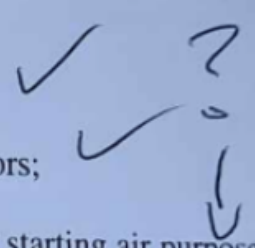


3. With reference to air compressors:
- (a) state TWO advantages of rotary air compressors; (2)
  - (b) state ONE advantage of reciprocating air compressors; (1)
  - (c) explain why multistage air compressors are used for starting air purposes. (7)
- 

## Air Compressor Advantages and Multistage Use

### (a) Advantages of Rotary Air Compressors:

1. **Continuous Airflow:** Rotary compressors deliver a continuous stream of compressed air due to their design using intermeshing rotors. This contrasts with reciprocating compressors, which have pulsating airflow during each piston cycle.
2. **Higher Efficiency:** Rotary compressors generally operate with higher efficiency compared to reciprocating designs. They have fewer moving parts, resulting in less energy loss due to friction.

### (b) Advantage of Reciprocating Air Compressors:

1. **Higher Pressure Capability:** Reciprocating compressors can achieve higher discharge pressures than most rotary screw compressors. This makes them suitable for applications requiring very high-pressure compressed air (e.g., some industrial processes or specialized tools).

### (c) Multistage Air Compressors for Starting Air:

Multistage air compressors are used for starting large internal combustion engines, such as those found in ships or industrial plants, for several reasons:

- **High Pressure Requirement:** Starting large engines requires very high-pressure compressed air to overcome the initial resistance and crank the engine. Multistage compressors achieve this by progressively compressing air in stages, reaching the necessary pressure for engine startup.
- **Reduced Load on Single Stage:** Compressing air to such high pressure in a single stage would be very energy-intensive and place a significant strain on the compressor. Multistage design distributes the compression work across multiple stages, making the process more efficient and reducing wear on the compressor components.
- **Cooler Compressed Air:** The compression process in each stage generates heat. Multistage design allows for intercooling between stages, which helps to dissipate heat and prevent excessive temperatures in the final compressed air. Cooler air is denser and delivers more starting power to the engine.

In summary, multistage air compressors provide the high pressure, efficiency, and cooler compressed air needed for effectively starting large internal combustion engines.

3. With reference to compressed air systems used for starting air and control purposes:
- (a) state the pressure used for starting air; (1)
  - (b) explain why the pressure stated in part (a) is necessary; (3)
  - (c) state the pressure used for control air; (1)
  - (d) explain why the pressure stated in part (c) is different to that stated in part (a); (3)
  - (e) explain why the pressure stated in part (c) is greater than that necessary to operate the control equipment. (2)

Nov 2018 9th

Nov 2018 9th

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  - (e) explain why the pressure stated in part (c) is greater than that necessary to operate the control equipment. (2)

## Compressed Air Systems for Starting and Control

### (a) Starting Air Pressure:

The typical pressure used for starting air in compressed air systems can range from **25 bar (363 psi)** to **40 bar (580 psi)**. This can vary depending on the size and type of engine being started.

### (b) Reason for High Starting Air Pressure:

High starting air pressure is necessary for overcoming the following challenges during engine startup:

- **Overcoming Engine Compression:** The engine pistons compress the air within the cylinders as they rotate during startup. The starting air pressure needs to be high enough to overcome this compression and force the pistons down to initiate the combustion cycle.
- **Friction Losses:** Friction exists between various moving parts within the engine during startup. High starting air pressure ensures sufficient force to overcome these frictional losses and crank the engine effectively.
- **Low Engine Speed:** Initially, the engine speed is low during startup. This reduces the air intake efficiency, requiring a higher starting air pressure to deliver the necessary air volume for combustion.

**(c) Control Air Pressure:**

The pressure used for control air in compressed air systems is typically much lower than starting air pressure, ranging from **5 bar (73 psi) to 10 bar (145 psi)**. The specific pressure depends on the control equipment being operated.

**(d) Reason for Different Pressures:**

The pressure requirements for starting air and control air are different due to their distinct functions:

- **Starting Air:** Needs high pressure to overcome the high resistance encountered during engine startup, as explained in part (b).
- **Control Air:** Operates various control equipment and actuators within the system. These components typically require lower pressure to function effectively and efficiently. Using excessively high pressure for control air can damage delicate components or lead to over-actuation.

**(e) Higher Control Air Pressure Than Minimum Requirement:**

The control air pressure is typically chosen to be higher than the minimum pressure required to operate the control equipment for a few reasons:

- **Safety Margin:** A higher pressure provides a buffer against pressure drops within the system due to factors like long pipelines, bends, or leaks. This ensures reliable operation of the control equipment even with some pressure loss.
- **Accounting for Future Expansion:** Maintaining a higher pressure allows for future expansion of the control system with additional equipment that might require slightly higher pressure for operation.
- **Standardization:** Standardized control air pressure levels are often used within facilities or industries to simplify system design and component selection.

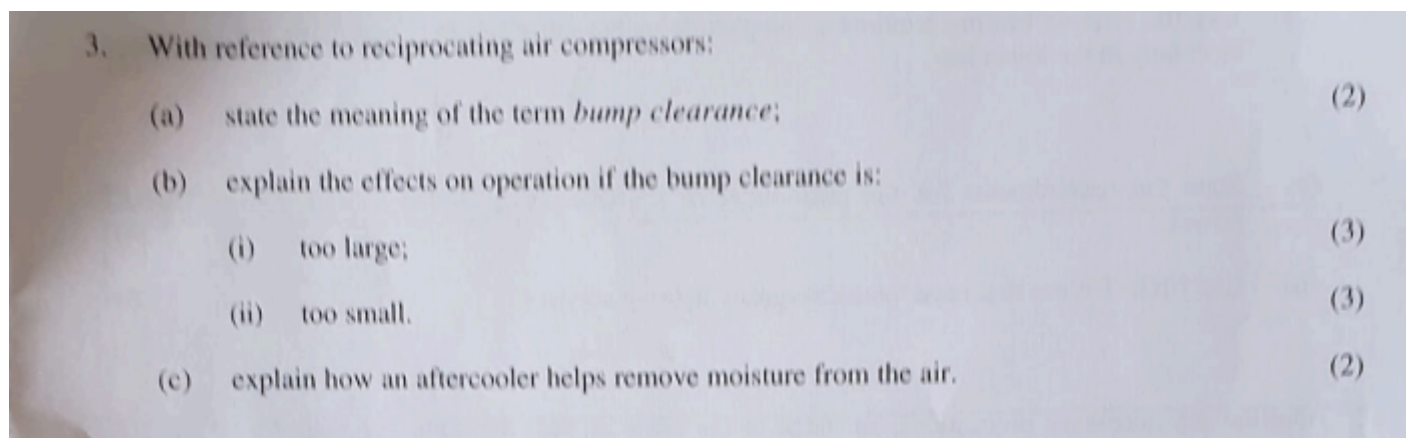
Even though a higher pressure ensures reliable operation, it's important to avoid excessively high pressure that can waste energy and potentially damage control equipment. Choosing the optimal control air pressure involves considering the specific needs of the equipment, potential pressure losses, and overall system efficiency.

