High Pressure Die Casting
(Die Casting)

Prof. Dr. Kerem Altuğ GÜLER

Die casting is characterized by a source of hydraulic energy that imparts high velocity to molten metal to provide rapid filling of a metal die. The die absorbs the stresses of injection, dissipates the heat contained in the metal, and facilitates the removal of the shaped part in preparation for the next cycle. The hydraulic energy is provided by a system that permits control of actuator position, velocity, and acceleration to optimize flow and force functions on the metal as it fills the cavity and solidifies.

The variety in die casting systems results from trade-offs in metal fluid flow, elimination of gas from the cavity, reactivity between the molten metal and the hydraulic system, and heat loss during injection.

The process varieties have many features in common with regard to die mechanical design, thermal control, and actuation. Four principal alloy families are commonly die cast: aluminium, zinc, magnesium, and copper-base alloys. Lead, tin, and, to a lesser extent, ferrous alloys can also be die cast. The two primary variations of the die casting process are the hot chamber process and the cold chamber process.

Some selected die casting alloys are given below:

Al alloys: A360, A380, A383, A384, B390, A413, 518

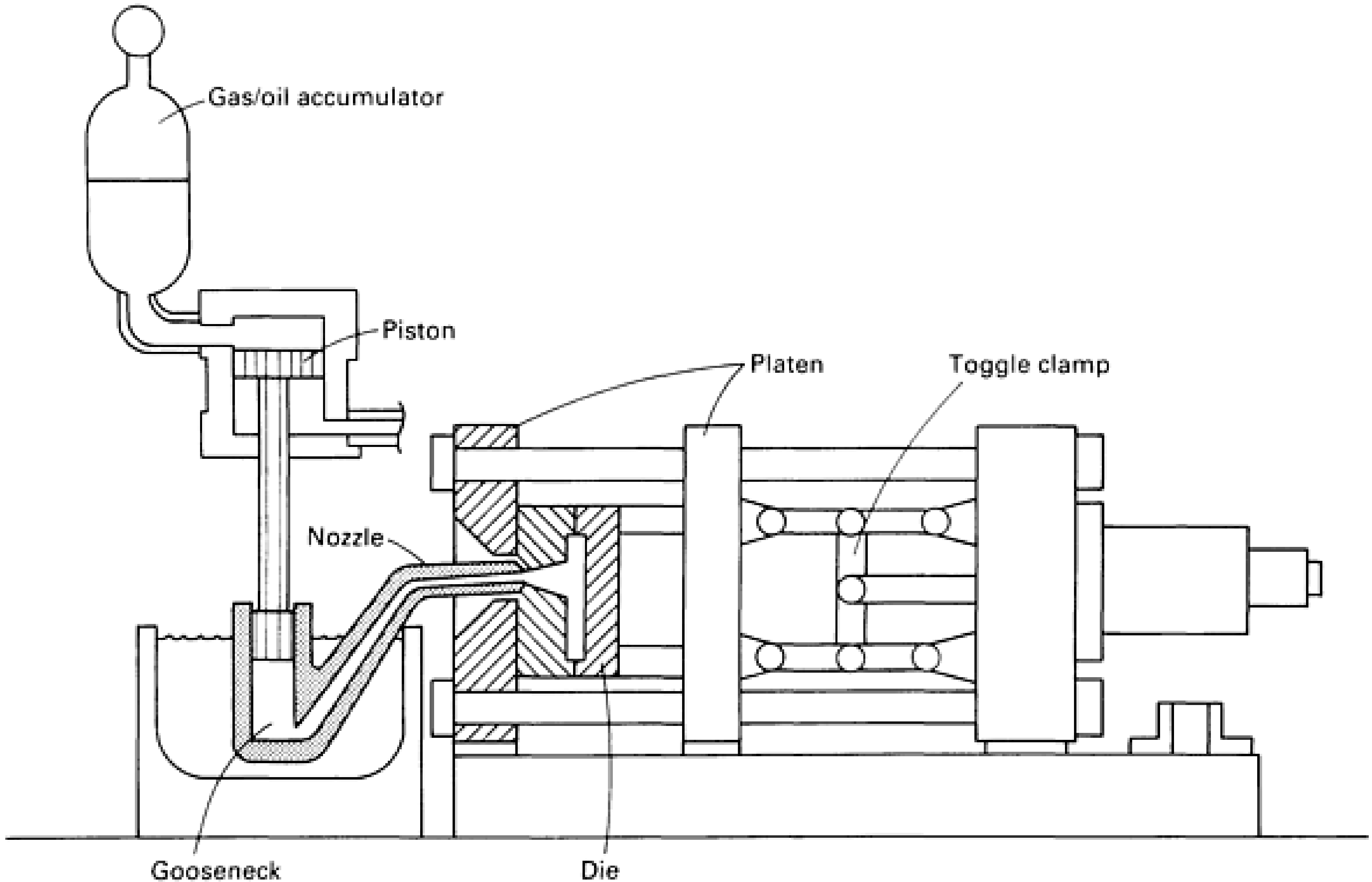
Cu alloys: C85800, C87900, C87800

Mg alloys: AZ91B, AM60A, AS41A

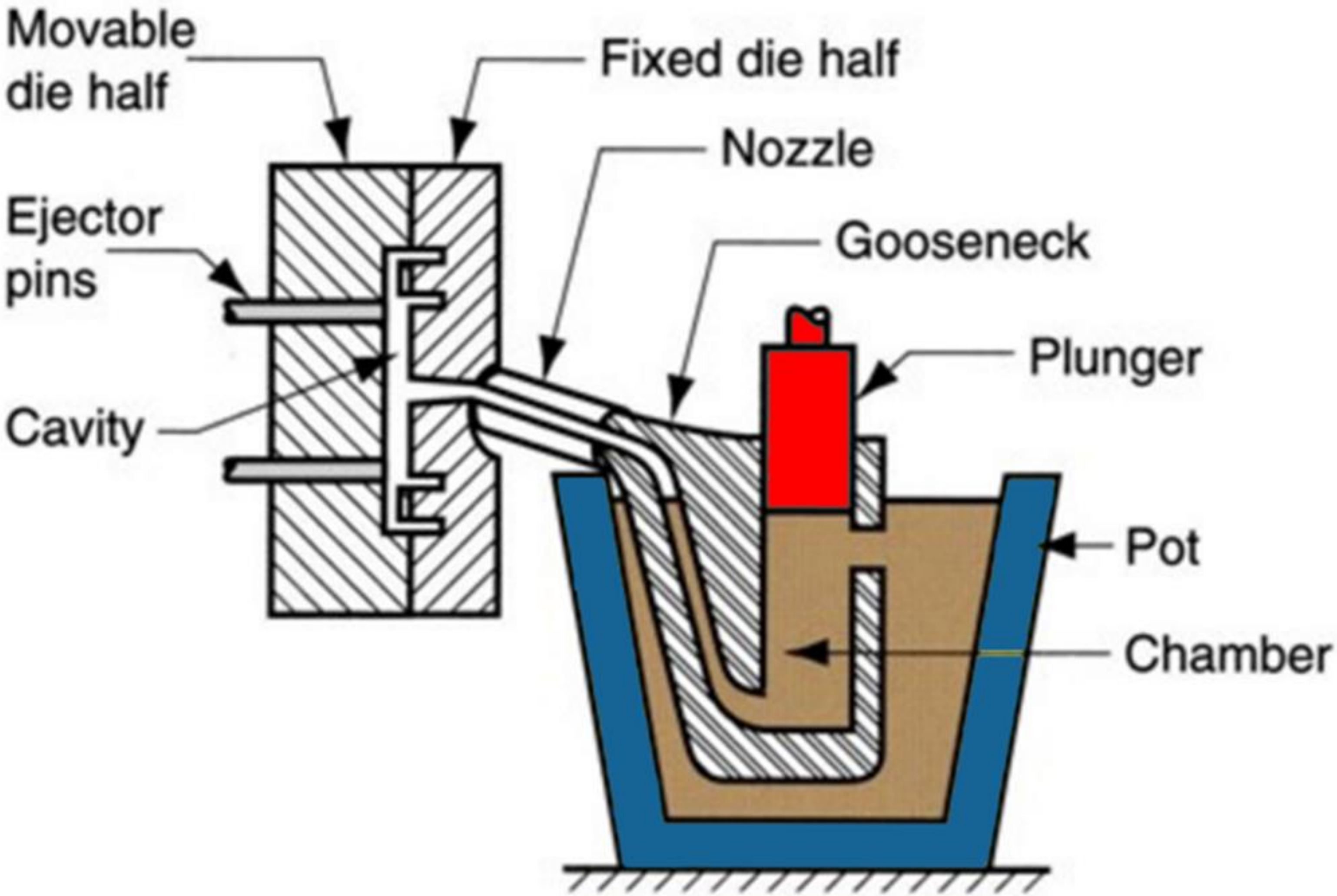
Zn alloys: AC40A, AG41A, Alloy 7, ILZRO 16

