BUREAU OF INDIAN STANDARDS

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Learning Science via Standards

Water Storage Tank

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Lesson 38

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STANDARDS CLUB

BUREAU OF INDIAN STANDARDS

Nurturing Young Minds as Ambassadors of Quality and Standards

Foreword

Everything around us, whether natural phenomena or manmade products can be explained through science. The product which are used in our daily life are outcome of conscious efforts by the mankind to fulfil and exceed the needs of the present and demands of the future. Students are taught science as part of their school curriculum, to enable them to understand the various scientific laws and principles and also to inculcate the habit of exploring the world through the lens of science. Quality characteristics of any product or service are decided based on the stated and implied needs and are generally described in a document called 'Standard'. Science and standards are inseparable and integral aspect of any product.

Bureau of Indian Standards (BIS), the national standards body of India, is mandated for establishment and promotion of standards and creating a quality ecosystem in the country. This is achieved through developing Indian Standards on products and services through the active involvement of relevant stakeholders and dissemination of information of such standards for their use and implementation across all sectors of economy. Academia, as an important stakeholder of BIS, has been contributing towards development of standards through research activities and providing inputs related to technological advancements in product development, their characteristics and use as well as methods of tests. BIS, on its part has also been promoting standards in academia through a variety of programmes. This has since been institutionalized in the form of "Standards Clubs" which are being established in educational institutions across India to nurture the young minds as ambassadors of quality and standards and prepare them for dealing with these aspects in future.

In this initiative of BIS, called "Learning Science via Standards", a series of Lesson Plans are made elaborating the various scientific concepts, laws and principles to help students understand their practical applications via standards. The series comprises of a variety of subjects for insights into the scientific laws and principles and relating them to the quality characteristics of products used in day-to-day life. First 10 Lesson Plans in the series are released on the occasion of World Consumer Rights Day on 15 Mar 2023. Second Set of 10 Lesson Plans were released on 10 Jun 2023 by Hon'ble Minister of State during the Governing Council Meeting of BIS.

The Lesson Plans are expected to serve as a useful tool for the teaching fraternity for imparting knowledge on scientific laws and principles through their practical applications in activities and products around us and facilitate an interactive learning experience for the students.

Water Storage Tank

A water tank in simple terms is a container for storing water. They are used to provide storage of water for use in many applications, drinking water, irrigation agriculture, fire suppression, agricultural farming, both for plants and livestock, chemical manufacturing, food preparation etc.. Water tank quality parameters include the general design of the tank, and choice of construction materials, linings. Throughout the history various materials have been used for making water storage tanks like wood, ceramic and stone. The Indus Valley civilization made use structures for storage of food grains and water tanks.

The recent technological developments have introduced plastics and resulted in adoption of new materials for these tanks such as Polyethylene, Polypropylene, fiberglass. Nowadays, plastic water tanks are used everywhere in homes and office building. Roto-moulded plastic water storage tanks being lighter in weight are easy in handling and can be easily fitted at any desired place. Hence, these storage tanks are preferred and are practically replacing the conventional tanks of steel, cement concrete or stone. These tanks are available in market in various sizes and shapes raging from 200 Ltrs to 20,000 Ltrs.

1. Manufacturing of Tanks by Rotational Moulding

Also called as roto-moulding, this method involves polyethylene resin placed inside a mould and rotated. The whole rotating assembly is placed inside an oven or a furnace at around 250℃. The resin melts and spreads across the mould uniformly due to the rotation and creates a hollowed structure with all the walls evenly thick taking the shape of the mould in the process. After a specific period, the mould is cooled and the molten plastic hardens in its new form, it is then taken out of the mould.

