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Refrigeration Unlocked: Innovations, Challenges and Solutions for Technicians

By Shaurya Anand, Research Associate,
The Energy and Resources Institute (TERI)

Introduction

Refrigeration technologies have come a long way since their inception, revolutionizing the way we store and preserve food. With the continuous pursuit of energy efficiency, convenience and sustainability, manufacturers have been developing and refining various technologies to meet the evolving demands of consumers. This article delves into key technological advancements that are reshaping the industry, focusing on their implications for service technicians.

Refrigeration plays a critical role across diverse aspects of daily life, encompassing not only residential and automotive settings but also less conspicuous domains such as cryogenic cooling. The considerable requirement for refrigeration across multiple temperature ranges has spurred the advancement of an extensive array of refrigeration and freezing methodologies. Among these, Vapour Compression Refrigeration System (VCRS) and Vapour Absorption Systems (VAS) are commonly favoured and widely employed for various applications.

VCRS - It is the most widely used refrigeration technology, particularly in large-scale applications such as industrial cooling, commercial refrigeration, and air conditioning. On the contrary, VAS is typically employed in specific scenarios where waste heat or alternative energy sources (such as natural gas or solar energy) are available.

Within the food industry, refrigeration holds vital significance as an integral component of the entire food supply chain, playing a crucial role in various stages, including processing, distribution, retail and ultimately reaching the end consumer's home.

Description of VCRS Cycle in a Cooling System

The VCRS operates within a closed-loop cycle and consists of four fundamental stages: compression, condensation, expansion, and evaporation. Each process and its significance is explained in Figure 1.

This continuous cycle is the foundation of modern cooling systems, playing a crucial role in industrial applications, commercial refrigeration, and domestic air conditioning.

Figure 2 illustrates the key components involved in the VCRS cycle.

1.Compression: The refrigerant is compressed, significantly increasing its temperature and pressure.

2.Condensation: The high-pressure refrigerant releases heat to the surroundings, causing it to condense into a liquid state.

3.Expansion: The refrigerant undergoes rapid expansion, resulting in a substantial drop in pressure and temperature.

4.Evaporation: As the low-pressure refrigerant absorbs heat from the surroundings, it evaporates, effectively extracting heat and enabling cooling.

Figure 1: Process in VCRS cycle

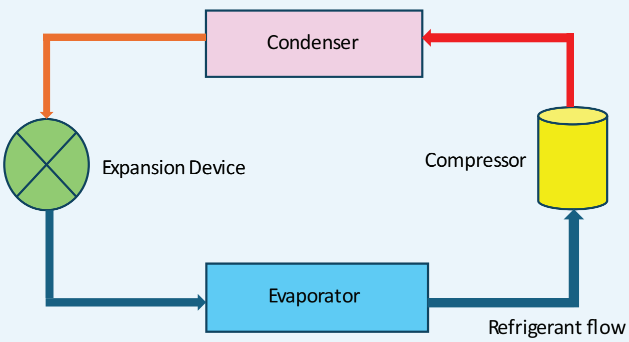


Figure 2: VCRS components

The practical implementation of VCRS requires careful consideration of technological aspects, ensuring both operational efficiency and reliability. Additionally, refrigeration and air conditioning products incorporating this cycle must comply with the testing standards set by the Bureau of Indian Standards (BIS), which are periodically updated to align with advancements in safety, efficiency, and environmental sustainability.

Figure 3 depicts a typical working refrigeration unit, the placement of the compressor at the bottom and the evaporator at the top capitalizes on natural convection, with warm air rising and cold air descending. This arrangement improves heat removal and cooling efficiency, ensuring effective circulation of cold air throughout the refrigerator while using the principles of heat transfer. An added advantage is that in bottom-mounted compressors, maintenance and repairs can be conducted without needing the use of a small ladder.

Servicing Challenges in the Vapour Compression Refrigeration Systems

The coefficient of performance (COP) measures the efficiency of the vapour compression cycle. Given that

- **Compressor Failures**: Nearly 80% of compressor failures are due to improper lubrication, liquid slugging, or refrigerant flood back—regular maintenance can prevent these costly issues.
- **Dirty Coils:** Higher Bills – A 1mm layer of dirt on condenser or evaporator coils can reduce system efficiency by up to 20%, leading to higher energy consumption.

