TA201A
Manufacturing Processes

Week-5

06 Sept, 2022

2022-2023 Semester-I

Lecture 5

Instructions

- Makeup lab:
  - Email Mr IP Singh Sir and cc to Mr AK Verma Sir and me
- Project report: Two copies
- Lab exam

Stainless Steels

Major alloying elements: Chromium, Cr

Imparts good corrosion resistance

Other alloying elements: Ni, Mn

Courtesy: Google images

Stainless Steels

TABLE • 6.4 Compositions and mechanical properties of selected stainless steels.

Type	Chemical Analysis, % Fe	Cr	Ni	C	Mn	Other[a]	Tensile Strength MPa	lb/in²	Elongation, %
Austenitic									
301	73	17	7	0.15	2		620	90,000	40
302	71	18	8	0.15	2		515	75,000	40
304	69	19	9	0.08	2		515	75,000	40
309	61	23	13	0.20	2		515	75,000	40
316	65	17	12	0.08	2	2.5 Mo	515	75,000	40
Ferritic									
405	85	13	—	0.08	1		415	60,000	20
430	81	17	—	0.12	1		415	60,000	20
Martensitic									
403	86	12	—	0.15	1		485	70,000	20
403[b]	86	12	—	0.15	1		825	120,000	12
416	85	13	—	0.15	1		485	70,000	20
416[b]	85	13	—	0.15	1		965	140,000	10
440	81	17	—	0.65	1		725	105,000	20
440[b]	81	17	—	0.65	1		1790	260,000	5

Compiled from [11].

[a]All of the grades in the table contain about 1% (or less) Si plus small amounts (well below 1%) of phosphorus, sulfur, and other elements such as aluminum.

[b]Heat treated.

Name one application of Austenitic, Ferritic and Martensitic steel each?

Stainless Steels

- Chemical and Food storage instruments are Austenitic steel (fcc)
- Utensils to Jet engine components are Ferritic steel (bcc),
- Cutlery and Surgical instruments are Martensitic steel (bct),

What is bct?

