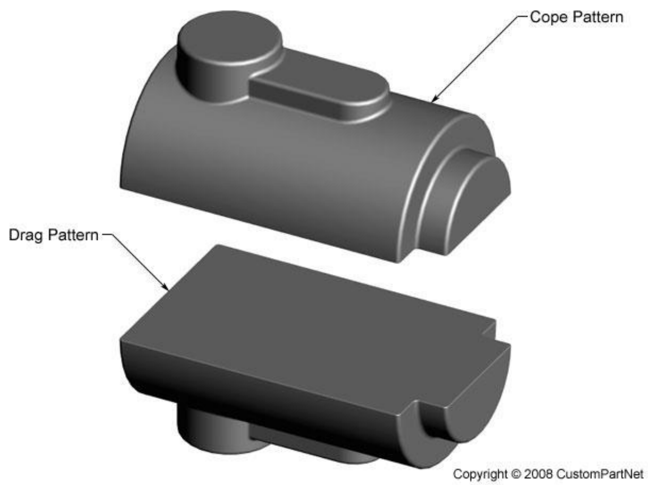
Patterns for mould making

Dr. Serhat ACAR

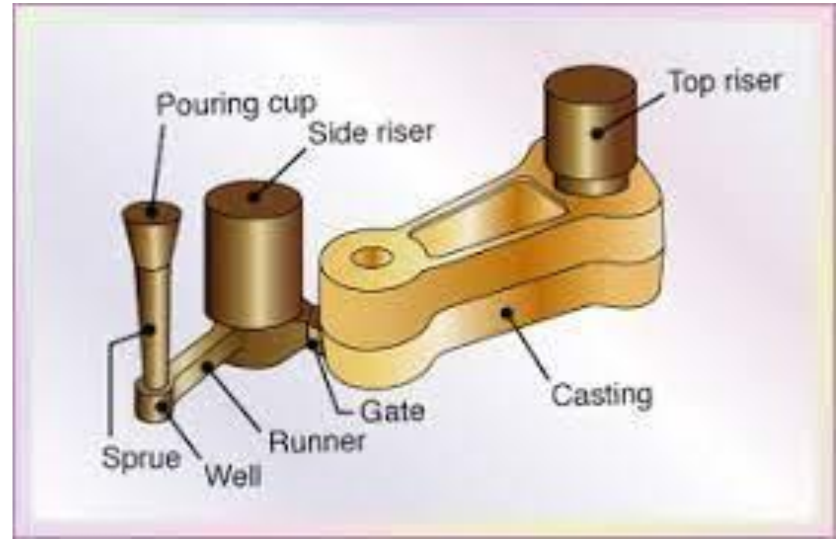
A PATTERN is a form made of wood, metal, plastic, or composite materials around which a moulding material (usually prepared sand) is formed to shape the casting cavity of a mould. Most patterns are removed from the completed mould halves and used repeatedly to make many duplicate moulds. Expendable patterns of such materials as wax or expanded polystyrene are made in quantity and are used only once to produce an individual mould.

Pattern Types (For permanent patterns)

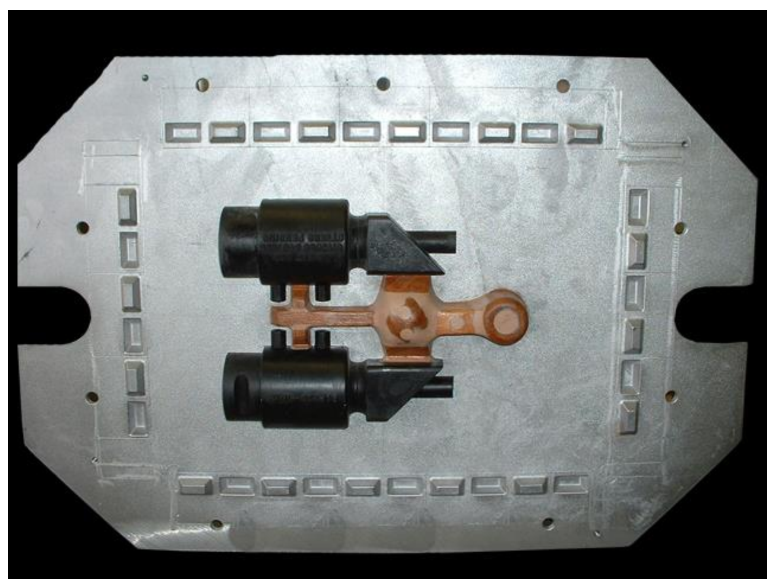
- Single free pattern
- Free pattern with runner (loose pattern)
- **Match plate pattern**
- Special pattern



Single free pattern



Free pattern with runner



Match plate pattern

Pattern materials

<u>Materials for permanent patterns</u>

- Wood (Must be dry and hard with low porosity.)

