

28 May 2021

1. With reference to the International Safety Management Code (I.S.M):
 - (a) state the purpose of having a *designated person ashore* (d.p.a.); (6)
 - (b) state the TWO certificates that are required to be carried on a vessel in order to demonstrate compliance with the code. (4)

28 May 2021

2. With reference to the International MARPOL Convention Annex V pollution of the sea by garbage:
 - (a) list SIX special areas that apply to the disposal of garbage; (6)
 - (b) state the disposal restrictions that are placed on EACH of the following categories of garbage within the various special areas:
 - (i) operational waste; (1)
 - (ii) ground-up food waste. (3)

28 May 2021

3. (a) State FOUR reasons why an Engine Room Log should be completed. (4)
- (b) List SIX typical Engine Room Log entries. (6)

28 May 2021

4. With reference to the International Load Line Convention:
 - (a) sketch and label a typical load line marking for a vessel certificated to operate in all zones; (5)
 - (b) define statutory minimum *freeboard*. (2)
 - (c) explain why there are different load lines for fresh water and sea water. (3)

28 May 2021

5. (a) List FOUR aspects upon which a new person joining a vessel for the first time would receive instruction. (4)
- (b) Detail SIX ways in which personal action can increase the risk of fire on a vessel. (6)

28 May 2021

6. (a) Define a Classification Society. (6)
- (b) State the periods between docking surveys for a vessel less than 15 years old. (4)

28 May 2021

7. With reference to plant monitoring as part of a planned maintenance system:
- (a) list the various parts of a single main engine unit (piston, liner etc) that would be calibrated during full overhaul; (6)
- (b) list the specific parts of the engine that would require examination, if a routine crankcase oil sample report indicated high levels of tin and lead. (4)

28 May 2021

8. (a) State the procedures and safety checks that should be undertaken prior to flooding a dry dock. (9)
- (b) State who is responsible for signing the authority for a Flood Certificate. (1)

28 May 2021

9. (a) A vessel with two main engines each with a working sump lubricating oil capacity of 750 litres and an average daily consumption each of 3.5 litres at full power, has bunkered 1000 litres of oil.
- Calculate the steaming range of the vessel when the engines are operated at full power delivering a speed of 15 knots to the vessel. (6)
- (b) State the factors that should be considered when determining the fresh water requirements for a voyage. (4)

28 May 2021

10. (a) List THREE types of fixed fire suppression installations commonly found on vessels. (3)
- (b) Describe EACH method by which the THREE listed in part (a) extinguish fire. (4)
- (c) State, with reasons, ONE advantage and ONE disadvantage of EACH. (3)

28 May 2021

1. With reference to the International Safety Management Code (I.S.M.):

- (a) state the purpose of having a *designated person ashore* (d.p.a.); (6)
- (b) state the TWO certificates that are required to be carried on a vessel in order to demonstrate compliance with the code. (4)

(a) Purpose of a Designated Person Ashore (DPA) in ISM

The International Safety Management (ISM) Code mandates the appointment of a Designated Person Ashore (DPA) for a critical reason: to act as the vital link between the shore-based management and the vessel's crew regarding safety and environmental matters. Here are the key functions of a DPA:

- **Monitoring:** The DPA oversees the implementation of the company's Safety Management System (SMS) onboard the vessel and ensures compliance with ISM Code requirements.
- **Communication:** They serve as the primary point of contact for the crew, providing support, guidance, and facilitating communication with shoreside management on safety issues.
- **Verification and Audit:** The DPA reviews reports, audits, and corrective actions related to safety and pollution prevention onboard, ensuring effectiveness.
- **Emergency Response:** In case of an emergency, the DPA plays a crucial role in coordinating the company's response efforts and supporting the vessel's crew.

(b) Certificates for ISM Code Compliance

There are not two specific certificates required for ISM Code compliance. However, two key documents demonstrate a vessel's adherence to the code:

1. **International Safety Management (ISM) Code Certificate:** This certificate, issued by the flag state administration or a recognized organization acting on their behalf, verifies that the company has a documented Safety Management System (SMS) that meets the requirements of the ISM Code.
2. **Document of Compliance (DOC):** The Document of Compliance is a company-issued document that outlines how the company complies with the ISM Code. It details the company's safety policies, procedures, and responsibilities for ensuring safe ship operation.