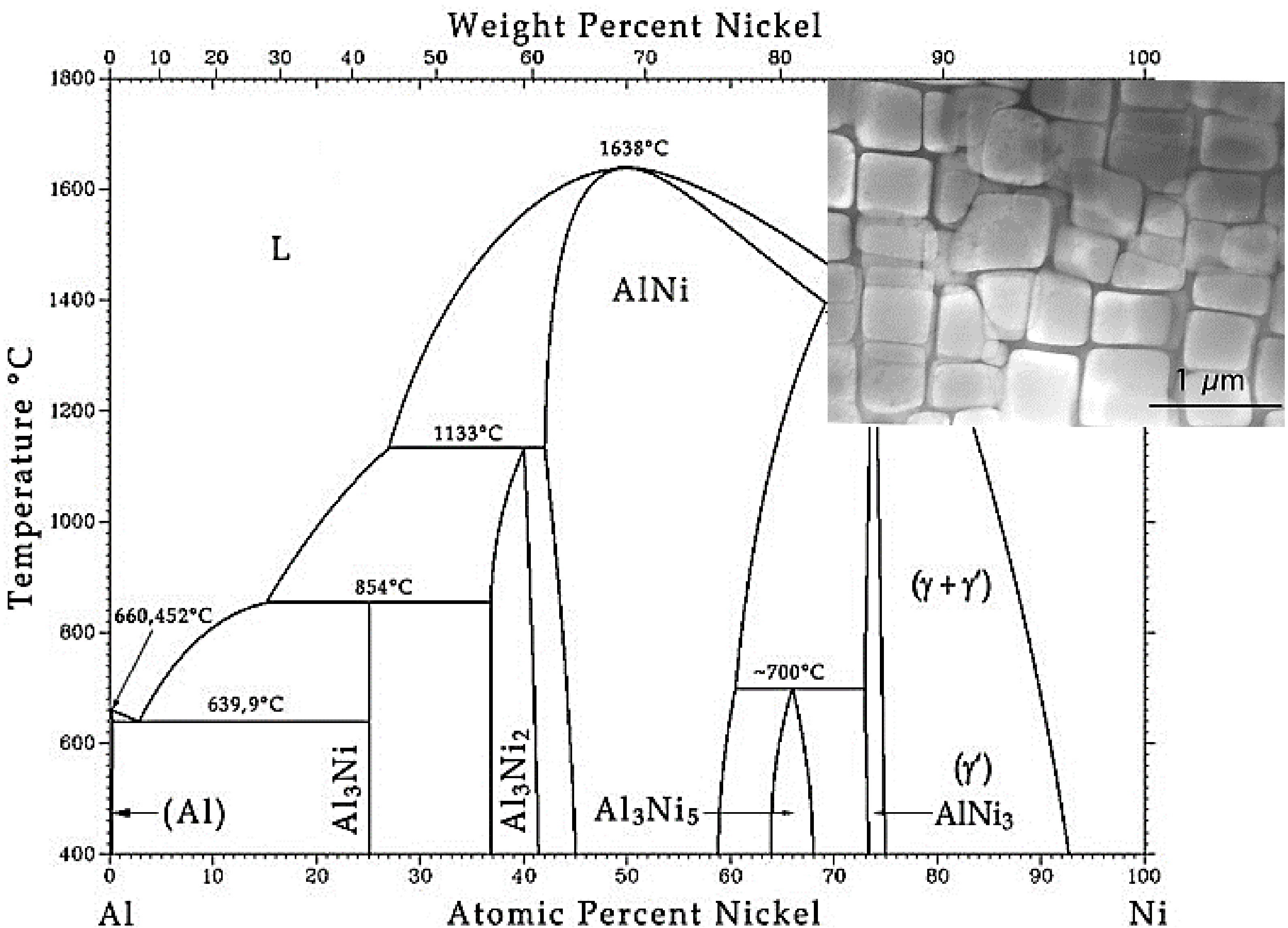
Courtesy: Google images

Materials: Strategic & Critical applications

Ni based alloys

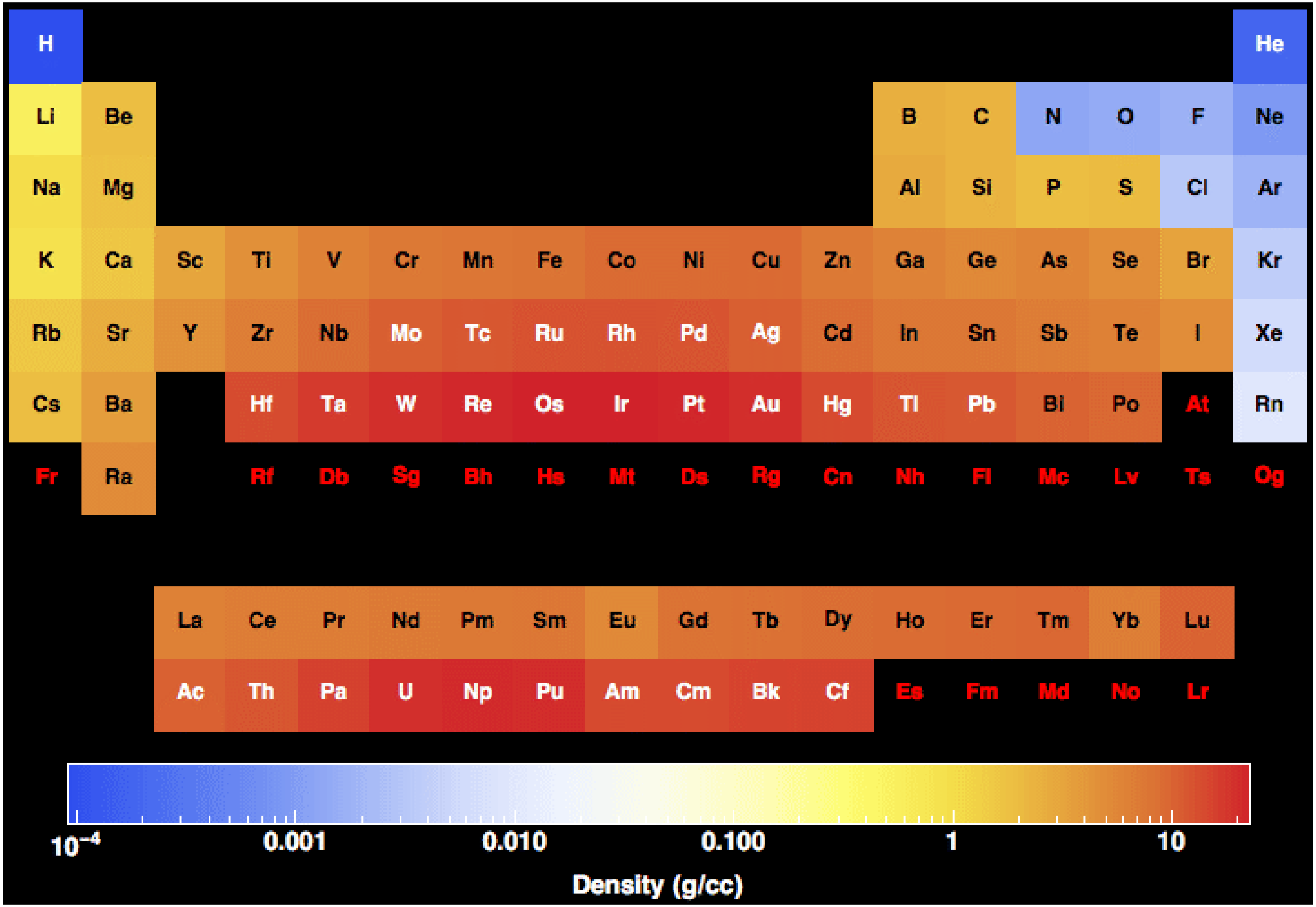
https://www.cam.ac.uk/research/news/super-superalloys-hotter-stronger-for-even-longer