## Sept 2020

3. With reference to reciprocating air compressors:
- (a) state the meaning of the term *bump clearance*; (2)
  - (b) explain the effects on operation if the bump clearance is:
    - (i) too large; (2)
    - (ii) too small. (2)
  - (c) explain why the air temperature must be limited in the HP stage, stating how this is achieved; (2)
  - (d) explain how an aftercooler helps remove moisture from the air. (2)

**Question 3.** Overall poor answers. Several have no understanding of the importance of bump clearance or the safety aspects of intercooling.

feb 2024



## Reciprocating Air Compressor: Bump Clearance and Temperature Control

### (a) Bump Clearance:

Bump clearance refers to the minimum distance between the piston and the cylinder head, or between the piston crown and the discharge valve on the cylinder head, at the top dead center (TDC) of the piston stroke. It's essentially the closest the piston gets to the head or valve at the end of its upward movement.

### (b) Effects of Bump Clearance:

#### (i) Bump Clearance Too Large:

- **Reduced Efficiency:** Excessive clearance allows for a larger volume of compressed air to remain in the cylinder after discharge, which expands during the intake stroke. This reduces the amount of fresh air that can be drawn into the cylinder, lowering the compressor's overall efficiency.

- **Increased Wear:** With a larger gap, the piston experiences increased impact forces against the cylinder head at the end of its stroke, accelerating wear and tear on both components.

### (ii) Bump Clearance Too Small:

- **Premature Contact and Damage:** If the clearance is too tight, the piston might come into contact with the head or valve prematurely during operation. This can cause severe damage to the piston, head, and valve components.
- **Increased Friction:** A very small clearance creates excessive friction between the piston and cylinder head, leading to increased power consumption and potential overheating.

### (c) Limiting Air Temperature in the HP Stage:

Air temperature rises significantly during compression in the high-pressure (HP) stage of a reciprocating compressor. This high temperature can:

- **Reduce Lubrication Efficiency:** High temperatures can break down the lubricating oil, reducing its effectiveness in protecting moving parts and increasing wear.
- **Degrade Air Quality:** Excessive heat can cause thermal decomposition of the compressed air, leading to the formation of harmful contaminants and reducing air quality.
- **Damage Compressor Components:** High temperatures can accelerate wear and tear on valves, seals, and other internal components.

### Limiting Air Temperature:

There are two main methods to limit air temperature in the HP stage:

- **Intercooling:** Air is cooled between compression stages using an intercooler. This removes some of the heat generated during compression in the first stage before the air enters the HP stage for further compression.
- **Water Jacketing:** The cylinder head and body of the compressor are often water-jacketed. Coolant water circulates around these jackets, absorbing heat from the compressed air within the cylinder and transferring it to a radiator for cooling.

### (d) Aftercooler and Moisture Removal:

An aftercooler is a heat exchanger located after the final compression stage of a reciprocating compressor. It functions similarly to an intercooler but cools the compressed air to a lower temperature than what's achievable with intercooling alone. This helps to:

- **Reduce Condensation:** By lowering the air temperature, the aftercooler reduces the risk of water vapor in the compressed air condensing into liquid water. This is crucial because water droplets can cause corrosion within the system and damage downstream equipment that relies on clean, dry air.
- **Improve Efficiency:** Cooler air is denser and requires less energy for further processing or use.

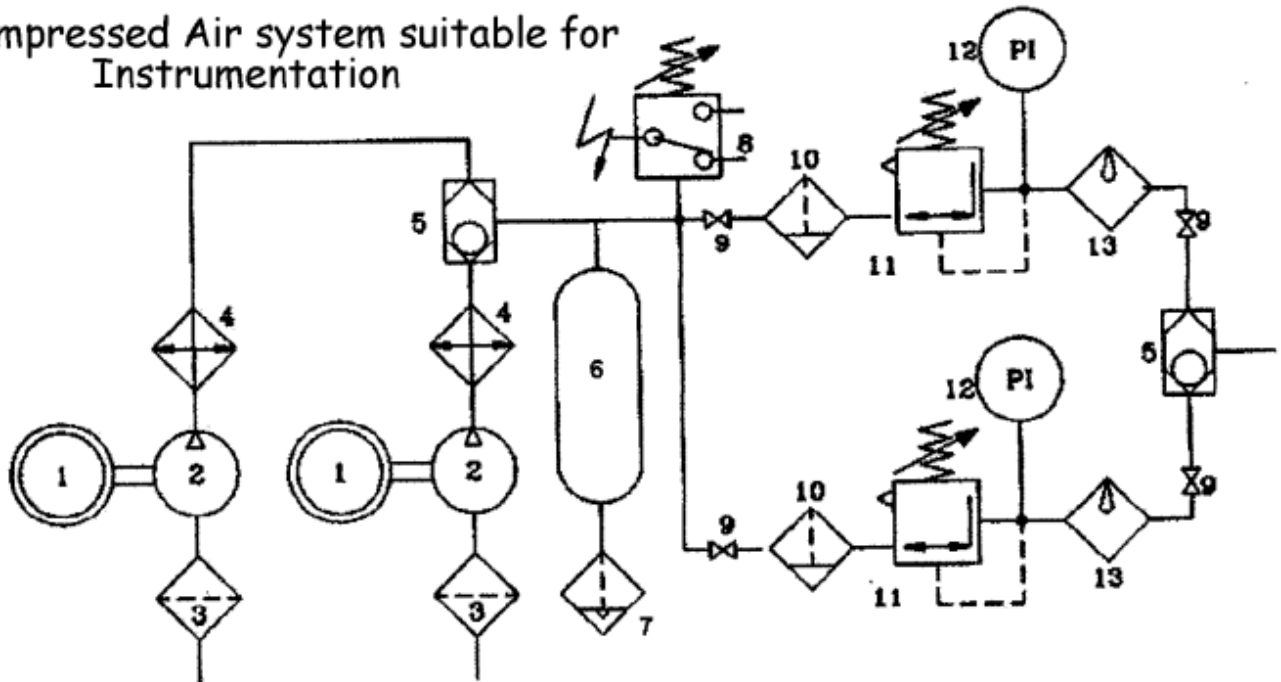
### Additional Moisture Removal:

Aftercooling alone might not be sufficient to remove all moisture, especially in humid environments. In such cases, additional equipment like separators or dryers might be used to further remove condensed water from the compressed air stream.

