Experiment Six

# Design of Gating and Feeding Systems

A: Tutorial on design of gating and feeding systems

## CLACULATIONS INVOLVING DESIGN OF FEEDING SYSTEM

### 1. CALCULATION OF FEEDER SIZE

The feeder must satisfy both of the following two requirements:

#### 1.1 Heat transfer criteria

$$M_C : M_N : M_F = 1 : 1.1 : 1.2 \quad (1)$$

where $M_F$, $M_C$ and $M_N$ are modulus of feeder, modulus of casting, and modulus of the neck of feeder at the junction of casting respectively. For calculation of modulus of an object, see **Fig.1** and **Fig. 2**.

#### 1.2 Feed volume criterion

$$V_F \geq \alpha V_C / (\varepsilon - \alpha) \quad (2)$$

where $\varepsilon$ is the efficiency of the feeder, $\alpha$ is the solidification shrinkage, and $V_F$ and $V_C$ are volume of feeder and casting respectively. For efficiency of differently shaped feeders, see **Fig. 3**.

The higher of the two values of feeder volume given by equations (1) and (2) satisfies both requirements and thus taken as the actual volume of the feeder.

### 2. DETERMINATION OF FEEDER SHAPE

According to Chvorinov, solidification time increases as the volume to area ratio or the modulus, M, increase. Thus

$$t \propto (V/A)^2 \quad \text{or,} \quad t = CM^2 \quad (3)$$

where, t is solidification time, and C is constant.

According to eq.(3), a sphere, having the smallest modulus per unit volume, is the ideal shape for a feeder. But a spherical feeder practically too difficult to mould and consequently cylindrical feeders are mostly used. For a relationship between casting shape (M) and its solidification time (t) for various metals and alloys, see **Fig. 4**.

### 3. FEEDING DISTANCE

In normal conditions, there is a limit to how far a feeder can feed along a flow path. Up to this distance from feeder, the casting will be sound. Beyond this distance the casting will exhibit porosity. For feeding distance rule, see **Fig. 5**.

### 4. INCREASING FEEING EFFICIENCY

There are number of ways by which the efficiency of a feeder can be increased. Some of the most common ways are:

1. Use feeder head with a higher feeding efficiency
2. Feeder insulation
3. Use of exothermic materials

## DESIGN OF GATING SYSTEM

### 1. DESIGN OF POURING BUSH/BASIN

Decide on the type of pouring basin used, **Fig. 6**:

- Conical pouring cup (can be used for small casting)
  - hand ladle filling (50 mm above the entrance to the sprue) monograms can be used.
  - poured directly from furnace (usually from a height) monogram can not be used.
- Pouring bush/basin (for larger casting)

### 2. DESIGN OF DOWN-RUNNER OR SPRUE

**2.1** Calculate the weight of liquid metal to be poured (includes the casting, the feeder, and all elements of gating system)

**2.2** Choose location and design of gating system.

**2.3** Determine/decide on total filling time of casting. See **Appendix 1** and **Appendix 2**.

Pouring time < solidification time of thinnest section of casting. Find solidification time from modulus or use **Fig.4**. Experience / trial and error are needed.

**2.4** Find average filling rate in the gating system

$$\text{Average filling rate, Kg/s} = \text{Weight of casting/ filling time} \quad (4)$$

**2.5** Select the velocity of flow

| | | |
|---|---|---|
| Al-bronze | : | 75 mm/s |
| Al-base and Mg-base alloys | : | 250 mm/s |
| Cu-base and Fe-base alloys | : | 500 mm/s |

**2.6** Calculate the effective metal head of casting

$$h_P = H - 0.5\, h_1^2/h_2 \quad (5)$$

$h_P$ = metal head pressure at sprue base, H = height of sprue, $h_1$ = height of casting above point of metal entry into the mould (or, height of casting in cope), $h_2$ = height of casting.