Superalloys: γ-γ' microstructure



Courtesy: Google images

Densities of elements



Courtesy: Google images

Light weight alloys

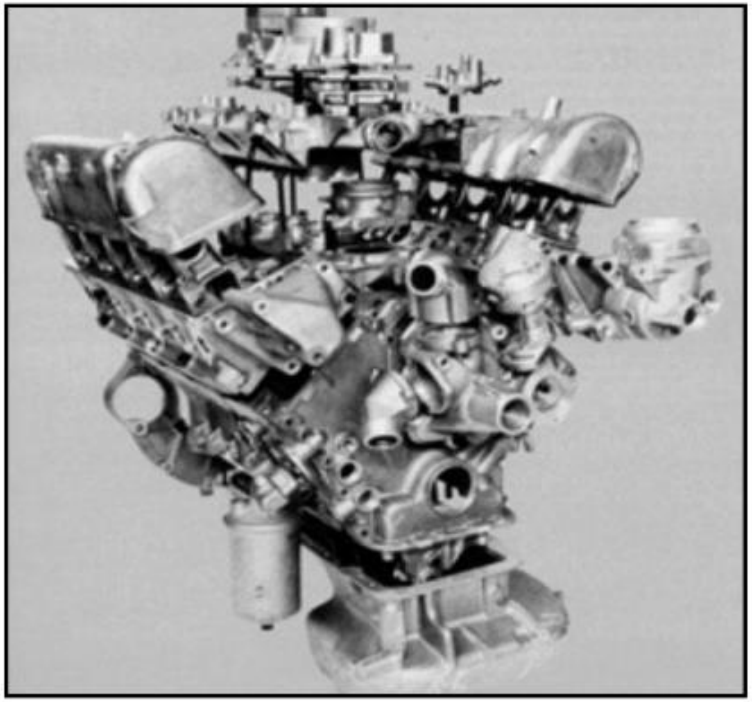
- Al Alloys
- Mg Alloys
- Ti-Al Alloys

Strength/Density = Specific strength

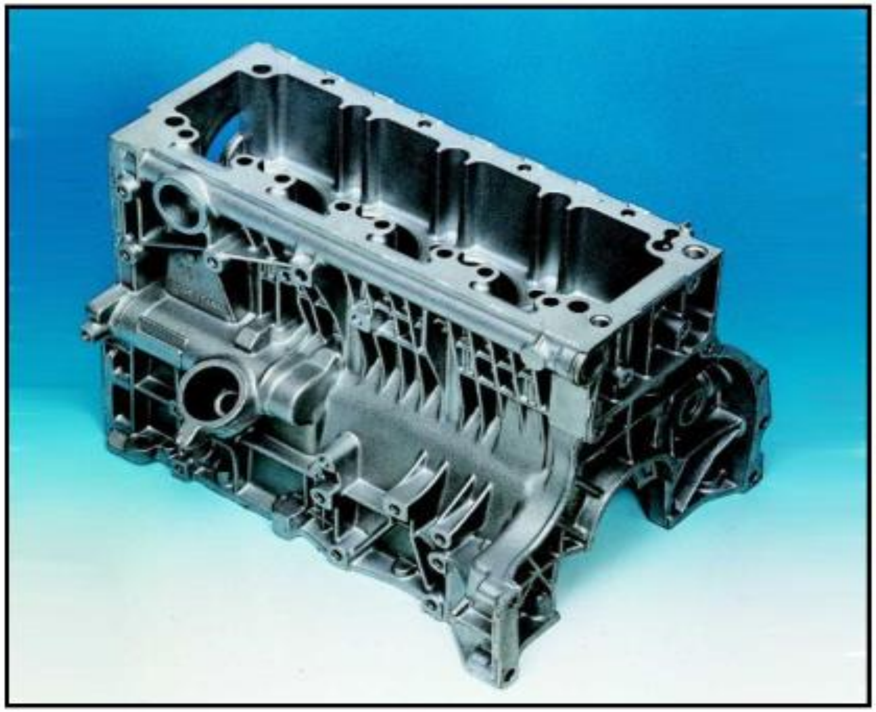
Material	Yield Strength (MPa)	Density, g/cc	Specific strength, (kN m/kg)
Low carbon steel (AISI 1010)	365	7.87	46.4
Stainless steel (304)	505	8.00	63.1
Brass	580	8.55	67.8
Titanium	344	4.51	76
CrMo Steel (4130)	560 - 670	7.85	71 - 85
Aluminium alloy (6061-T6)	310	2.70	115

Wikipedia

Al-Si alloys



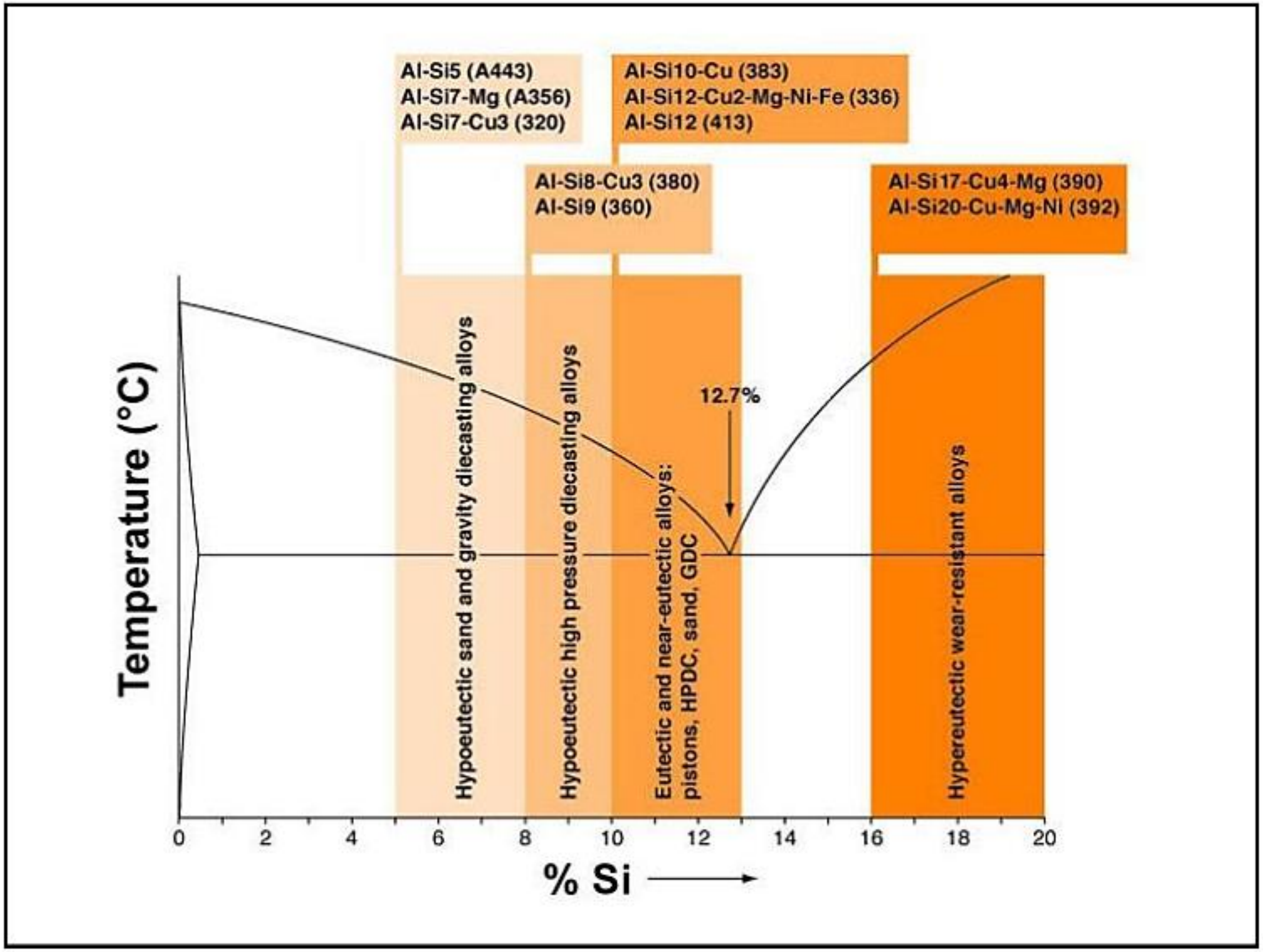
Mercedes 450 SLC-5-1 Engine



Renault Safrane cylindre block

Courtesy: Google images

Al-Si alloys



Schematic Al-Si phase diagram showing the composition ranges for the most common foundry alloys

https://www.european-aluminium.eu/media/1544/aam-products-6-cast-alloys-and-products.pdf

Al-Si alloys

- Al-Si alloy has very good fluidity and castability
- Mg addition can result in better mechanical properties (wheels, suspension parts)
- Al-Si-Cu-Mg alloys are used for power train components such as engine blocks, cylinder heads, pistons and die castings

What are the advantages of Al over steel?