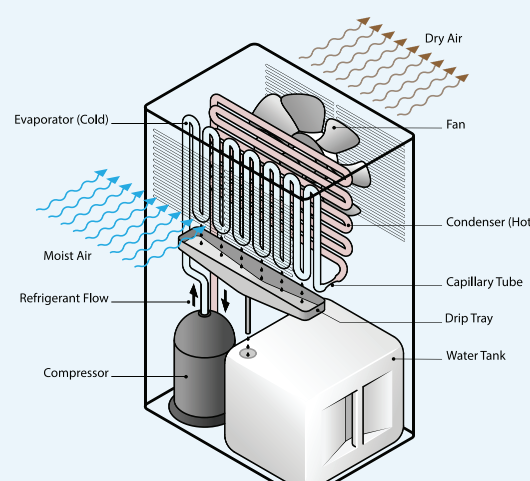


Figure 3: A typical domestic refrigeration unit

the primary purpose of a refrigeration system is to remove heat—a process that requires energy input—the COP indicates how effectively this goal is achieved. Below are some common issues that can impact the COP:

- Compressor Leakage/Failure: The compressor is the heart of any vapour compression system, in any refrigeration system. Compressor malfunctions—often caused by inadequate lubrication, overheating, liquid slugging, or refrigerant flood back—can lead to costly downtime and energy inefficiencies. Regular maintenance, proper refrigerant management, and advanced diagnostic tools can help mitigate these issues.
- Fouling in Evaporators and Condensers: Fouling, which involves any insulating layer that restricts heat transfer between water and refrigerant, can result from algae growth, sedimentation, scale, or slime. This problem increases head pressure, leading to higher energy consumption by the compressor. Maintaining clean evaporator and condenser surfaces and adhering to effective water treatment protocols are essential practices for technicians to prevent such issues.
- Motor Cooling Issues: The motor in a vapour compression system is typically the largest consumer of energy. Drops in efficiency often stem from cooling problems, such as blocked air filters or dirty air passages. Regular checks of chiller logs, particularly comparing amperage and voltage, are vital to uncover potential cooling issues.
- Liquid Line Restrictions: If a technician observes low evaporator pressure, it is advisable to check the liquid line for possible restrictions. Common signs of a restricted liquid line include:

    1. High discharge temperatures
    2. Low current draw
    3. Elevated superheat levels
    4. Low condensing pressures
    5. Frost formation near the restriction
    6. Bubbles in the sight glass

In commercial refrigeration, liquid line restrictions can reduce system capacity by as much as 50%. While experienced technicians may spot issues through visual inspections or system history, newer technicians might need to conduct specific tests. The temperature drop test is one method to identify restriction points. When pinpointing is difficult, a freeze test can be employed, particularly if multiple components (e.g., evaporator, feeder tubes, metering device) are involved. Thermal imaging stands out as a reliable, advanced tool for detecting restrictions, providing real-time temperature readings for accurate diagnosis.

Essential Equipment for Technicians: To ensure refrigeration systems are maintained in a safe and operational condition; technicians should have the list of comprehensive equipment depicted in Figure 4:

Technicians must be fully prepared with the right tools to detect the exact issue for keeping systems running efficiently and safely.

In conclusion, a well-maintained VCRS system is crucial for efficient and reliable cooling operations. By understanding common issues, employing effective troubleshooting techniques, and utilizing appropriate tools, technicians can ensure optimal performance and minimize downtime. Regular maintenance, including cleaning, inspecting, and adjusting system components, is essential to prolong the lifespan of the system and reduce energy consumption. By staying updated with industry advancements and adhering to best practices, technicians can contribute to the sustainable and efficient operation of VCRS systems.