**2.7** Calculate the choke area

$$A = W / [\, \rho t C \sqrt{(2gh_P)}\, ] \quad (6)$$

A = choke area, W = casting weight (total, including all elements), ρ = density of molten metal (Al-base alloys = 2500 $kg/m^3$; Cu-, Fe-, Ni-, and Co-base alloys = 7000 $kg/m^3$ for), $h_P$ = effective height of metal head, C = discharge coefficient (= 0.8), g = acceleration due to gravity (=9.8 $m/s^2$), t = pouring time, s.

**2.8** Calculate the sprue exit area. [ Use Law of Continuity, $Q = A_1v_1 = A_2v_2$ ]

**2.9** Calculate the sprue top area. [ Use Bernoulli's Theorem, $v^2 = 2gh$ and then using law of continuity to obtain the equation $A_1 = A_2 \sqrt{(h_2/h_1)}$ ]

$A_1$ = sprue top area, $A_2$ = sprue bottom area, $h_1$ = distance between ladle and spure top, and $h_2$ = distance between ladle and sprue bottom.

**2.10** Design of sprue base (or, well).

### 3. DESIGN OF RUNNER AND GATES

**3.1** Design of runner and ingate. Use proper gating ratio. See **Fig. 7**.

**3.2** Avoid hot spot in the gate junction gate modulus ≈ 1/2 local casting modulus. See **Fig. 8**.
( ⇒ gate thickness = 1/2 local casting thickness)

### 4. INCLUSIONS CONTROL

Use one or more inclusion control systems (Filters, dross trap or swirl trap) in the gating system to avoid entry of sand, oxide film and other inclusions into the mould cavity.

## Use of Nomogram

Calculation in steps 8, 9 and 11 can be made with the use of Nomogram. Once the average fill rate and sprue height have been decided, the sprue bottom area, gate area, and sprue top area can be found out from such nomogram. For the present case, nomogram shown in **Fig. 9** will be used.

Assumptions made in the preparation of the monograms:

**1.** Unpressurised gating system.

**2.** Initial pouring rate ≈ 1.5 x average pouring rate.

**3.** c = 0.8 (sprue loss), k = 0.5 (basin los)

**4.** Critical gate velocity: 250 mm/s for Al-base alloys; 500 mm/s for Cu- and Fe-base alloys.

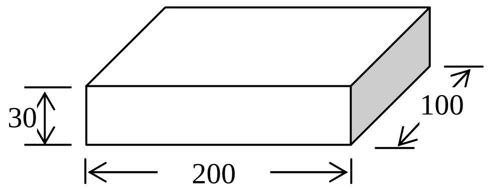
**5.** 20% safety factor oversize of the sprue top area

**6.** $h_1$ = 50 mm (height of liquid at the pouring basin)

**4.** Density data: 2500 kg/m$^3$ for Al-base alloys; 7000 kg/m$^3$ for Cu-, Fe-, Ni-, and Co-base alloys.

## CASE STUDY

To design a suitable feeding and gating systems for the following aluminium alloy casting (dimensions are in mm).



## Appendix 1:

## Calculation of Pouring Time Base on Experimented Rules

Often experimentally determined equations are used to calculate pouring time and pouring rate for typical foundry alloys. Some those equations are mentioned below.

**1. Grey iron castings**

(a) Thin walled castings of thickness 2.5 – 15 mm and weight less than 450 kg

$$t = S \sqrt{W} \quad \text{seconds}$$

W = weight of liquid metal poured, kg

S = coefficient taking into account of casting wall thickness

| Thickness of casting, mm | 2.5 – 3.5 | 3.5 – 8.0 | 8.0 – 15.0 |
|---|---|---|---|
| S | 1.63 | 1.85 | 2.20 |

(b) In fps unit:

$$t = k\,(0.95 + \delta/0.853)\sqrt{W} \quad \text{seconds}$$

k = a fluidity factor obtainable from the **Fig. 10**. ( k = Fluidity factor from fig. /40 ).