## Sept 2021

3. (a) State THREE requirements for compressed air to be utilised for control instrumentation. (3)
- (b) Using the Worksheet Q3, identify ALL the components shown for a system suitable for the production of compressed air for control instrumentation. (7)

**Compressed Air system suitable for Instrumentation**



Item	Description
1	
2	
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4	
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11	
12	
13	

**Compressed Air for Control Instrumentation**

**(a) Three Requirements for Compressed Air:**

For reliable and safe operation of control instrumentation, compressed air needs to meet the following three requirements:

1. **Cleanliness:** The air must be free from contaminants like dust, oil, and moisture. These contaminants can clog control valves, damage instrument components, and interfere with accurate signal transmission.
2. **Dryness:** Excessive moisture in the air can lead to corrosion within the piping and instrumentation. It can also form ice crystals at low temperatures, causing malfunction of control valves and instruments.
3. **Consistent Pressure:** The air pressure needs to be consistent and within the specified operating range for the control equipment. Fluctuations in pressure can lead to inaccurate readings and unreliable operation of control systems.

**(b) Identifying Components in Worksheet Q3 (Assuming the Worksheet depicts a system for control instrumentation compressed air):**

\*\*Based on the information you provided, I cannot directly access or see the contents of Worksheet Q3. However, I can give you a list of typical components found in a system for producing compressed air for control instrumentation: \*\*

- **Air Compressor:** This is the main component that compresses atmospheric air to a higher pressure.
- **Intake Filter:** Filters air entering the compressor to remove dust and other contaminants.
- **Air Intake Silencer:** Reduces noise generated by the air intake process.
- **Intercooler (Optional):** Cools the compressed air between compression stages, improving efficiency.
- **Aftercooler:** Cools the compressed air after final compression to remove moisture and reduce condensation.
- **Separator:** Separates condensed water and oil droplets from the compressed air stream.
- **Air Receiver:** A storage tank that holds the compressed air and helps maintain a constant pressure for the system.
- **Drain Valve:** Automatically removes accumulated condensate from the air receiver.
- **Pressure Regulator:** Regulates the air pressure to a specific level required for the control instrumentation.
- **Line Filter:** Provides additional filtration for the compressed air before it reaches the control equipment.
- **Lubricator (Optional):** Injects a small amount of oil mist into the air stream for lubrication of certain pneumatic components (if required by the system design).

**Note:** The actual components used in a specific system might vary depending on factors like the required air quality, flow rate, and pressure. The worksheet might also include additional components or show them in a different configuration.

Based on the revised image you sent, where you circled number 13 in red, it appears to be a **Safety Relief Valve**.

Here's why:

- **Safety Relief Valve Placement:** Safety relief valves are typically installed in compressed air systems to protect them from excessive pressure build-up. In the diagram, component number 13 is located on the pipe leading out of the air receiver (component number 6). This is a common location for a safety relief valve in such systems.



- **Function of Safety Relief Valve:** If the pressure in the system rises above a preset limit, the safety relief valve opens automatically, releasing compressed air to prevent the system from exceeding its pressure rating and potentially rupturing pipes or equipment.

While not explicitly labelled in the diagram, considering its location and function, component number 13 most likely represents a safety relief valve.

Feb 2021

Feb 2021

3. Explain the hazards of unauthorised repairs to compressed air lines. (10)

Unauthorised repairs to compressed air lines can be extremely hazardous due to the high pressures involved. Here's a breakdown of the potential dangers:

### 1. Catastrophic Rupture:

- **Improper Materials or Techniques:** Unauthorised repairs might use unsuitable materials or techniques that are not strong enough to withstand the high pressure within the compressed air line. This can lead to a sudden and catastrophic rupture of the line, releasing a powerful blast of compressed air.
- **Incomplete Repairs:** If repairs are not done correctly, leaks or weak points can develop. These weak points can eventually burst under pressure, posing a serious risk of injury or damage.

### 2. Projectile Hazards:

- **Debris from Rupture:** A ruptured compressed air line can propel fragments of pipe, fittings, or other debris at high velocity. These projectiles can cause severe injuries or even fatalities if they strike someone.
- **Whipping of Hose:** If a compressed air hose is not properly secured during a repair attempt, the sudden release of pressure can cause it to whip violently. This whipping hose can strike workers or damage nearby equipment.

### 3. Loss of Pressure Control:

- **Leaks:** Poorly executed repairs can introduce leaks into the system. Leaks not only waste compressed air but can also lead to pressure fluctuations within the system. This can cause erratic operation of downstream equipment and potentially pose safety risks depending on the application.
- **System Failure:** Unauthorised repairs could compromise the integrity of the entire compressed air system. This can lead to unexpected system failures, potentially shutting down critical processes or leaving equipment inoperable during emergencies.

### 4. Fire Hazards:

- **Ignition of Flammable Materials:** Compressed air can create sparks if it comes into contact with certain materials. If the repair area contains flammable materials like oil or solvents, these sparks could ignite a fire.
- **Overheating of Equipment:** Loss of compressed air due to leaks can lead to equipment designed to utilize compressed air (e.g., pneumatic tools) to overheat. Overheating can increase the risk of electrical faults or fires.

## 5. Exposure to Compressed Air:

- **Direct Contact:** Direct contact with a high-pressure air stream can cause serious injuries like ruptured eardrums, tissue damage, or even air embolism (air bubbles entering the bloodstream). This can occur if a repair is not done properly and someone comes into contact with the released air.

**It's crucial to emphasize that only trained and authorized personnel should perform repairs on compressed air lines. They will have the proper knowledge, skills, and equipment to ensure safe and effective repairs.**

Nov 2021

Nov 2021

3. (a) Sketch a starting air reservoir, labelling ALL mountings. (8)
- (b) State TWO coatings that can be used to protect the interior surface of a large air reservoir against corrosion. (2)

Question 3. Well answered

## Starting Air Reservoir and Corrosion Protection

### (a) Starting Air Reservoir Mountings:

A starting air reservoir is a pressure vessel used to store compressed air for engine starting purposes. Here's a description of the typical mountings used for a starting air reservoir:

- **Saddle Supports:** These are the most common type of mounting. The reservoir rests on two or more cradles (saddles) welded or bolted to a solid foundation. The saddles distribute the weight of the reservoir evenly and provide stability.
- **Trunnion Mounts:** For larger or horizontal reservoirs, trunnion mounts might be used. Trunnions are cylindrical shafts welded to the ends of the reservoir that fit into bearing blocks on the support structure. This allows the reservoir to pivot slightly, accommodating thermal expansion and contraction.
- **Bracket Mounts:** In some cases, particularly for smaller reservoirs, brackets welded or bolted to the reservoir shell can be used to secure it directly to a wall or support structure.