Compare the strength of Al and steel!

Casting [Chapters -10 &11 :Groover]

- Solidification: Fundamentals
- Classifications of casting processes
- Fundamentals of Casting
- Sand Mold Casting
- hrinkage, Riser Design
- Other kinds of Casting
- Casting Defects

Casting

Dhokra (also spelt *Dokra*) art form : Lost-wax casting: 4000 years

Moradabad

“Pital Nagari” or “City of Brass”

Exports goods worth Rs.4000 Crore

Turbine Blade

Wikipedia
https://www.iitk.ac.in/designbank/Moradabad/History.html

Casting

- Casting: Process in which molten metal flows by gravity or other force into a mold where it solidifies in the shape of the mold cavity
- Step involved are
  1. Melt the metal
  2. Pour it into a mold
  3. Allow it to freeze

Courtesy: Google images

Casting: Advantages and Disadvantages

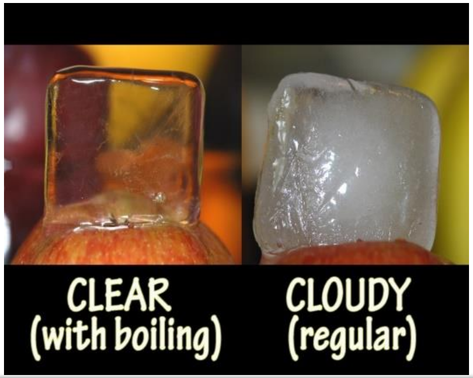
Capabilities and advantages

- Can create complex part geometries
- Net shape / near net shape
- Can produce large parts (> 100 Tons)
- Any metal that can be heated to liquid state
- Mass production feasibility

Disadvantages

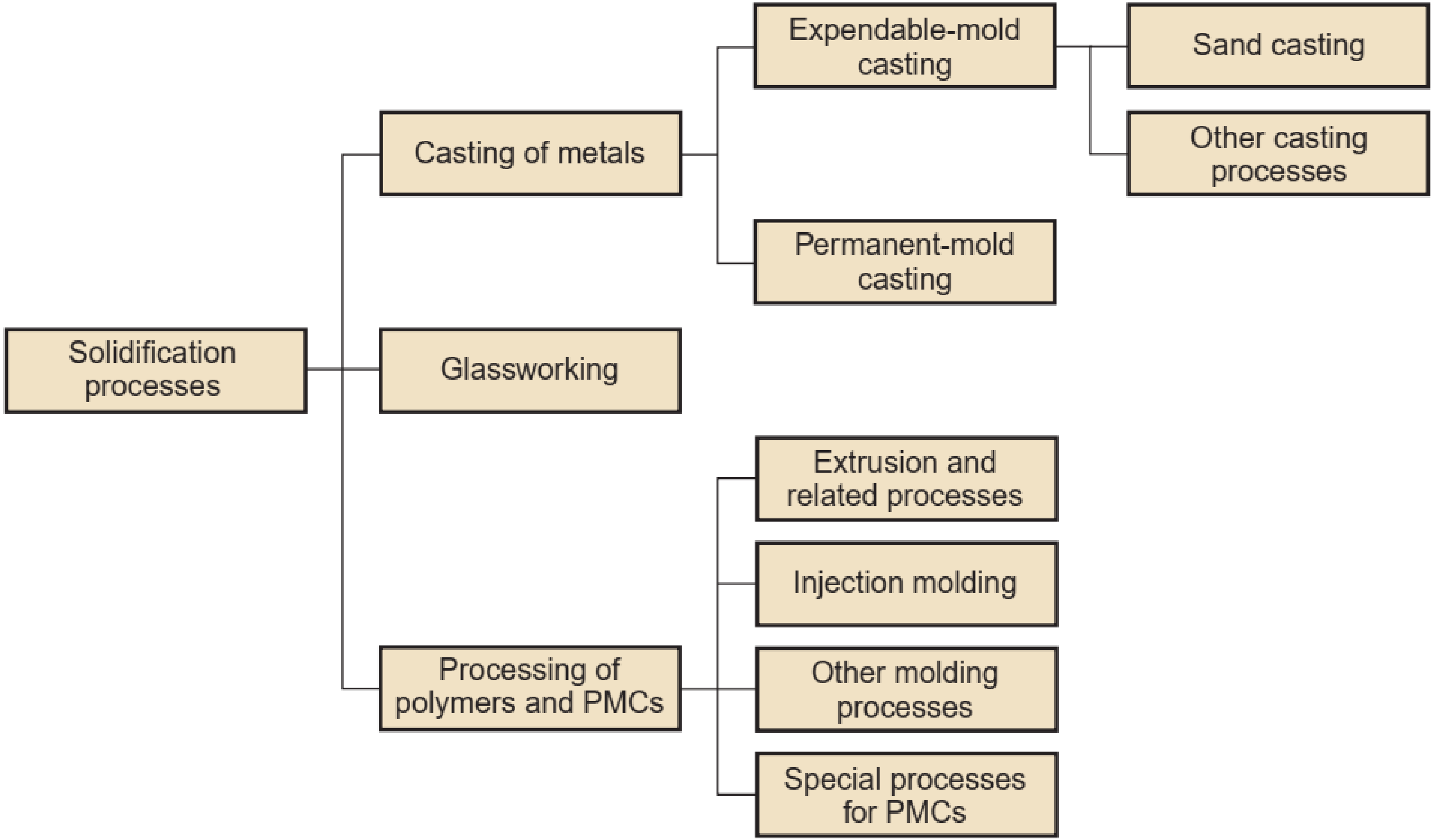
- Mechanical properties: Mechanical strength is poor
- Porosity
- Poor dimensional accuracy: Secondary processes are required
- Surface finish
- Safety hazard to humans during processing of molten metals

Freeze normal water and boiled water?