The hot chamber process

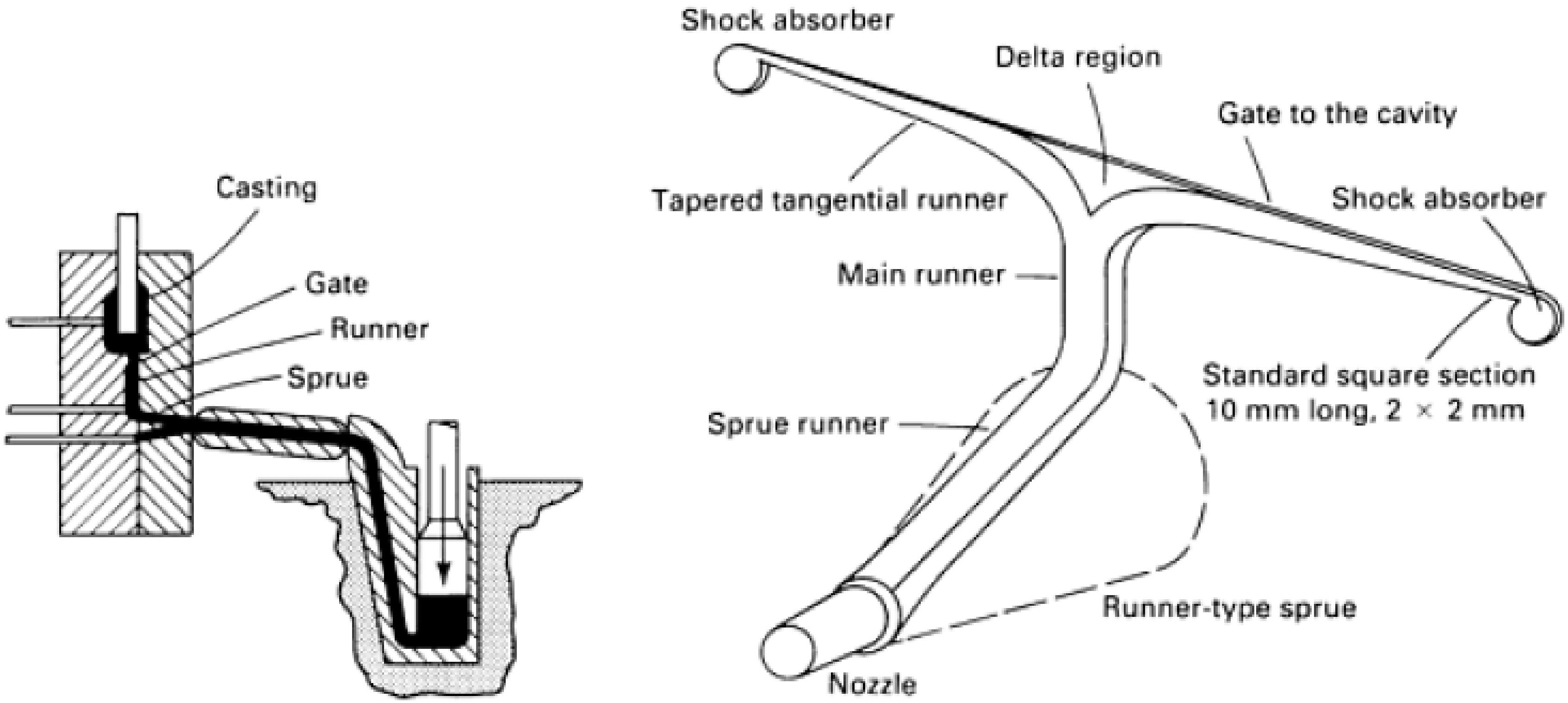
It is the original process invented by H.H. Doehler. It continues to be used for lower-melting materials (zinc, lead, tin, and, more recently, magnesium alloys). Hot chamber die casting places the hydraulic actuator in intimate contact with the molten metal The hot chamber process minimizes exposure of the molten alloy to turbulence, oxidizing air, and heat loss during the transfer of the hydraulic energy. The prolonged intimate contact between molten metal and system components presents severe materials problems in the production process.



Schematic showing the principal components of a hot chamber die casting machine



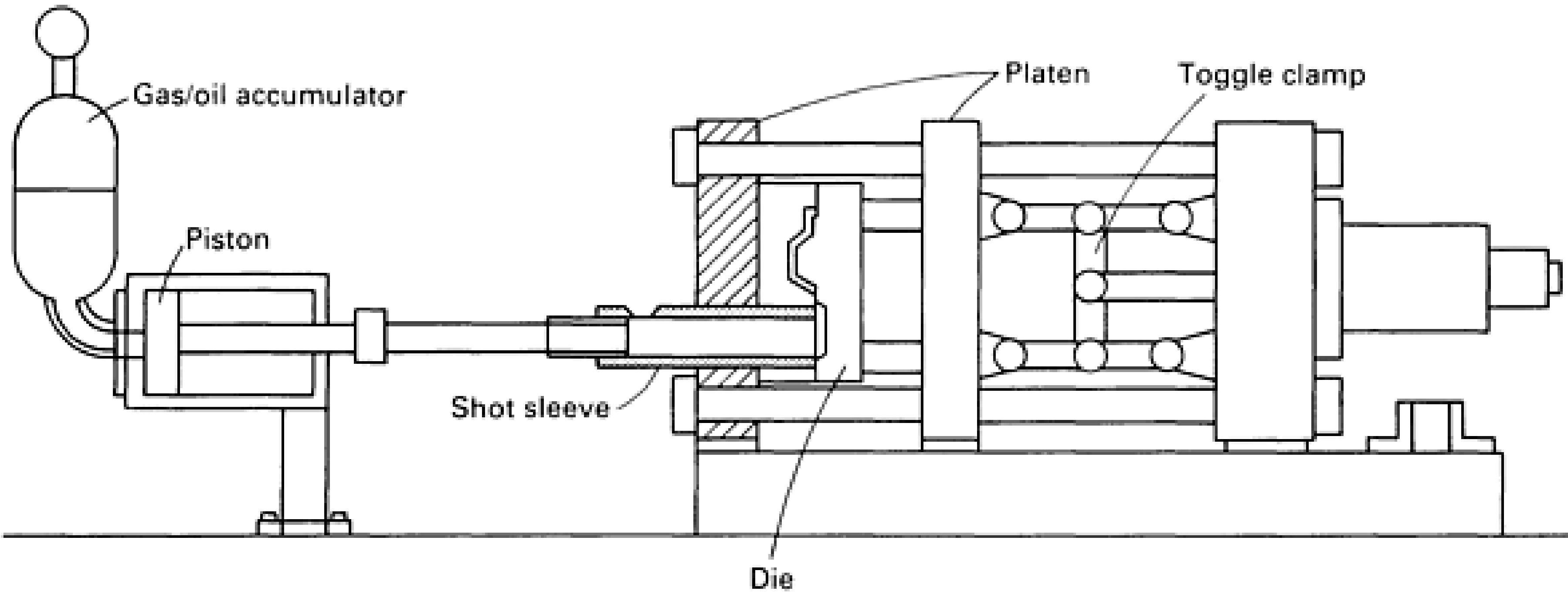
Movable die half
Fixed die half
Nozzle
Ejector pins
Gooseneck
Plunger
Cavity
Pot
Chamber



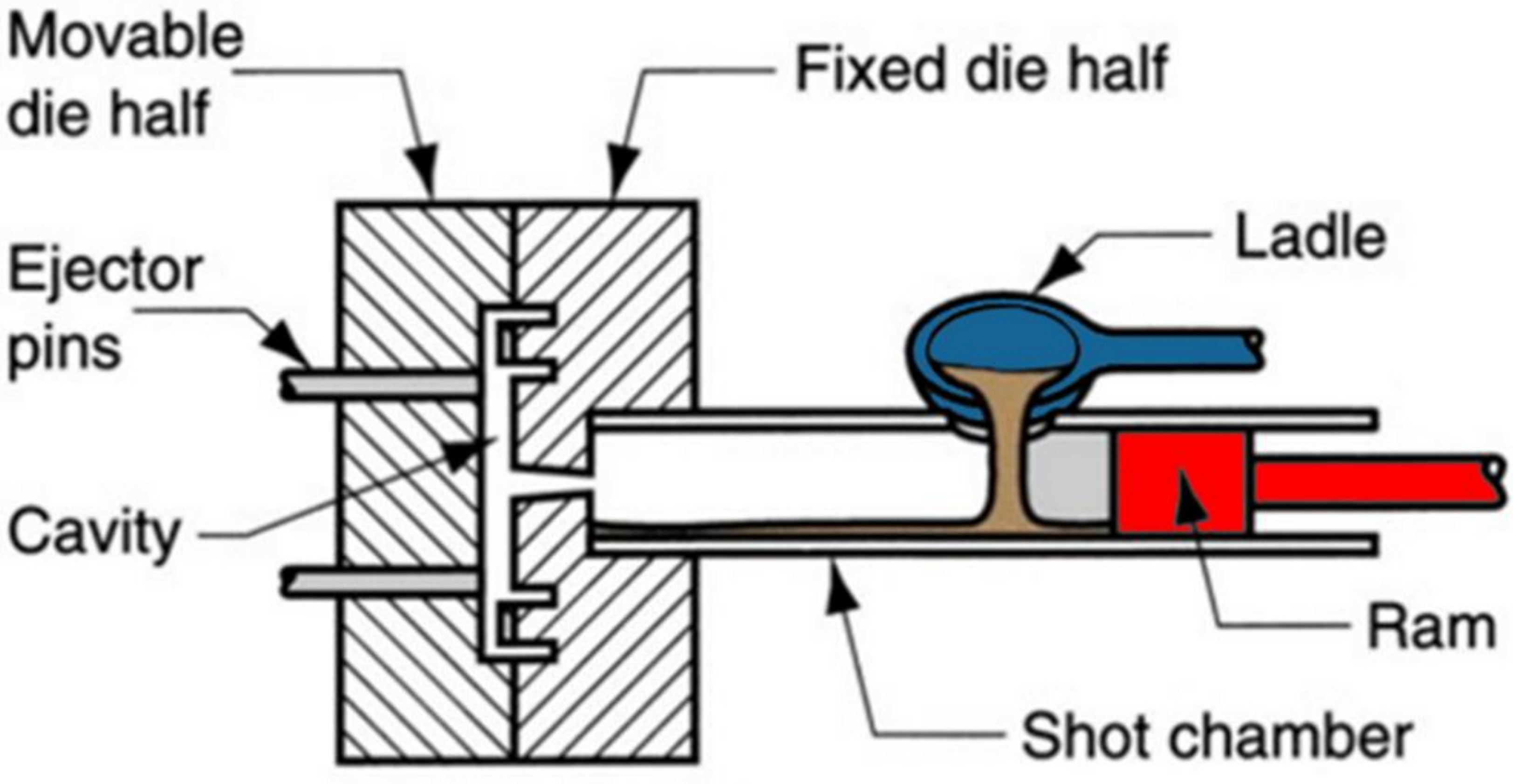
Schematics showing gating system hot chamber die casting machines