### Additional Considerations:

- **Anchor Bolts:** Regardless of the mounting type, the reservoir will likely be secured to the foundation using anchor bolts to prevent excessive movement or tipping due to forces exerted during pressurization or engine starting.
- **Vibration Isolation:** In some applications, vibration isolation pads or mounts might be placed between the reservoir and its supports to dampen vibrations transmitted to the surrounding structure.

### (b) Coatings for Interior Corrosion Protection:

The interior surface of a large air reservoir is susceptible to corrosion due to moisture present in the compressed air. Here are two common coatings used for protection:

#### 1. Zinc Rich Epoxy:

- **Composition:** This coating consists of a zinc-rich primer with an epoxy resin topcoat. The zinc particles in the primer act as sacrificial anodes, corroding preferentially to protect the steel substrate. The epoxy topcoat provides additional protection against moisture and chemical attack.
- **Benefits:** Zinc rich epoxy offers good adhesion, flexibility, and cathodic protection. It's a widely used and cost-effective solution for protecting air receiver interiors.

#### 2. Polyurethane:

- **Properties:** Polyurethane coatings are known for their excellent chemical resistance, abrasion resistance, and flexibility. They form a tough, impermeable barrier against moisture and corrosive elements.
- **Applications:** Polyurethane coatings are a good choice for air receivers operating in harsh environments or where there might be exposure to contaminants in the compressed air.

### Additional Considerations:

- **Surface Preparation:** The success of any coating system relies heavily on proper surface preparation. The interior surface of the air receiver needs to be thoroughly cleaned and blasted to remove rust, mill scale, and other contaminants before coating application.
- **Coating Selection:** The choice of the most suitable coating depends on factors like operating pressure, temperature, budget, and potential exposure to contaminants within the compressed air system. Consulting with a qualified coatings specialist is recommended for selecting the optimal coating solution.

## Nov 2020

3. (a) Explain the circumstances under which EACH of the following devices fitted to an air compressor may operate;
- (i) fusible plug; (4)
  - (ii) bursting disc. (4)
- (b) State where EACH device in part (a) may be fitted. (2)

**Question 3.** Although the question asks about air compressors, many answer concerning fusible plugs on receivers. Few actually give the consequences of the devices not being present / not operating.

## Safety Devices in Air Compressors and Their Operation

### (a) Circumstances of Operation:

#### (i) Fusible Plug:

A fusible plug is a safety device that melts and releases compressed air when the temperature inside the air compressor exceeds a predetermined safe limit. This typically occurs under the following circumstances:

- **Internal Component Failure:** If a component within the compressor, such as bearings or pistons, seizes or malfunctions, it can generate excessive heat. This heat can melt the fusible plug, releasing pressure and preventing catastrophic failure of the compressor itself.
- **Loss of Cooling:** If the compressor's cooling system fails, such as due to a water pump malfunction or clogged radiator, the internal temperature can rise significantly. A melted fusible plug would then vent the pressure before overheating damages the compressor.
- **Accidental Overheating:** In rare cases, operator error or external factors might lead to overheating of the compressor. A fusible plug can act as a last line of defense by releasing pressure and potentially preventing an explosion.

#### (ii) Bursting Disc:

A bursting disc is a pressure relief device that ruptures and releases compressed air when the pressure inside the air compressor or its associated piping exceeds a predetermined safe limit. This typically occurs under the following circumstances:

- **Pressure Regulator Failure:** If the pressure regulator malfunctions and fails to maintain the desired pressure level, the pressure within the system can continue to rise. A bursting disc

would then rupture to prevent the system from exceeding its pressure rating and potentially rupturing pipes or equipment.

- **Blocked Discharge Line:** If the discharge line from the compressor becomes blocked due to debris or ice buildup, the pressure within the compressor can rise rapidly. A bursting disc would then rupture to relieve the pressure and prevent damage to the compressor itself.
- **Sudden System Surge:** In rare cases, a sudden surge in demand for compressed air can cause a temporary pressure spike within the system. A bursting disc can act as a safety measure by rupturing and releasing some of the pressure to prevent system overpressurization.

## (b) Location of Devices:

### (i) Fusible Plug:

The fusible plug is typically located on the discharge side of the compressor, near the cylinder head or intercooler outlet. This placement allows it to respond quickly to temperature changes within the compressor itself.

### (ii) Bursting Disc:

The bursting disc can be located in several places within the compressed air system, depending on the specific application and potential failure points. Here are some common locations:

- **Aftercooler Outlet:** Protects the aftercooler and downstream piping from excessive pressure due to a blocked discharge line or malfunctioning pressure regulator.
- **Compressor Discharge Line:** Provides a safety measure close to the pressure source in case of a sudden pressure surge or regulator failure.
- **Air Receiver:** May be used as an additional safety measure on the air receiver itself, protecting it from overpressurization.

**Note:** The specific placement of these devices may vary depending on the manufacturer's recommendations, local regulations, and the specific design of the compressed air system. Consulting the manufacturer's documentation and relevant safety codes is crucial for ensuring proper placement and operation of these safety devices.

## May 2021

3. With reference to a fully automatic, water cooled starting air compressor:
- (a) state the alarms that should be fitted; (4)
  - (b) explain how damage from overpressure is prevented in EACH of the following:
    - (i) intercoolers; (3)
    - (ii) water jackets. (3)

**Question 3.** Many candidates state such things as High Temperature, High Pressure. Without mentioning the medium being measured then these are meaningless.

## Alarms and Overpressure Protection in a Starting Air Compressor

### (a) Alarms for a Fully Automatic, Water-Cooled Starting Air Compressor:

A fully automatic, water-cooled starting air compressor should be equipped with several alarms to ensure safe operation and prevent potential damage. Here are some essential alarms:

- **High Discharge Pressure Alarm:** Alerts operators if the compressed air discharge pressure exceeds a predetermined safe limit. This can indicate a problem with the pressure regulator, blocked discharge line, or other issues.
- **Low Discharge Pressure Alarm:** Warns operators if the compressed air discharge pressure falls below the minimum required level. This can be due to insufficient compressor performance, leaks in the system, or other problems.
- **High Cooling Water Temperature Alarm:** Signals an issue if the water temperature in the cooling jackets or intercooler exceeds a safe limit. This can be caused by insufficient water flow, malfunctioning cooling system components, or excessive heat generation within the compressor.
- **Low Cooling Water Level Alarm:** Alerts operators if the water level in the cooling system reservoir falls below a safe minimum level. This can lead to overheating of the compressor and potential damage.
- **Low Starting Air Reservoir Pressure Alarm:** Warns operators if the pressure in the starting air reservoir falls below the minimum level required for engine starting. This can indicate leaks in the system or insufficient compressor operation.
- **Compressor Running Time Alarm:** May be used to alert operators when the compressor has been running continuously for an extended period. This can be helpful for preventative maintenance purposes.

