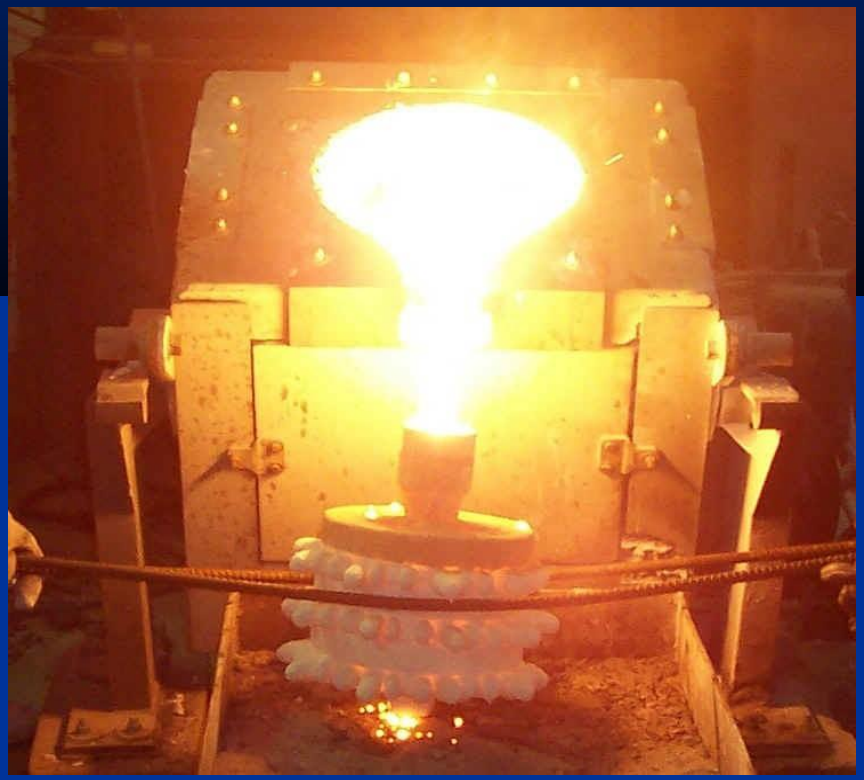
Metal Casting and Solidification

Monil Salot

Syllabus

- **Casting design and analysis of casting defects:**
- Preliminary stages & production stages, process & alloy selection, physical design features, quality assessment & control. Categories of defects, gas defects, shrinkage defects, contraction defects, compositional errors & segregation, inclusions & sand defects, shaping faults.

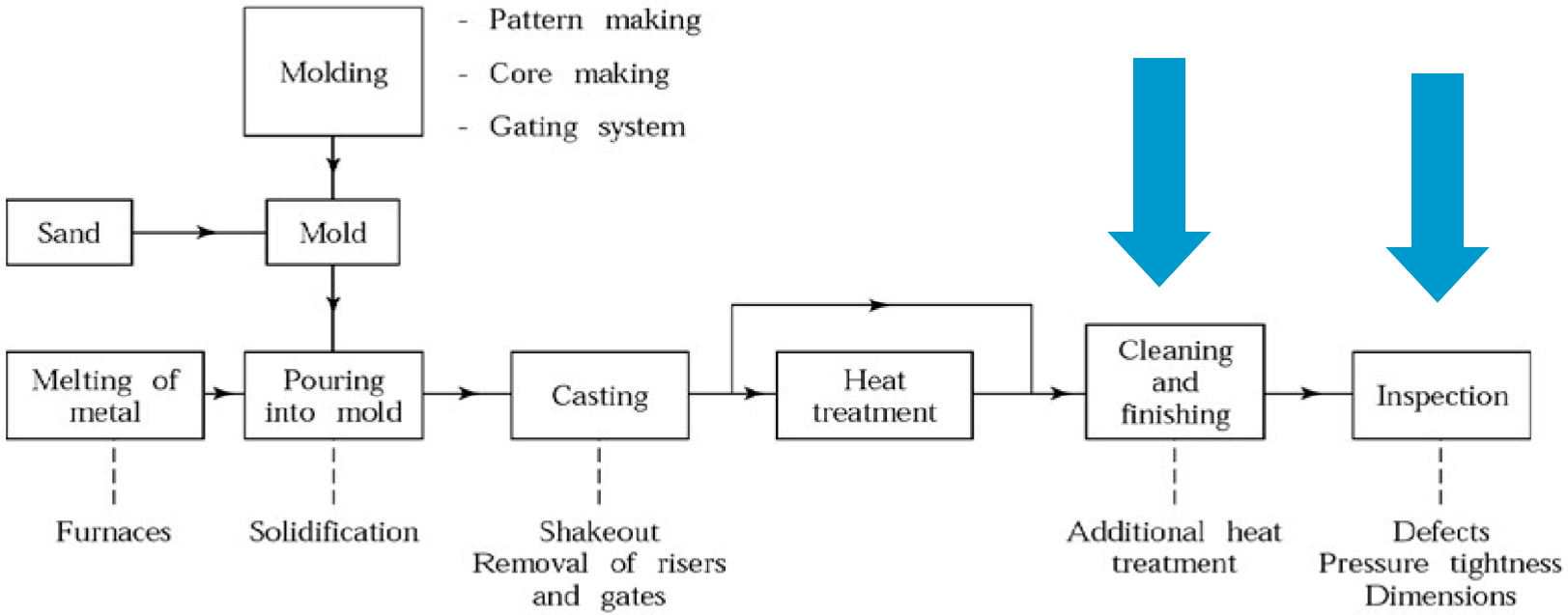
CASTING QUALITY CONTROL



AGENDA

- INTRODUCTION TO CASTING QUALITY CONTROL.
- CASTING DEFECTS, FACTORS RESPO NSIBLE , REMEDIES.
- CLEANING OF CASTINGS
- INSPECTION METHODS AND TESTING METHODS TO EVALUATE A CAST.
- Q / A