$\delta$ = average thickness of casting, inch

W = weight of metal poured, pound

(c) For castings of weight > 450 kg:

$$t = k\,(0.95 + \delta/0.853)\,W^{1/3} \quad \text{seconds}$$

**2. Shell moulded ductile iron (vertical pouring)**

$$t = k_1 \sqrt{W} \quad \text{seconds}$$

$k_1$ = 1.8 (for section 3/8 – 1 inch)

$k_1$ = 1.4 (for thinner sections)

$k_1$ = 2.0 (for heavier sections)

**3. Steel castings:**

$$t = K \sqrt{W} \quad \text{seconds}$$

K = 1.2 for 100 lb casting

K = 0.4 for 100,000 lb casting

(K values plotted against log W)

**4. Copper alloys:**

$$t = S\,(\delta G)^{1/3} \quad \text{seconds}$$

$\delta$ = average thickness of castings, mm

S = 1.3 – 1.8 (for bottom gated systems; lower value for brass, higher value for tin bronze)

S = 1.9 – 2.8 (for top gates systems; lower value for brass, higher value for tin bronze)

## Appendix 2:

## Calculation of Pouring Rate

To calculate the optimum pouring rate for different metals, the following equations can be applied.

**1. Ferrous metals and copper-base alloy castings**

$$R = \frac{W^P}{\left(1.34 + \frac{t}{13.77}\right)} \text{ kg/s}$$

where W = weight of casting, kg, t = critical casting thickness, mm, and P = constant (depends upon the weight of casting).

The value of constant P for different castings is as follows:

| Casting weight, kg | up to 500 | 500-5000 | 5000-15000 |
|---|---|---|---|
| Constant, P | 0.50 | 0.67 | 0.70 |

**2. Light metal castings**

$$R = b\sqrt{W} \text{ kg/s}$$

where b = constant, depends on wall thickness. Typical values of b:

| Wall thickness, mm | below 6 mm | 6-12 mm | above 12 mm |
|---|---|---|---|
| Constant, b | 0.99 | 0.87 | 0.47 |

The pouring rate thus obtained from these two equations has to be corrected for metal fluidity k and the effect of friction (f factor) in the gating system. The adjusted pouring rate $R_a$ can be calculated according to the following equation:

$$R_a = R / (k \, . \, f)$$

For all metals other than grey and malleable cast iron, k can be taken as unity. In case of grey and malleable cast iron, the metal fluidity can be calculated from the carbon equivalent (see **Fig. 10**).

| *Shape* | H/D | *Modulus* | | | |
|---|---|---|---|---|---|
| | | *100% Cooled area* | | *Base uncooled* | |
| Sphere | | $\frac{D}{6}$ | 0.167$D$ | — | — |
| Cube | | $\frac{D}{6}$ | 0.167$D$ | $\frac{D}{5}$ | 0.200$D$ |
| Cylinder | 1.0 | $\frac{D}{6}$ | 0.167$D$ | $\frac{D}{5}$ | 0.200$D$ |
| | 1.5 | $\frac{3D}{16}$ | 0.188$D$ | $\frac{3D}{14}$ | 0.214$D$ |
| | 2.0 | $\frac{D}{5}$ | 0.200$D$ | $\frac{2D}{9}$ | 0.222$D$ |
| Infinite cylinder | ∞ | $\frac{D}{4}$ | 0.250$D$ | – | – |
| Infinite plate | | $\frac{D}{2}$ | 0.500$D$ | – | – |