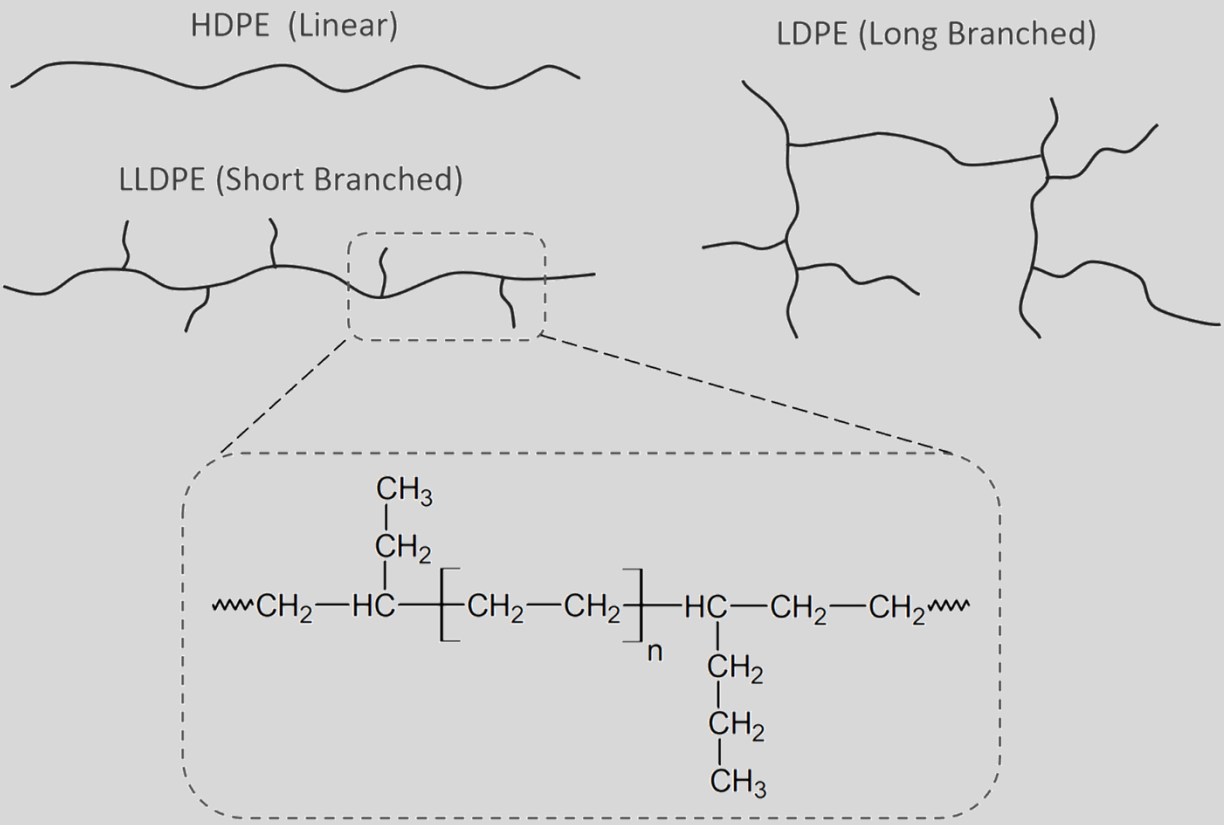
This method is very material efficient and very little goes to waste making it more economical and environmentally friendly. The most common use for this method is for big and hollow parts. These parts include car parts, bins, kayaks, road cones, pet houses and storage tanks.

The moulds that are used in rotational moulding are highly intricate to make products customizable and changeable. This can include things like special inserts and curves as well as logos and slots. These can be placed into the mould to change the final product shape. Moulds are generally made of stainless steel for durability and resistance to temperature.

2. Material of Water Storage Tanks

High Density Polyethylene is the most common material used in the manufacturing of Water Storage Tanks.

High-density polyethylene (HDPE) and low-density polyethylene (LDPE) are two common polyethylenes with differing structures but similar properties. HDPE has a linear structure and is opaque, while LDPE is a transparent branched version of PE. Both materials have excellent strength and chemical resistance alongside malleability and manufacturability.



While both HDPE and LDPE are polymers of Ethylene, the linear chains and branched chains are the reason for slight variation in properties of these two materials.