Sand Casting Steps



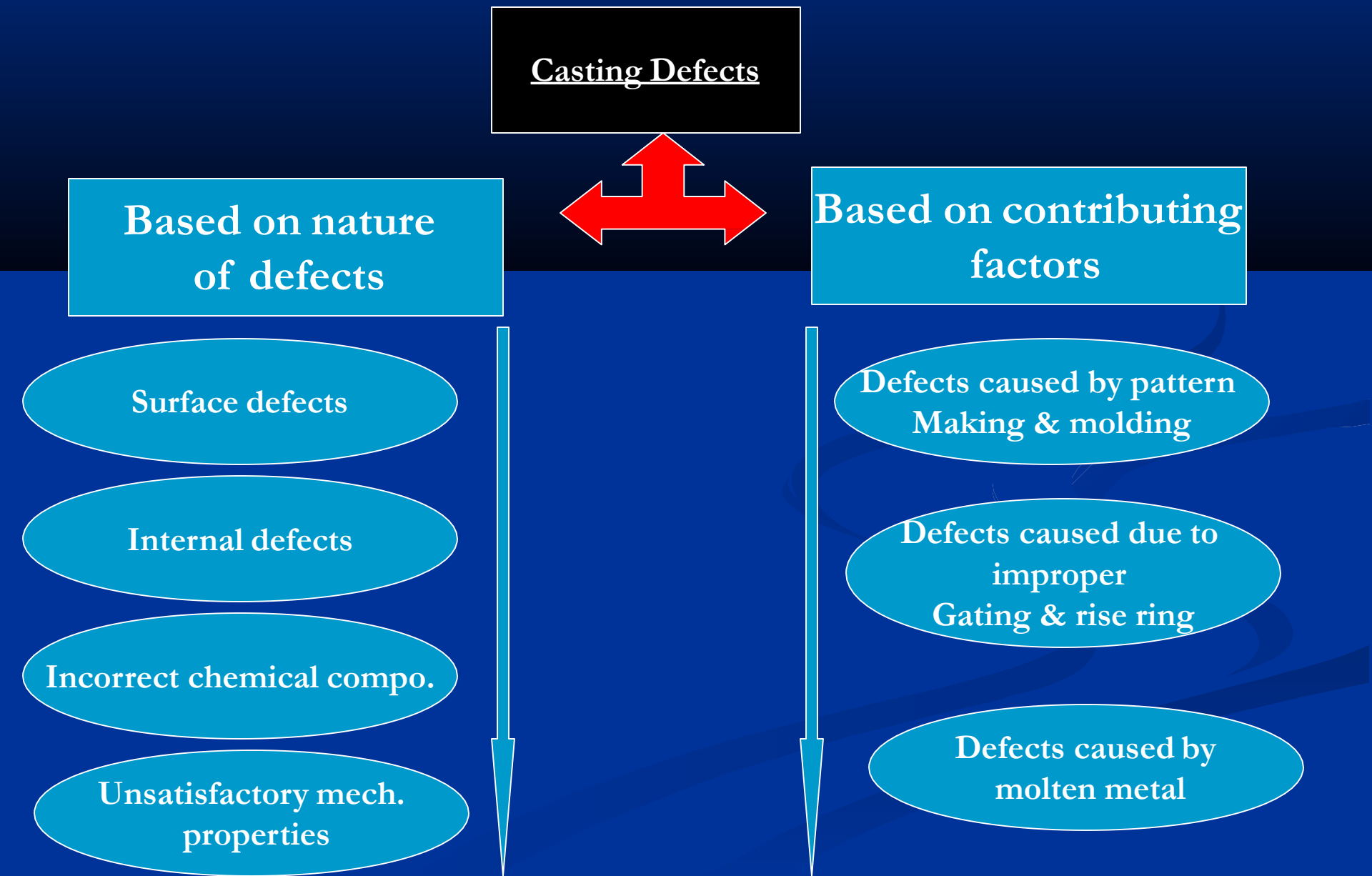
Introduction

- Reduces total output, increases the cost of production.
- Casting defects may be defined – those characteristics that create a deficiency or imperfection to quality specifications imposed by design and service requirements.
- Even in modern foundries the rejection rate – as high upto 20% of the number of casting produced.
- Hence all efforts must be taken to bring down the percentage of rejection.
- For this to happen one should have sound knowledge of principles of casting, casting design, potential defects, causes, remedies for same, inspectional methods, testing methods.

Types of Defects

- Based on Location:
  - External
  - Internal
- Based on Type:
  - Geometric
  - Integrity
- Based on Size/Severity:
  - Small/Minor
  - Large/Major
- Based on Process:
  - Moulding-related
  - Filling-related
  - Solidification-related.
- Based on Cause:
  - Raw materials
  - Product design
  - Tooling design
  - Process parameters
  - Process control
- Based on Stage:
  - Casting
  - Rough machining
  - Finish machining
  - Service
- Based on Reparability:
  - Repairable
  - Irreparable

CLASSIFICATION OF CASTING DEFECTS



BASED ON NATURE OF DEFECTS

- **Surface defects** : may be visible on surface
  incorrect shape & size, laps, flashes, poor surface finish.
- **Internal defects** : these are present in interior of cast. Can be revealed through NDT techniques.
- **Incorrect chemical composition** – formation of undesirable microstructure.
- **Unsatisfactory mechanical properties –** low quality, poor percent of usage.

BASED ON CONTRIBUTING FACTORS

- **Defects caused by pattern making and moulds**: results in incorrect dimensions, poor surface finish, flash, mismatch.
- **Defects – improper gating & risering** results in cold shut, misrun, inclusions, pulls, shrinkage cavities.
- **Defects caused – molten metal** results in cold shut, metal penetration, porosity.

CAUSES FOR DEFECTS

- Unsuitable and unsatisfactory raw materials.
- Application of unsatisfactory casting principles.
- Use of improper tools, equipment, appliances or patterns.
- Unprofessional management.
- Unsatisfactory setting up of procedures, poor work discipline, lack of training.

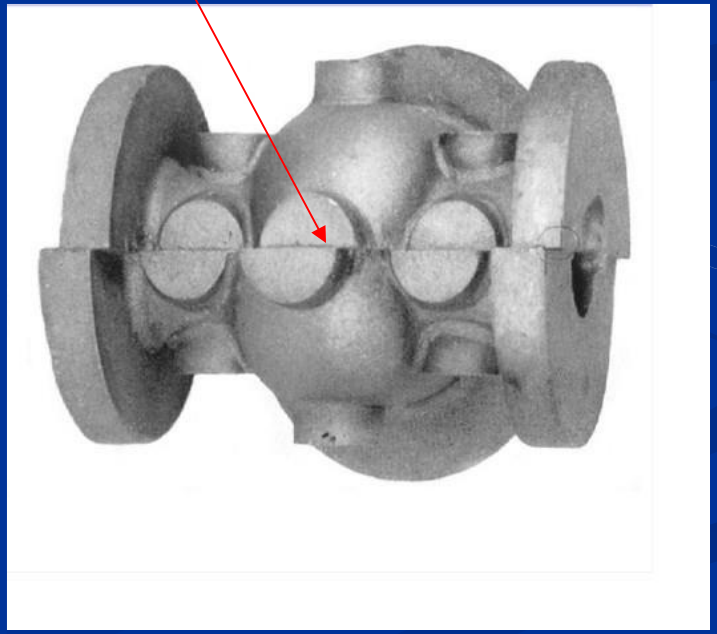
CASTING DEFECTS ,FACTORS RESPONSIBLE FOR THEM AND REMEDIES

- CORE SHIFT
- WRAPED CASTING
- SWELL
- FIN
- BLOW HOLES
- PIN HOLES
- GAS HOLES
- SHRINKAGE CAVITY
- HOT TEAR
- INCLUSIONS
- MISRUN AND COLD SHUT
- EXPANSION SCABS

CORE SHIFT

- Results in mismatch of the section.
- Usually easy to identify.
- Can be repaired provided with in tolerable limits.
- Misalignment of flasks is a common cause.
- Can be prevented by ensuring proper alignment of pattern, die parts, molding boxes.

CORE SHIFT



WARPED CASTING

- Warpage - Undesirable deformation in a casting.
- Large cross sections or intersections are particularly prone to warping.
- Can be reduced by proper casting design, judicious use of ribs.
- Cannot be eliminated but allowances can be given along with machining allowance, to remove by machining.

