
99.65(a)	0.28	...	...	2.65	Trace	0.31	8.1	28.2	63.4
99.61(a)	0.24	...	...	2.45	0.2	27.3	48.5	21.6	2.4
99.43(a)	0.31	...	...	2.70	tr	0.9	3.2	14.2	81.7
>99.1(b)	<0.35	<0.2	~50	2.4	<8	17-22	18-30	22-26	18-38
99.1	0.77	...	No flow	4.8	Trace	3	...	...	...
99.2	<0.7	...	9-13	4.9-5.5	7-14	←20-30→	←20-30→	15-30	30-50

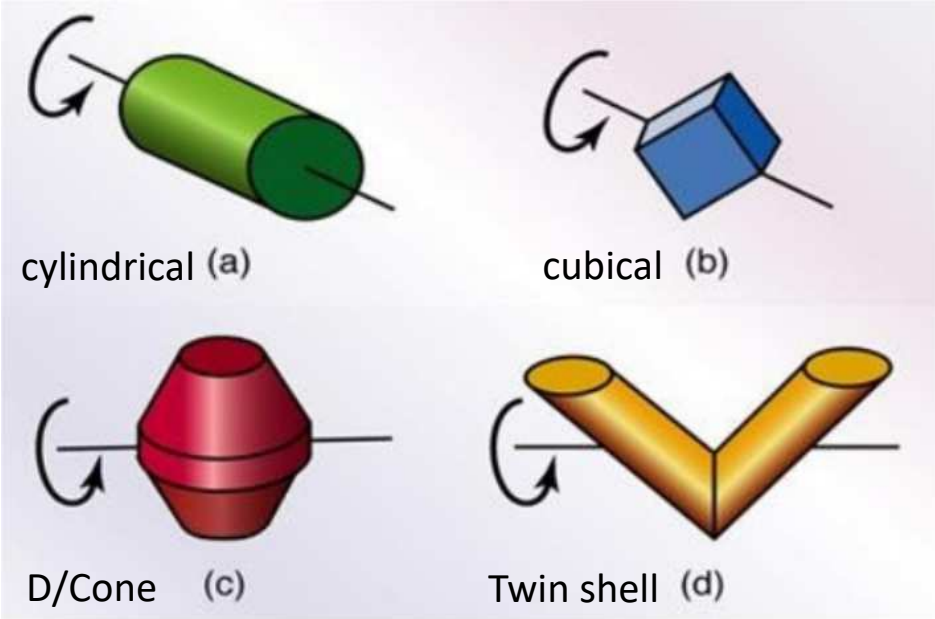
(a) Water atomized plus reduced. (b) Contains magnesium

Mo	1.20	1.50	%
Si	0.80	1.20	%
V	0.85	1.15	%
C	0.35	0.42	%
Mn	0.25	0.50	%
P		0.030	%
S		0.020	%
O		0.035	%
N		0.02	%
Fe	balance		

Particle size distribution	Min	Max	Unit
> 45 µm, ASTM B 214		5	%
< = 15 µm, ASTM B 822		5	%
Apparent density, ASTM B 212	3.50		g/cm³
Flowability, ASTM B 213	12	25	sec/50g

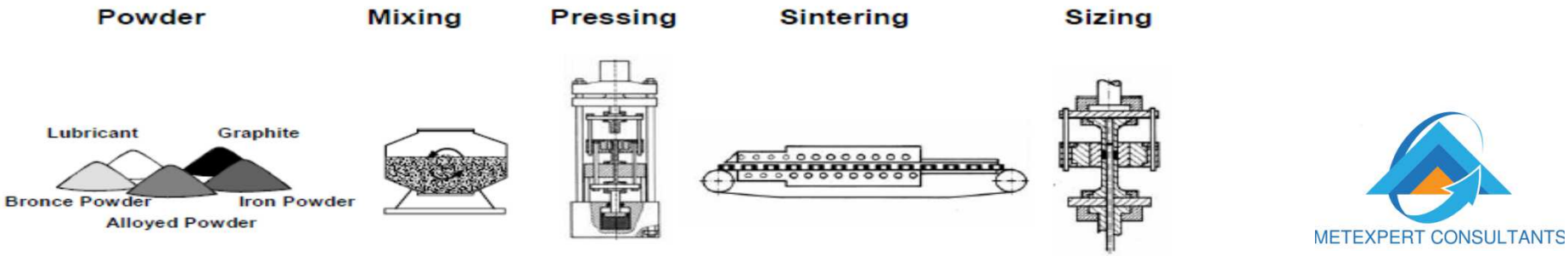
BLENDING

Different blending volumes



Double cone blender

Process Steps of Powder Pressing



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Thank you for your patience
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K G S PRASAD RAO