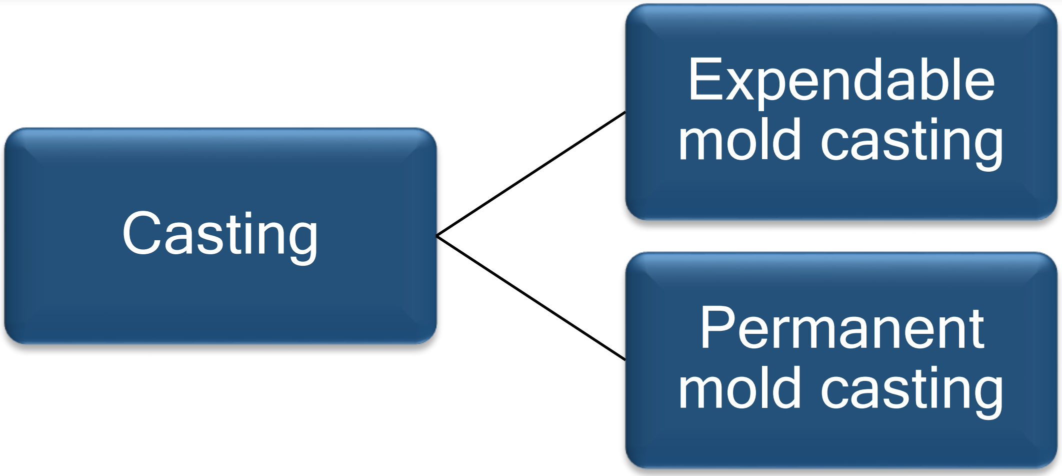


Courtesy: Google images

Casting: Classification



Casting of metals: Classification



Expendable:
not reusable

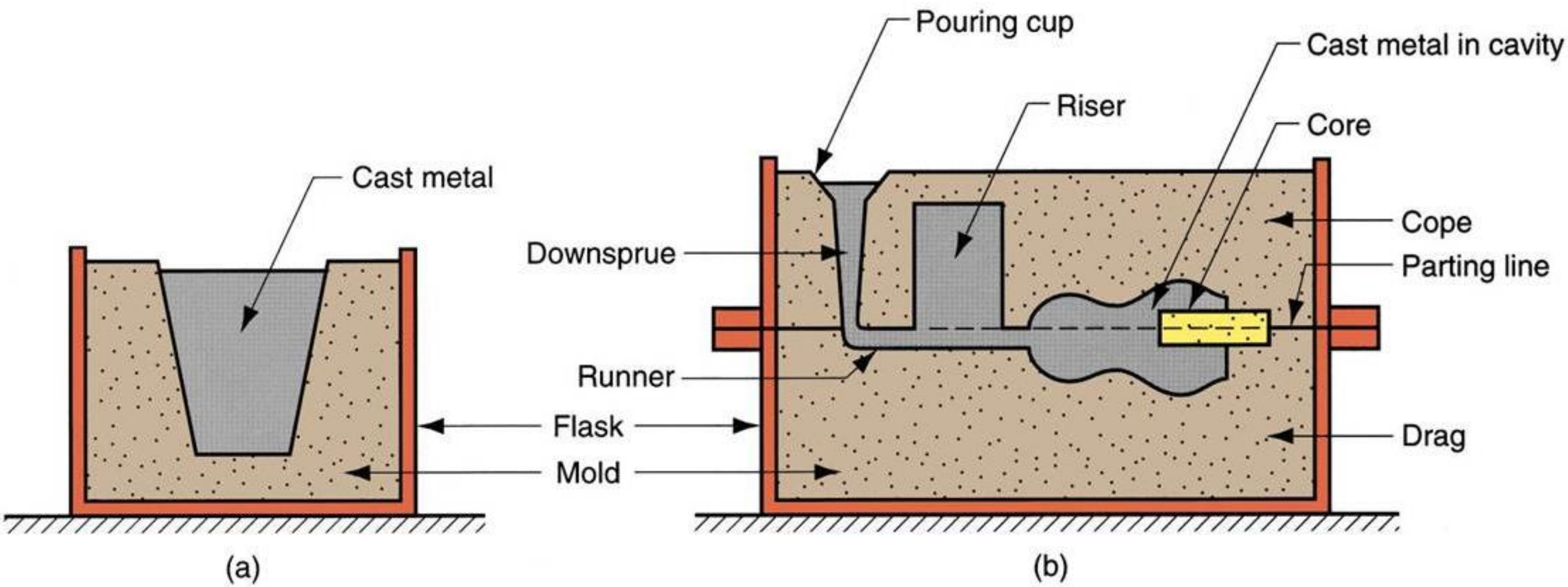
- Expendable mold / permanent pattern processes
  - mold broken to remove part eg: sand casting with wooden pattern
  - Advantage : complex shapes possible
  - Disadvantage : production rate is limited

- Expendable mold / expendable pattern processes
  - mold broken to remove part eg: sand casting with thermocol pattern

- Permanent mold processes – mold multiple usage eg: die casting
  - Advantage : higher production rates
  - Disadvantage : geometries limited by need; open mold