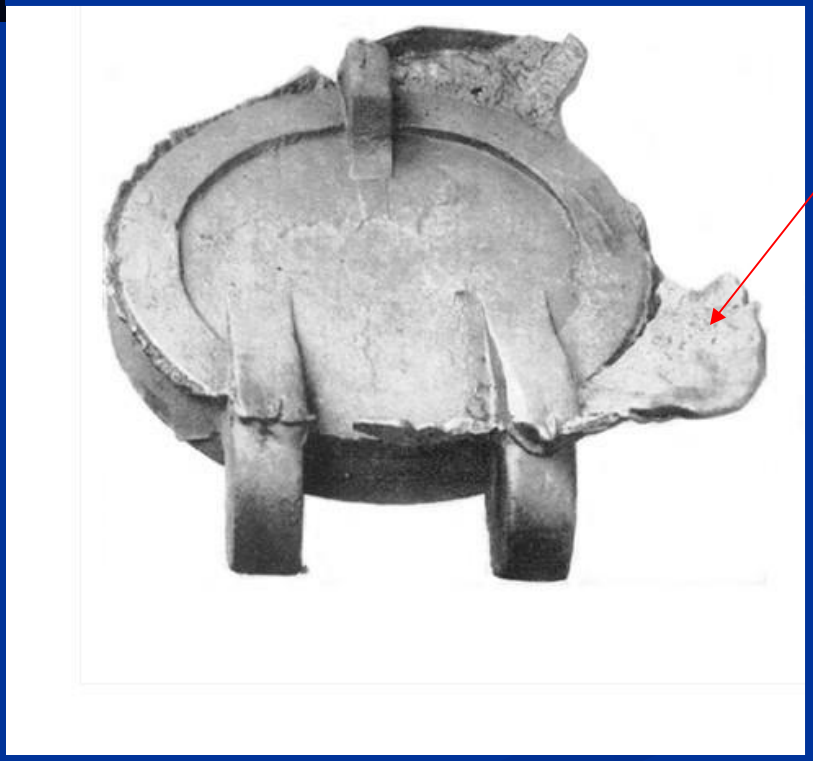
SWELL

- Swell- enlargement of the mould cavity by metal pressures, results – localized or overall enlargement of castings
- Caused due to insufficient ramming of the sand.
- Also due to rapid pouring of molten metal.
- Also due to insufficient weighting of mould
- Remedies – avoid rapid pouring, provide sufficient ram on sands , proper weighting of moulds.

FIN

- A thin projection of metal – not a part of cast.
- Usually occur at the parting of mould or core sections.
- Causes - Incorrect assembly of cores and moulds, improper clamping, improper sealing.
- Remedy is proper clamping of cores and mould.

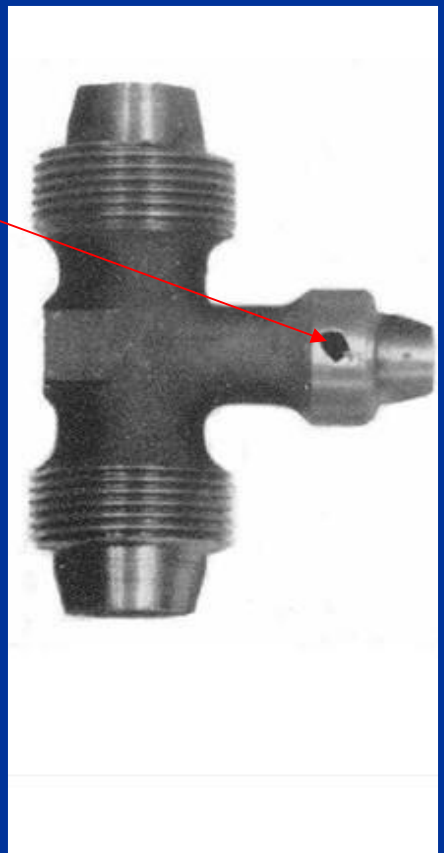
FINS OR FLASH



BLOW HOLES

- They are entrapped gases.
- This is result of gases from mould, molten metal and steam sand.
- Remedy is to provide sufficient permeability, making vent holes, use minimum quantity of water.
- Also use of dry sand moulds, use of no bake sands.

BLOW HOLE

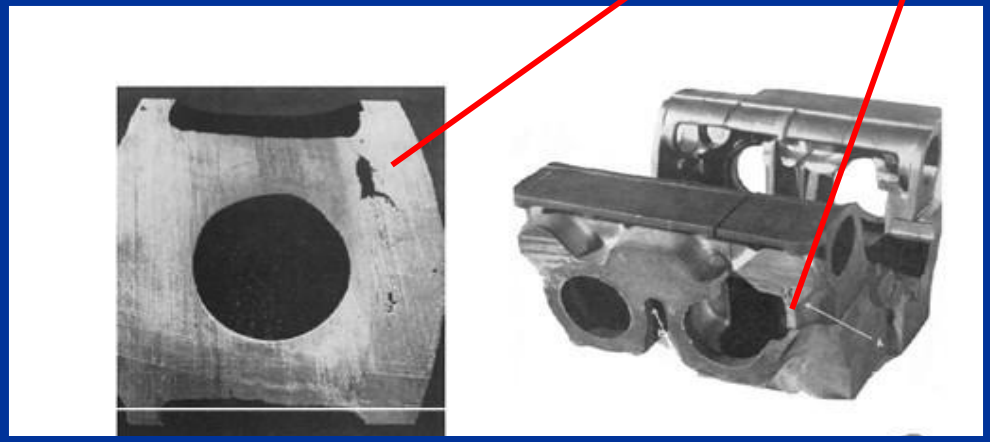


SHRINKAGE CAVITY

- It is a void or depression in the casting caused mainly by uncontrolled solidification.

- Remedy is apply principles of casting, provide adequate risers, feeders, which supply the molten metal to compensate the shrinkage.

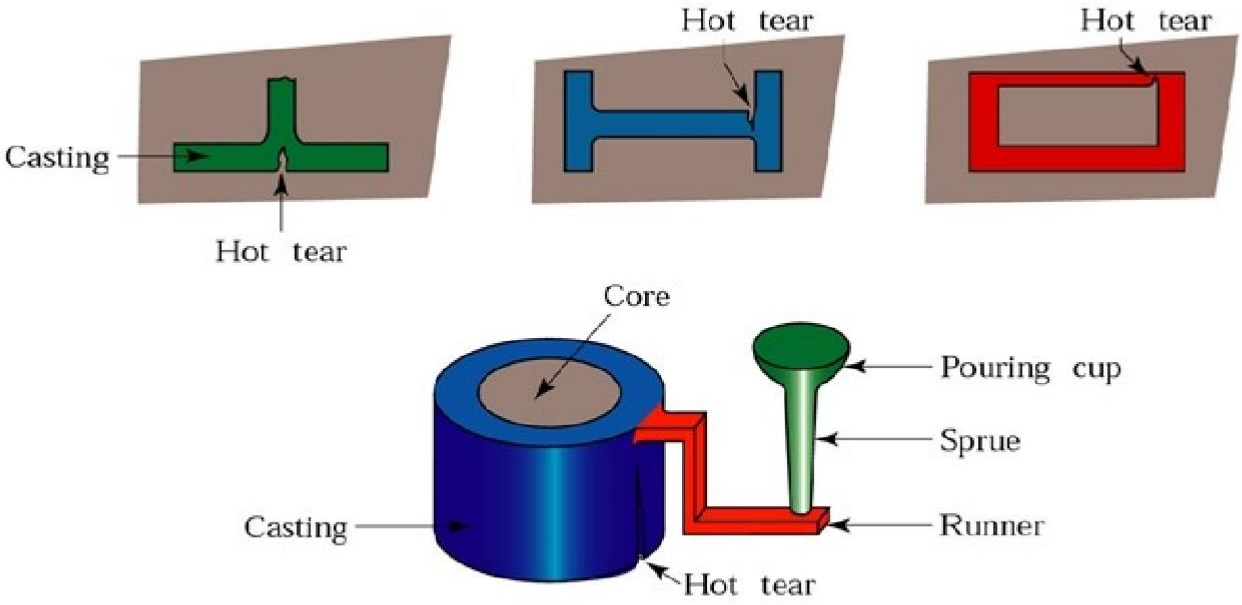
Shrinkage cavity



HOT TEAR

- If the mould surface is rigid, it restrains solidifying casting from contraction and resulting in development of cracks or tear, also called pulls.
- Remedy is avoid excessive ramming.
- Controlled ramming should be done.