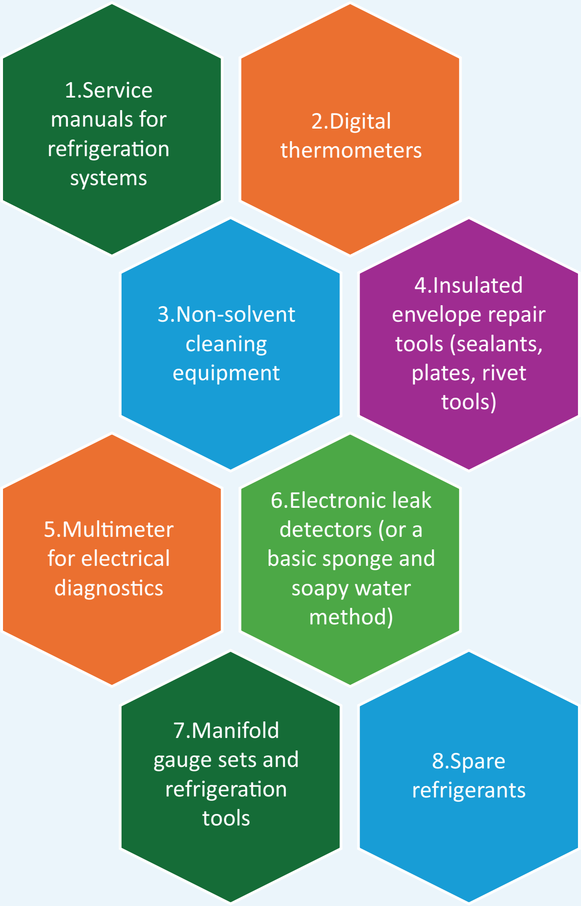


Figure 4: Essential equipment listings for RAC service technicians

Sustainable Servicing Practices for Refrigeration and Air Conditioning Systems

Cooling systems such as room air conditioners and refrigerators are indispensable in modern households, providing thermal comfort, preserving perishable goods and supporting a healthy lifestyle. To maintain optimal performance and prolong their lifespan, regular service is essential. From a service technician's perspective, the focus is often on minimizing immediate costs; however, it is important to recognize that environmentally conscious servicing practices often align with better long-term cost savings. What may seem like the cheapest, quickest fix often leads to higher expense and environmental harm over time. For instance, systems designed with efficiency in mind and maintained meticulously may require a greater initial investment. But these costs are quickly offset by savings on energy and repair expenses, delivering a faster return on investment than initially expected. Similarly, constructing larger or high-efficiency components, such as advanced heat exchangers, may result in a small increase in green house gas (GHG) emissions during manufacturing, but these emissions are greatly outweighed by the reduction in energy consumption and associated emissions within just the first year of operation. Emphasizing on well-engineered designs and diligent maintenance not only enhances system performance but also contributes to sustainability, benefiting both the client and the environment in the long run.

The decision to service cooling systems such as room AC and refrigerators is never a singular one; instead, it is a cumulative of multiple factors. These are listed in Table 1.

Deciding whether to repair, replace components, or fully replace a refrigeration system requires a balanced approach that considers technical feasibility,

Figure 5: Leak detection is one of the crucial steps in servicing cooling systems

Table 1: Factors influencing AC and refrigeration system: Repair vs. Replacement decisions

Factors	Recommended Actions
1 Severity of Leakage	▪ For minor leaks, perform leak detection and repair as per service manual based on BIS IS 8148:2018 regulation ▪ If leakage is severe, recurring, and unrepairable, evaluate replacing the affected component (e.g., piping, valves, seals) ▪ Full system replacement is only necessary if chronic leaks compromise efficiency, environmental compliance, or safety
2 Refrigerant Charge & Type	▪ Retrofitting may be possible for certain systems (e.g., split ACs, VRF), but for older systems such as chillers with obsolete refrigerants, replacement may be more cost-effective
3 System's Age & Efficiency	▪ If the system is less than 10 years old, prioritize maintenance and efficiency upgrades (e.g., variable-speed compressors, improved insulation) ▪ For 15+ year-old systems with poor Coefficient of Performance (COP) and outdated technology, replacement may be more economical
4 Component Availability & System Compatibility	▪ If replacement components (compressors, heat exchangers) are available and cost-effective, prefer repairs over full replacement ▪ If compatible substitutes are unavailable due to technological obsolescence, consider a phased upgrade
5 Availability of Skilled Technicians	▪ Repair and maintenance should be conducted only by certified & trained technicians ▪ If trained personnel are unavailable for older technologies, transitioning to newer, serviceable systems may be necessary

environmental impact, regulatory compliance, and long-term cost-effectiveness.

While minor leaks, component failures, and ageing systems can often be addressed through targeted repairs and retrofits; severe refrigerant leaks, outdated technology, and regulatory phase-outs, on the other hand, may justify full system replacement.

Ensuring preventive maintenance, implementing energy-efficient solutions, and employing certified servicing professionals are essential for extending system lifespan and reducing refrigerant emissions.

Ultimately, the most sustainable decisions lie in proactive maintenance, smart retrofits, and strategic transitions to low-GWP and high-efficiency systems, ensuring long-term reliability, cost savings, and climate resilience.