    - Pine, - Hornbeam

- Metal (Can be produced with machining or casting)

    - Al alloys, - Cu alloys, - Cast iron, - Steel,

    - Pb-Sn alloys

- Polymeric

    - Phenolic resins, -Epoxy resins, -Polyurethane

- Plaster (Can be coated with plastic and prepared with fibre reinforcements.)

Characteristic	Pattern material			
	Wood	**Aluminum**	**Cast iron**	Polyurethane
Machinability	E	G	F	**G**
Wear resistance	P	G	E	**E**
Strength	P	G	E	**F**
Repairability	E	F	G	**E**
Corrosion resistance	**E**	**E**	**P**	**E**

E, Excellent; G, Good; F, Fair; P, Poor

Some characteristics of permanent pattern materials

Materials for expendable patterns

- Wax (for investment casting)

Ingredient	Composition, %
Hard wax[a]	40
Microcrystalline wax	25
Soft resinous plasticizers[b]	15
Hard resins[b]	20
Antioxidant	0.05

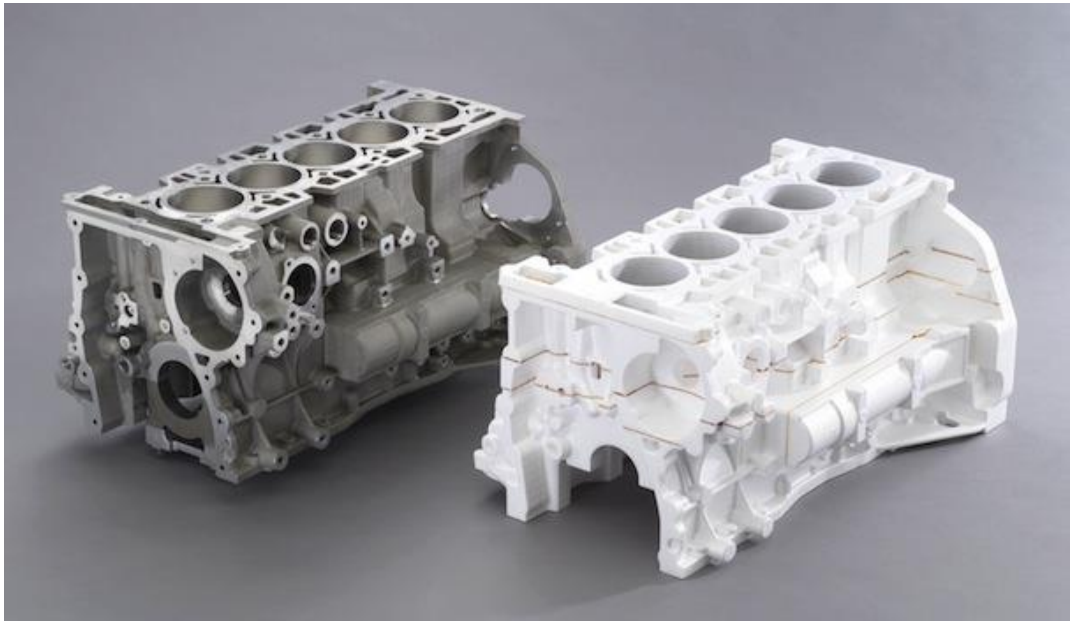
(a) Microcrystalline, amorphous.