**Fig.1:** Moduli of some common shapes.

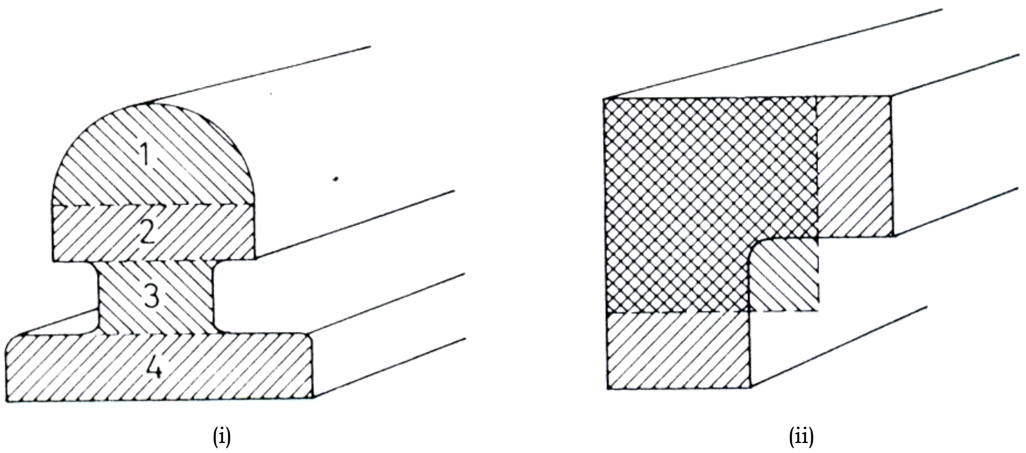



**Fig. 2:** Method of determination of modulus value of irregular shapes. The cross-section is determined either (i) by subdivision into simple shapes and (ii) by approximated by substitute shapes.

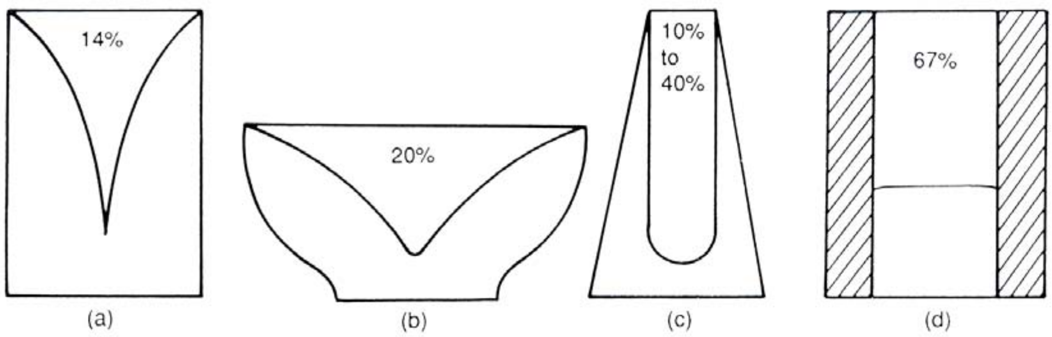



**Fig. 3:** Metal utilisation of feeders o various forms moulded in sand. The (a) cylindrical and (b) hemospherical heads have been treated with normal feeding compounds; (c) the efficiency of the reverse tapered heads depends on detailed geometry; (d) shows an exothermic sleeve.