From servicing perspective, it is important to carefully analyse and categorize the issues with normal functioning of a refrigerator. Table 2 outlines various concerns, accompanied by inspection points and recommended corrective measures.

The future of RAC servicing will involve a shift towards increased emphasis on sustainability and long-term efficiency. As technological advancements continue, refrigeration systems will likely incorporate smarter, more energy-efficient components. Servicing strategies will evolve to prioritize environmental considerations alongside cost-effectiveness. Proactive maintenance, guided by comprehensive diagnostic tools like those in Table 2, will play a key role in optimizing performance

Table 2: Guide for diagnosing and servicing refrigerators

Conditions	Inspection Points	Remedial Actions
No cooling	1. Is the power cord disconnected from the electrical outlet? 2. Verify if the power switch is in the OFF position. 3. Inspect the power switch fuse for any short-circuits. 4. Assess the voltage output of the power outlet.	1. Connect the plug to the electrical outlet. 2. Activate the switch to the ON position. 3. Substitute with a standard fuse. 4. If the voltage is insufficient, consult an electrician to rewire if necessary.
Food items in the refrigerators are frozen	1. Are the food items positioned near the cooling air outlet? 2. Check that the control is adjusted to the 'cold position'. 3. Is the ambient temperature below 5°C?	1. Ensure at least a 10 cm gap around the appliance. 2. Adjust the control to the 'mid-position'. 3. Set the control to the 'warm position'.
Poor cooling ability	1. Ensure adequate clearance around the appliance. 2. Avoid placing the appliance near heat sources, or direct sunlight. 3. Check proper room ventilation and temperature control. 4. Check the put-in temperature before handling. 5. Minimize door openings and ensure proper closure. 6. Confirm damper control is set to 'cold position'.	1. Position the appliance with approximately a 10 cm gap. 2. Ensure that the appliance is away from heat-emitting devices. 3. Maintain a lower ambient room temperature. 4. Insert food items after they have sufficiently cooled. 5. Minimize the frequency of door openings and secure them tightly. 6. Adjust the control to the 'mid-position'.
Condensation or frost accumulation inside the appliance's chamber	1. Are liquid food items being stored? 2. Check if the stored items are hot. 3. Has the consumer often opens the appliance's door, or is the door securely closed?	1. Use plastic wrap to securely seal liquid food items. 2. Insert food items only after they are sufficiently cooled. 3. Minimize the frequency of door openings and ensure it is tightly closed.
Occurrence of abnormal noise	1. Is the appliance positioned on a stable and level surface? 2. Have any unnecessary items been placed behind the appliance? 3. Check if that the 'tray drip' is securely fastened. 4. Check if the cover of the mechanical compartment at the bottom and front has been removed.	1. Modify the 'adjust screw' to achieve a stable placement. 2. Remove any objects obstructing its placement. 3. Securely affix it to its original position. 4. Reinstall the cover at its original location.

and minimizing environmental impact. Certified technicians will be essential in navigating the multifaceted decisions outlined in Table 1, ensuring that the servicing landscape aligns with both economic and ecological objectives. Overall, the future of refrigerator servicing will be characterized by a commitment to innovation, sustainability and the seamless integration of cutting-edge technologies.

Safety Tools and Techniques for Technicians Handling Flammable Refrigerants

Amid growing concerns over climate change, the cooling industry is increasingly adopting climate-friendly refrigerants, such as hydrocarbons (e.g., R290/propane), ammonia (R717), and certain hydrofluoroolefins (HFOs), due to their low GWP. This shift aligns with global efforts, including the Kigali Amendment to the Montreal Protocol, to reduce greenhouse gas emissions. Compared to traditional high-GWP refrigerants like HFCs R410A and R134a, these alternatives have a significantly smaller environmental footprint, appealing to sustainability-focused companies. However, the flammability of these refrigerants poses safety risks, especially for service technicians handling them. Even minor leaks can create fire or explosion risks, particularly in confined or poorly ventilated spaces. Addressing these risks requires specialized equipment, including PPE, non-sparking tools, explosion-proof detectors, and robust emergency protocols. Technicians must prioritize safety by mastering refrigerant handling, recovery, leak detection, and emergency response. This chapter outlines the essential tools, procedures and guidelines needed to safely manage flammable refrigerants in the HVACR field.