While LDPE and HDPE can both be processed using injection moulding and additive manufacturing, LDPE is best suited for injection moulding whereas HDPE can help achieve high dimensional accuracy. The products manufactured from LDPE include, drip irrigation pipes, plastic transparent bags, wash bottles used in chemical labs, etc.

3. Properties of HDPE

a) HPDE has a density of around 0.95 g/cc. Since this is less than the density of water, a solid HDPE block floats in water. It has a melting temperature of around 130°C.

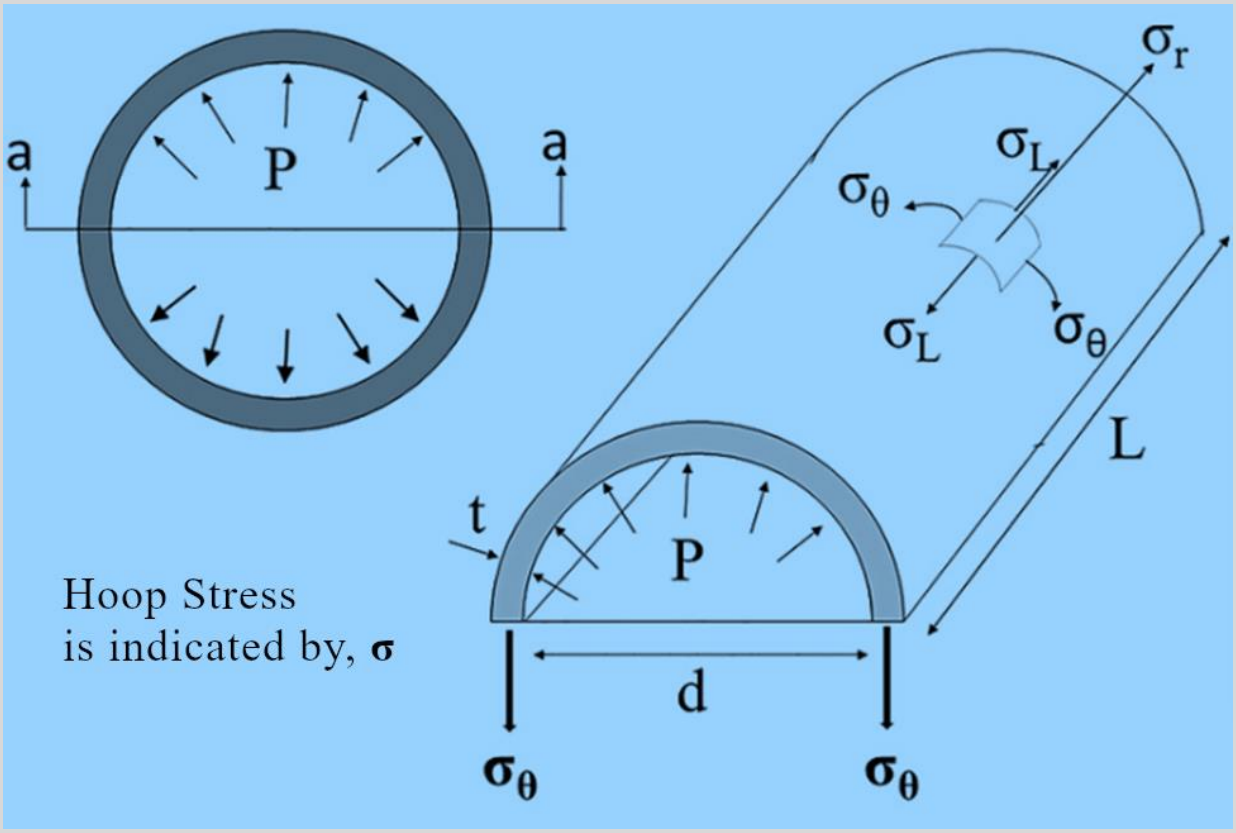
b) Tensile strength of 38 MPa

c) Shore Hardness D 65-75

d) Chemical resistance: Excellent resistance to most solvents, alcohols, dilute acids and alkalis. Moderate resistance to oils and greases.