The cold chamber process

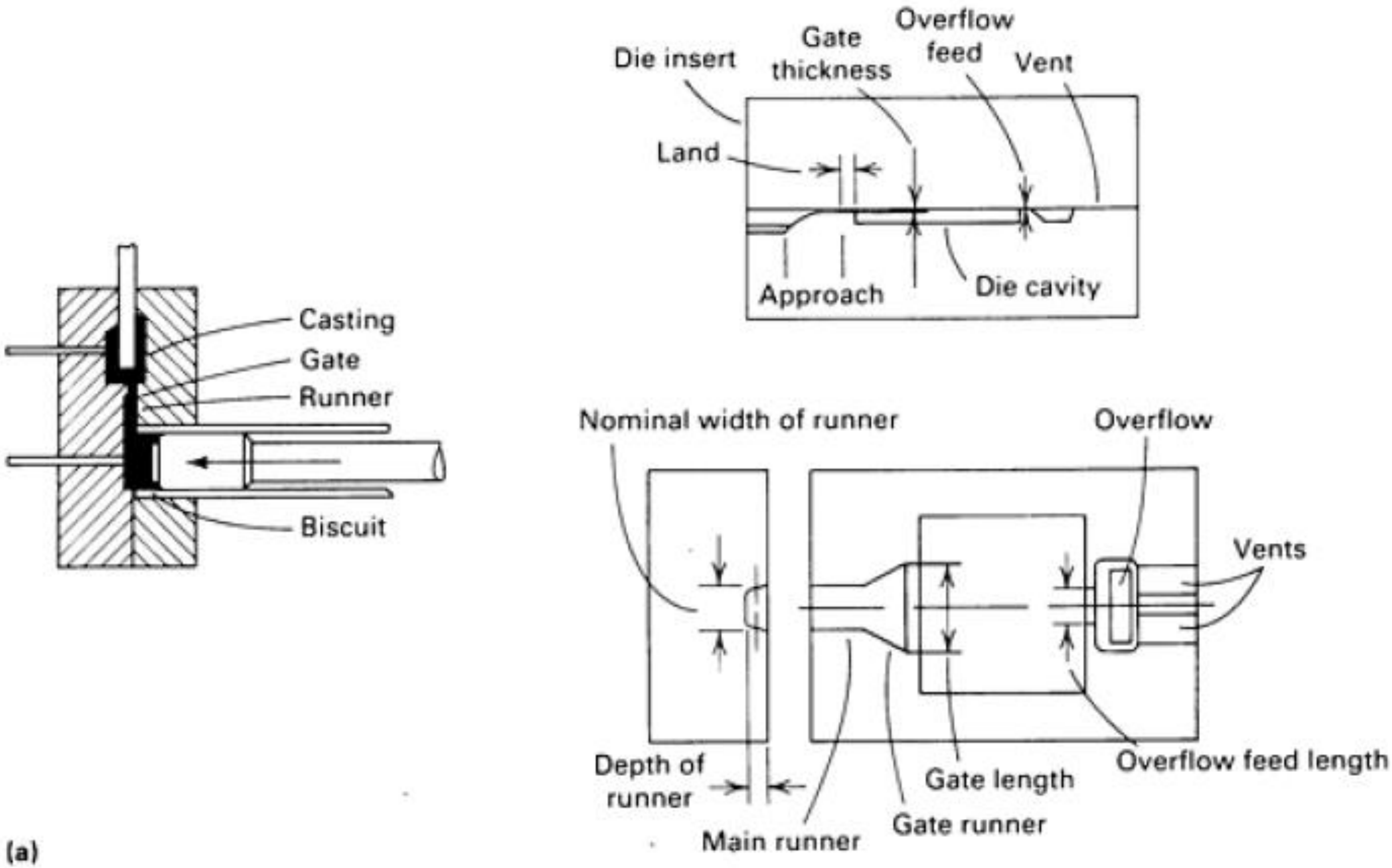
This process solves the materials problem by separating the molten metal reservoir from the actuator for most of the process cycle. Cold chamber die casting requires independent metering of the metal and immediate injection into the die, exposing the hydraulic actuator for only a few seconds. This minimal exposure allows the casting of higher-temperature alloys such as aluminium, copper, and even some ferrous alloys. Also magnesium alloys can be cast with the cold chamber process.



Schematic showing the principal components of a cold chamber die casting machine


Movable
die half
Fixed die half
Ejector
pins
Ladle
Cavity
Ram
Shot chamber

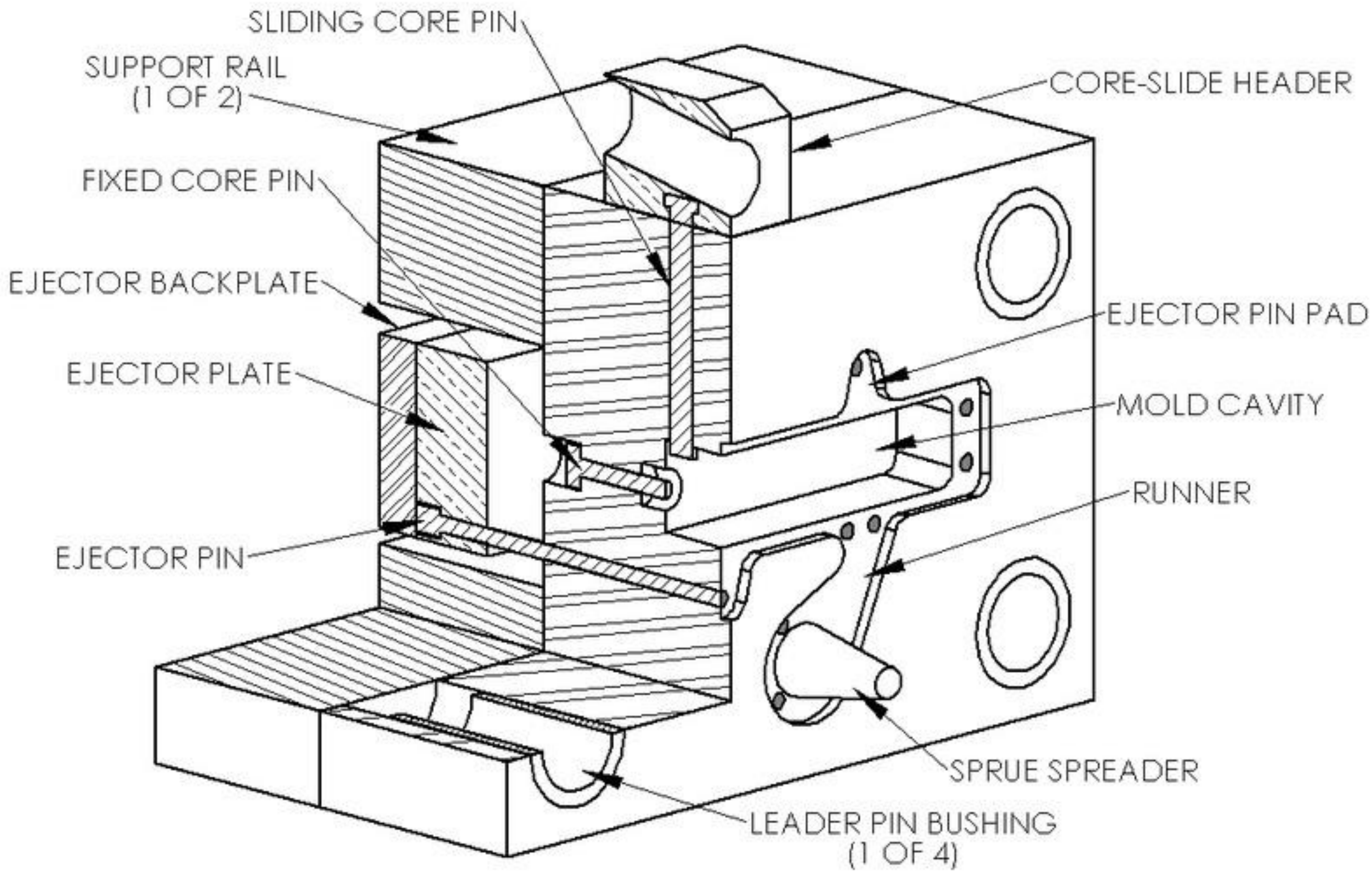

HD-500C



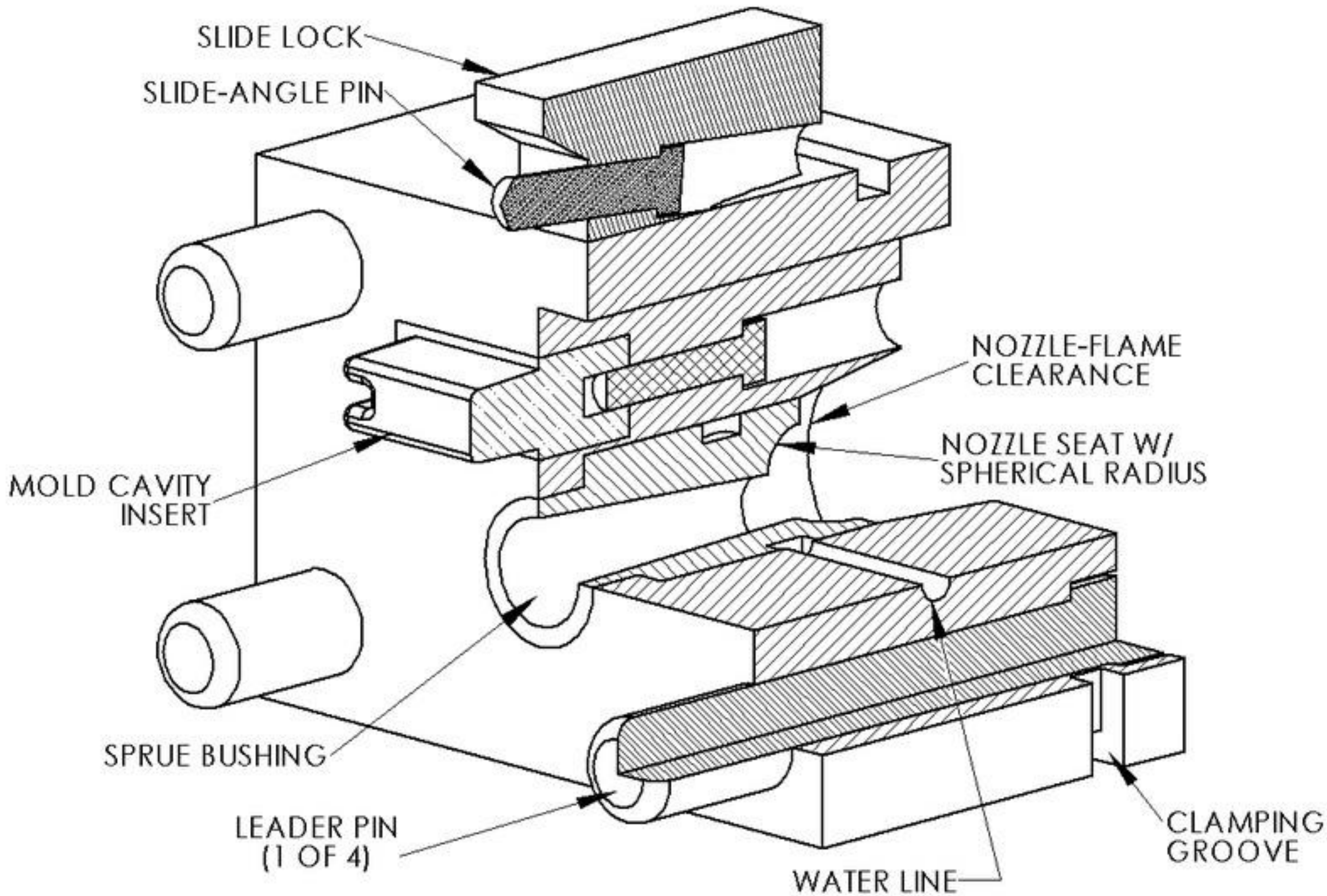
Schematics showing gating systems for cold chamber die casting machines