(b) Amorphous

A typical pattern wax formulation

- Polymeric foam (for lost foam casting)
  - **EPS,** - EPMMA, - Copolymers

Wax pattern and cast part



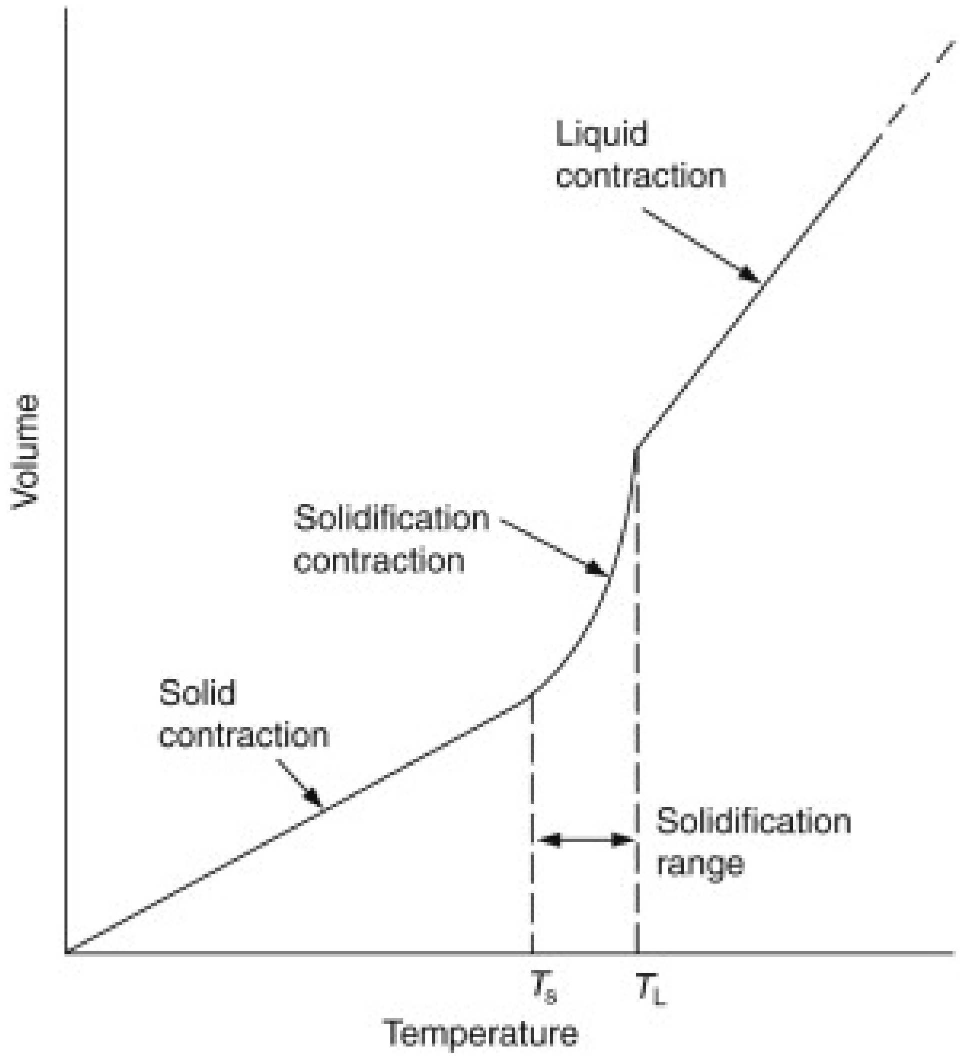
Foam pattern and cast part

Selection of pattern type

The type of pattern or core box used and the pattern or core box material used for a given set of castings depend on the following fundamental factors:

- The number of castings to be produced
- The moulding or coremaking process to be employed
- The casting design
- The dimensional tolerances required

Stages of shrinkage formation



Pattern allowances

Although a pattern is used to produce a casting of desired dimensions, it is not dimensionally identical to the casting. A number of allowances must be made on the pattern to ensure that the finished casting is dimensionally correct, to ensure that the pattern can be effectively removed from the mould, and to allow for cores to be firmly anchored.

- Shrinkage allowance
- Machining allowance
- Distortion allowance (especially for special shapes)
- Draft or taper

Shrinkage allowance is the correction factor built into the pattern to compensate for the contraction of the metal casting as it solidifies and cools to room temperature. The pattern is intentionally made larger than the final desired casting dimensions to allow for solidification and cooling contraction of the casting. This allowance for contraction is sometimes called patternmaker's shrinkage. The total contraction is volumetric, but is usually expressed linearly. Because different shrinkage allowances must be used for the individual types of metals cast, it is not possible to use the same pattern equipment for different cast metals without expecting dimensional changes. It must be emphasized that these shrinkage allowances are only guidelines and can only be applied with considerable knowledge of the actual casting design and the foundry moulding techniques to be used.