### (b) Overpressure Protection:

#### (i) Intercoolers:

- **Pressure Relief Valve:** Intercoolers are typically equipped with a pressure relief valve set to a specific pressure limit. If the pressure within the intercooler exceeds this limit due to a blocked

discharge line or other issues, the relief valve opens and releases excess compressed air, preventing the intercooler from rupturing.

- **Bursting Disc (Optional):** In some cases, an additional bursting disc can be installed as a secondary safety measure. This disc will rupture at a higher pressure than the relief valve, providing a final line of defense in case the relief valve fails to function properly.

### (ii) Water Jackets:

- **Pressure Relief Valve (Less Common):** Water jackets are generally less susceptible to overpressure compared to intercoolers. However, in some high-pressure applications, a pressure relief valve might be used on the water jacket circuit. This valve would open and release excess pressure if the water system experiences a blockage or malfunction.
- **Temperature Monitoring and Alarms:** The primary protection for water jackets is continuous monitoring of the cooling water temperature. High-temperature alarms alert operators to potential overheating before pressure becomes a critical issue. By addressing the cause of the high temperature (e.g., low water flow, clogged passages), overpressure in the water jackets can be prevented.

### Additional Considerations:

- **Safety Valves Settings:** The pressure relief valves on the intercoolers and water jackets (if used) need to be set at appropriate pressure levels. These settings should be based on the manufacturer's recommendations and the pressure rating of the equipment they are protecting.
- **Regular Maintenance:** Regular inspection and maintenance of the pressure relief valves and bursting discs (if used) are crucial to ensure their proper operation in case of an overpressure event.

Nov 2018 2nd

Nov 2018 2nd

3. With reference to compressed air systems used for starting air and control purposes:
- (a) state the pressure used for starting air; (1)
  - (b) explain why the pressure stated in part (a) is necessary; (3)
  - (c) state the pressure used for control air; (1)
  - (d) explain why the pressure stated in part (c) is different to that stated in part (a); (3)
  - (e) explain why the pressure stated in part (c) is greater than that necessary to operate the control equipment. (2)

I can definitely help you with that! Here's the breakdown of compressed air systems for starting air and control purposes:

#### (a) Starting Air Pressure:

The typical pressure used for starting air in compressed air systems can range from **25 bar (363 psi) to 40 bar (580 psi)**. This can vary depending on the size and type of engine being started.

**(b) Reason for High Starting Air Pressure:**

High starting air pressure is necessary to overcome the following challenges encountered during engine startup:

- **Overcoming Engine Compression:** As the engine pistons rotate during startup, they compress the air trapped within the cylinders. The starting air pressure needs to be high enough to overcome this compression and force the pistons down to initiate the combustion cycle.
- **Friction Losses:** Friction exists between various moving parts within the engine during startup. High starting air pressure ensures sufficient force to overcome these frictional losses and crank the engine effectively.
- **Low Engine Speed:** Initially, the engine speed is low during startup. This reduces the air intake efficiency, requiring a higher starting air pressure to deliver the necessary air volume for combustion.

**(c) Control Air Pressure:**

The pressure used for control air in compressed air systems is typically much lower than starting air pressure, ranging from **5 bar (73 psi) to 10 bar (145 psi)**. The specific pressure depends on the control equipment being operated.

**(d) Reason for Different Pressures:**

The pressure requirements for starting air and control air are different due to their distinct functions:

- **Starting Air:** Needs high pressure to overcome the high resistance encountered during engine startup, as explained in part (b).
- **Control Air:** Operates various control equipment and actuators within the system. These components typically require lower pressure to function effectively and efficiently. Using excessively high pressure for control air can damage delicate components or lead to over-actuation.

**(e) Higher Control Air Pressure Than Minimum Requirement:**

The control air pressure is typically chosen to be higher than the minimum pressure required to operate the control equipment for a few reasons:

- **Safety Margin:** A higher pressure provides a buffer against pressure drops within the system due to factors like long pipelines, bends, or leaks. This ensures reliable operation of the control equipment even with some pressure loss.
- **Accounting for Future Expansion:** Maintaining a higher pressure allows for future expansion of the control system with additional equipment that might require slightly higher pressure for operation.
- **Standardization:** Standardized control air pressure levels are often used within facilities or industries to simplify system design and component selection.

Even though a higher pressure ensures reliable operation, it's important to avoid excessively high pressure that can waste energy and potentially damage control equipment. Choosing the optimal



control air pressure involves considering the specific needs of the equipment, potential pressure losses, and overall system efficiency.

May 2024

3. Explain why EACH of the following may have fusible plugs fitted:

(a) air compressor;

10

(5)

(b) air receiver.

6 (5)

Oct 2020

Oct 2020

3. Explain why EACH of the following may have fusible plugs fitted:

(a) air compressor;

(5)

(b) air receiver.

(5)

## Fusible Plugs in Air Compressors and Air Receivers

Fusible plugs are safety devices designed to melt and release compressed air when the temperature inside the equipment exceeds a predetermined safe limit. Here's why they might be fitted in:

### (a) Air Compressor:

- **Internal Component Failure:** If a component within the compressor, such as bearings or pistons, seizes or malfunctions, it can generate excessive heat. This heat can melt the fusible plug, releasing pressure and preventing catastrophic failure of the compressor itself. Examples include:
  - Seized piston rings causing excessive friction
  - Broken connecting rod leading to internal impact
- **Loss of Cooling:** If the compressor's cooling system fails due to a water pump malfunction, clogged radiator, or other issues, the internal temperature can rise significantly. A melted fusible plug would then vent the pressure before overheating damages the compressor.
- **Accidental Overheating:** In rare cases, operator error or external factors might lead to overheating of the compressor. A fusible plug can act as a last line of defense by releasing pressure and potentially preventing an explosion.