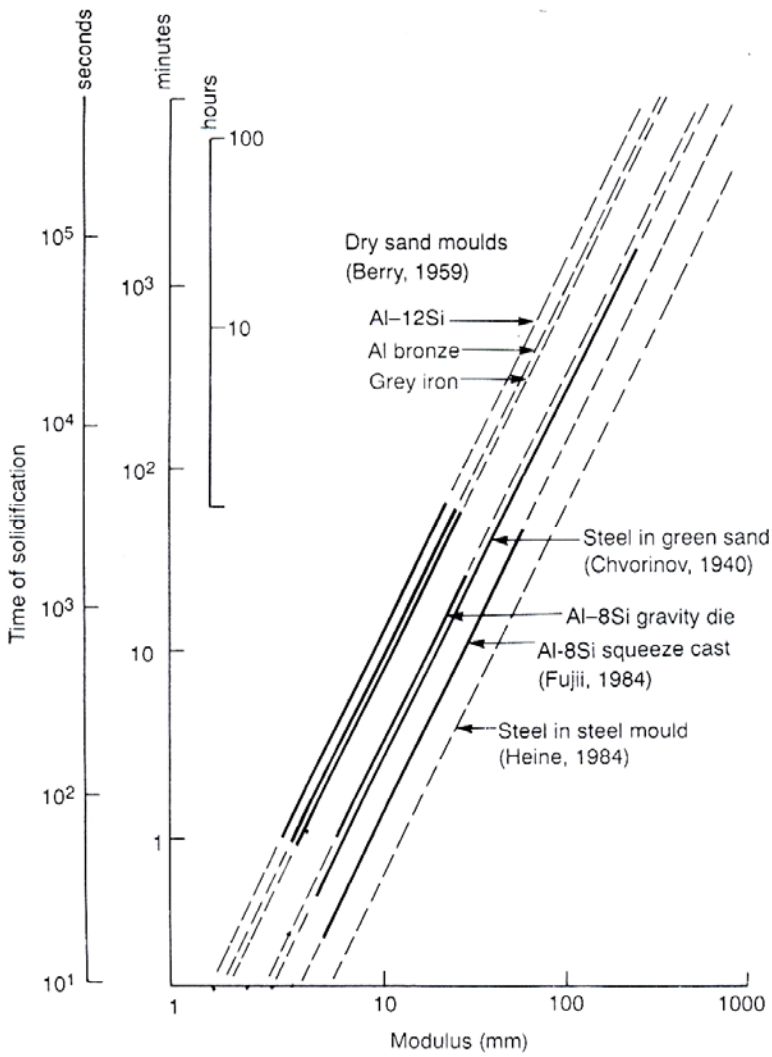



**Fig. 4:** Freezing times for plate-shaped castings in different alloys and moulds.

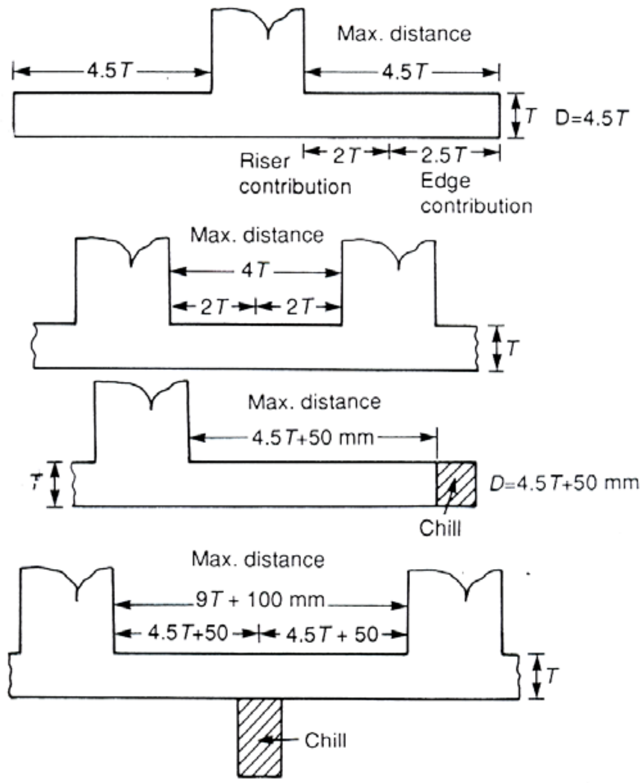



**Fig. 5:** Feeding distance relations for plates.

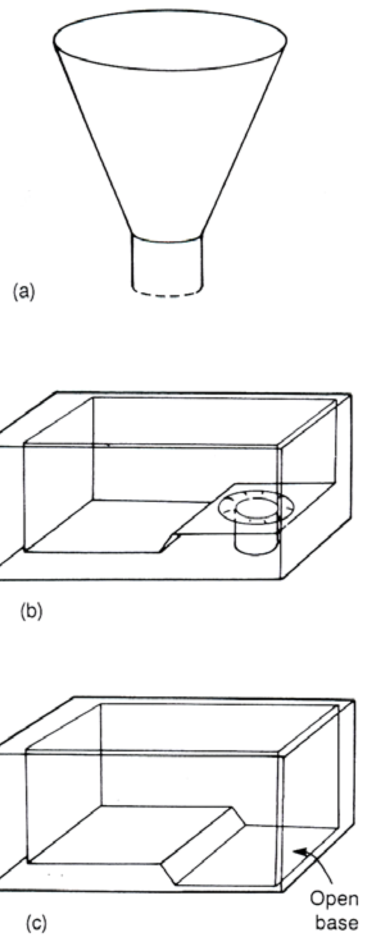



**Fig. 6:** (a) A simple funnel pouring cup, not recommended in general; (b) a weir bush of excellent design, whose upward circulation will assist in the separation of slag and dross, but which would need to be carefully matched to the entrance diameter of the sprue in the cope; and (c) an offset bush with an open base recommended for general use.