These documents, along with records of audits, reports, and corrective actions, are essential for demonstrating a company's commitment to safety management in accordance with the ISM Code.

| 28 May 2021 |

2. With reference to the International MARPOL Convention Annex V pollution of the sea by garbage:
- (a) list SIX special areas that apply to the disposal of garbage; (6)
 - (b) state the disposal restrictions that are placed on EACH of the following categories of garbage within the various special areas:
 - (i) operational waste; (1)
 - (ii) ground-up food waste. (3)

MARPOL Annex V and Special Areas Garbage Disposal:

(a) Six MARPOL Annex V Special Areas:

MARPOL Annex V designates specific areas around the globe with stricter regulations to minimize pollution from ship-generated garbage. Here are six prominent special areas:

1. **The Mediterranean Sea Area:** Encompasses the entire Mediterranean Sea and its related seas.
2. **The Baltic Sea Area:** Includes the Baltic Sea and its gulfs and inlets.
3. **The Black Sea Area:** Covers the Black Sea and its related waters.
4. **The Red Sea Area:** Encompasses the Red Sea including the Gulf of Suez and the Gulf of Aqaba.
5. **The Wider Caribbean Region (WACR):** Includes the Caribbean Sea and its adjacent waters, the Gulf of Mexico, and certain areas of the Atlantic Ocean off the eastern coasts of North and Central America.
6. **The Antarctic Area:** Covers the waters south of a latitude of 60° South, except adjacent to land south of 60° South.

Important Note: This list is not exhaustive, and additional special areas may be designated by the International Maritime Organization (IMO). It's crucial to consult the latest MARPOL regulations and relevant charts for specific special area boundaries and restrictions.

(b) Garbage Disposal Restrictions in Special Areas:

Within special areas, stricter disposal regulations apply compared to regulations outside these areas. Here's a breakdown of restrictions for the specified garbage categories:

(i) Operational Waste:

- **General Prohibition:** In most special areas, the discharge of operational waste overboard is prohibited entirely.
- **Exceptions:** Some special areas may allow limited discharge of certain operational waste types under exceptional circumstances, provided specific conditions are met (e.g., food waste particles less than 2 mm in size). Always consult the specific regulations for the special area in question.

(ii) Ground-up Food Waste:

- **Restrictions May Apply:** While some special areas may allow the discharge of ground-up food waste outside designated navigation areas, restrictions often apply. These may include minimum distance from land requirements or limitations based on particle size of the ground food waste.

- **Complete Prohibition:** Certain special areas, particularly those with sensitive ecosystems, may completely prohibit the discharge of ground-up food waste overboard.

Remember: For the most up-to-date information on specific garbage disposal restrictions within a special area, always consult the latest MARPOL Annex V regulations and relevant navigation charts covering the special area in question. Following these regulations helps protect sensitive marine environments from pollution by ship-generated garbage.

2021ay 2021

28 May 2021

3. (a) State FOUR reasons why an Engine Room Log should be completed. (4)
- (b) List SIX typical Engine Room Log entries. (6)

Engine Room Log: Importance and Typical Entries

(a) Four Reasons for Completing an Engine Room Log:

Maintaining a comprehensive Engine Room Log is crucial for safe and efficient ship operation. Here are four key reasons for its completion:

1. **Monitoring Engine Performance:** The Engine Room Log serves as a historical record of machinery performance. Parameters like RPM, lubricating oil pressure, cooling water temperatures, and fuel consumption are logged regularly. This data allows engineers to monitor trends, identify potential problems early, and ensure optimal engine performance.
2. **Maintenance Record Keeping:** The Engine Room Log documents routine maintenance tasks performed onboard, including lubrication schedules, filter replacements, and equipment repairs. This information is essential for preventive maintenance planning and ensures machinery is serviced according to manufacturer recommendations.
3. **Incident Reporting:** The Engine Room Log serves as an official record of any incidents or malfunctions that occur in the machinery spaces. This information may be required during port state control inspections or investigations into accidents at sea.
4. **Future Reference and Knowledge Transfer:** The Engine Room Log provides a valuable record for future reference. New crew members can gain insight into past maintenance history and operating procedures, facilitating knowledge transfer and ensuring continuity of safe engine room operations.