4. Science in Water Storage Tank

a) Shape – Tanks are cylindrical in shape to ensure the hoop stress on the wall of the cylinder are uniform across the cross section. A non-cylindrical shape with pressure inside the cylinder is prone to bending. The bottom surface of the cylinder is flat and is supported by the floor on which the tank rests. If the tank is not supported by a flat floor, the bottom surface would bulge.



b) Ribs and Moment of Inertia: Ribs are provided on the tank surface to provide additional strength. Ribs increase the durability and quality while reducing material consumption.

The Moment of Inertia (I) is a term used to describe the capacity of a cross-section to resist bending. When ribs are provided in the cylindrical surface of the tank, the suface is well protected against bending inward or outward radially due to moment of inertia of the ribs.

c) Addition of Carbon Black: When polymeric material is exposed to ultraviolet (U.V) light, it degrades, losing its mechanical properties. This happens due to the chain or chemical cross-linking breakages. The mechanical properties of the polymers change. This is called photo-degradation of the polymer. A solution to overcome this problem is addition of Carbon Black to the HDPE Resin which turns the tank black. Carbon black acts as stabilizer, which has been found to be the most effective stabilizer for polyethylene plastic with respect to degradation due to light and weathering. Carbon black absorbs light from the entire range of the solar spectrum and protects the interior of the plastic from the penetration of high energy photons thereby protecting the chemical cross-linking and bonds. Stability of tank is very important when the material is subjected to exposure to sunlight and weathering over long periods of time. Hence most of the HDPE Tanks are black in colour for increasing the life.

d) Dispersion of Carbon Black: Dispersion of Carbon Black is another important parameter which is checked by placing a molten sample of the material in a microscope. The carbon black will be able to absorb the radiation from the Sun. Any areas where the carbon black is non-uniformly dispersed are affected by the high energy sun-light and thereby degradation of mechanical properties occur.

e) Anti-Oxidants: Antioxidants are used in high-density polyethylene (HDPE) to prevent oxidation, which is a chemical reaction that can cause the polymer to degrade and become brittle. Oxidation is caused by the interaction of oxygen with the polymer chains, and it can be accelerated by heat, light, and other environmental factors.

Antioxidants work by scavenging free radicals, which are unstable molecules that can initiate the oxidation process. There are two main types of antioxidants used in HDPE: primary antioxidants and secondary antioxidants.

- Primary antioxidants are the first line of defense against oxidation. They react with free radicals to form stable products, which prevents the oxidation process from continuing.
- Secondary antioxidants are not as reactive as primary antioxidants, but they can help to stabilize the polymer chains once they have been damaged by oxidation.

The type and amount of antioxidants used in HDPE depends on the specific application. For example, HDPE that is used for structural purposes may have high amounts of anti-oxidants.

However, the anti-oxidants are not permitted in the manufacturing of HDPE tanks as they are carcinogenic (cancer causing).

f) **Impact Load:** An impact load is a type of force or load that is applied suddenly and with a relatively high magnitude, often causing a sudden change in velocity or direction of an object. Impact loads can occur in a variety of situations, such as a car collision, a dropped object hitting the ground, or a hammer striking a surface.

This test is performed on an inverted tank by dropping a weight of 2.5 kg from 3 m height on the bottom surface of the tank. If the tank surface is brittle then it would crack.