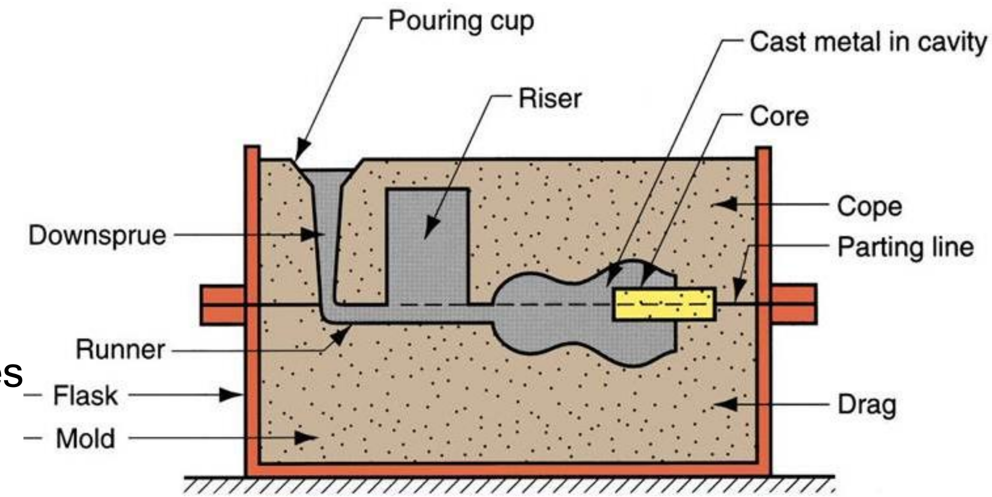
Expendable mold casting

- Open Vs. Closed mold



Casting Process

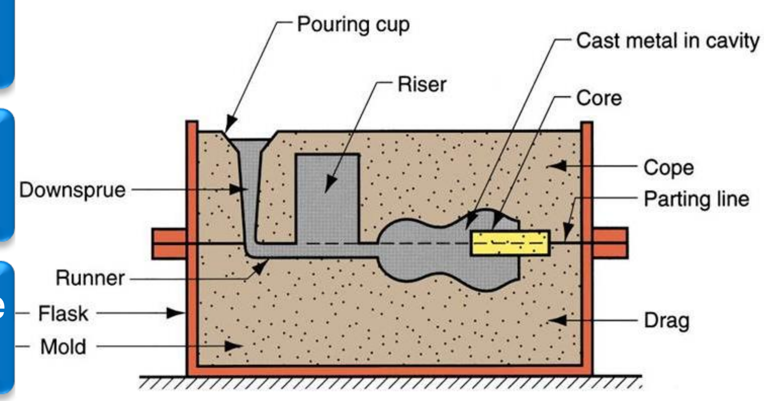
- Cope: Upper half part of the mold
- Drag: Lower half part of the mold
- Cope and drag contained in a box
  - → Flask, which is divided into two halves



- Parting line
- Pattern: mold cavity is formed by means of pattern (wood, plastic, metal etc.)
- Cavity: formed by packing sand around the pattern followed by its (pattern) removal from the cavity
- Core: internal surfaces are determined by core

Gating System

- Gating system
  - Downsprue — Metal enters
  - Runner — Leads into main cavity
  - Pouring cup — Minimize turbulence and splash



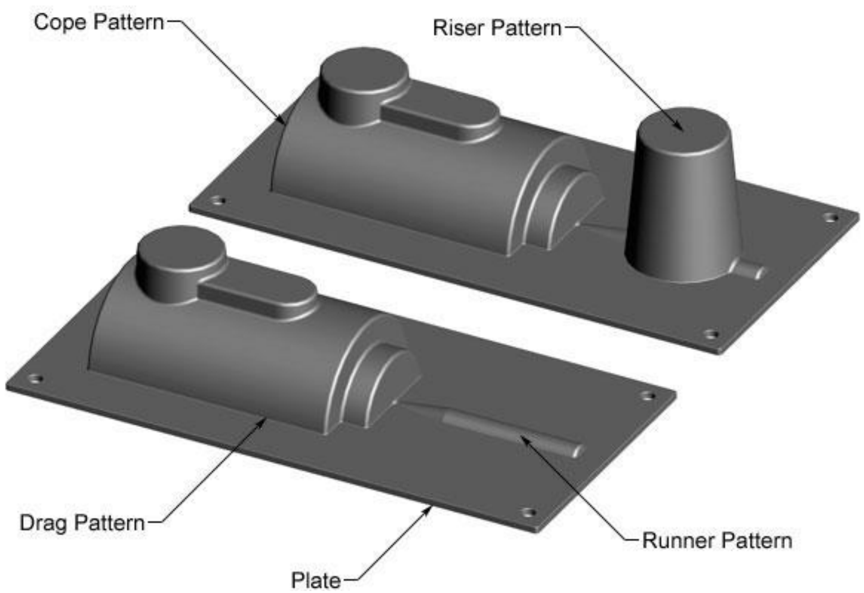
- Gating system: channel(s) by which molten metal flows into the cavity from outside the mold
- Riser: Reservoir serving as source of liquid for compensating shrinkage
  - Must solidify last
- Removal of gases and sand
  - Sand: Natural
  - Permanent: drilled/machined vent holes