Hot Tears


Casting
Hot tear
Hot tear
Hot tear
Core
Pouring cup
Sprue
Casting
Runner
Hot tear

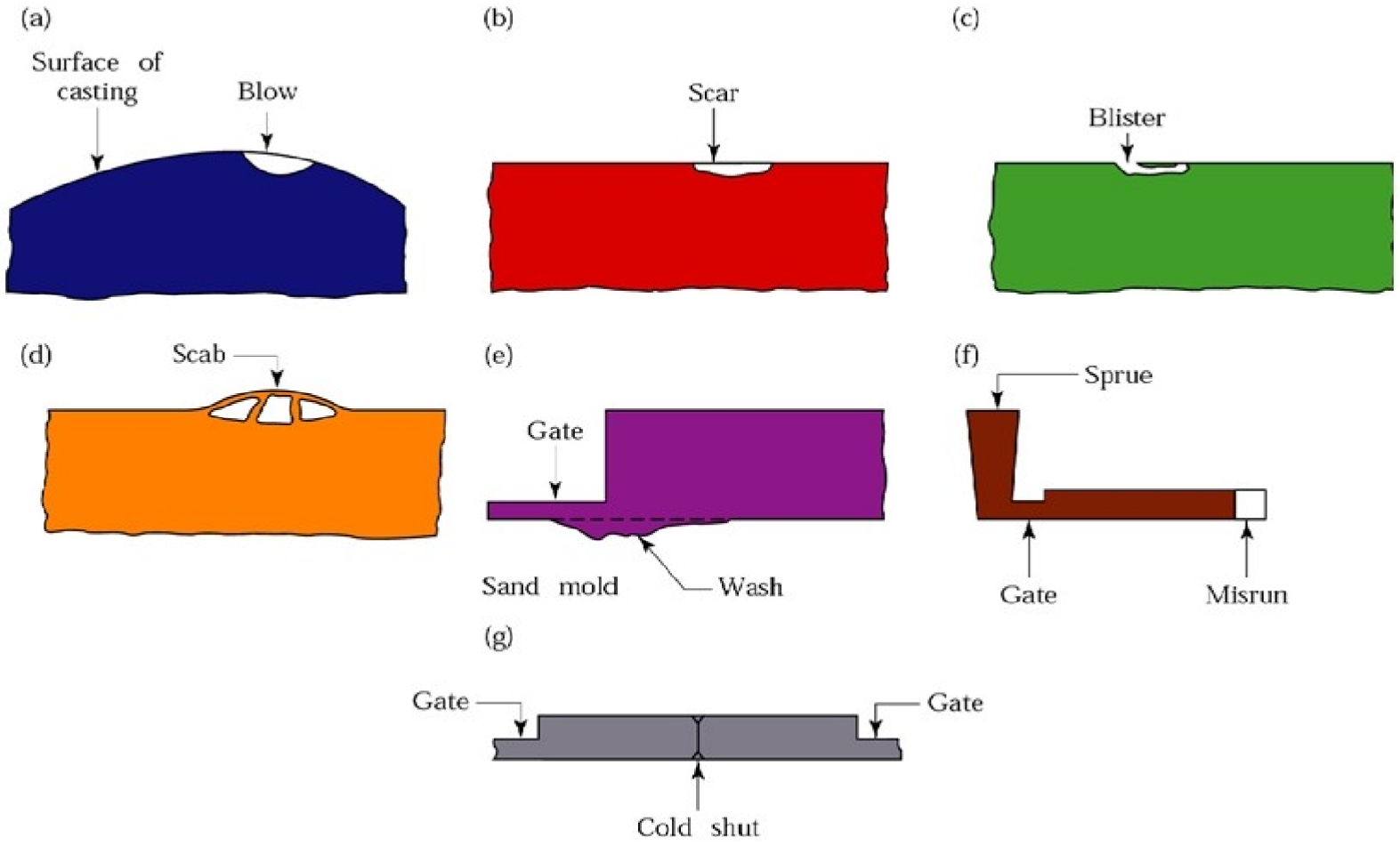
METAL PENETRATION

- When molten metal penetrates in the spaces between sand grains.
- Result - sand will be tightly held to the casting.
- Remedy – good optimum mould hardness.

MISRUN & COLDSHUT

- Misrun occurs particular section of casting is solidified before filling .
- when two streams of molten metal which are too cold to meet and do not fuse then results in coldshut.
- Prevented by proper casting design.

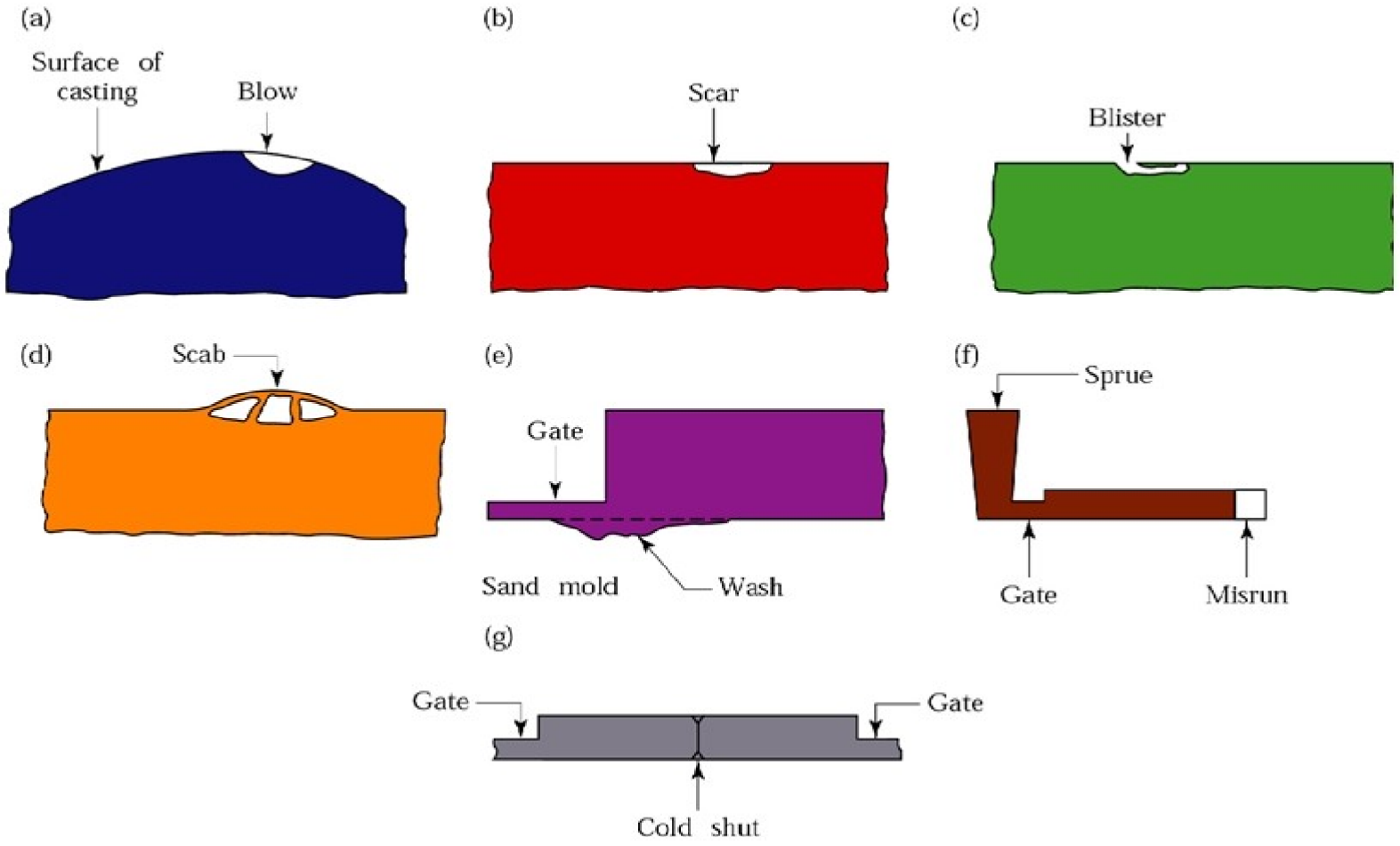
Casting Defects



EXPANSION SCABS

- This is due to expansion property of sand.
- Due to high temperature sand will expand.
- Low thermal stability of sand used.
- This expansion is prevented by mould condition, results in cracks, poor surface finish.
- Remedy is to reduce use clay content.
- Use of additives which reduce thermal expansion of sand.