### (b) Air Receiver:

- **Overheating:** While less common than in the compressor itself, the air receiver could experience overheating if the compressed air entering it is excessively hot (lack of proper intercooling or aftercooling) or if there's a malfunction in the pressure relief valve. The fusible plug would then melt and release pressure to prevent the air receiver from rupturing.
- **Fire Exposure:** In the unfortunate event of a fire near the air receiver, the fusible plug could melt due to the external heat. This would release the compressed air and potentially prevent the receiver from exploding due to excessive internal pressure caused by the fire.

### Important Note:

While fusible plugs provide a safety measure, they are considered a last line of defense. It's crucial to maintain the compressor and air receiver properly, ensuring proper cooling and functioning pressure relief valves, to prevent situations that would trigger the fusible plug. Early detection and addressing the root cause of overheating is essential for safe operation.

Sept 18th 2020

Sept (18th) 2020

3. Sketch a system that is capable of supplying compressed air suitable for use in pneumatic control equipment.

(10)

## Compressed Air System for Pneumatic Control Equipment

Here's a breakdown of a system capable of supplying clean, dry, and consistent compressed air suitable for use in pneumatic control equipment:

### Components:

1. **Air Compressor:**
  - The heart of the system, it uses pistons or vanes to compress atmospheric air to a higher pressure.
2. **Air Intake Filter:**
  - Removes dust, dirt, and other contaminants from the incoming air before it enters the compressor to protect internal components and prevent wear.
3. **Air Intake Silencer (Optional):**
  - Reduces noise generated by the air intake process, improving the working environment.
4. **Intercooler (Optional):**
  - Cools down the compressed air after it leaves the first stage of compression in a two-stage compressor. This improves efficiency and reduces the risk of condensation in downstream piping.

**5. Aftercooler:**

- Cools down the compressed air significantly after final compression. This helps to remove moisture and reduce the risk of condensation forming within the system, which can damage control equipment.

**6. Separator:**

- Separates condensed water and oil droplets from the compressed air stream. This further ensures clean, dry air for control equipment.

**7. Air Receiver:**

- A storage tank that holds the compressed air and helps to maintain a constant pressure for the control instrumentation system. It also allows for fluctuations in air demand to be met without the compressor needing to constantly cycle on and off.

**8. Drain Valve (Automatic and Manual):**

- The automatic drain valve periodically removes accumulated condensate from the air receiver to prevent corrosion and ensure clean air. A manual drain valve allows for additional draining as needed.

**9. Pressure Regulator:**

- Regulates the air pressure down to a specific level required by the control equipment. This ensures the equipment operates efficiently and avoids damage from excessive pressure.

**10. Line Filter:**

- Provides additional filtration for the compressed air before it reaches the control equipment, removing any remaining contaminants that might have passed through the previous filtration stages.

**11. Lubricator (Optional):**

- Injects a small amount of oil mist into the compressed air stream for lubrication of certain pneumatic components (e.g., cylinders, valves) if required by the system design. Not all control equipment needs lubrication.

**12. Control Panel:**

- May house controls for the system, including switches for the compressor and solenoid valve, pressure regulator adjustments, and possibly alarm systems. The specific features will vary depending on the system complexity.

**13. Solenoid Valve(s):**

- These electrically operated on/off valves control the flow of compressed air to specific control equipment based on electrical signals from the control system. Multiple solenoid valves can be used to manage air flow to different actuators or processes.

**Additional Considerations:**

- **Piping:** The system will utilize appropriate piping to transport the compressed air. Material selection and proper installation are crucial to ensure pressure integrity and minimize pressure drops.
- **Dehydration Systems (Optional):** In some applications where extremely dry air is critical, additional dehydration systems like desiccant dryers might be used to further remove moisture from the compressed air.
- **System Monitoring:** Pressure gauges and other monitoring tools may be used to track system performance and identify potential issues like pressure drops or leaks.

By utilizing these components and proper maintenance practices, this system can ensure a reliable supply of clean, dry, and consistent compressed air for optimal operation of pneumatic control equipment.

April 2021

## April 2021

3. (a) Sketch a relief valve suitable for use on the air side of a compressor. (7)
- (b) Explain how the valve sketched in part (a) is reset after overhaul. (3)

### (a) Relief Valve for Air Compressor:

A relief valve suitable for use on the air side of a compressor is typically a **pilot-operated pressure relief valve**. Here's a breakdown of its key features:

- **Function:** This valve automatically opens and releases compressed air when the pressure within the system exceeds a predetermined safe limit. This protects the compressor and downstream equipment from overpressure damage.
- **Components:**
  - **Main Valve:** The main valve assembly directly regulates the flow of compressed air. It opens when the pressure overcomes a spring force or a combination of spring and pilot pressure.
  - **Pilot Valve:** A smaller valve that senses the system pressure and controls the main valve indirectly. It often uses a diaphragm or piston to sense pressure.
  - **Spring:** Provides a pre-set force that opposes the system pressure acting on the main valve.
  - **Adjustment Mechanism:** Allows for setting the desired pressure relief level by adjusting the spring preload or pilot pressure.
- **Operation:** As the system pressure rises, it acts on the pilot valve. When the pressure reaches the set point, the pilot valve opens, relieving pressure from the top of the main valve piston or diaphragm. The system pressure then overcomes the spring force, pushing the main valve open and releasing compressed air until the pressure falls below the set point. The pilot valve then closes, and the spring reseats the main valve, stopping the flow of air.

### (b) Resetting a Pilot-Operated Relief Valve After Overhaul:

After the valve is disassembled, cleaned, and inspected during an overhaul, resetting it for proper operation involves the following steps:

1. **Reassemble the Valve:** Carefully reassemble the valve components according to the manufacturer's instructions. Ensure proper alignment of parts and proper tightening of all connections.
2. **Adjust the Spring Preload (Optional):** Some relief valves have an external adjustment mechanism for setting the spring preload, which determines the opening pressure. If the spring

preload hasn't been changed during disassembly, it might not require adjustment. Consult the manufacturer's instructions for the specific valve model.

3. **Pilot Pressure Adjustment (Optional):** In some pilot-operated valves, the pilot pressure can be adjusted to influence the opening pressure. This adjustment might be done using an external screw or by adjusting the pilot valve spring tension. Again, consult the manufacturer's instructions for the specific model.
4. **Pressure Testing:** With the valve reinstalled in the system, conduct a pressure test using an external pressure source. Gradually increase the pressure and observe the relief valve operation. It should open at the desired set pressure and close once the pressure falls below the setpoint. This ensures the valve functions correctly after the overhaul.

**Important Note:** The specific steps for resetting a relief valve can vary depending on the manufacturer and model. Always refer to the manufacturer's instructions and service manuals for detailed procedures and safety precautions for your specific valve. It's crucial to ensure the valve is set to the correct pressure relief level for safe operation of the compressed air system.