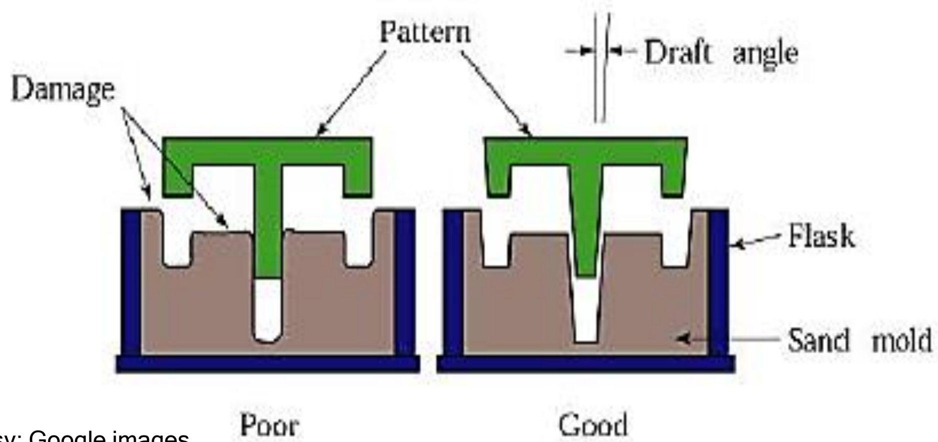
Patterns

Pattern types:
(a) single
(b) split
(c) match plate

Lost form casting: where the pattern is lost after casting

Typical metal match-plate pattern used in sand casting



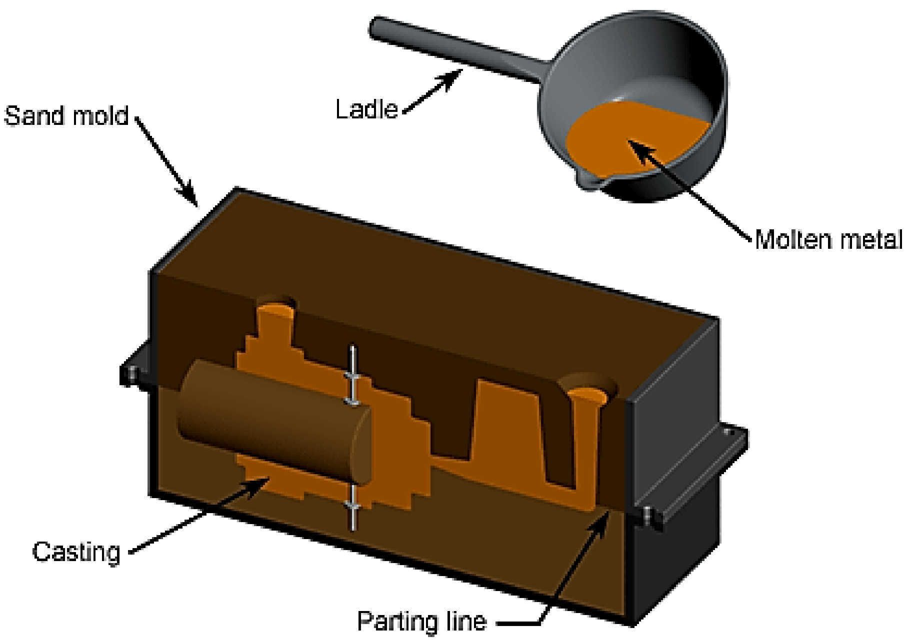


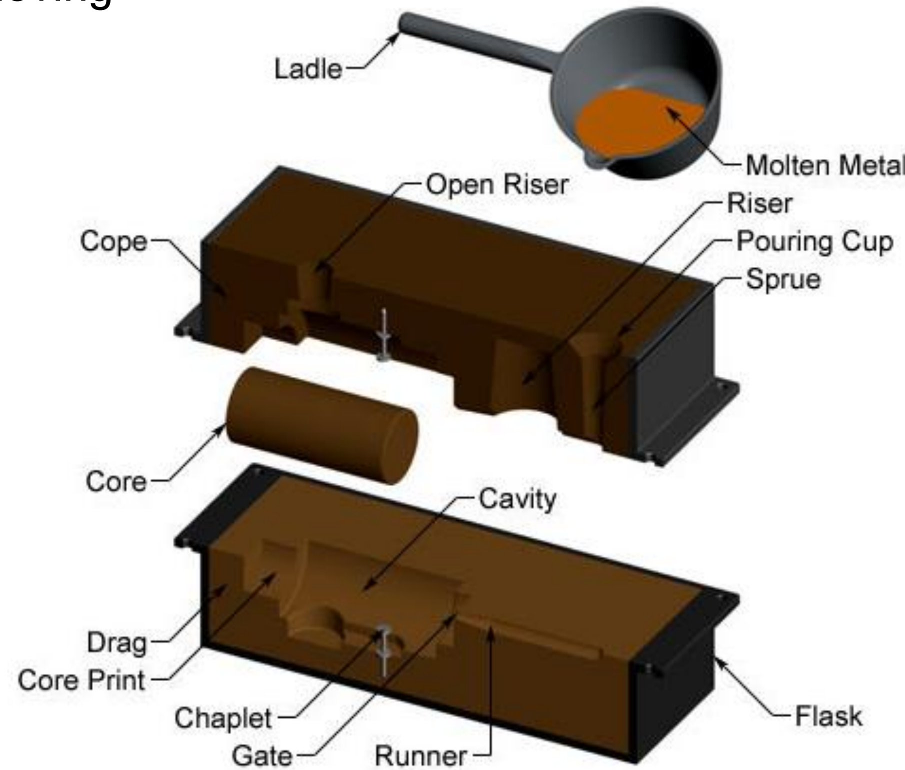
Taper in patterns for ease of removal from the sand mold

Courtesy: Google images

Cores - made of sand aggregates

- Possess:
  - Strength
  - Permeability
  - Thermal stability
  - Collapsibility
- Anchored by core prints (buoyancy of molten metal tends to displace core)
- Chaplets are used to keep the core from moving





Courtesy: Google images

Block Casting

- BMW Engine block casting
  - https://www.youtube.com/watch?v=N2hYTdrzujI

Heating analysis

- Heating to a desired temperature
- Heat energy requirement
  - Heat solid to the melting temperature
  - Solid to liquid: Heat of fusion
  - Heat molten metal to the desired temperature for pouring: Superheat.

$$\Delta H = \rho V\{C_s(T_m - T_o) + \Delta H_f + C_\ell(T_p - T_m)\}$$

ρ = density of metal (gm/cm^3)
V = volume of metal (cm^3)
Cs = Specific heat of solid metal (J/gm/°C)
C_ℓ = Specific heat of liquid metal (J/gm/°C)
ΔH_f = Heat of fusion on unit mass (J/gm)
Tp = Pouring Temperature (°C)
Tm = Melting temperature (°C)
To = Starting/ ambient temperature (°C)

Find out ΔH for Al ?