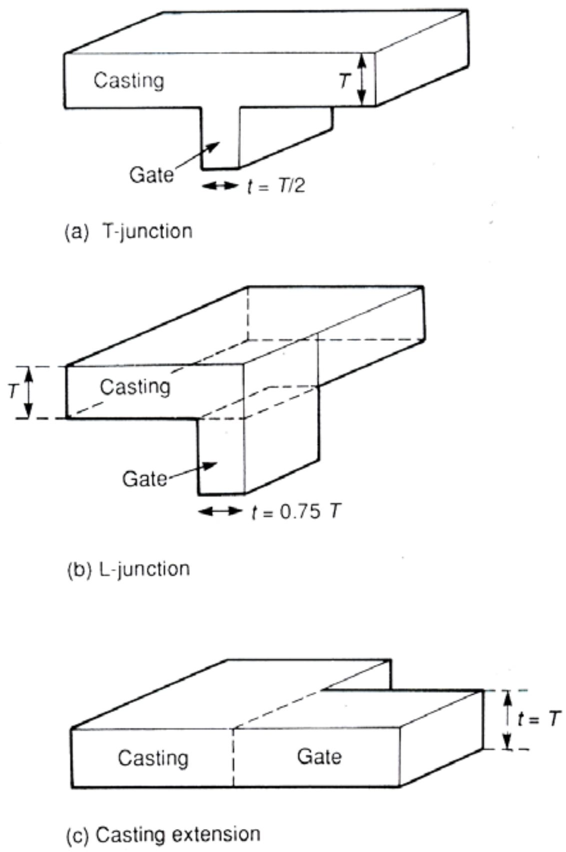



**Fig. 7:** The maximum allowable gate thickness to avoid a hot spot at the junction with the casting.

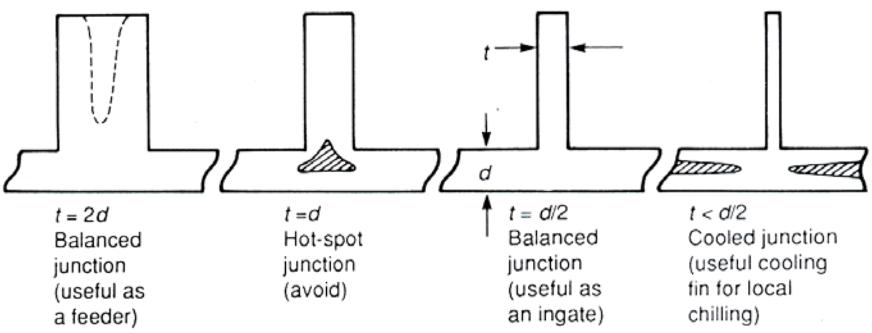



**Fig. 8:** A spectrum of T-junctions, showing