Product Design for the Process

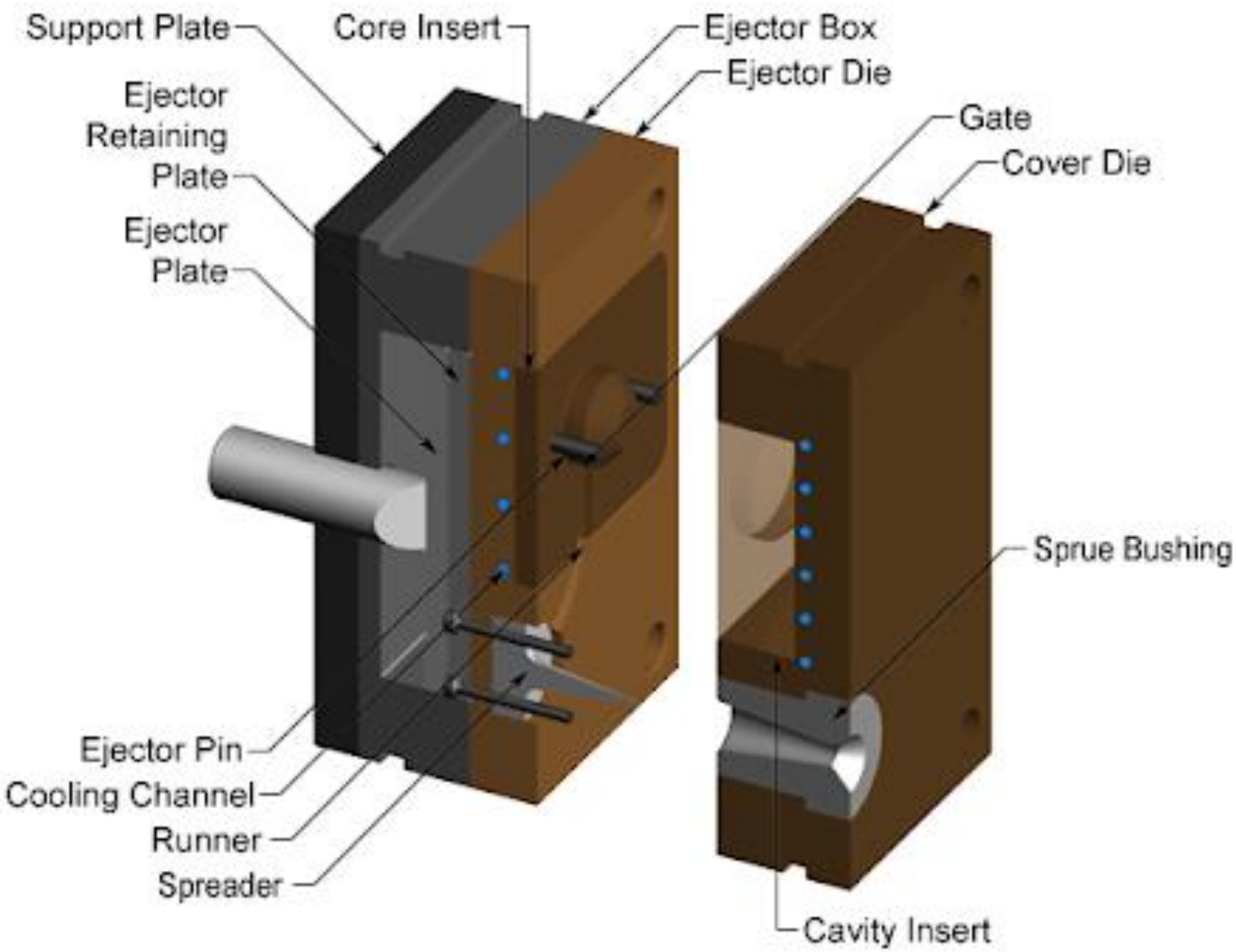
Product design and die design are intimately related. The principal features of a die casting die are illustrated in figures given below. The high-speed nature of the process allows the filling of thin-wall complex shapes at high rates (of the order of 100 parts per hour per cavity). This capability places additional demands on the casting designer because traditional feeding of solidification shrinkage is almost impossible. The inability to feed in the traditional sense demands that machining stock be kept to a minimum; high-integrity surfaces should be preserved.