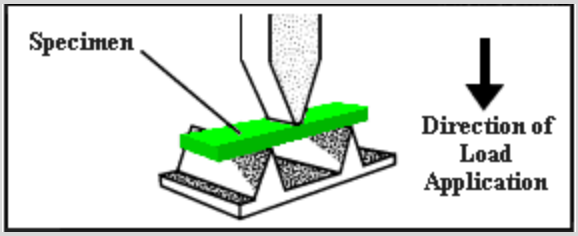
Brittleness in HDPE is caused by a number of factors like temperature, morphology, and additives in HDPE as explained below:

- **Temperature:** HDPE becomes more brittle as the temperature decreases.
- **Crystallinity:** The more crystalline a material is, the more brittle it will be. HDPE is a semi-crystalline material, and the degree of crystallinity can vary depending on the manufacturing process. Higher crystallinity will lead to greater brittleness.
- **Additives:** Some additives can also make HDPE more brittle. For example, antioxidants can increase the brittleness of HDPE by preventing the formation of crosslinks between polymer chains.
- **Contamination:** Any contaminants in the material during processing like
- **Defects:** Defects in the material, such as voids or cracks, can also make HDPE more brittle.

Ductile-Brittle Transition Temperature: The ductile-brittle transition temperature (DBTT) of HDPE is typically around -40°C (-40°F). This means that below this temperature, HDPE will become brittle and more likely to crack. The DBTT is a function of a number of factors, including the material's composition, microstructure, and temperature. For example, steels with a higher carbon content typically have a lower DBTT than steels with a lower carbon content. The DBTT is also affected by the presence of defects, such as voids or cracks.

g) **Top Load Resistance:** During regular use of tank the silt gets deposited on the surfaces and needs cleaning. In this situation, a human should be able to clean the empty tank. The tank is expected to bear the load of a human on its top surface. In this test, the tank is filled to 98 percent of its net capacity and is subjected to compression by means of a 100 kg load applied at the top flat surface for not less than 4 hours. After removal of the load the test specimen is inspected for deformation or crack on the surface and after 4 hours of the removal of the load the flat surface shall return to normal position.

Tanks that fail the top load resistance test may not be able to handle the weight, which could lead to accidents or injuries if someone stands or places heavy objects on the tank. The conformity of the water tank in this test ensures that the tank is strong enough to support heavy weights without getting damaged.

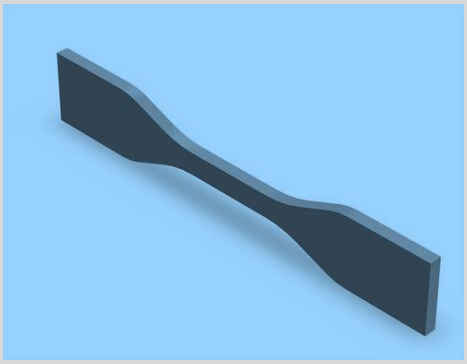


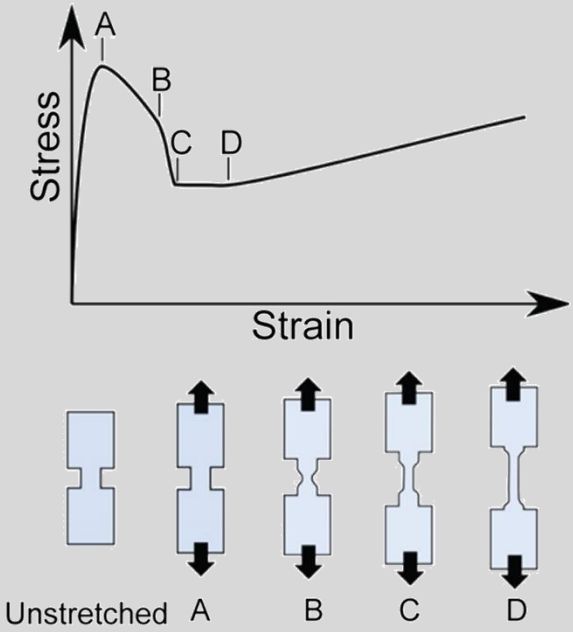
h) **Flexural modulus:** The flexural modulus, also known as the bending modulus or the modulus of

elasticity in bending, is a material property that describes a material's ability to resist deformation or bending when a force is applied to it. It is a measure of a material's stiffness and is typically expressed in units of pressure, such as Pascals (Pa) or pounds per square inch (psi).

i) **Tensile Strength:** The tensile strength of a material is the maximum amount of tensile stress that it can accept before failure (such as breaking or permanent deformation). Tensile strength specifies the point at which a material goes from elastic to plastic deformation. It is expressed as the minimum tensile stress (force per unit area) needed to split the material apart.