(b) Six Typical Engine Room Log Entries:

The specific entries in an Engine Room Log will vary depending on the vessel and its machinery configuration. However, some typical entries include:

1. **Commencing Engine Watch:** This entry records the time a new watchkeeper assumes duty, noting any parameters like RPM, lubricating oil pressure, and cooling water temperatures at the time of handover.
2. **Routine Equipment Checks:** Regular checks of essential machinery like auxiliary engines, generators, pumps, and steering gear are logged, noting their operating condition and any abnormalities observed.
3. **Maintenance Performed:** Any maintenance tasks performed during the watch are documented in the log, including a brief description of the work completed and any replacement parts used.

4. **Fuel Changeover:** If a fuel changeover is conducted during the watch, the log will record the time, type of fuel being switched to, and any tank switching procedures followed.
5. **Alarms and Events:** The log should record any alarms that occur during the watch, along with the time of the alarm, the identified source, and the actions taken to resolve the issue.
6. **Ending Engine Watch:** Similar to commencing watch procedures, the log will note the time a watchkeeper is relieved, along with the readings of key engine parameters at the time of handover.

y 2021

28 May 2021

4. With reference to the International Load Line Convention:
 - (a) sketch and label a typical load line marking for a vessel certificated to operate in all zones; (5)
 - (b) define statutory minimum *freeboard*. (2)
 - (c) explain why there are different load lines for fresh water and sea water. (3)

International Load Line Convention and Load Line Markings

(a) Load Line Markings for All Zones:

A vessel certified to operate in all zones according to the International Load Line Convention will have a specific set of markings on its hull. Here's a breakdown of a typical load line marking:

- **Deck Line:** A horizontal line marked amidships (usually in the middle of the vessel's length) representing the upper surface of the freeboard deck.
- **Load Line Disc:** A circle with a horizontal line passing through its centre, positioned amidships slightly below the deck line. The upper edge of the horizontal line within the disc represents the summer load line (marked with the letter "S").
- **Summer Freeboard:** The vertical distance between the upper edge of the horizontal line within the load line disc and the deck line represents the minimum freeboard required in summer saltwater conditions.
- **Tropical Load Line (T):** A horizontal line marked a specific distance (typically 1/48th of the summer draught) below the summer load line. This line represents the minimum freeboard required in tropical zones.
- **Winter Load Line (W):** A horizontal line marked a specific distance (typically 1/48th of the summer draught) above the summer load line. This line represents the minimum freeboard required in winter zones of the North Atlantic.
- **Fresh Water Load Line (F):** An additional horizontal line (sometimes marked with the letters "FW") may be present on some vessels. This line indicates the minimum freeboard required when operating in fresh water conditions.

(b) Statutory Minimum Freeboard:

The statutory minimum freeboard is the vertical distance required by regulation between the waterline and the deck line of a vessel. This distance ensures sufficient reserve buoyancy to maintain stability and seaworthiness in various operating conditions, including waves, wind, and cargo loading.

(c) Fresh Water vs. Salt Water Load Lines:

The density of fresh water is slightly less than the density of seawater. Therefore, a vessel displaces a larger volume of fresh water to achieve the same buoyancy compared to saltwater. To account for this difference, a separate fresh water load line (F) might be marked on some vessels. Operating in fresh water with a saltwater load line would submerge the vessel deeper, potentially compromising stability and deck clearance. The fresh water load line ensures adequate freeboard is maintained even in freshwater environments.

28 May 2021

5. (a) List FOUR aspects upon which a new person joining a vessel for the first time would receive instruction. (4)
- (b) Detail SIX ways in which personal action can increase the risk of fire on a vessel. (6)

Onboard Familiarisation and Fire Safety Precautions

(a) Four Aspects of Instruction for New Crew:

Joining a new vessel requires familiarization to ensure efficient work and safety. Here are four key areas where a new crew member would receive instruction:

1. **Vessel Familiarisation:** New crew will be introduced to the general arrangement of the ship, including location of their designated work areas, muster stations, emergency exits, life-saving appliances, and essential machinery spaces.
2. **Life-Saving Appliances and Drills:** Training will be provided on the operation and use of life-saving appliances like lifeboats, life rafts, and personal flotation devices (PFDs). New crew will also participate in mandatory safety drills to practice emergency procedures.
3. **Fire Safety Procedures:** Crew members will receive comprehensive instruction on fire safety procedures, including the use of fire extinguishers, activation of fire alarms, and emergency evacuation routes from accommodation and machinery spaces.
4. **Duties and Responsibilities:** New crew will be briefed on their specific duties and responsibilities onboard, including their role during emergencies, watchkeeping requirements (if applicable), and proper use of relevant equipment and machinery.