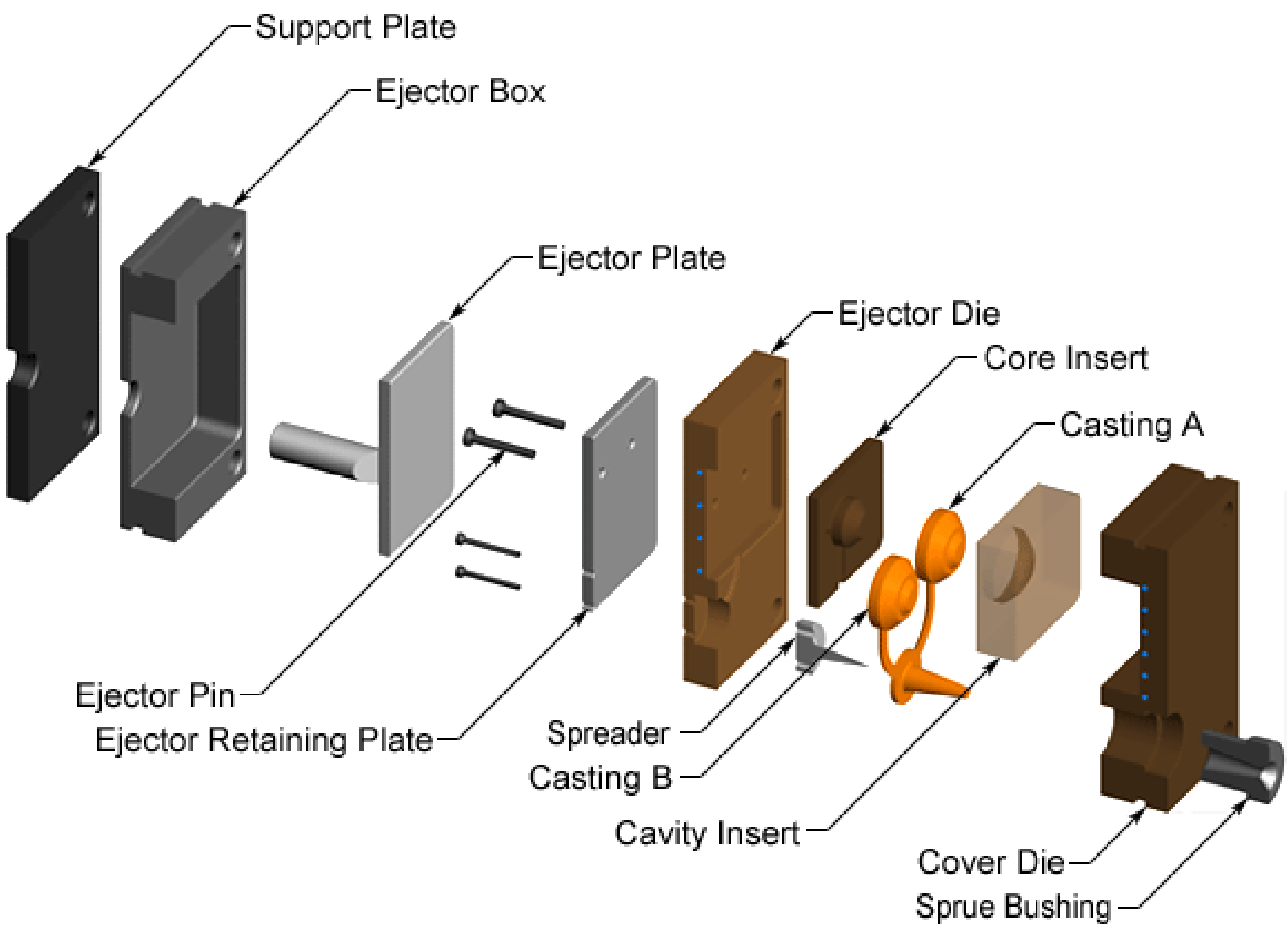
Ejector die half

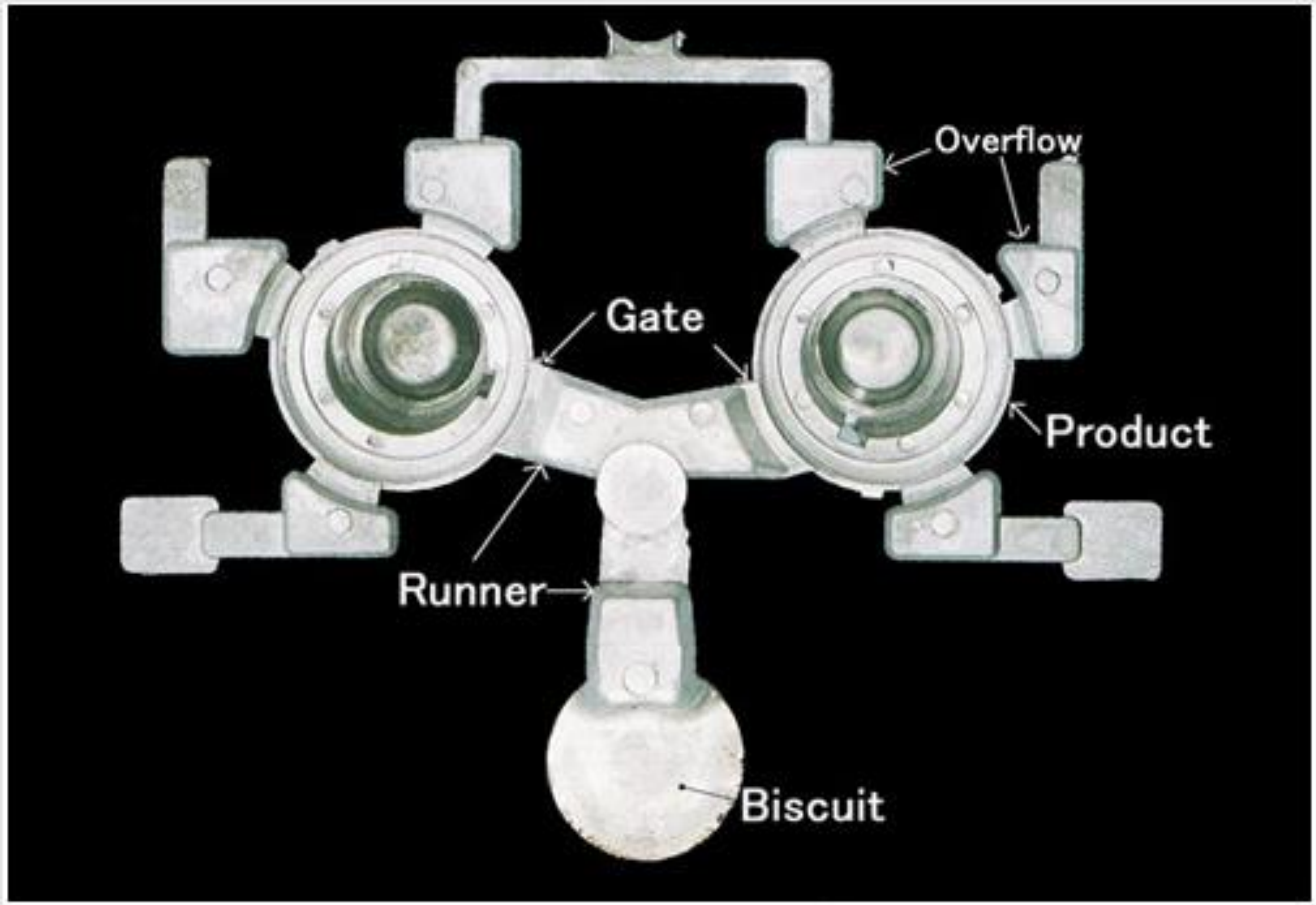


Cover die half



Support Plate
Core Insert
Ejector Box
Ejector Die
Gate
Cover Die
Ejector Retaining Plate
Ejector Plate
Sprue Bushing
Ejector Pin
Cooling Channel
Runner
Spreader
Cavity Insert

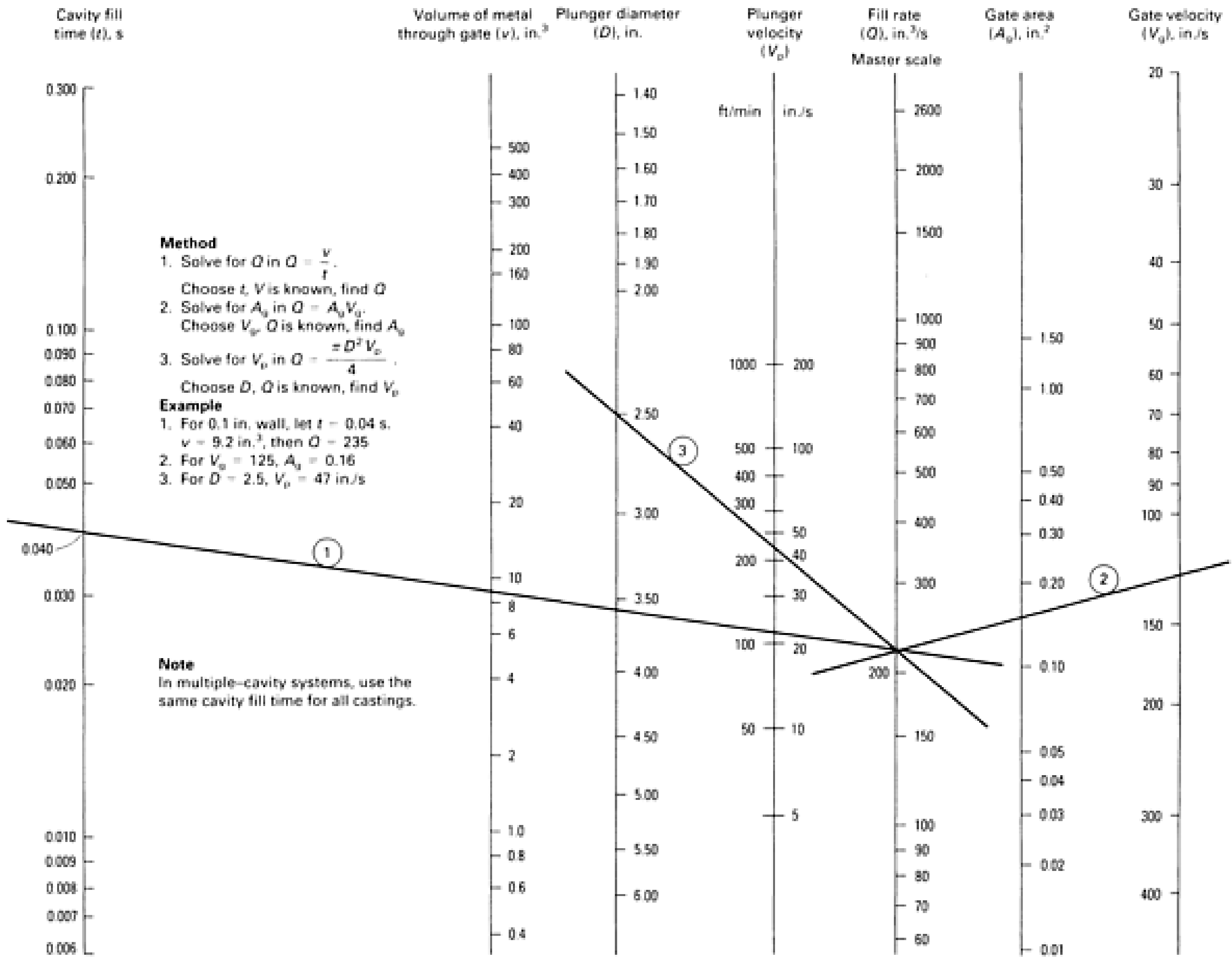

Support Plate
Ejector Box
Ejector Plate
Ejector Die
Core Insert
Casting A
Ejector Pin
Ejector Retaining Plate
Spreader
Casting B
Cavity Insert
Cover Die
Sprue Bushing



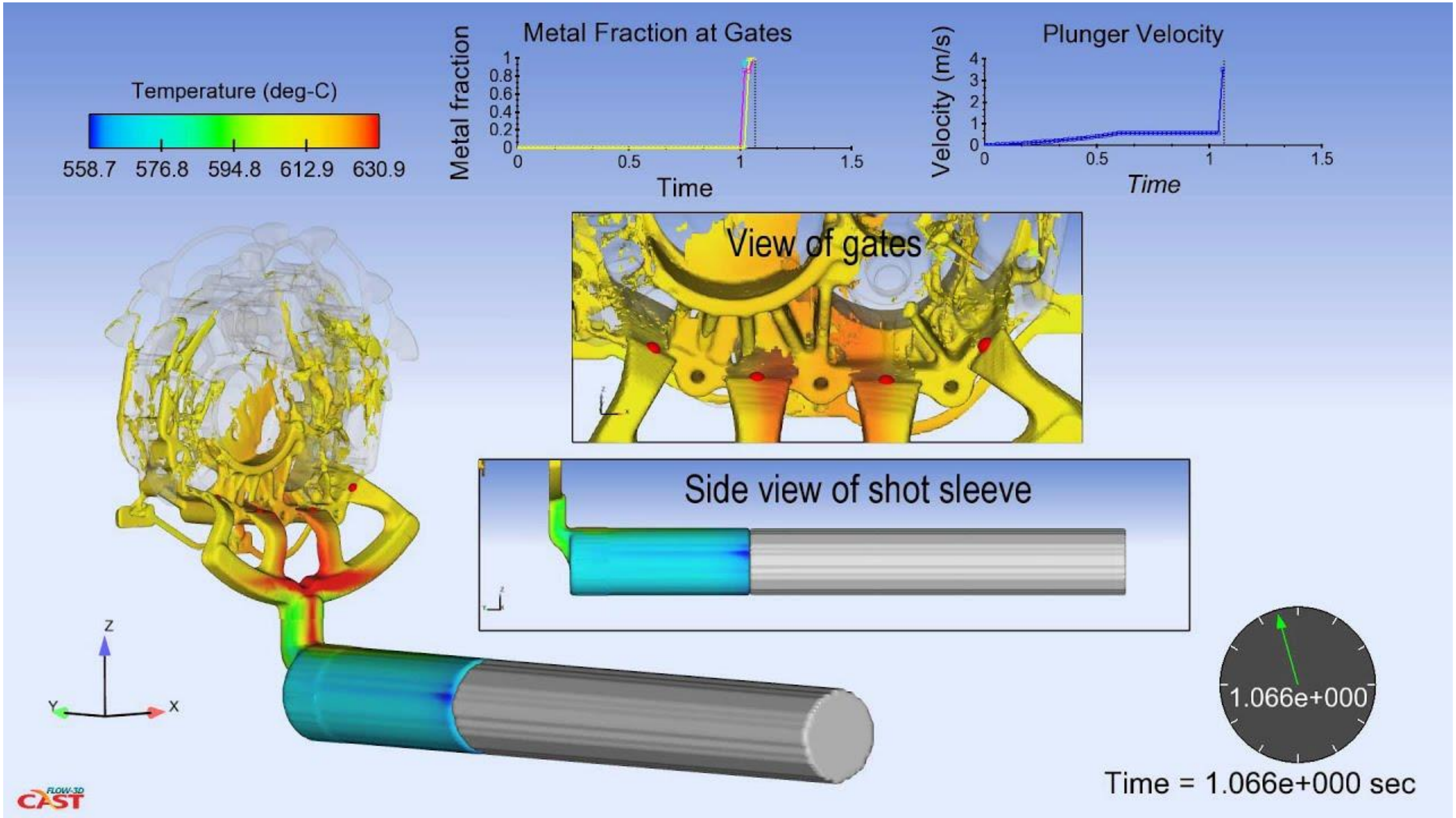
Overflow
Gate
Product
Runner
Biscuit

Since the invention of the die casting process, many die castings have been successfully made with gating systems designed by experience only. Each company has a reservoir of this closely guarded experience. Trial-and-error adjustments at the casting machine are frequently part of the learning. However, the decline of the presence of the artisan in the foundry is forcing a move toward analytically based gating design, but the analysis base is still tempered with the fine tuning of experience. This is especially true in gate location and local angle of entry, which are directly affected by part shape and secondary operations.

One of the first analysis methods was the ADCI/DCRF Nomograph which solves geometric relationships for the bulk flow design. The selection of a fill time for the casting is based on experience and experiment. The limited selection of plunger diameters for a given machine restricts the design. The cold chamber process links the volume of metal to plunger diameter by filling the shot sleeve about two-thirds full. The nomograph is used to develop a required volume fill rate Q.