Volumetric solidification shrinkage of some metals and alloys

Metal or alloy	Volumetric solidification contraction (%)	Metal or alloy	Volumetric solidification contraction (%)
Aluminum	6.6	70%Cu–30%Zn	4.5
Al–4.5%Cu	6.3	90%Cu–10%Al	4
Al–12%Si	3.8	Gray iron	Expansion to 2.5
Carbon steel	2.5–3	Magnesium	4.2
1% carbon steel	4	White iron	4–5.5
Copper	4.9	Zinc	6.5

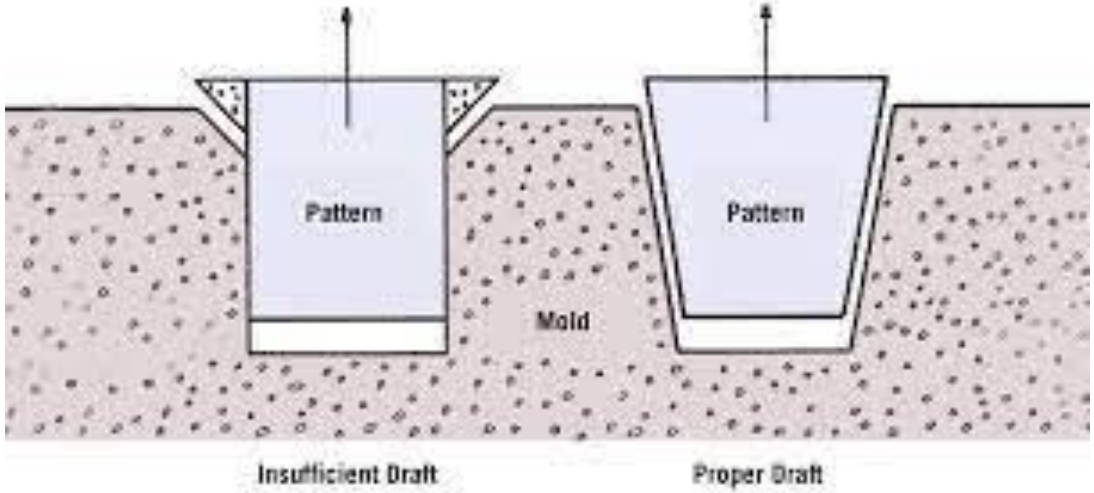
Typical pattern shrinkage allowances for various casting materials

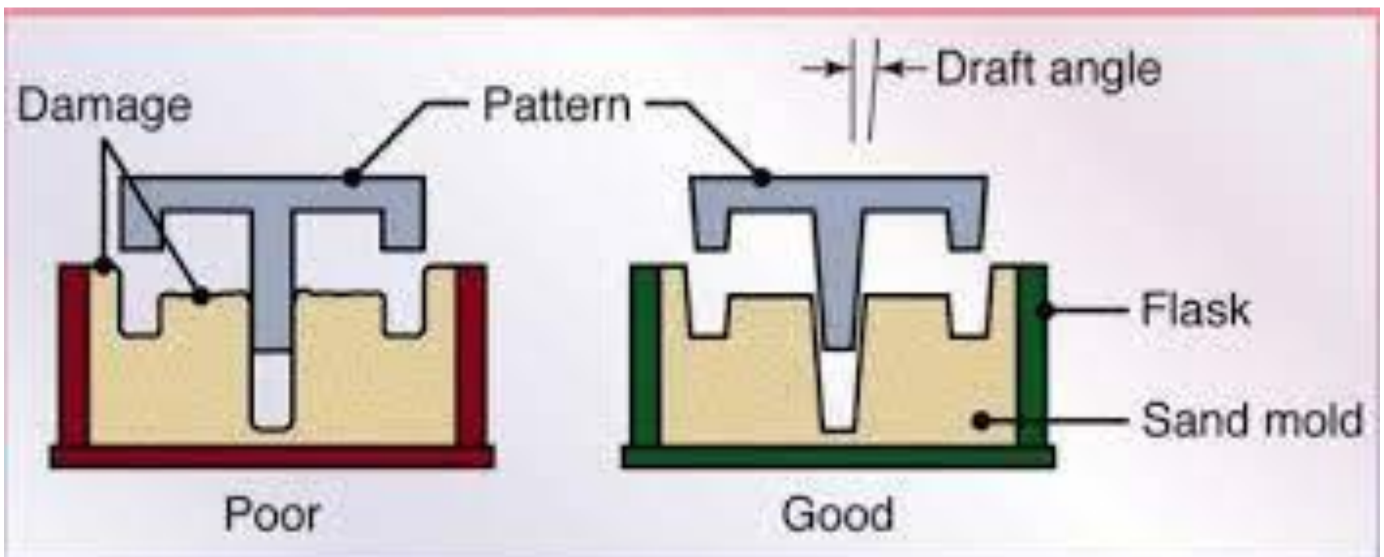
Alloy being cast	Allowance	Approximate shrinkage, %	Shrinkage allowance	
			mm/m	in./ft
Steel	1 in 64	1.6	15/7	3/16
Gray cast iron	1 in 100	1.0	8/4	1/10
Ductile cast iron	1 in 120	0.8	7/8	3/32
Aluminum	1 in 77	1.3	13/1	5/32
Brass	1 in 70	1.4	14/4	11/64