FEb 19th 2021

Feb 19th 2021

3. With reference to air compressors, explain EACH of the following:

(a) why an air filter is important; (4)

(b) why the compressor should not be allowed to run with a dirty air filter. (6)

## Importance of Air Filters in Air Compressors

### (a) Why an Air Filters are Important:

Air filters play a critical role in protecting air compressors and ensuring their efficient operation. Here's a breakdown of their importance:

1. **Prevents Contamination:** Atmospheric air contains various contaminants like dust, dirt, moisture, and even airborne particles. An air filter captures these contaminants before they enter the compressor. This protects the internal components from:
  - **Abrasive Wear:** Dirt and dust particles can act like sandpaper, causing wear and tear on pistons, rings, bearings, and other moving parts within the compressor. This can lead to reduced efficiency, increased maintenance needs, and shortened lifespan of the compressor.
  - **Corrosion:** Moisture in the air can lead to rust formation on internal components. This can cause sticking valves, reduced performance, and potential internal damage.
2. **Maintains Performance:** By removing contaminants, air filters help the compressor operate efficiently. Clean air allows for smoother movement of internal parts, minimizing friction and wear. This translates to:
  - **Increased Efficiency:** A clean compressor requires less energy to compress air, reducing operating costs.

- **Consistent Performance:** A clean compressor can maintain consistent air pressure and flow, ensuring reliable performance for downstream equipment.
3. **Protects Downstream Equipment:** Contaminants that pass through a faulty filter can reach downstream equipment like pneumatic tools, actuators, and control systems. This can lead to:
- **Malfunctions:** Contaminants can jam or damage valves, solenoids, and other delicate components within the equipment.
  - **Reduced Lifespan:** Abrasive wear and corrosion caused by contaminants can shorten the lifespan of downstream equipment.

### (b) Why Not Run a Compressor with a Dirty Air Filter:

Running a compressor with a dirty air filter can have several negative consequences:

1. **Increased Wear and Tear:** As mentioned earlier, dirt and debris will accelerate wear on internal components. This can lead to premature failure and costly repairs.
2. **Reduced Efficiency:** A clogged filter restricts airflow, forcing the compressor to work harder to draw in sufficient air for compression. This translates to higher energy consumption and operating costs.
3. **Potential Overheating:** Restricted airflow can also lead to overheating within the compressor. This can damage internal components and reduce the lifespan of the compressor.
4. **Downstream Equipment Damage:** A dirty filter allows contaminants to reach downstream equipment, potentially causing malfunctions and reduced lifespan.
5. **Pressure Fluctuations:** A clogged filter can lead to pressure fluctuations within the system as the compressor struggles to maintain airflow. This can negatively impact the performance of downstream equipment.

**In conclusion, using a clean air filter is essential for protecting your air compressor, ensuring efficient operation, and safeguarding downstream equipment.** Regularly inspect and replace air filters according to the manufacturer's recommendations to maintain optimal performance and longevity of your compressed air system.

July 2021

July 2021

3. With reference to air receivers;
- (a) list FOUR fittings on an air receiver; (4)
  - (b) describe the operation of TWO safety devices. (6)

## Air Receiver Fittings and Safety Devices

### (a) Four Fittings on an Air Receiver:

1. **Inlet Connection:** This fitting allows compressed air from the compressor to enter the receiver for storage.
2. **Outlet Connection:** This fitting allows compressed air to flow out of the receiver to supply downstream equipment.

3. **Drain Valve:** This valve allows for manual or automatic draining of condensate (water) that accumulates at the bottom of the receiver due to moisture in the compressed air.
4. **Pressure Relief Valve:** A safety device that automatically releases compressed air if the pressure within the receiver exceeds a preset safe limit.

### (b) Description of Two Air Receiver Safety Devices:

1. **Pressure Relief Valve:**
  - **Function:** This valve acts as a last line of defense to prevent the air receiver from rupturing due to excessive pressure.
  - **Operation:** The relief valve remains closed under normal operating pressure. If the pressure within the receiver rises above the set point due to a malfunctioning pressure regulator, compressor over-pressurization, or other issues, the valve opens. This allows compressed air to escape from the receiver until the pressure falls below the set point. The valve then automatically closes and seals again.
2. **Safety Relief Valve (Optional):**
  - **Function:** In some cases, an additional safety relief valve might be used alongside the pressure relief valve. This valve typically has a higher pressure rating than the pressure relief valve and serves as a backup safety measure.
  - **Operation:** The safety relief valve functions similarly to the pressure relief valve. It remains closed under normal operation and opens automatically to release compressed air if the pressure exceeds its much higher set point. This additional layer of safety ensures the receiver doesn't rupture even in case of a malfunctioning pressure relief valve.

### Additional Note:

Some air receivers may have additional fittings depending on the specific application. These might include:

- **Level Gauge:** Provides a visual indication of the condensate level within the receiver.
- **Temperature Gauge:** Monitors the temperature of the compressed air within the receiver.
- **Pressure Gauge:** Indicates the air pressure within the receiver for monitoring purposes.

It's crucial to maintain these safety devices and fittings properly to ensure the safe and reliable operation of the compressed air system.

March 19th 2021

March 19th 2021

3. With reference to main air receivers:

- (a) list FOUR safety features, stating the purpose of EACH: (8)
- (b) state the pressure at which the relief valve should lift. (2)

## Main Air Receiver Safety Features



**(a) Four Safety Features and their Purposes:****1. Pressure Relief Valve:**

- **Purpose:** This is the primary safety feature and acts as a last line of defense. It automatically releases compressed air if the pressure within the receiver exceeds a predetermined safe limit (typically set pressure + 10%). This prevents the receiver from rupturing due to excessive pressure buildup.

**2. Safety Relief Valve (Optional):**

- **Purpose:** Provides an additional layer of safety. This valve, typically set at a higher pressure than the pressure relief valve, acts as a backup in case the primary valve malfunctions. It opens automatically to release compressed air if the pressure exceeds its set point, preventing catastrophic failure.

**3. Drain Valve:**

- **Purpose:** Allows for the removal of accumulated condensate (water) from the bottom of the air receiver. Moisture in the compressed air can cause corrosion and weaken the receiver walls over time. Regularly draining the condensate helps to prevent this and maintain the integrity of the receiver.

**4. Pressure Gauge:**

- **Purpose:** Provides a visual indication of the air pressure within the receiver. This allows operators to monitor the system pressure and ensure it stays within the safe operating range. It also helps identify potential pressure drops or malfunctions within the compressed air system.