Casting Defects



CLEANING OF CASTINGS

- This operation is also referred a fettling.

Operations may be

- Knocking out of dry sand cores.
- Removal of gates and risers.
- Extraction of fins and unwanted projections.
- Cleaning and smoothening of surface.
- Repairing the casting, to fill up defects.

Knocking out of dry sand cores

- Dry sand cores can be removed by rapping or knocking with an iron bar.
- For quicker removal hydraulic and pneumatic equipments can be used.
- These devices also helps in cleaning and smoothening.

Removal of gates and risers.

- Choice of removal methods – depend upon size and shape, type of cast.
- Using hammer to knock off, this is particularly suitable for brittle materials.
- Sawing- may be band saw, circular saw, power hacksaw.
- Using flame generated by oxyacetylene gas.
- Employing abrasive cutting machines.

Extraction of fins and unwanted projections

- This operation is also called snagging.
- Methods include – using grinders
- Chipping with hand tool.
- Flame cutting.
- Using electric arc equipment.
- Filing.

Cleaning and smoothening of casting

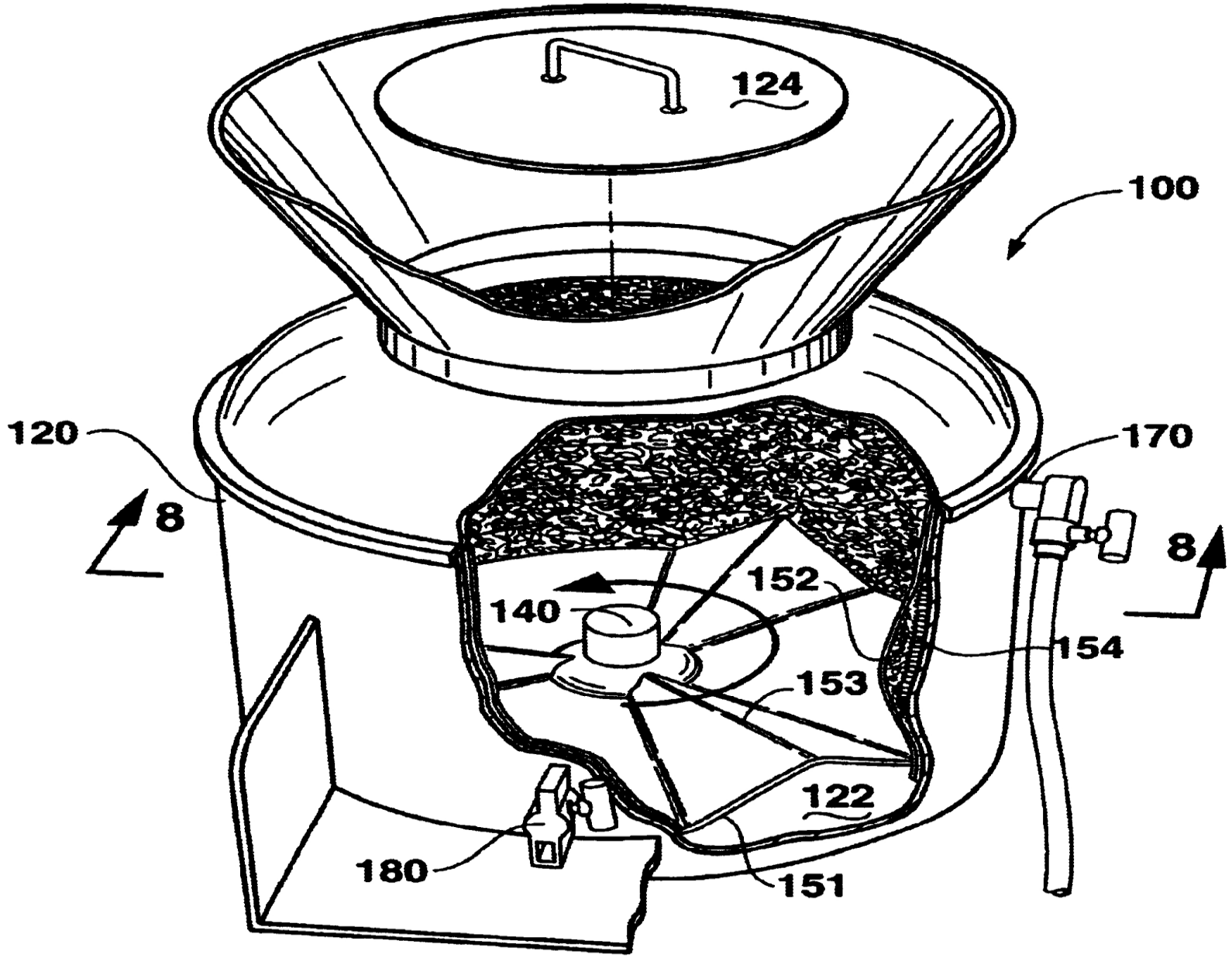
- ***Manual method*** –
- Done using wire brush
- Extremely tedious and time consuming.
- As a result mechanical methods are employed

Cleaning and smoothening of casting

- Mechanical methods include –
  - Tumbling
  - Compressed air impact cleaning
  - Mechanical impact cleaning or shot blasting
  - Hydro blasting.

Tumbling

- Components are place sin barrel along with steel rods
- Barrel is then rotated its central axis – peening action takes place – casting are cleaned.
- Care should be taken – not to charge very tightly to prevent any relative motions.
- Hard castings - are not fragile enough are suitable for tumbling.