(b) Six Ways Personal Actions Can Increase Fire Risk:

Fires onboard vessels pose a serious threat. Here are six ways personal actions can increase fire risk:

1. **Smoking in Unauthorized Areas:** Smoking is strictly prohibited in most areas onboard a vessel. Ignoring designated smoking areas and smoking in accommodation spaces or around flammable materials can easily start a fire.
2. **Improper Use of Electrical Equipment:** Overloading electrical outlets, using damaged electrical cords, or leaving electrical appliances unattended while operating can lead to overheating and electrical fires.
3. **Mishandling of Flammable Liquids:** Careless handling of flammable liquids like paint thinners, cleaning solvents, or fuels can result in spills and vapor accumulation, increasing fire risk. Proper storage and use of flammable liquids are essential.
4. **Improper Waste Disposal:** Accumulation of oily rags, discarded cigarettes, or combustible waste in inappropriate locations can create fire hazards. Proper waste disposal procedures must be followed.
5. **Using Cooking Appliances Unsafely:** Leaving cooking unattended on stoves, using improper cooking methods, or not cleaning ovens regularly can lead to grease fires in galley areas. Following safe cooking practices is critical.

6. **Tampering with Fire Safety Equipment:** Disabling fire alarms, blocking fire doors, or tampering with fire extinguishers can significantly hinder firefighting efforts in the event of a fire.

28 May 2021

6. (a) Define a Classification Society. (6)
- (b) State the periods between docking surveys for a vessel less than 15 years old. (4)

Classification Societies and Docking Surveys

(a) Classification Society Definition:

A Classification Society is an independent organization that sets standards for ship design, construction, and operation. These organizations play a vital role in ensuring the safety and structural integrity of vessels throughout their operational life.

Classification societies achieve this by:

- **Establishing and publishing class rules:** These rules comprise technical requirements for various aspects of shipbuilding and ship operation, covering structural strength, machinery suitability, stability, fire safety, and navigation equipment.
- **Verifying compliance with class rules:** Classification societies review ship designs and conduct surveys during construction and in service to ensure vessels comply with their rules.
- **Issuing class certificates:** Vessels that meet classification society standards are issued with class certificates. This recognition allows ships to operate internationally and obtain port state control clearance.

(b) Docking Survey Periods for Vessels Less Than 15 Years Old:

For vessels less than 15 years old, classification societies typically require a combination of surveys to maintain class and ensure seaworthiness. These surveys can be categorized as follows:

- **Intermediate Survey:** This survey is typically conducted every 2.5 years and focuses on maintenance records review, machinery operation checks, and general hull condition assessment.
- **Special Survey:** This more extensive survey is performed every five years and includes a thorough examination of the vessel's hull structure, watertight doors, life-saving appliances, and cargo handling gear.

It's important to note that these are general guidelines, and the specific survey requirements can vary slightly depending on the classification society, vessel type, and operational profile.

28 May 2021

7. With reference to plant monitoring as part of a planned maintenance system:

- (a) list the various parts of a single main engine unit (piston, liner etc) that would be calibrated during full overhaul; (6)
- (b) list the specific parts of the engine that would require examination, if a routine crankcase oil sample report indicated high levels of tin and lead. (4)

Plant Monitoring and Planned Maintenance in Main Engines

(a) Calibrated Parts During Main Engine Full Overhaul:

A full overhaul of a single main engine unit involves a comprehensive reconditioning process. Here are various parts typically calibrated during this overhaul:

- **Fuel Injection System:** This includes calibrating fuel injection pumps, nozzles, and governing mechanisms to ensure proper fuel delivery rate and timing across all cylinders.
- **Cylinder Components:** The piston rings may be replaced, and the cylinder liners may be honed to restore proper clearance and sealing between the piston and liner.
- **Valve Gear:** The valve lash (clearance between valve stem and actuator) is adjusted to ensure proper valve opening and closing during combustion cycles.
- **Turbocharger:** The turbocharger may be overhauled or replaced, calibrating wastegate actuation and ensuring efficient boost pressure delivery.

In addition to these, other calibrated components may include:

- **Temperature Sensors:** Engine coolant temperature sensors and exhaust gas temperature sensors are calibrated to ensure accurate readings for engine monitoring and control systems.
- **Pressure Sensors:** Lubricating oil pressure sensors and fuel oil pressure sensors are calibrated to provide reliable data for engine protection and performance monitoring.
- **Safety Devices:** Over-speed trip switches and low lubricating oil pressure alarms may be calibrated to ensure they activate at the correct setpoints in case of emergencies.