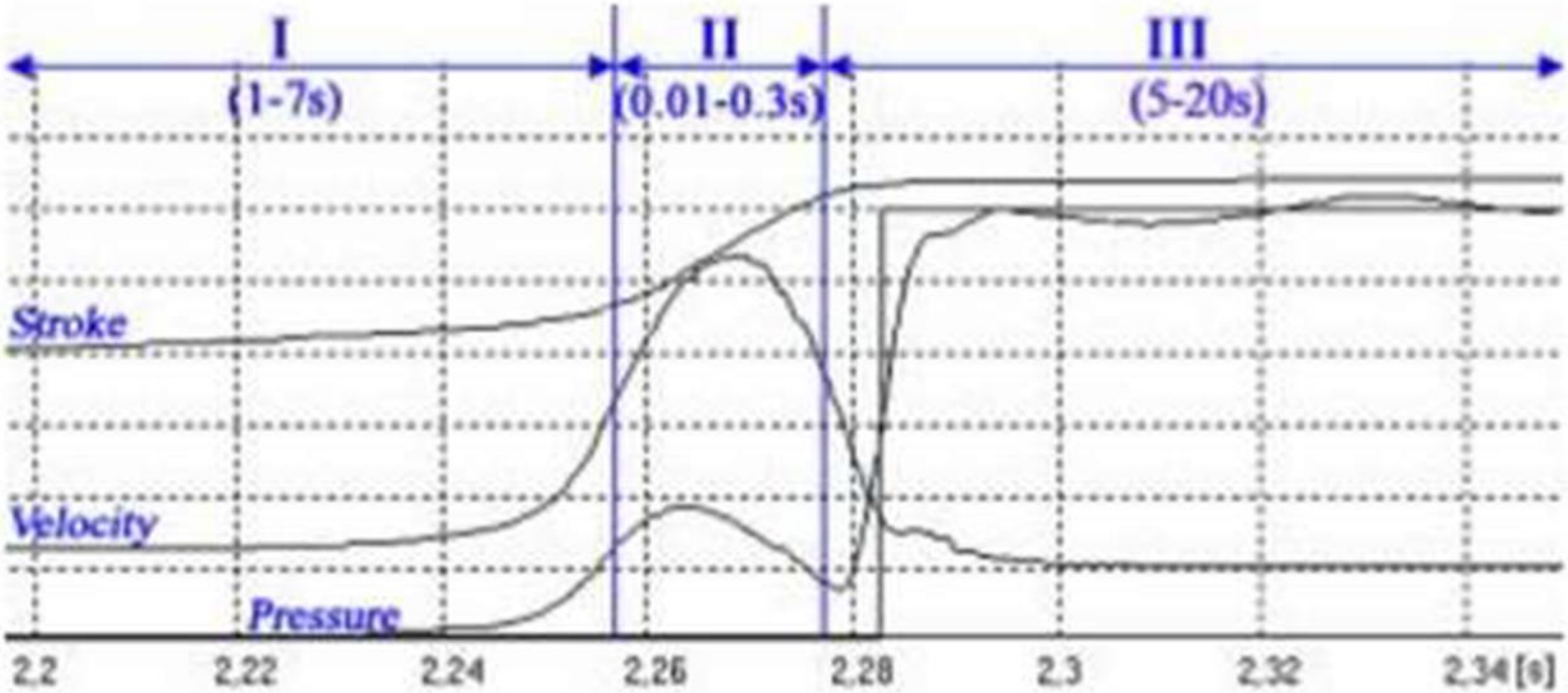


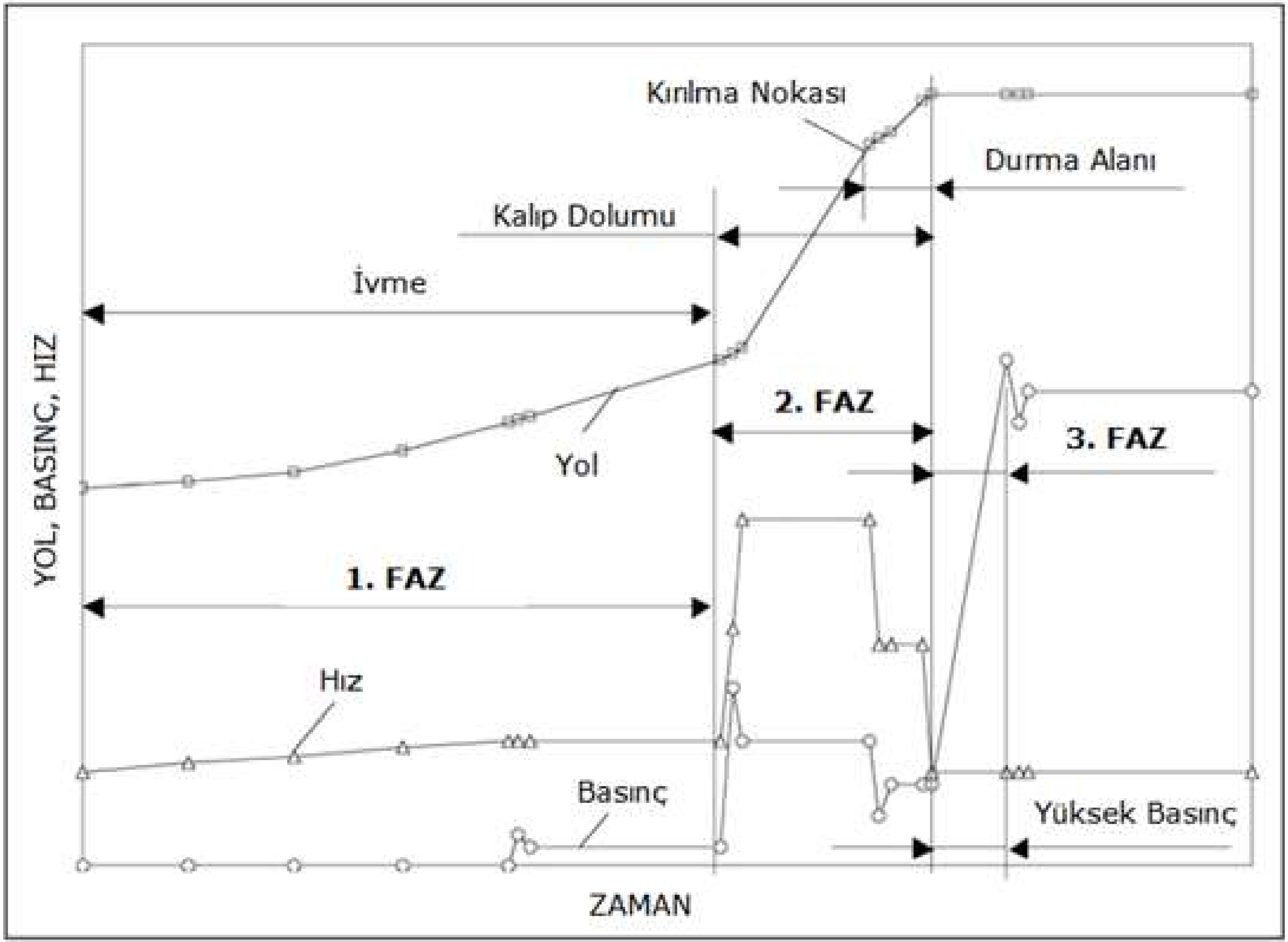
Nomograph used to determine the volume fill rate Q required for different casting process parameters



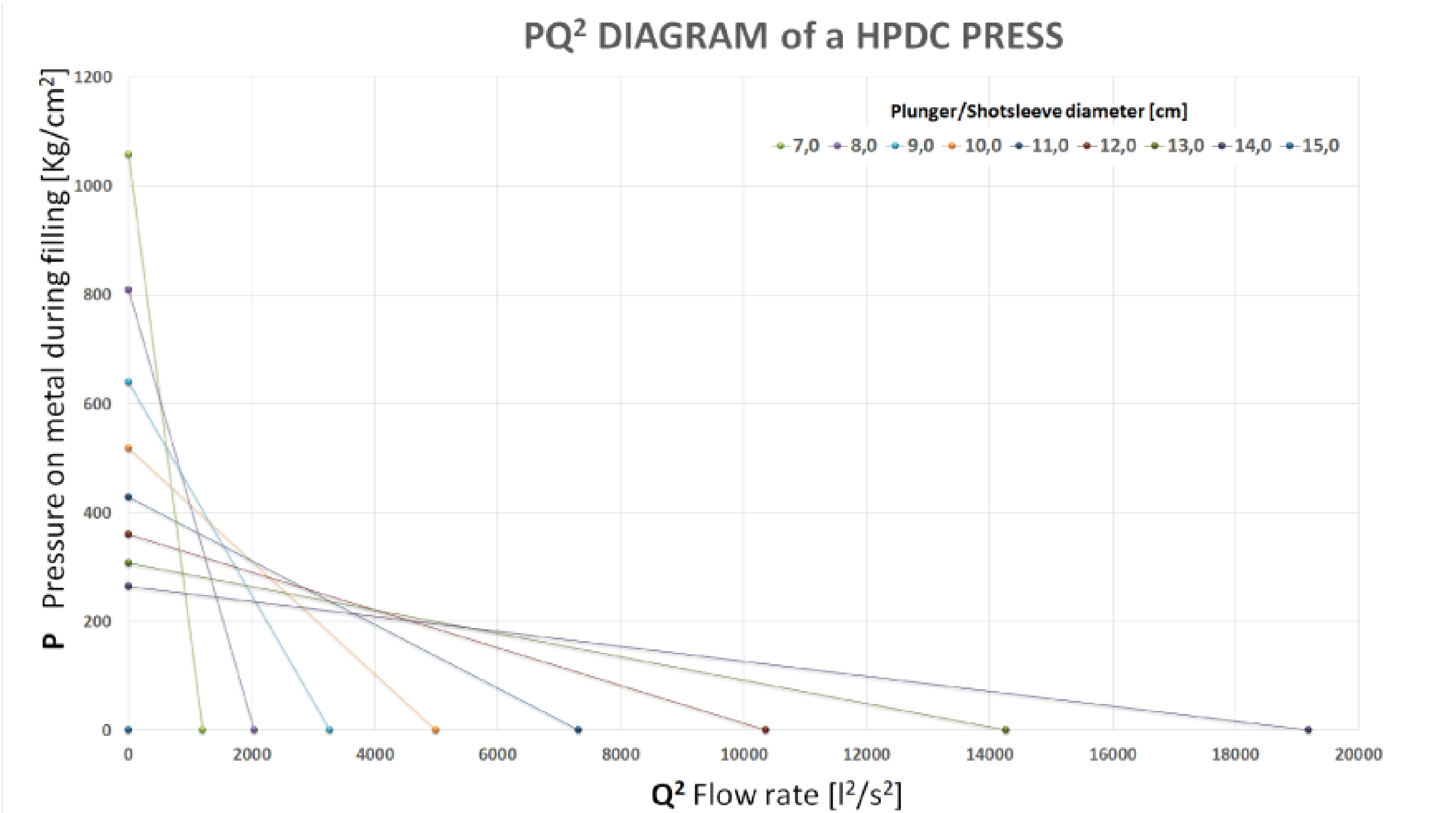
Casting simulation example for die casting