Tensile Testing is one of the most common tests on any material be it plastic, steel or a textile. The reason for this is that any product or a component is used, it has a defined design load. Since the component or product cannot be manufactured and checked for its performance, a sample is drawn from the material to assess its capability to bear the loads expected in actual usage. The test helps us determine how strong the tank is when it is pulled or stretched. We want the tank to be able to withstand external forces without breaking or tearing. The higher the tensile strength, the better the tank can handle stretching forces.



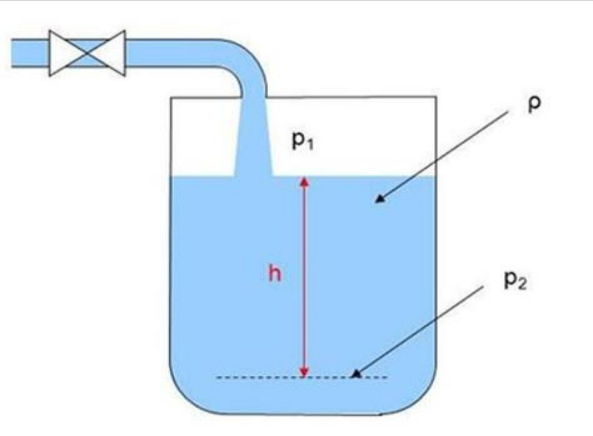


The stress-strain graph plotted for tensile testing of polymers vary from that of metals, and also varies for different polymers. In Tensile Testing, the stress HDPE can bear initially increases steeply. At point A as shown in the graph above, the material starts to yield, or deformation begins. Then the stress reduces due to the formation of necking till point B, this is considered the second yield point. Necking is defined as localized deformation of the tensile testing sample. Further at point C, the necking propagates and elongates uniformly. Subsequently, at point D polymer tends to harden due to straining due to microstructural locking between chains, called strain-hardening. Finally, the sample under tensile load breaks.

The test also helps us understand how flexible the tank is when it is bent or twisted. The tank should be able to flex without cracking or losing its shape. The flexural modulus measures the stiffness or rigidity of the tank. Tanks that fail the tensile strength and flexural modulus test may develop cracks or fractures when stretched or bent.

j) Hydrostatic Pressure Law: Hydrostatic pressure is the pressure that is exerted by a fluid at equilibrium at a given point within the fluid, due to the force of gravity. Hydrostatic pressure increases in proportion to depth measured from the surface because of the increasing weight of fluid exerting downward force from above.

The pressure due to the liquid at a given depth depends only upon the density of the liquid, the acceleration of gravity and the distance below the surface of the liquid. It does not depend on the volume of the liquid.



The formula that gives the P pressure on an object submerged in a fluid is therefore:

$$(P2 - P1) = \rho \times g \times h$$

Where, ρ is Density of the fluid,

g is Acceleration due to gravity

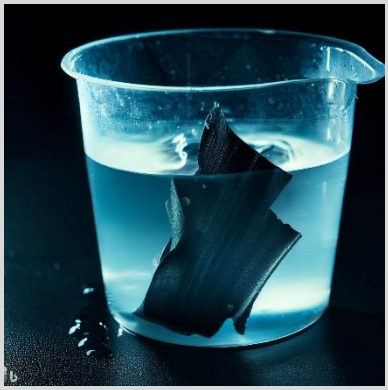
h is Height of the fluid above the object

In the context of water storage tanks, the hydrostatic pressure law is relevant when considering the tank's ability to withstand the pressure exerted by the stored water. The hydrostatic pressure law is crucial in evaluating the structural integrity and performance of rotational moulded polyethylene water storage tanks. These tanks need to be designed for their wall thickness and manufactured to withstand the hydrostatic pressure exerted by the water without deformation, leakage, or failure.

k) Resistance to Deformation test is crucial in ensuring that polyethylene water storage tanks are structurally sound, capable of withstanding external forces, and can perform reliably throughout their service life.

l) Migration Stability of Plastics: Migration is the process of chemicals from plastic materials moving into water. This can happen during the use of plastic products, or during the disposal of plastic products.