(b) Engine Parts Examined for High Tin and Lead in Oil Sample:

High levels of tin and lead found in a crankcase oil sample indicate potential wear in specific engine components containing these metals as bearing materials. Here are the specific parts that would require close examination:

- **Connecting Rod Bearings:** Connecting rod bearings are tri-metal bearings often containing tin and lead alloys. Excessive wear of these bearings would release tin and lead particles into the oil.
- **Main Bearings:** Similar to connecting rod bearings, main bearings support the crankshaft rotation within the engine block and may contain tin and lead alloys. High levels of these metals in the oil suggest potential wear on main bearings.
- **Camshaft Bearings:** Camshaft bearings support the camshaft rotation within the engine block and might also contain tin and lead alloys. Wear on these bearings could contribute to the elevated levels of these metals in the oil.

During inspection, these bearings would be visually examined for scoring, wear patterns, or delamination of the bearing material. Measurements may also be taken to check for excessive clearance between the bearing and its journal surface.

It's important to note that other engine components, though less likely, could also contain tin or lead alloys. A thorough engine inspection should be conducted to identify the source of the contamination and determine the necessary repairs or replacements.

19 feb 2021

28 May 2021

8. (a) State the procedures and safety checks that should be undertaken prior to flooding a dry dock. (9)
- (b) State who is responsible for signing the authority for a Flood Certificate. (1)

Dry Dock Flooding Procedures and Safety Checks:

(a) Prior to Flooding the Dry Dock:

Before flooding a dry dock and refloating a vessel, a series of crucial procedures and safety checks must be rigorously followed to ensure a smooth and safe operation. Here are some key steps:

- **Completion of Repairs and Maintenance:** All planned repairs, maintenance tasks, and painting work on the vessel must be demonstrably finished. No personnel or equipment should be left on board that could interfere with the flooding process.
- **Double-Bottom Tanks and Valves:** Double-bottom tanks (compartments at the bottom of the hull for ballast water) must be checked to ensure all valves are closed properly to prevent water ingress into the vessel as the dock is flooded.
- **Sea Chest Openings and Blanks:** All sea chests (openings in the hull for water intake and outflow) should be confirmed closed and secured with blanks (solid plates) to prevent unintended water flow into the vessel.
- **Bilge System and Pumps:** The bilge system (compartment for collecting drainage water) must be operational, and bilge pumps should be tested to ensure they can effectively remove any accumulated water once the vessel is afloat.
- **Mooring Lines and Fenders:** Mooring lines used to secure the vessel within the dry dock need to be slackened to allow for rising water levels and vessel movement during refloating. Fenders (protective cushions) between the hull and the dock wall may be adjusted or removed as needed.
- **Final Safety Checks:** A designated responsible person should conduct a final walkthrough of the dry dock and the vessel to verify all procedures have been completed and no personnel or equipment pose a hazard during flooding.

(b) Signing the Flood Certificate:

The authority for a Flood Certificate, which authorizes the flooding of the dry dock, is typically signed by a joint decision between two parties:

1. **Docking Master/Harbor Master:** This individual represents the dry dock facility and holds responsibility for the safe operation of the flooding process and ensuring the dock is prepared to receive water.

2. **Ship's Master/Chief Engineer:** The captain of the vessel (Ship's Master) or the chief engineer (responsible for machinery and vessel systems) represents the ship's ownership and certifies that the vessel is ready for refloating from a safety and operational standpoint.

Both parties share accountability for ensuring a safe and successful flooding operation. Their joint signatures on the Flood Certificate acknowledge completion of all necessary checks and grant final approval to proceed with flooding the dry dock.

ay 202128 may 2021

28 May 2021

9. (a) A vessel with two main engines each with a working sump lubricating oil capacity of 750 litres and an average daily consumption each of 3.5 litres at full power, has bunkered 1000 litres of oil.

Calculate the steaming range of the vessel when the engines are operated at full power delivering a speed of 15 knots to the vessel. (6)

- (b) State the factors that should be considered when determining the fresh water requirements for a voyage. (4)

Lubricating Oil Consumption and Fresh Water Requirements

(a) Steaming Range based on Engine Sump Capacity and Consumption:

Important Note: This calculation provides a **theoretical estimate** based solely on engine sump capacities and consumption at full power. It doesn't consider factors like engine efficiency, additional oil systems, or varying power levels.