Phases of Die Casting

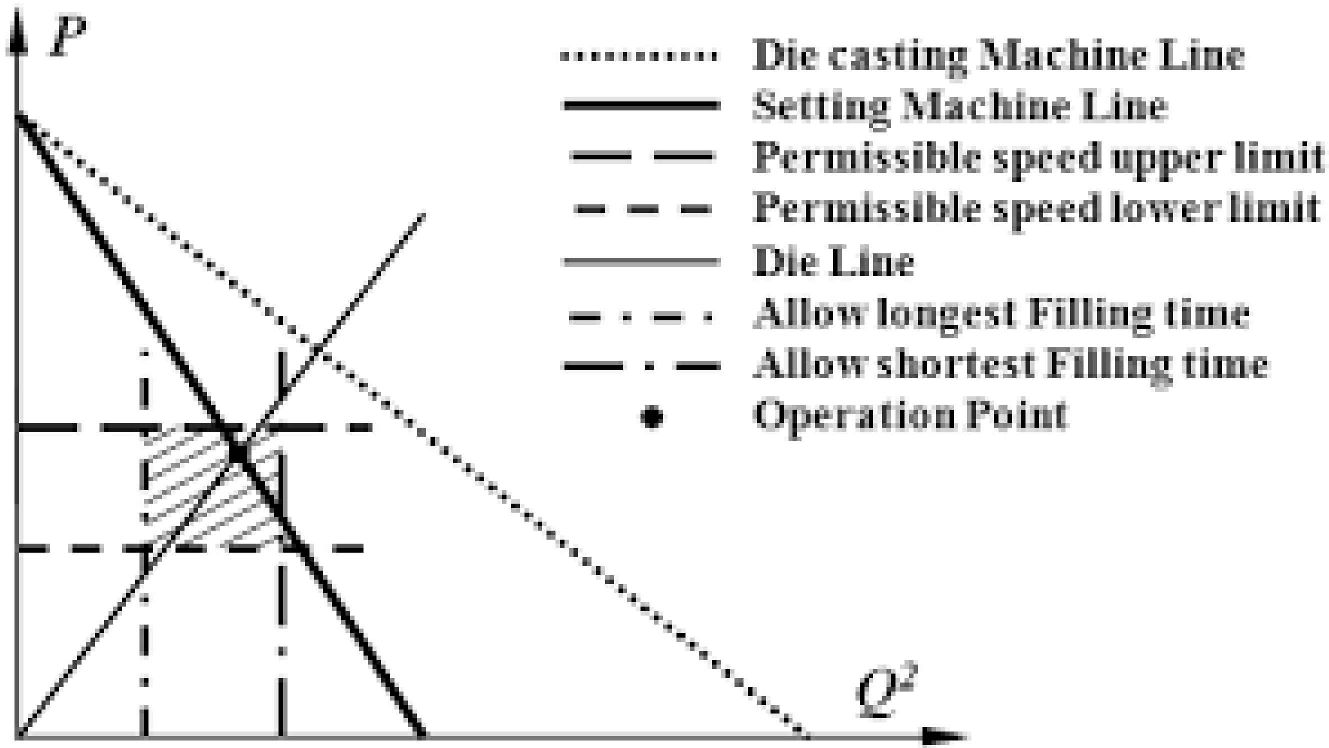




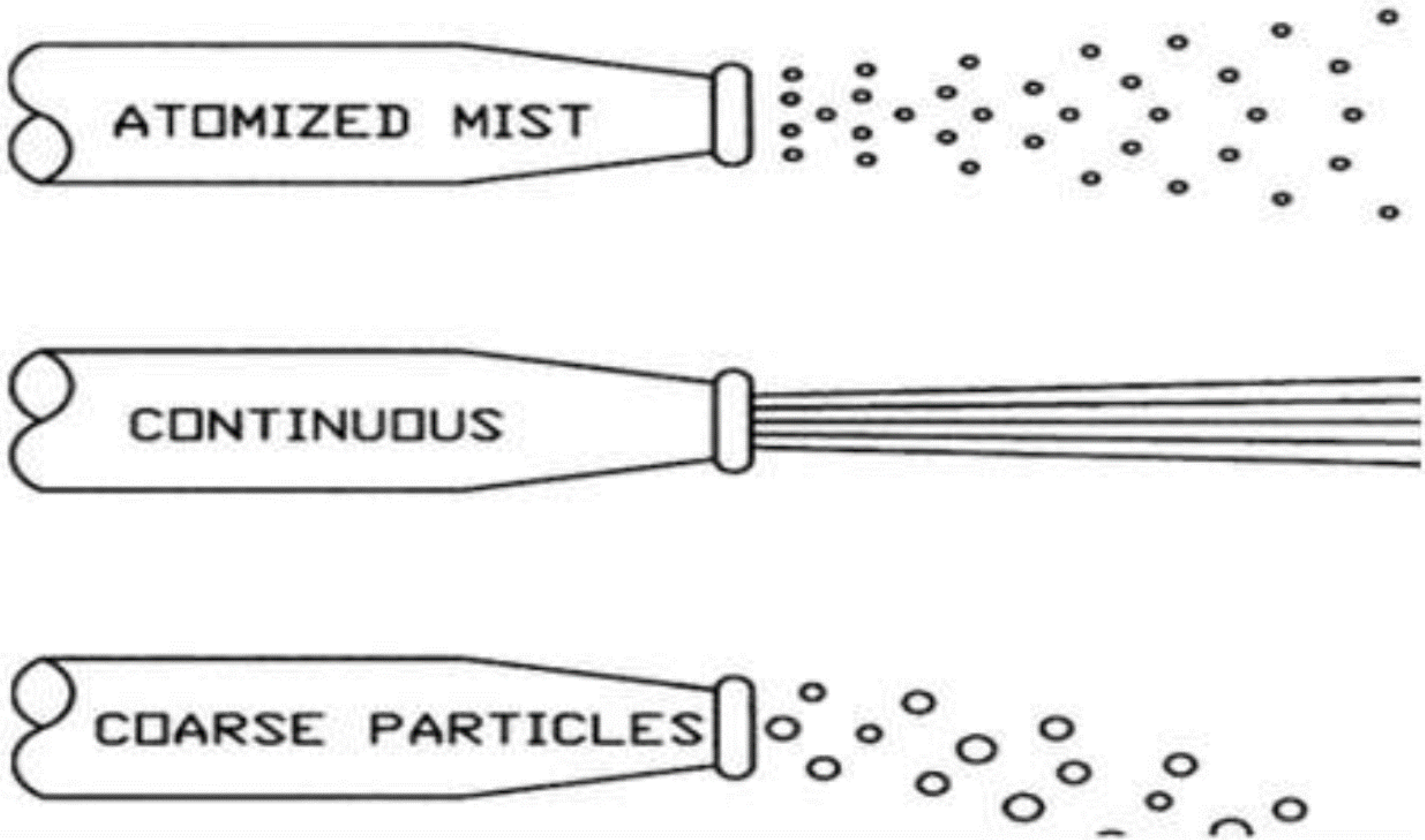
Kırılma Nokası
Durma Alanı
Kalıp Dolumu
İvme
2. FAZ
3. FAZ
Yol
1. FAZ
Hız
Basınç
Yüksek Basınç
YOL, BASINÇ, HIZ
ZAMAN