how some are hot, some are cold, and some are neither.

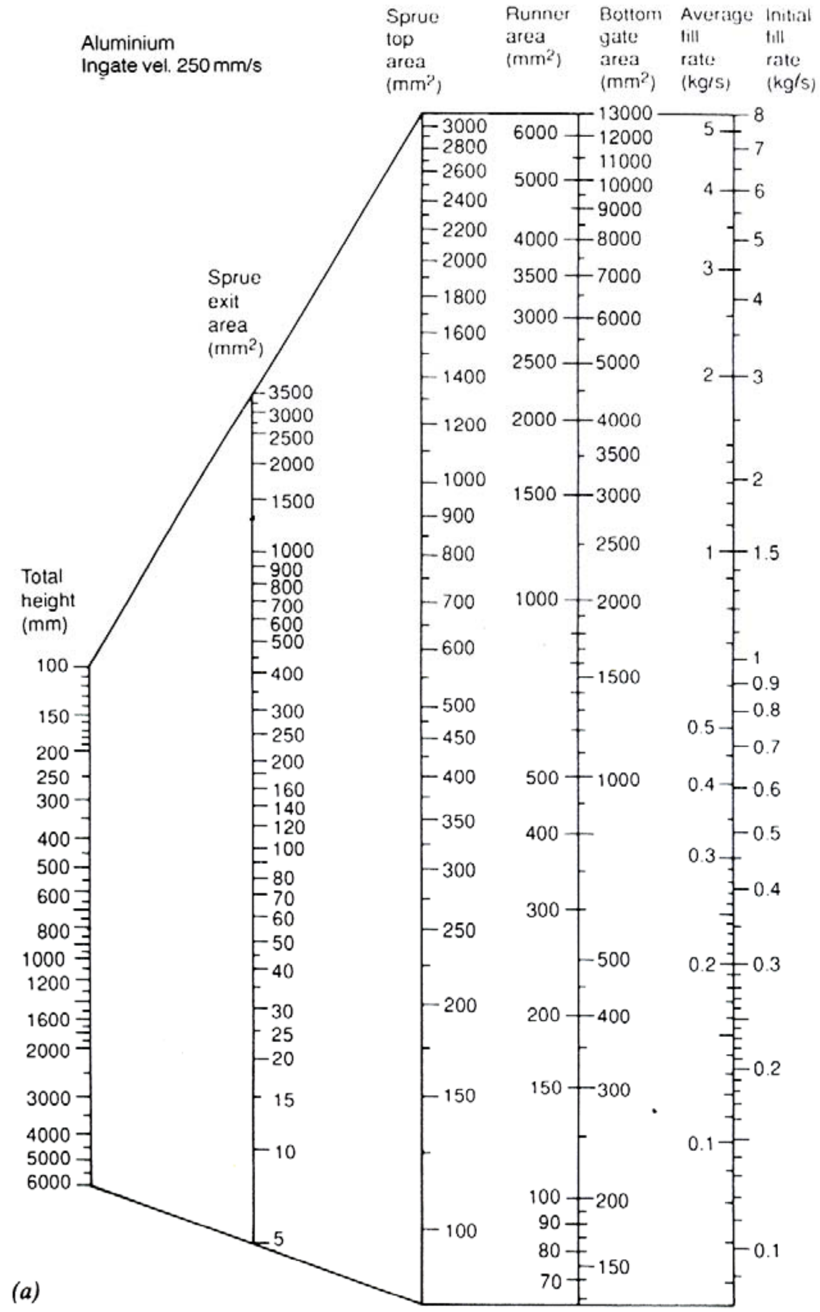



**Fig. 9:** (a) A nomogram for the calculation of running systems for aluminium alloys.

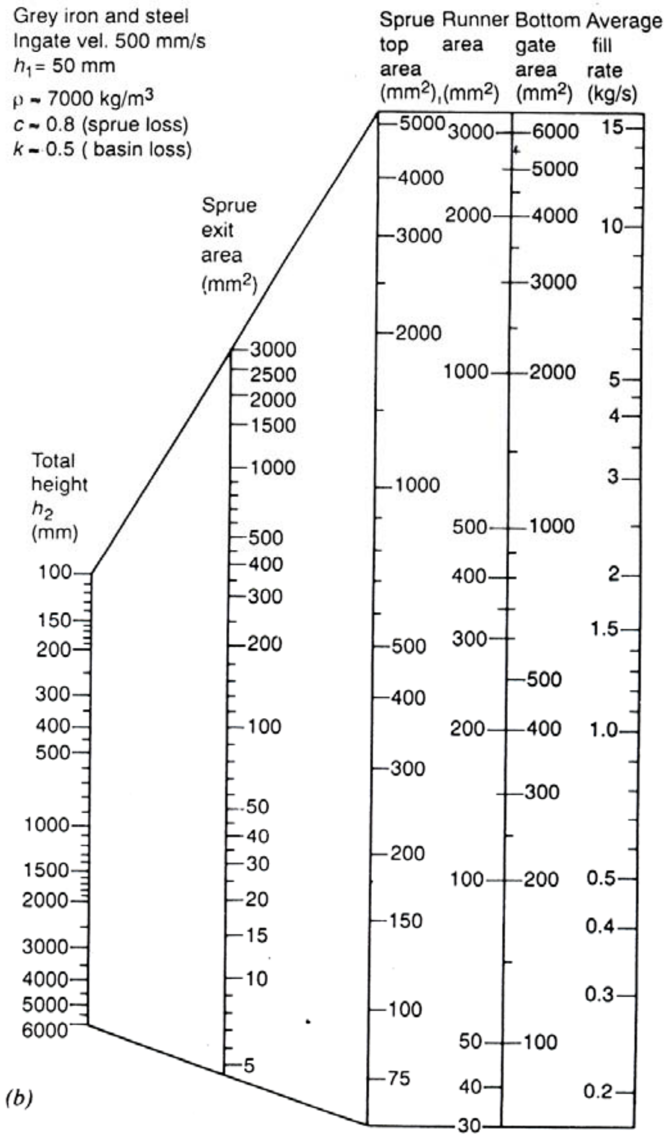