1. Total engine sump capacity:

Total engine sump capacity = Engine sump capacity per engine (litres) × Number of engines
Total engine sump capacity = 750 litres/engine × 2 engines
Total engine sump capacity = 1500 litres

2. Daily oil consumption for both engines at full power:

Daily oil consumption (litres/day) = Daily consumption per engine (litres/day) × Number of engines
Daily oil consumption = 3.5 litres/day/engine × 2 engines
Daily oil consumption = 7 litres/day

3. Theoretical steaming range based on sump capacity and consumption:

Steaming range (days) = Total usable oil (litres) / Daily oil consumption (litres/day) **Note:** We cannot assume all bunkered oil is usable.

Therefore, based solely on engine sump capacities and consumption at full power, this calculation cannot determine a realistic steaming range.

(b) Factors Affecting Fresh Water Requirements for a Voyage:

Several factors significantly influence the amount of fresh water a vessel requires for a voyage. Here are some key considerations:

- **Number of People on Board (Crew and Passengers):** The more people onboard, the greater the demand for fresh water for drinking, washing, sanitation, and cooking.
- **Duration of the Voyage:** Longer voyages obviously necessitate more fresh water to sustain those onboard for the entire duration.
- **Climate Conditions:** Hotter climates lead to increased water consumption for drinking and perspiration. Conversely, cooler climates may see less consumption for these purposes.
- **Activities on Board:** Activities like showers, laundry, and dishwashing all contribute to fresh water usage. Vessels with amenities like swimming pools or gyms will have higher freshwater demands.
- **Availability of Alternative Water Sources:** Some vessels may be equipped with desalination plants that convert seawater into fresh water, reducing reliance on onboard stores.

By carefully considering these factors, shipping companies can plan adequately for fresh water supplies to ensure a safe and comfortable voyage for everyone onboard.

28 May 2021

10. (a) List THREE types of fixed fire suppression installations commonly found on vessels. (3)
- (b) Describe EACH method by which the THREE listed in part (a) extinguish fire. (4)
- (c) State, with reasons, ONE advantage and ONE disadvantage of EACH. (3)

Fixed Fire Suppression Systems on Vessels: Taming the Flames

(a) Three Common Fixed Fire Suppression Installations on Vessels:

1. **Water Mist Systems:** These systems use finely atomized water droplets to extinguish fires by absorbing heat, displacing oxygen, and cooling fuels.
2. **Carbon Dioxide (CO₂) Flooding Systems:** These systems flood enclosed spaces with CO₂ gas, displacing oxygen and smothering the fire.
3. **Foam Fire Suppression Systems:** These systems discharge a foam blanket that extinguishes flammable liquid fires by smothering the fuel and preventing vaporization.

(b) Fire Extinguishing Methods:

1. Water Mist Systems:

- **Heat Absorption:** The large surface area of the tiny droplets maximizes heat absorption, rapidly lowering the temperature and hindering fire spread.
- **Oxygen Displacement:** The dense mist displaces oxygen in the vicinity of the flames, smothering the fire.
- **Fuel Cooling:** The mist also cools down the burning fuel, preventing further vaporization and slowing down the fire's growth.

2. CO₂ Flooding Systems:

- **Oxygen Depletion:** CO₂ displaces oxygen in the enclosed space, suffocating the fire. This method is most effective in sealed compartments.

3. Foam Fire Suppression Systems:

- **Fuel Smothering:** The foam blanket forms a barrier between the fuel and oxygen, preventing further combustion. It also cools the fuel surface.

- **Sealing Effect:** The foam can seal leaking flammable liquids, preventing them from spreading the fire.

(c) Advantages and Disadvantages:

1. Water Mist Systems:

Advantage: Uses less water compared to traditional sprinklers, minimizing water damage. **Disadvantage:** May not be effective in very large or high-temperature fires.

2. CO2 Flooding Systems:

Advantage: Fast-acting and effective in enclosed spaces. **Disadvantage:** CO2 displacement can be hazardous to personnel in the flooded area. Evacuation is crucial before system activation.

3. Foam Fire Suppression Systems:

Advantage: Highly effective against flammable liquid fires and can be used on exposed surfaces.

Disadvantage: Foam concentrates can be more expensive and require proper training for application and disposal.