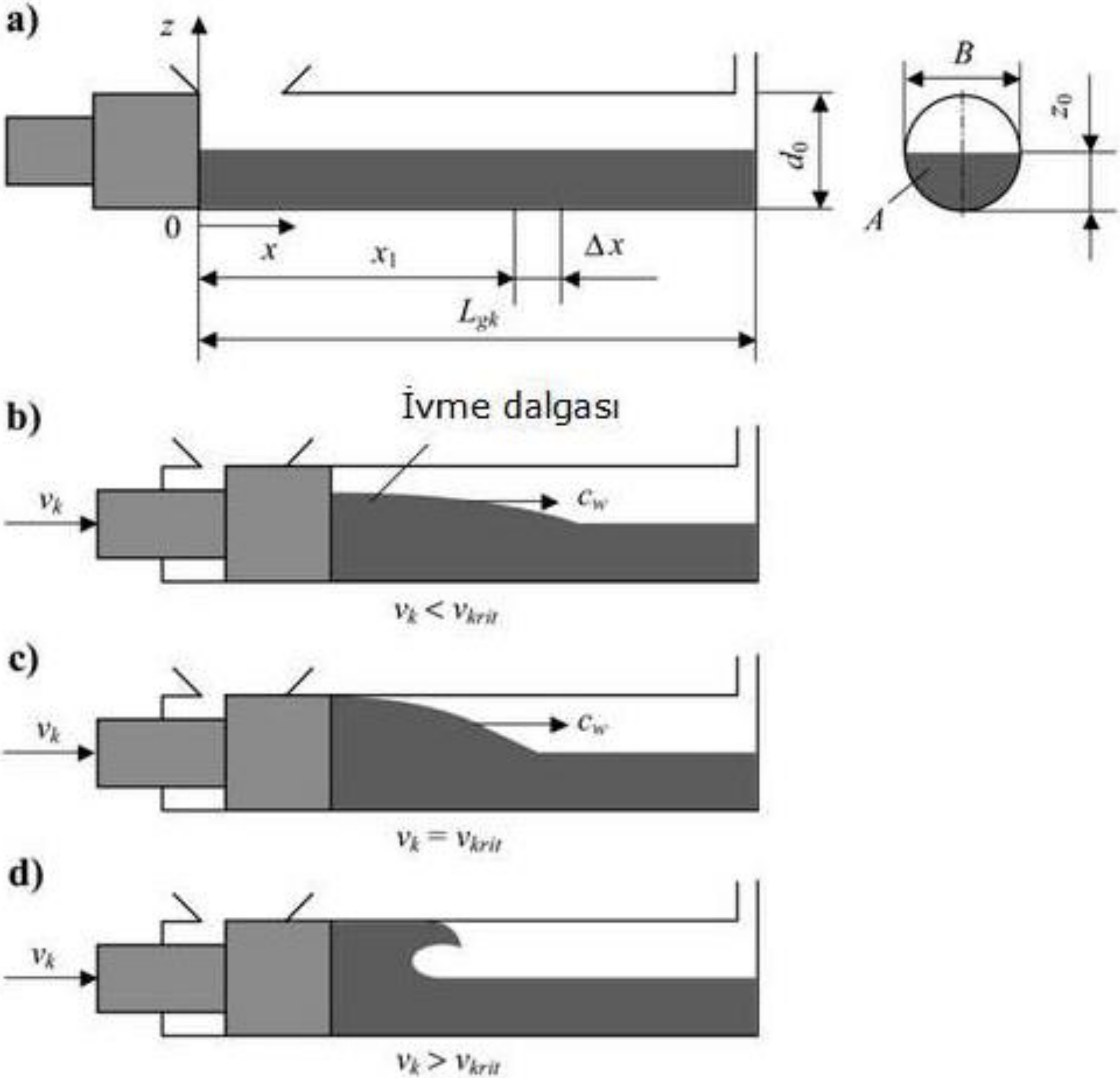


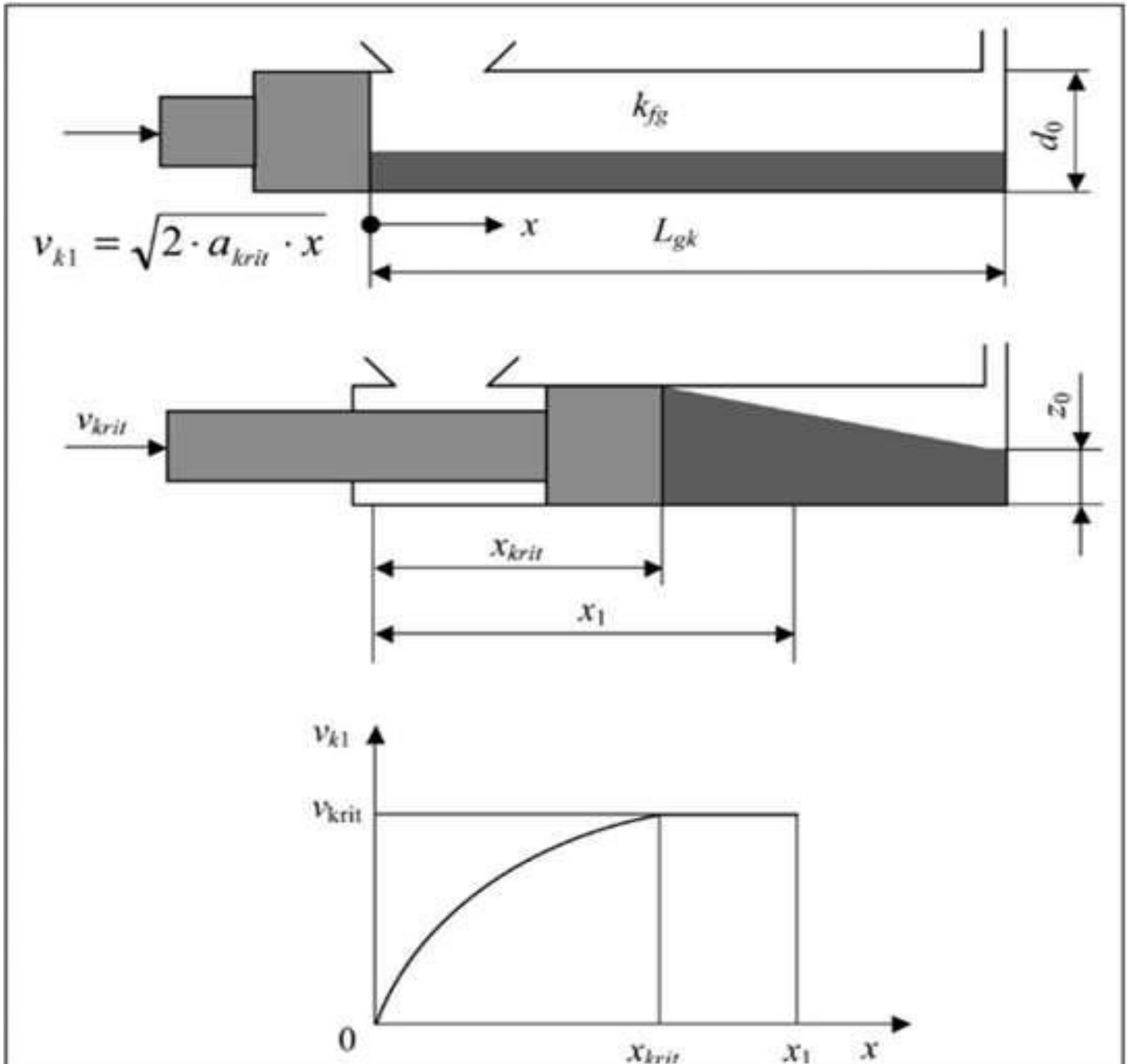
PQ² DIAGRAM of a HPDC PRESS
Plunger/Shotsleeve diameter [cm]
7,0
8,0
9,0
10,0
11,0
12,0
13,0
14,0
15,0
P Pressure on metal during filling [Kg/cm²]
1200
1000
800
600
400
200
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Q² Flow rate [l²/s²]



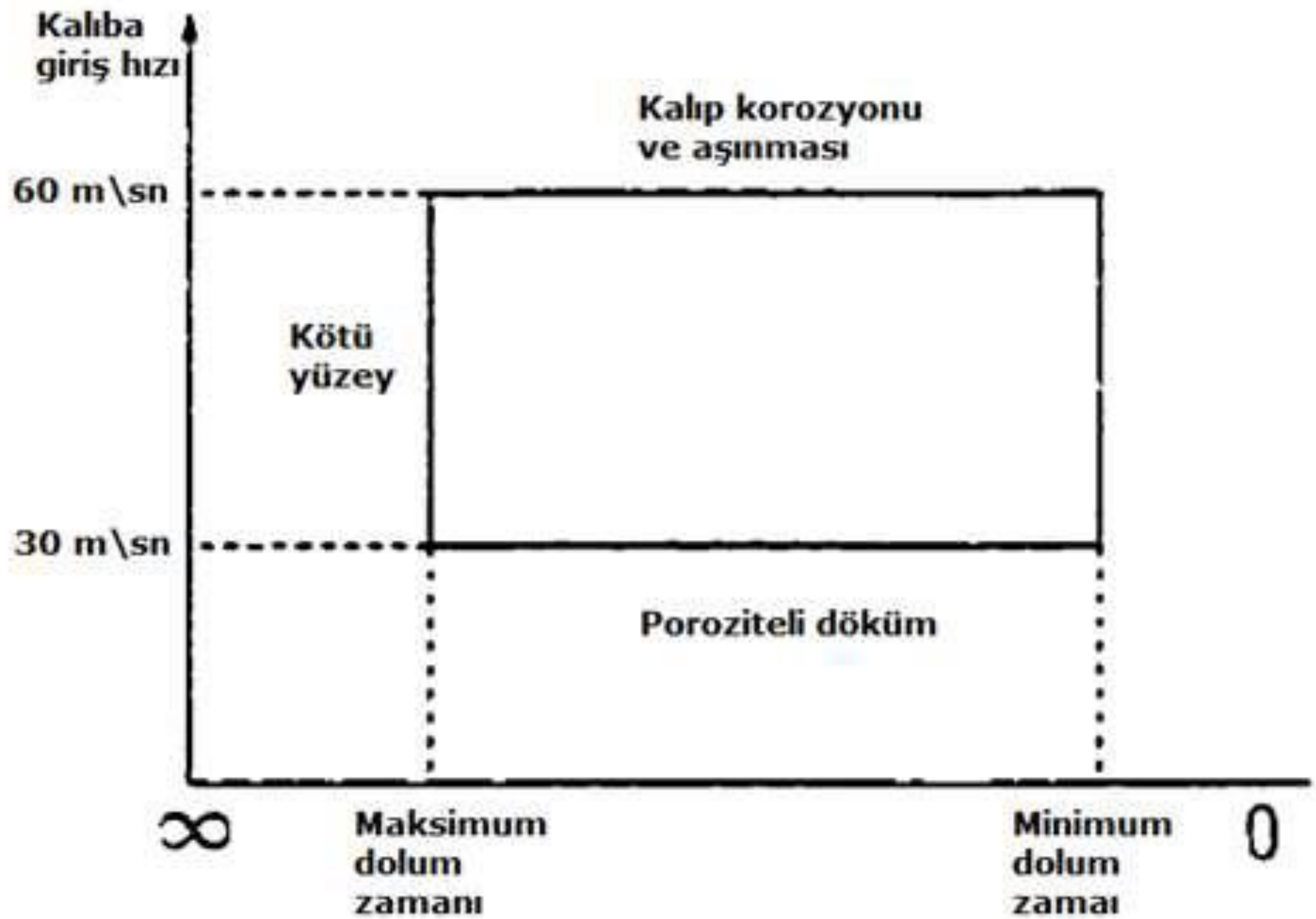
P
Q²
Die casting Machine Line
Setting Machine Line
Permissible speed upper limit
Permissible speed lower limit
Die Line
Allow longest Filling time
Allow shortest Filling time
Operation Point


ATOMIZED MIST
CONTINUOUS
COARSE PARTICLES


a)
z
B
z_0
d_0
A
0
x
x_1
Δx
L_{gk}
b)
İvme dalgası
v_k
c_w
$v_k < v_{krit}$
c)
v_k
c_w
$v_k = v_{krit}$
d)
v_k
$v_k > v_{krit}$



k_{fg}
d_0
$v_{k1} = \sqrt{2 \cdot a_{krit} \cdot x}$
x
L_{gk}
v_{krit}
z_0
x_{krit}
x_1
v_{k1}
v_{krit}
0
x_{krit}
x_1
x



Metalin kalıba giriş hızı (m\s)= Piston alanı x piston hızı \ Giriş yolluk kesit alanı

Video links

- https://www.youtube.com/watch?v=_LlRof0K0OQ
- https://www.youtube.com/watch?v=0JH2WEVruJc
- https://www.youtube.com/watch?v=9mN1HFyg3iM
- https://www.youtube.com/watch?v=h2A7oUMeLmM
- https://www.youtube.com/watch?v=h8MUjb-HeJw
- https://www.youtube.com/watch?v=VfbF3kW2kXk
- https://www.youtube.com/watch?v=zZMoMi0Un1A
- https://www.youtube.com/watch?v=Jh1tyvPgrL0
- https://www.youtube.com/watch?v=FEbJFbN4PfA
- https://www.youtube.com/watch?v=IBc9kNP0Oj4&t