**(b) Pressure Relief Valve Lifting Pressure:**

The pressure relief valve on a main air receiver should typically be set to lift at a pressure that is **10% higher than the maximum allowable working pressure** of the receiver. This provides a safety margin to prevent the receiver from rupturing in case of sudden pressure surges or malfunctions.

**Important Note:**

The specific pressure settings for safety devices should be based on the manufacturer's recommendations and relevant safety codes for your region. Never tamper with these settings or bypass safety devices. Regularly inspect and maintain these safety features to ensure they function properly and can protect your compressed air system.

March 26th 2021

March 26th 2021

3. With reference to compressed air systems, explain the purpose of EACH of the following:

- (a) fusible plug on compressor discharge; (4)
- (b) fusible plug on air receiver; (3)
- (c) bursting disc on water cooled air compressor. (3)

**Fusible Plugs and Bursting Discs in Compressed Air Systems**



Compressed air systems utilize safety devices to prevent catastrophic failures due to excessive pressure or temperature. Here's a breakdown of the purpose of each component you mentioned:

#### (a) Fusible Plug on Compressor Discharge:

- **Purpose:** This acts as a last line of defense against overheating within the compressor itself. The plug is made of a low-melting-point metal alloy. If the temperature within the compressor exceeds a predetermined safe limit due to:
  - **Internal component failure:** Seized bearings, broken pistons, etc., can generate excessive heat.
  - **Loss of cooling:** Malfunctioning cooling system (water pump, clogged radiator) causing internal overheating.
  - **Accidental overheating:** Operator error or external factors leading to excessive heat buildup.
- The fusible plug melts and releases compressed air, preventing pressure buildup and potential explosion of the compressor casing.

#### (b) Fusible Plug on Air Receiver:

- **Purpose:** While less common, a fusible plug in the air receiver can offer additional protection in specific scenarios:
  - **Overheating:** If excessively hot compressed air enters the receiver due to inadequate inter/aftercooling or a malfunctioning pressure relief valve, the receiver could overheat. The fusible plug might melt and release pressure to prevent rupture.
  - **Fire Exposure:** In the unfortunate event of a fire near the air receiver, the external heat could melt the fusible plug. This would release compressed air and potentially prevent the receiver from exploding due to excessive internal pressure.

**Important Note:** Fusible plugs are a last resort safety measure. It's crucial to maintain proper cooling and functioning pressure relief valves in the compressor and receiver to prevent situations that would trigger the fusible plug. Early detection and addressing the root cause of overheating is key.

#### (c) Bursting Disc on Water Cooled Air Compressor:

- **Purpose:** A bursting disc is a pressure relief device typically used in conjunction with a pressure relief valve, especially in water-cooled systems.
- **Location:** It can be located in various places within the system, depending on the specific design and potential failure points. Common locations include:
  - **Aftercooler Outlet:** Protects the aftercooler and downstream piping from excessive pressure due to a blocked discharge line or malfunctioning pressure regulator.
  - **Compressor Discharge Line:** Provides a safety measure close to the pressure source in case of a sudden pressure surge or regulator failure.
- **Function:** The bursting disc ruptures and releases compressed air if the pressure within the system exceeds a predetermined safe limit. This can occur due to:
  - **Malfunctioning pressure regulator:** The regulator fails to maintain the desired pressure, leading to pressure buildup.
  - **Blocked discharge line:** Debris or ice buildup restricts the flow of compressed air, causing pressure to rise rapidly.

- **Sudden system surge:** A temporary pressure spike within the system due to unexpected demand.
- **Difference from Relief Valve:** A Bursting Disc typically has a higher pressure rating compared to a pressure relief valve. The relief valve is the primary pressure relief device, while the bursting disc acts as a backup safety measure in case the relief valve fails to function properly.

May 28th 2021

May 28th 2021

3. With reference to compressed air systems used for starting air and control purposes:
- (a) state the pressure used for starting air; (1)
  - (b) explain why the pressure stated in part (a) is necessary; (3)
  - (c) state the pressure used for control air; (1)
  - (d) explain why the pressure stated in part (c) is different to that stated in part (a); (3)
  - (e) explain why the pressure stated in part (c) is greater than that necessary to operate the control equipment. (2)

## Compressed Air System Pressures: Starting vs. Control

Compressed air systems utilize different pressures for starting air and control purposes due to their distinct requirements. Here's a breakdown:

### (a) Starting Air Pressure:

The typical pressure used for starting air in compressed air systems can range from **25 bar (363 psi) to 40 bar (580 psi)**. This can vary depending on the size and type of engine being started.

### (b) Reason for High Starting Air Pressure:

High starting air pressure is necessary to overcome the following challenges encountered during engine startup:

- **Overcoming Engine Compression:** As the engine pistons rotate during startup, they compress the trapped air within the cylinders. The starting air pressure needs to be high enough to overcome this compression and force the pistons down to initiate the combustion cycle.
- **Friction Losses:** Friction exists between various moving parts within the engine during startup. High starting air pressure ensures sufficient force to overcome these frictional losses and crank the engine effectively.
- **Low Engine Speed:** Initially, the engine speed is low during startup. This reduces the air intake efficiency, requiring a higher starting air pressure to deliver the necessary air volume for combustion.

### (c) Control Air Pressure:

The pressure used for control air in compressed air systems is typically much lower than starting air pressure, ranging from **5 bar (73 psi) to 10 bar (145 psi)**. The specific pressure depends on the control equipment being operated.

#### (d) Reason for Different Pressures:

The pressure requirements for starting air and control air are different due to their distinct functions:

- **Starting Air:** Needs high pressure to overcome the high resistance encountered during engine startup, as explained in part (b).
- **Control Air:** Operates various control equipment and actuators within the system. These components typically require lower pressure to function effectively and efficiently. Using excessively high pressure for control air can damage delicate components or lead to over-actuation.

#### (e) Higher Control Air Pressure Than Minimum Requirement:

The control air pressure is typically chosen to be **higher than the minimum pressure required to operate the control equipment** for a few reasons:

- **Safety Margin:** A higher pressure provides a buffer against pressure drops within the system due to factors like long pipelines, bends, or leaks. This ensures reliable operation of the control equipment even with some pressure loss.
- **Accounting for Future Expansion:** Maintaining a higher pressure allows for future expansion of the control system with additional equipment that might require slightly higher pressure for operation.
- **Standardization:** Standardized control air pressure levels are often used within facilities or industries to simplify system design and component selection.

Even though a higher pressure ensures reliable operation, it's important to avoid excessively high pressure that can waste energy and potentially damage control equipment. Choosing the optimal control air pressure involves considering the specific needs of the equipment, potential pressure losses, and overall system efficiency.