1. Understanding the Risks of Flammable Refrigerants

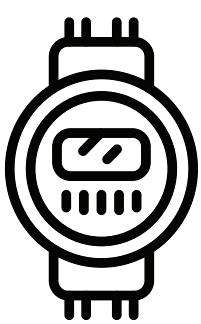
Technicians working with flammable refrigerants need a thorough understanding of the risks involved. These include:

- **Fire and Explosion Hazard**: Flammable refrigerants can ignite from sparks or open flames, with increased risk in confined spaces where vapor concentrations accumulate.
- **Chemical Exposure**: Although refrigerants are generally non-toxic, prolonged exposure can cause respiratory issues and skin or eye irritation.

2. Personal Protective Equipment

Technicians should wear specific personal protective equipments (PPEs) to protect themselves when working with flammable refrigerants:

- **Flame-Resistant Clothing**: Protects against burns from accidental ignition.
- **Goggles and Face Shields**: Safeguard eyes and face from refrigerant splashes and vapours.
- **Gloves**: Chemical-resistant gloves (e.g., neoprene or nitrile) prevent skin irritation and frostbite.
- **Respiratory Protection**: Use respirators with organic vapour cartridges in poorly ventilated areas to avoid inhaling harmful refrigerant vapours.



3. Ventilation and Gas Detection

Proper ventilation is crucial when working with flammable refrigerants to prevent gas accumulation and reduce explosion risks.

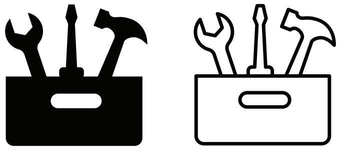
Ventilation Fans and Exhaust Systems: Use portable fans and exhaust systems to disperse vapours and keep concentrations below the lower explosive limit.

- **Gas Detection Systems**: Employ multi-gas detectors to monitor for flammable gases, with alerts for unsafe refrigerant concentrations.
- **Explosion-Proof Equipment**: Ensure all fans, lighting and electrical equipment are explosion-proof to eliminate ignition risks.

4. Explosion-Proof Tools

Regular tools, like drills and grinders, can create sparks, which could ignite refrigerants in the cooling systems. When working with flammable refrigerants, technicians should use:

- Non-Sparking Tools: Tools made from materials like brass, bronze, or certain plastics that do not produce sparks on impact are recommended.
- Intrinsically Safe Equipment: These include tools and meters that are designed for use in hazardous environments and reduce the possibility of an ignition source.



5. Purging, Recovery and Leak Detection

Purging and recovery procedures need to be carefully followed to ensure the safe handling of flammable refrigerants.

- **Proper Refrigerant Recovery**: Use approved recovery machines designed for flammable refrigerants, as standard machines may be unsafe.
- **Leak Detection with Safety Tools**: Employ certified leak detectors for flammable refrigerants, such as ultrasonic or infrared types, to avoid spark risks.
- **Purging with Nitrogen**: Purge cooling systems with nitrogen beforehand to reduce residual refrigerant and minimize fire or explosion risks.

6. Fire Safety Equipment

A robust fire safety plan and availability of proper equipments are vital for technician safety.

- **Class B Fire Extinguishers**: Essential for handling flammable liquid fires, including refrigerants; ensure a Class B or multi-purpose extinguisher is available.
- **Automatic Fire Suppression Systems**: Provide added protection in workspaces frequently handling flammable refrigerants.
- **Emergency Shut-Off Devices**: Quickly halt refrigerant flow during leaks to prevent fires or explosions from escalating.

7. Training and Certification

Technicians handling flammable refrigerants should undergo regular training to stay updated on safety practices and technological advancements.

- **Certification Courses**: Complete certified training on refrigerant handling, covering physical properties, risk management and recovery equipment operation.
- **Hands-On Training**: Gain practical experience with emergency procedures, leak detection and safety equipment use.
- **Emergency Response Drills**: Participate in routine drills and refresher courses to prepare for worst-case scenarios involving flammable refrigerants.

8. Labelling and Warning Signs

Proper labelling of refrigerant cylinders, containers and storage areas is essential for safety.

- **Flammability Labels**: Flammable refrigerants should be clearly labelled with standardized warning symbols to ensure technicians are aware of the hazards.
- **Storage Area Signs**: Flammable refrigerants should be stored in well-ventilated areas with clear "No Smoking" and "Flammable Gas" signages to minimize risks.