The machine finish allowance provides for sufficient excess metal on all cast surfaces that require finish machining. The required machine finish allowance depends on many factors, including the metal cast, the size and shape of the casting, casting surface roughness and surface defects that can be expected, and the distortion and dimensional tolerances of the casting that are expected. Accurate patterns combined with automated molding can often produce close-tolerance castings with a minimum machine finish allowance that can reduce final machining costs considerably.

Distortion Allowances. Certain cast shapes, such as large flat plates and domeor U-shaped castings, sometimes distort when reproduced from straight or perfect patterns. This distortion is caused by the nonuniform contraction stresses during the solidification of irregularly shaped designs. Minor distortions are normally corrected by mechanically pressing or straightening the casting, but if distortions are consistent and prominent, the pattern shape can be intentionally changed to counteract the casting distortions. The "distorted" pattern will then produce a distortion-free casting. Prior consultation with the foundry is necessary to review their experience with the warpage distortion of similarly shaped castings.

Draft is taper allowed on the vertical faces of a pattern to permit its removal from the sand or other moulding medium without tearing of the mould walls. (On vertically parted moulds, draft is required on horizontal pattern surfaces.) The amount of draft required depends on the shape and size of the casting, the moulding process used, the method of mould production, and the condition of the pattern. A draft angle of approximately 1.5° (16 mm/m, or 0.2 in./ft) is often added to design dimensions. The draft angle may be higher when manual moulding techniques are used. Interior surfaces usually require somewhat more draft than exterior surfaces, and deep pockets or cavities may require considerably more draft.

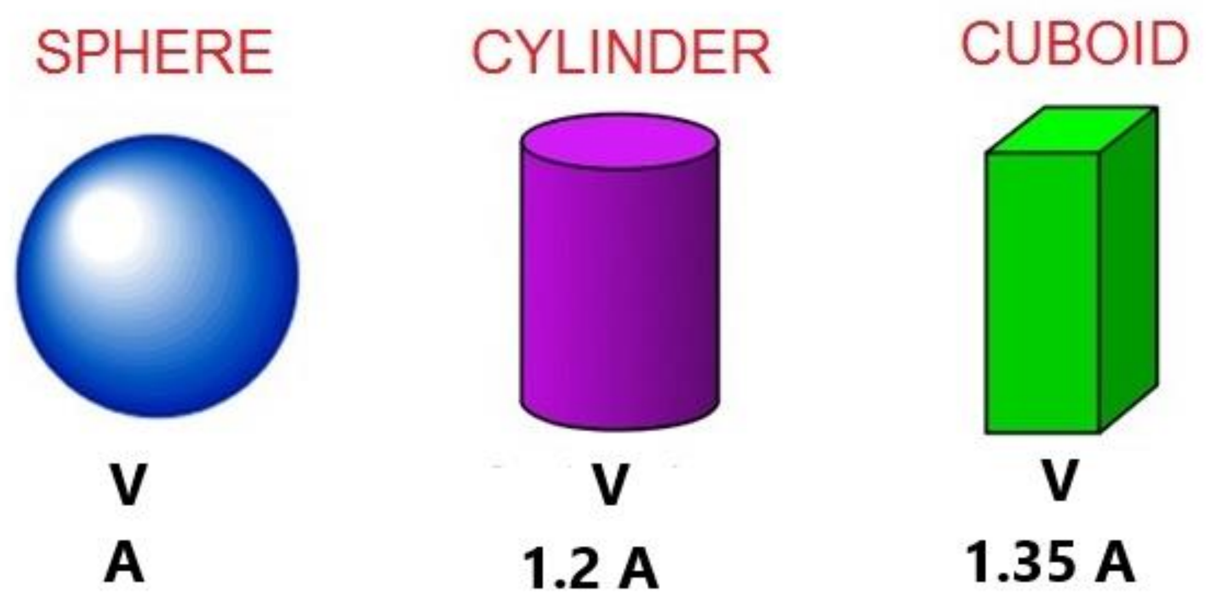

Pattern
Pattern
Mold
Insufficient Draft
Proper Draft


Draft angle
Damage
Pattern
Flask
Sand mold
Poor
Good

In castings, solidification must be directed to risers (feeders) and runner system. This is called directional solidification. For this purpose:

- Prepare optimum runner and riser system for appropriate thermal gradient.
- Use effective shaped risers on the right places.
- If required use chillers.
- Use different types of sands in different places of moulds. These sands must have different thermal properties.

Shape of riser



$ts_{sphere} = 1.5\ ts_{cylinder}$

$ts_{sphere} = 2\ ts_{cuboid}$

$$Module\ (M) = \frac{Volume\ (V)}{Surface\ Area\ (A)}$$

$$solidification\ time\ (ts) \propto \left(\frac{V}{A}\right)^2$$

$M_R^2 > M_C^2$ (10 - 15%)

R: Riser

C: Casting

Properties effects the fluidity of alloys

- Casting temperature (Amount of superheat)
- Thermal properties of molten material
- Thermal properties of mould material
- Design of the runner system
- Mould wetting ability of the cast metal
- Surface roughness of the mould wall
- Section thickness of the cast part
- Solidification range of the alloy (Liquidus and solidus temperatures)

Fluidity of Molten Metal

A term commonly used to describe the ability of the molten metal to fill mold cavities is fluidity. This term consists of two basic factors: (1) characteristics of the molten metal; and (2) casting parameters. The following characteristics of molten metal influence fluidity:

1. **Viscosity.** Fluidity decreases as viscosity and the viscosity index (its sensitivity to temperature) increase.

2. **Surface tension.** A high surface tension of the liquid metal reduces fluidity. Oxide films developed on the surface of the molten metal have a significant adverse effect on fluidity; an oxide film on the surface of pure molten aluminum, for example, triples the surface tension.

3. **Inclusions.** As insoluble particles, inclusions can have a significant adverse effect on fluidity. This effect can be verified by observing the viscosity of a liquid, such as oil, with and without fine sand particles in it; it will be noted that the former will have lower viscosity.

4. **Solidification pattern of the alloy.** Fluidity is inversely proportional to the freezing range thus, the shorter the range (as in puremetals and eutectics), the higher the fluidity becomes. Conversely, alloys with long freezing ranges (such as solid-solution alloys) have lower fluidity.

The following casting parameters influence fluidity and the fluid flow and thermal characteristics of the system:

1. **Mold design.** The design and dimensions of such components as the sprue, runners, and risers all influence fluidity to varying degrees.

2. **Mold material and its surface characteristics.** The higher the thermal conductivity of the mold and the rougher its surfaces, the lower is fluidity. Heating the mold improves fluidity, although it also increases the solidification time, resulting in coarser grains and hence lower strength.

3. **Degree of superheat.** Defined as the increment of temperature above an alloy’s melting point, superheat improves fluidity by delaying solidification.

4. **Rate of pouring.** The lower the rate of pouring into the mold, the lower the fluidity, because the metal cools faster.

5. **Heat transfer.** Heat transfer directly affects the viscosity of the liquid metal, and hence its fluidity.

The term castability is generally used to describe the ease with which a metal can be cast to produce a part with good quality. Because this term also includes casting practices, the factors listed above have a direct effect on castability.

Flow characteristics. An important consideration in fluid flow in gating systems is the presence of turbulence, as opposed to laminar flow of fluids. The **Reynolds number**, Re, is used to characterize this aspect of fluid flow; Re represents the ratio of the inertia to the viscous forces in fluid flow, and is expressed as

$$Re = vD\rho/\eta$$

where v is the velocity of the liquid, D is the diameter of the channel, and ρ and η are the density and viscosity, respectively, of the liquid. The higher the Reynolds number, the greater is the tendency for turbulent flow. In ordinary gating systems Re ranges from 2000 to 20,000; Re values of up to 2000 represent laminar flow. Between 2000 and 20,000 the flow is a mixture of laminar and turbulent, and is generally regarded as harmless in gating systems for casting. However, Re values over 20,000 represent severe turbulence, resulting in air entrainment and dross formation.