The chemicals that can migrate from plastic into water include,



- **Plasticizers:** These are chemicals that are added to plastics to make them more flexible. Some common plasticizers include phthalates.
- **Monomers:** These are the basic building blocks of plastics. Some common monomers include bisphenol A (BPA) and styrene.

- **Oligomers:** These are small molecules that are formed when monomers combine. Some common oligomers include ethylene glycol dimethacrylate (EGDMA) and trimethylolpropane trimethacrylate (TMPTMA).

The amount of plastic that migrates into water depends on a number of factors, including the type of plastic, the temperature of the water, and the length of time the plastic is in contact with the water.

The migration of plastics into water negatively affects the health and environment. These negative effects can be minimized by the following:

- Using plastics that are less likely to release chemicals. Some plastics, such as polyethylene terephthalate (PET), are less likely to release chemicals than other plastics
- Recycling plastics instead of disposing of them in landfills. When plastics are recycled, they are less likely to release chemicals into the environment.

The Water Storage Tanks must not leach harmful chemicals into water. Overall Migration test is done to determine the amount of harmful chemicals migrated into potable water. By conducting this test, we can identify any potential risks and take necessary measures to prevent contamination. Conformity to this test ensures that the water remains safe, free from contamination, and meets the required standards.

5. Some Interesting Facts

i) Rotational moulding, also known as roto-moulding, is the primary manufacturing process used to produce polyethylene water storage tanks. It involves heating and rotating a mould filled with powdered polyethylene, allowing the material to evenly coat the interior of the mould and form the tank's shape.

ii) Polyethylene water tanks are lightweight yet durable, making them easy to transport and install. They are resistant to impact, corrosion, and UV radiation, ensuring a long lifespan and minimal maintenance requirements.

iii) The rotational moulding process allows for the creation of seamless, one-piece water tanks, eliminating the need for joints or seams that could potentially leak.

iv) Polyethylene water tanks can be manufactured in various sizes and capacities to suit different water storage needs, ranging from small residential tanks to large industrial storage tanks.

v) The insulation properties of polyethylene help maintain water temperature, preventing excessive heat gain or loss.

vi) Polyethylene water tanks are commonly used for storing potable water, irrigation water, rainwater harvesting, and other non-potable water applications.

vii) Polyethylene water tanks are known for their excellent chemical resistance, allowing for the safe storage of a wide range of liquids.

viii) In addition to their use for water storage, polyethylene tanks can also be utilized for storing other substances like chemicals, fuels, or agricultural products.

6. Questions

1. Which manufacturing process is commonly used for producing water tanks?

a) Injection moulding
b) Blow moulding
c) Rotational moulding
d) Extrusion moulding

Answer: c) Rotational moulding

2. What material is commonly used for manufacturing water tanks?

a) Stainless steel
b) Fiberglass
c) Polyethylene
d) Aluminium

Answer: c) Polyethylene

3. What is the primary factor influencing the size of a water tank?

a) Material thickness
b) Water temperature
c) Water pressure
d) Required storage capacity

Answer: d) Required storage capacity

4. What is the purpose of UV stabilization in water tanks?

a) To improve aesthetic appearance
b) To enhance chemical resistance
c) To reduce thermal expansion
d) To protect against photo-degradation

Answer: d) To protect against photo-degradation

5. Which factor determines the strength and impact resistance of a water tank?

a) Capacity
b) Wall thickness
c) Colour pigmentation
d) Surface texture

Answer: b) Wall thickness

6. Which test is performed to evaluate the effect of plastic material on water in HDPE Tanks?

a) Migration Test
b) Impact test
c) Thermal conductivity test
d) Hydrostatic pressure test