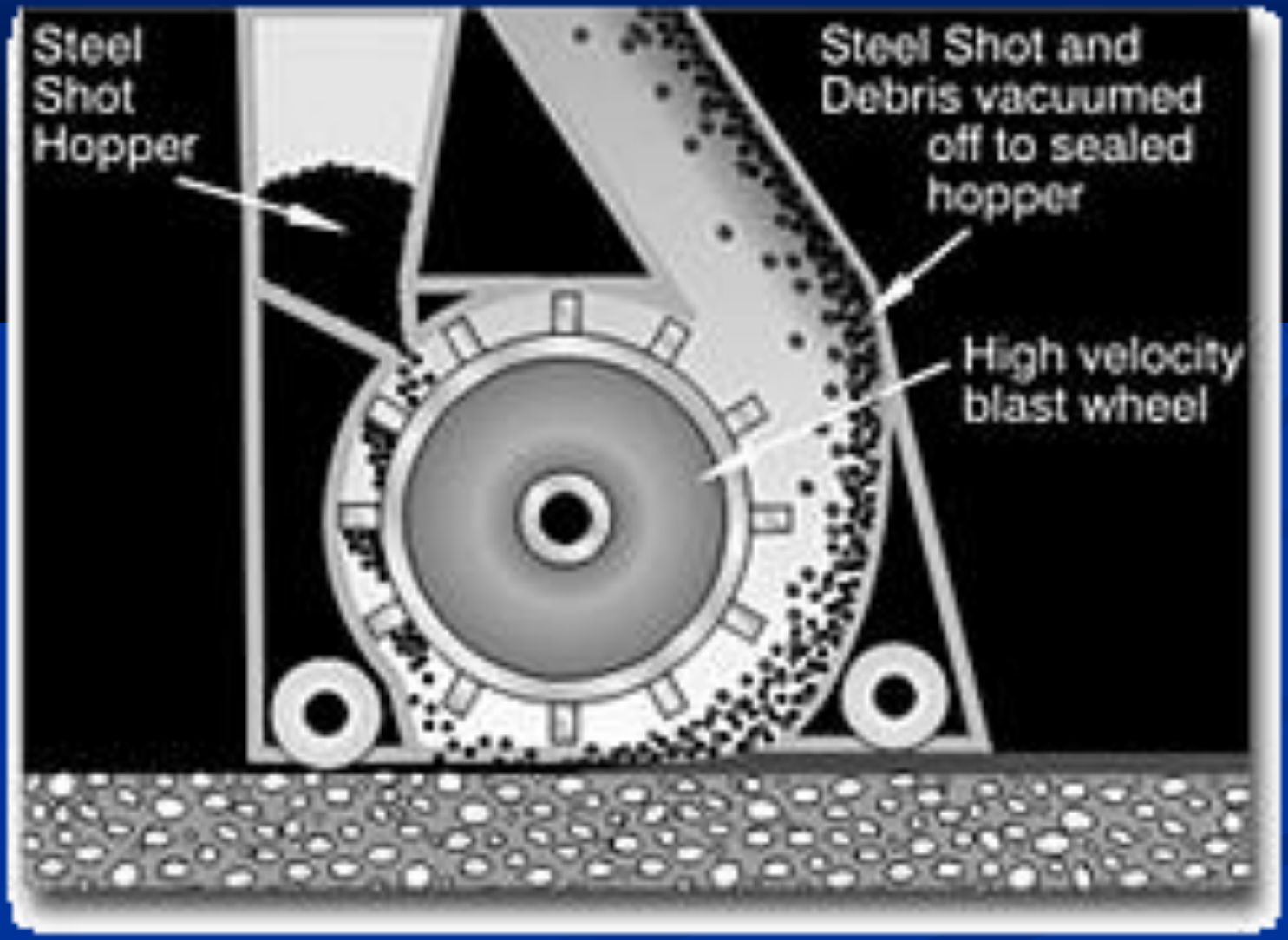

124
100
120
8
170
8
152
140
154
153
122
180
151

Compressed air impact cleaning

- Stream of suitable abrasive particles along with compressed air is directed – at high velocities.
- This is done in tightly closed chambers.
- Due to impact surface gets cleaned.

Mechanical impact cleaning or shot blasting

- Abrasive particles are thrown by centrifugal force.
- Has vane rotating at speed of 1800 to 2500 rpm.
- Abrasive particles are fed at angular positions near the centre.
- Centrifugal force causes particles to move outwards the periphery until it reaches the outer tips and is thrown at workpiece.
- Due to impact surface is cleaned.


Steel
Shot
Hopper
Steel Shot and
Debris vacuumed
off to sealed
hopper
High velocity
blast wheel

Hydro blasting

- High velocity stream – 15% sand and 85% water is directed against the surface through nozzle.
- Thus by nozzle pressure increases – up to 600 m / min.
- Smallest casting that can be cleaned, weighs at least 120 kgs.
- Provisions are made to recover sand.

INSPECTION OF CASTING

- PROCESS INSPECTION
- VISUAL INSPECTION
- DIMENSIONAL INSPECTION

PROCESS INSPECTION

- Inspection done while parts are being processed.
- This is helpful to detect defects at the start and allow the corrections.
- This is an preventive act.

VISUAL INSPECTION

- Simplest and most fastest inspectional methods.
- Most commonly employed.
- Usually good to check surface defects.
- Fails to identify internal defects.

DIMENSIONAL INSPECTIION

- Before casting are to be machined dimensional inspection is done.
- Castings are placed on surface plate or surface table with angle - measuring instruments.
- Various measuring instruments are employed for a first set of castings, so as to standardize subsequent castings.

TESTING METHODS

- PRESSURE TESTING
- DESTRUCTIVE TESTING
- NON DESTRUCTIVE TESTING

PRESSURE TESTING

- Casting that is used for containing or conveying liquids, gases, such type are subjected to pressure testing.
- It is tested for any leaks through their walls.
- Leaks may be detected by submerging the complete casting under water for gas pressures.
- Or by visual inspection by liquid pressures.

DESTRUCTIVE TESTING

- This test is done causing harm to the casting i.e. by destroying it.
- Various tests include fatigue tests, compression tests, creep tests etc.

NON DESTRUCTIVE TESTING

- Here parts to be tested are inspected for internal defects and surface defects without destroying the component.
- Various methods available are:
  - Liquid penetrate test LPI
  - Magnetic particle inspection MPI
  - X – Ray radiography XRR
  - Ultrasonic testing UT
  - Eddy current test ECT
  - Gamma ray radiography GRR

Liquid penetrant test

- Surface preparation
- Penetrant application
- Penetrant dwell
- Excess Penetrant removal
- Developer application
- Indication development
- Inspection
- Clean surface.

Magnetic Particle Inspection - MPI

- Most satisfactory method Used to find surface and sub surface defects.
- It is quick, cheap, very sensitive
- Can only be applied to ferrous metals like steel, cast iron etc

Principle - MPI

- When a metal placed in magnetic field, magnetic flux are intersected by the defect – magnetic poles are induced on either side of discontinuity.
- Abrupt change in path of flux – local leakage
- This can detected when magnetic particles are attracted towards defective region.
- Magnetic particles piles up in defective region.

Procedure

- **Preparation of specimen**
  - Surface should be cleaned thoroughly, free from rust, grease, oil, paint etc.
  - Cleaning of surface can be done using wire steel brushes, shot blasting technique or by using solvents.

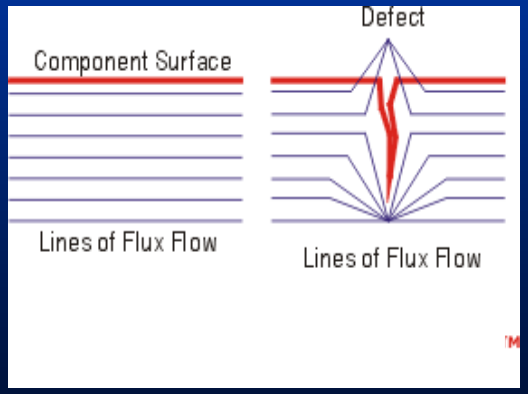
Magnetization

- To induce magnetic lines – two methods – permanent magnet – electromagnet.
- Electromagnet is proffered as it has capability to produce stronger magnetic field.
- Magnetization – two types – longitudinal or for parallel defects – circular or for perpendicular defects.
- For a defect to be detected flux lined should pass perpendicular line.