**Fig. 9:** (b) A nomogram for the calculation of running systems for grey irons and carbon steels.

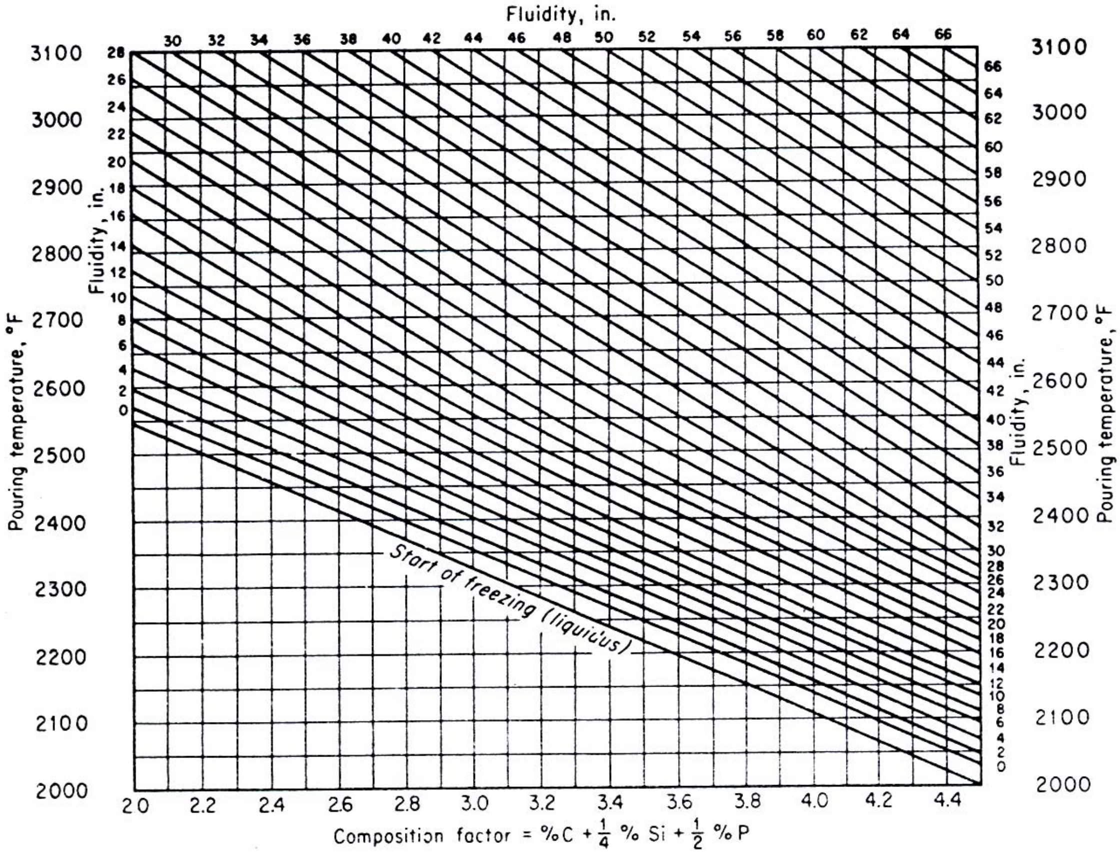



**Fig. 10:** Fluidity related to pouring temperature and composition of grey and malleable cast iron.