Answer: a) Migration Test

7. What is the purpose of adding Carbon Black in HDPE Resin?

a) For absorption of UV light
b) For increasing the melting point
c) For anti-microbial property
d) For cost reduction

Answer: a) For absorption of UV light

8. What is the purpose of anti-oxidants in polymers?

a) For arresting free radicals
b) For increasing the melting point
c) For anti-microbial property
d) For cost reduction

Answer: a) For arresting free radicals

9. Pressure of water column depends on?

a) Acceleration due to gravity
b) Volume of water
c) Height of water column
d) Width of the container in which water exists

Answer: a) & c)

10. Dispersion of Carbon Black content can be observed in?

a) Manometer
b) Test Tube
c) Micrometre
d) Microscope

Answer: d) Microscope

Lesson Plan Subjects

Published

1.	Caustic Soda	**21.**	Ballpoint Pen
2.	Football	**22.**	Bicycle
3.	Cement	**23.**	Electric Iron
4.	Gas Stove	**24.**	Loudspeakers
5.	Geyser	**25.**	Pasteurized Milk
6.	Helmet	**26.**	Paver Blocks
7.	LED Bulb	**27.**	Plugs and Socket
8.	LPG Cylinders	**28.**	Solar Flat Plate Collectors
9.	Cement Ash Brick	**29.**	Precast Concrete
10.	Paints	**30.**	Stainless Steel
11.	Boric Acid	**31.**	Weighing balance
12.	Ceiling Fan	**32.**	Steel Bar
13.	Cables	**33.**	Thermometer
14.	Ceramics Tiles	**34.**	Tyres for buses and trucks
15.	Rear View Mirrors	**35.**	Vacuum Flask
16.	Headphones	**36.**	Water Meter
17.	Milk Powder	**37.**	Wheel Rim
18.	Pressure Cooker	**38.**	Water Storage Tank
19.	Plywood	**39.**	PVC Pipes
20.	Multipurpose dry batteries	**40.**	Refrigerator

Forthcoming…

41.	Drinking Water	**47.**	CNG Cylinders
42.	Electric Mixer	**48.**	Hearing Aids
43.	Family Sized Biogas Plant	**49.**	Microwave Oven
44.	Fire Extinguisher	**50.**	Solid and Hollow Block
45.	Power Threshers	**51.**	Submersible Pump set
46.	Conduits	**52.**	Geosynthetics

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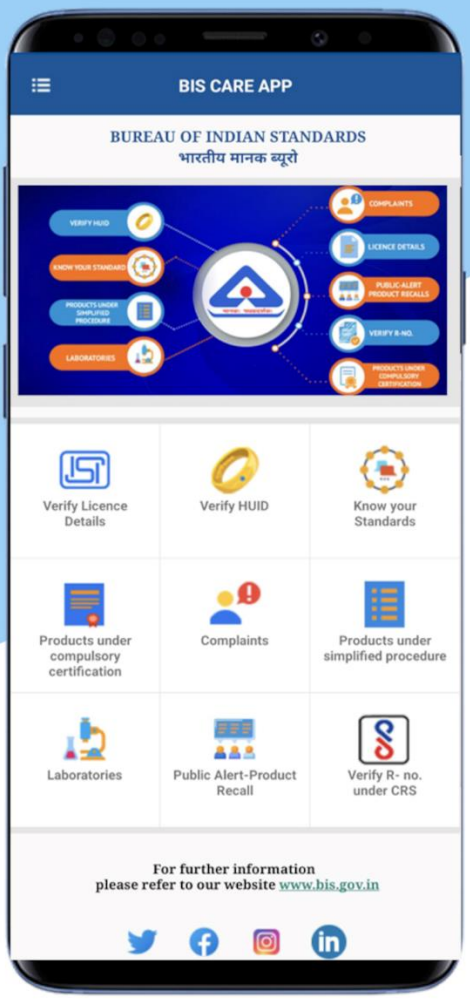

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