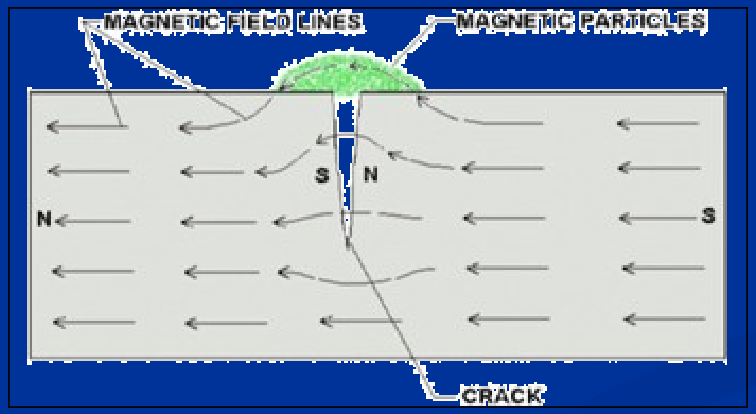
Application of magnetic particles

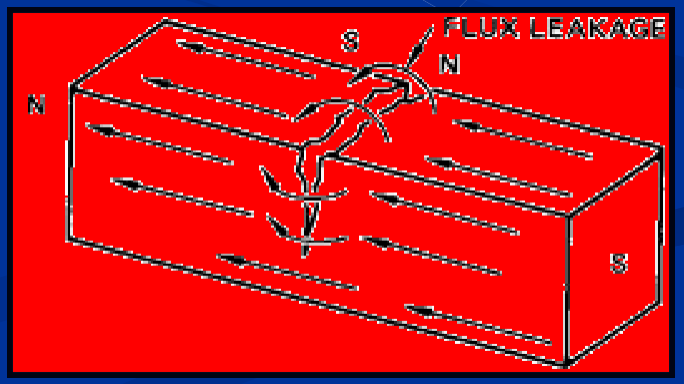
- Magnetic particles are applied uniformly so that they move on the surface freely.
- The particles must be as fine as possible.
- Generally pulverized iron oxide, carbonyl iron powder are used.
- Powder can be of
  - Powder suspended in liquid petroleum
  - Dry powder
  - Fluorescent powder – can be viewed in UV light.

Inspection of defect



- Generally carried out in good light.
- If no defects then regular pattern, if presence of defects then flux lines distorted.
- Magnetic particles spreads out at the point of defects indicating presence of defect.



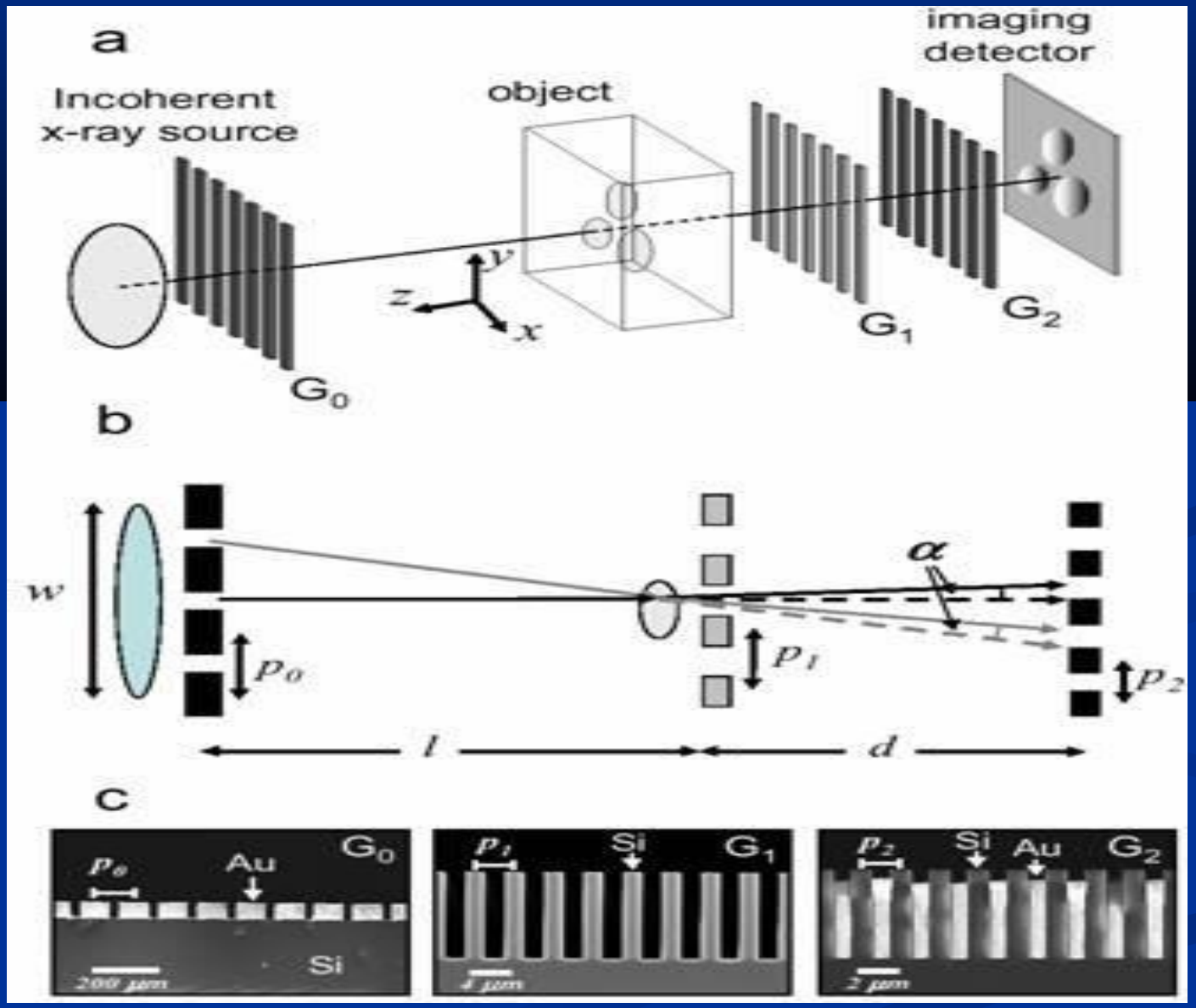


X – ray radiography

- X – Rays are produced when high energy electrons collide with the nucleus of an atom .
- The x – ray equipment ---which produces incandescent light, placed near a highly charged cathode, causing the electrons to flow from the cathode which is attributed by the anode or target.
- The intensity of x – rays produced is directly proportional to the number of electrons produced at the filament.
- The pattern of the x – ray so produced depends on the shape of the target.