Engineering analysis of pouring

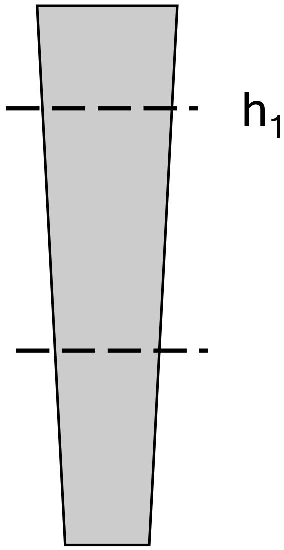
Care:

1. Pouring Temperature
2. Pouring rate
3. Turbulence

Bernoulli's Theorem:

Sum of the energies (head, pressure, kinetics and friction) at any two points in a flowing liquid are equal.

$$h_1 + \frac{P_1}{\rho} + \frac{v_1^2}{2g} = h_2 + \frac{P_2}{\rho} + \frac{v_2^2}{2g} + \Delta F$$



h = head (cm)
P = pressure on the liquid (N/cm^2)
ρ = density (gm/cm^3)
ΔF = head loss due to friction (cm)
v = velocity of liquid (cm/sec)
g = gravitational acceleration (cm/s^2)

1 and 2 are any two locations in the flowing liquid

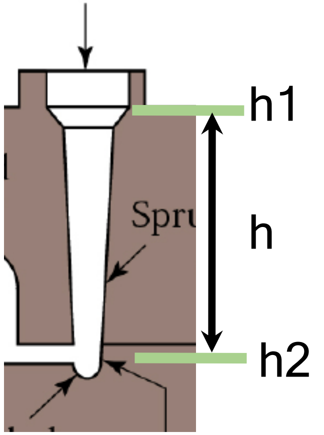
Pouring Analysis

$$h_1 + \frac{v_1^2}{2g_1} = h_2 + \frac{v_2^2}{2g}$$

(Simplified Bernoulli's equation: Ignoring friction force and realizing that P ≈ 1atm at both places)

From the figure, we see that $h_2 = 0$; $v_1 = 0$

$$h_1 + \cancel{\frac{v_1^2}{2g}} = \cancel{h_2} + \frac{v_2^2}{2g} \Rightarrow h_1 = \frac{v_2^2}{2g}$$



Hence, $\boxed{v_2 = \sqrt{2gh}}$ *v_2 = Flow velocity at point (2)*

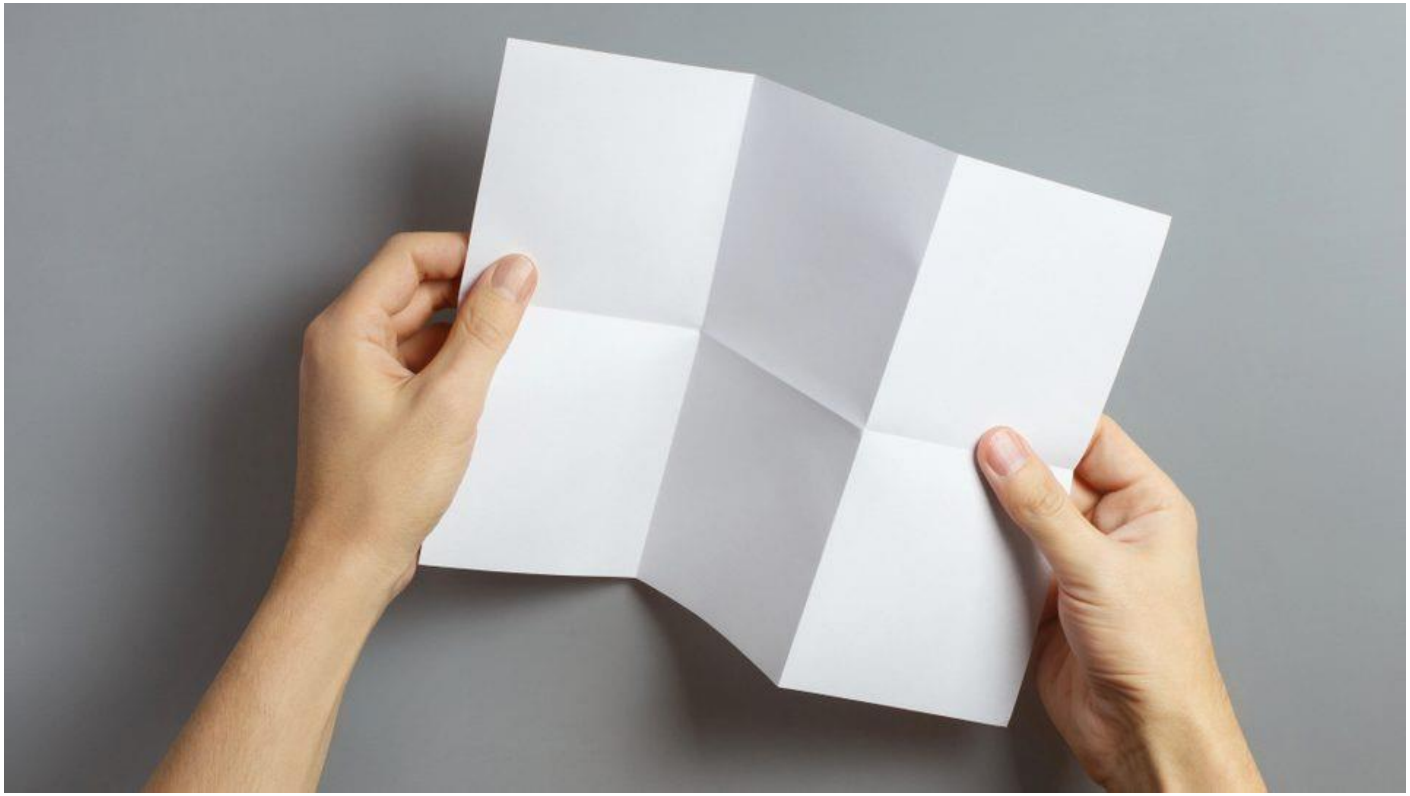
Another important relationship during pouring is the **Continuity law:**
Volume rate flow = Constant through out the liquid

$\boxed{Q = v_1 \times A_1 = v_2 \times A_2}$ A_1 & A_2 area (cm^2) *Hence, velocity increases area decreases,*

Q: Why the sprue is tapered downward to reduce the area?

Fun Fact….

- What's the maximum number of times that you can fold a piece of paper?



Courtesy: Google images