Handling flammable refrigerants requires specialized tools, safety training and adherence to guidelines. By providing technicians with the right tools, knowledge and protocols, service providers and affiliated organizations can minimize risks and promote a safer work environment.

Regular reviews and training on new refrigerant safety development ensure technicians are always prepared, enhancing both personal safety and environmental sustainability.

Exciting News for the RAC Service Sector in India: New Era in Certification of Service Technicians

On September 13, 2024, the Ministry of Environment, Forest, and Climate Change (MoEFCC) hosted an event in New Delhi to commemorate the 30th World Ozone Day. The ministry emphasized the crucial role of service technicians, announcing that a new certification system for RAC service technicians has been approved by the National Council for Vocational Education and Training (NCVET) under the National Skill Qualification Framework (NSQF) of the Ministry of Skill Development and Entrepreneurship (MSDE). The initiative will be implemented as part of HPMP Stage III, aiming to train and certify 25,000 RAC technicians by 2030.

The newly approved certification system for RAC service technicians will enhance workforce skills, support sustainable practices for ozone protection, and broaden job opportunities.

Figure 6: MoU signing between GIZ, ESSCI and Ozone Cell, for training and certification on World Ozone Day 2024

Mr Suresh Rawat from Patparganj has 10 years of experience working as a full-time room air conditioners (RAC) service technician.

From the field:

Mr Suresh Rawat from Patparganj has 10 years of experience working as a full-time RAC service technician.

What is the nature of your job?

Ans: I work full-time with Voltas as a RAC technician and electrician. My work involves servicing domestic air conditioning units.

What type of refrigerants do you deal with in your job and how do you handle flammable refrigerants?

Ans: I typically work with R-22, R-32 and R-410 refrigerants. I gained initial knowledge about these refrigerants during my ITI training, then I acquired detailed handling skills through hands-on job experience.

Are you professionally trained? What training have you undergone, i.e., ITI, GIZ, ISHRAE, Skill India, etc. Have you heard about them before?

Ans: I have completed practical training from Voltas Private Limited on servicing and maintenance of air conditioning. Also, I have learnt AC servicing on the job from my seniors and my experience of 10 years. I have undergone GIZ training on good service practices as well.

Would you be interested in upcoming training to remain updated with the new technologies and refrigerants?

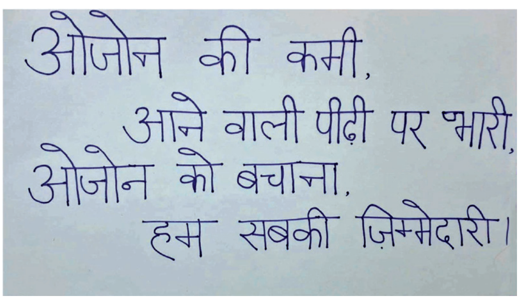
Ans: Most of my training takes place during the off-season. I do feel that my current skills are adequate, but I am not equipped to service next-generation ACs, so training focusing on that subject will be helpful for me.

What type of information would you like to see in the newsTRAC newsletter for service technicians, any suggestions?

Ans: I feel that information focusing on the servicing of the latest technologies in AC units and information on new emerging refrigerants on the job will be useful.

NATIONAL SLOGAN WRITING COMPETITION WINNERS ON THE OCCASION OF 30th WORLD OZONE DAY - 2024

FIRST PRIZE



Saatvik Verma
Class 8, Section E
Summer Fields School,
Kailash Colony, New Delhi – 110048

SECOND PRIZE

Mukesh Kumar and Kamlesh K Yadav
Class 12, Section H
KJ Somaiya Junior College of
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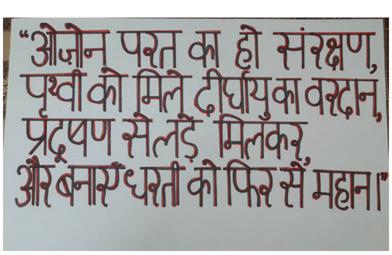
Vidyavihar, Mumbai – 400077

THIRD PRIZE



Shubhankar Agarwal
Class 9, Section G
New Green Field School, Saket, A-2,
Mandir Marg, New Delhi – 110017

Boiling Point of Water °C	Vapor Pressure in Microns
100	7,59,968
50	92,456
30	31,750
10	8,641
0	4,572
-10	1,722
-23.35	500

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For further information

Ozone Cell, Ministry of Environment, Forest and Climate Change

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