X – ray radiography

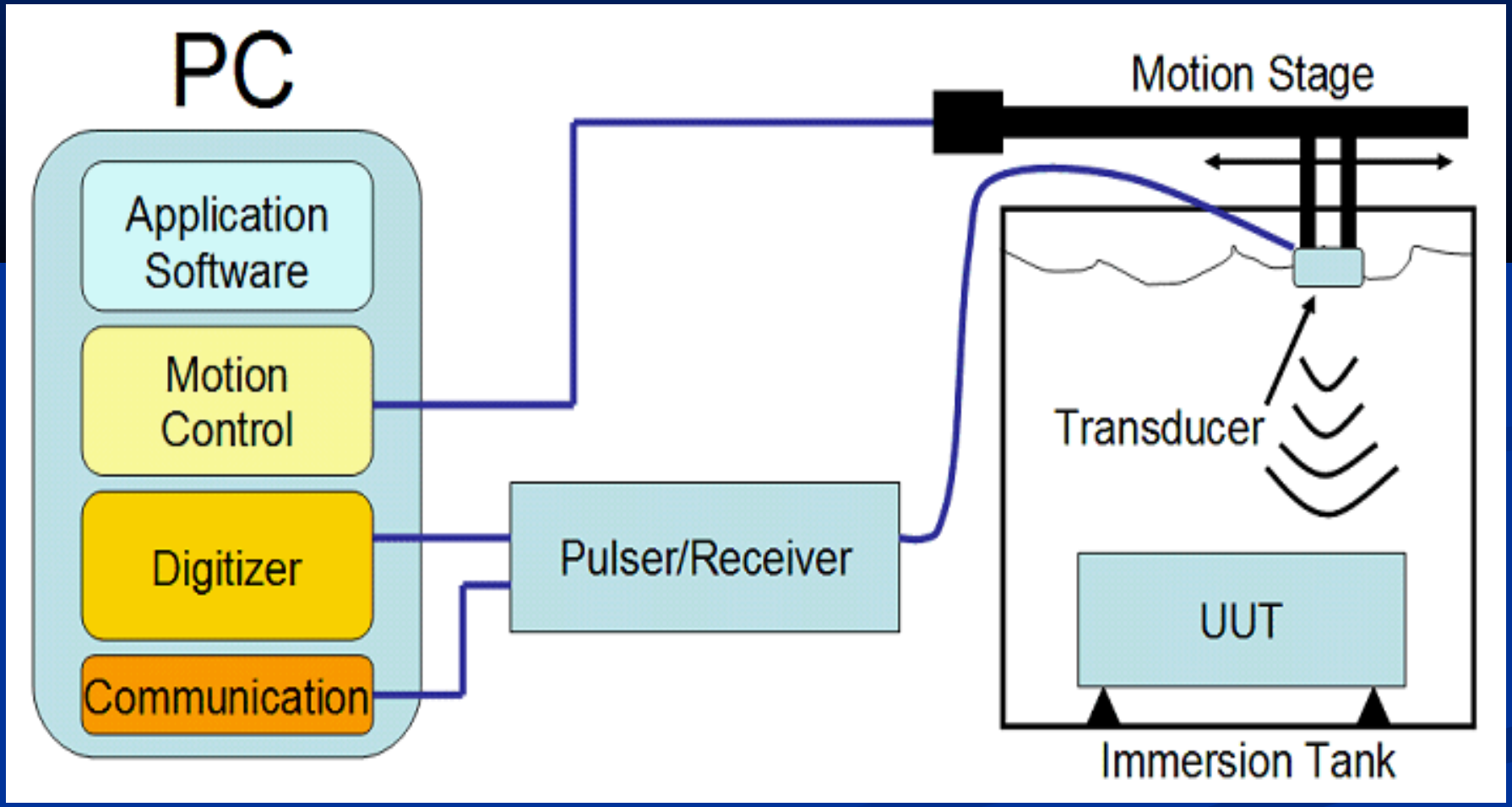
- A radiographic film is placed next to the part to be tested and x rays are directed against the part.
- The x – rays will pass through the part to be tested proportional to the density and thickness of the part.
- The absorption of x – rays is directly proportional to the density of and thickness of the part. If the part has no defects, the x- rays will pass uniformly through the part.
- However if there are any defects such as porosity which leads to lesser density, the penetration of x – rays will be move through them which shows as darker areas on the film.
- X – Rays technique is effective in locating cracks, slay inclusions, porosity, blow holes, pin holes etc.
- X- Rays can be used for inspection of casting in all type

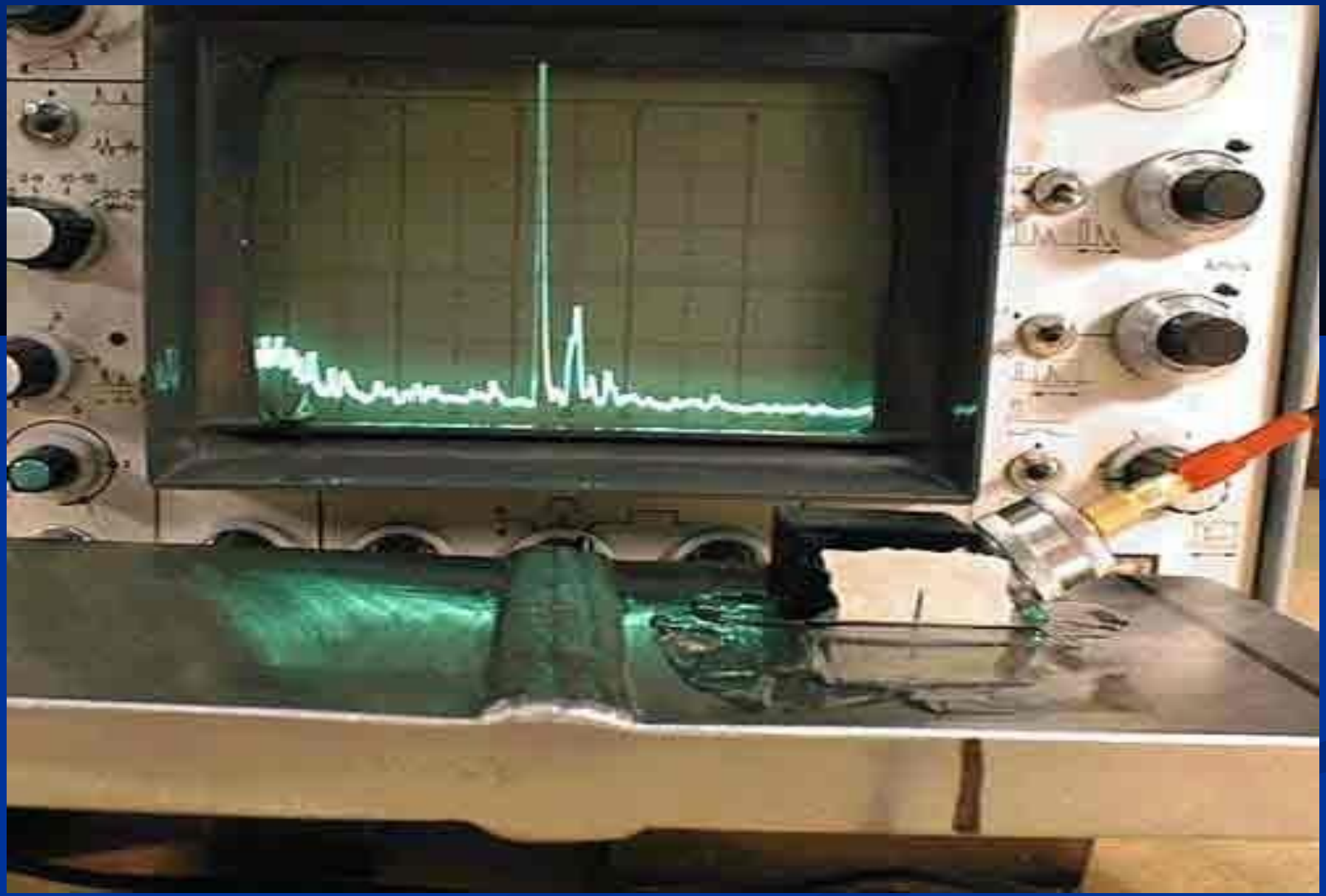

a
imaging
detector
Incoherent
x-ray source
object
y
z
x
G0
G1
G2
b
w
α
p0
p1
p2
l
d
c
p0
Au
G0
Si
200 μm
p1
Si
G1
4 μm
p2
Si
Au
G2
2 μm

Ultrasonic Testing

- Ultrasonic Testing (UT) uses high frequency sound energy to conduct examinations and make measurements.
- Ultrasonic testing is based on piezoelectric effect which converts electrical energy to mechanical energy thus generating ultrasonic waves
- Ultrasonic waves are generated when a high frequency alternating current of about a million times per second is impressed across the forces of piezoelectric materials like quartz crystal.
- The crystal expands in full half of the cycle and contracts when the electric field is increased, thus producing mechanical vibrations.

UT arrangement





Ultrasonic Testing

- When there is a discontinuity (such as a crack) in the wave path, part of the energy will be reflected back from the flaw surface
- The reflected wave signal is transformed into an electrical signal by the transducer and is displayed on a screen
- In the applet below, the reflected signal strength is displayed versus the time from signal generation to when an echo was received. Signal travel time can be directly related to the distance that the signal traveled
- From the signal, information about the reflector location, size, orientation and other features can sometimes be