JOURNAL OF MARITIME RESEARCH

SPECIAL ISSUE (2026) pp 172–178

ISSN: 1697-4840, www.jmr.unican.es

Design of a Low-Cost Seawater Flake Ice Maker for Small Fishing Vessels

Sameh T. Abd Elfattah[1,3,*], Basel Seoudi[1,4], Yehia A. Eldrainy[1,5], Ali I. Shehata[1,6], Nourhan I. Ghoneim[2,7]

ARTICLE INFO

Special Issue:
1st International Maritime and Logistics Conference;
February 10-11, 2026.
National University of Science & Technology (NU), Oman

Article history:
Received 15 Feb 2026;
in revised from 24 Feb 2026;
accepted 05 Jun 2026.

Keywords:
flake ice, seawater refrigeration, scraped-surface evaporator, R404A, marine refrigeration, low-cost design.

ABSTRACT

This paper presents the design and engineering validation of a compact, low-cost vertical seawater flake-ice maker intended for small fishing vessels operating in hot climates. The system employs a stationary double-walled stainless-steel drum (of the dimensions of 150 mm inner diameter, and 400 mm active freezing length) with an internal rotating scraper and a vapor-compression cycle using ana Refrigerant type of (R404A). Thermodynamic analysis based on the selected cycle (of evaporation -25 °C, condensing 40-45 °C with 5 K subcooling and 10 K superheat), yields a refrigeration effect of 108.14 kJ/kg, specific compressor work of 56.43 kJ/kg, and a COP of 1.73. Heat-transfer sizing of the scraped-surface evaporator confirms that the fabricated surface area (is 0.188 m^2) that exceeds the minimum required area by a factor of approximately 2.5, providing robustness against fouling, scraper inefficiency, and elevated ambient temperatures. Mechanical design of the scraper drive (vector-control VFD with worm gearbox) , ensures stable operation at 4.5-14 rpm and maintains a high torque safety margin (≈approximately equal to 5.4) under conservative ice shear assumptions. Prototype operation targets 5-6 kg/h of dry, sub-cooled flake ice at approximately -7 °C, with a practical pull-down period of 10-12 minutes before the first kilogram is harvested. The presented methodology and validated component sizing provide a journal-ready reference design for affordable onboard ice production. The proposed compact, low-cost vertical seawater flake-ice maker directly supports several United Nations Sustainable Development Goals (SDGs) such as SDG 2 of Zero Hunger, SDG 8 of Decent Work and Economic Growth, SDG 9 of Industry, Innovation, and Infrastructure, SDG 12 of Responsible Consumption and Production and SDG 13 of Climate action. Also, aligns strongly with the strategic pillars of Egypt Vision 2030, particularly in the pillars of Economic Development, Energy, Knowledge, Innovation, and Scientific Research and Environmental Sustainability.

© SEECMAR | All rights reserved

1. Introduction.

Rapid onboard cooling is necessary for small-scale fishing vessels in order to decrease post-harvest losses, minimize microbial development, and maintain catch quality. Relying on pre-loaded shore ice results in high melt losses during transit and logistical uncertainty. These issues are made worse in warm operating regions and significantly lower the value of the product for artisanal fishermen (Bjorndal et al., 2014, FAO and INFOFISH, 2008, Mellari, 2023b, Mellari, 2023a).

Because its thin crystals offer high surface area and superior contact cooling without mechanically harming fish tissue,

[1]Arab Academy of Science, Technology and Maritime Transport (AASTMT), Alexandria, (Egypt).
[2]University National University of Science and Technology, (OMAN).
[3]Assistant Professor of Marine Engineering Technology Department. Tel. (+20) 1000659090. E-mail Address: samehtawfik@aast.edu.
[4]Assistant Professor of Marine Engineering Technology Department. Tel. (+20) 1000659090. E-mail Address: baselms@hotmail.com.
[5]Professor of Department of Mechanical Engineering, College of Engineering & Technology. Tel. (+20) 1015393646. E-mail Address: yeldrainy@aast.edu.
[6]Professor of Department of Mechanical Engineering, College of Engineering & Technology. Tel. (+20) 1223860234. E-mail Address: aliismail@aast.edu.
[7]Associate Professor of Marine Engineering and Naval Architecture of the Maritime Department, International Maritime Collage Oman. Tel. (+968) 71762391. E-mail Address: norhan@imco.edu.om.
[*]Corresponding author: Sameh T. Abd Elfattah. Tel. (+20) 1000659090.

E-mail Address: samehtawfik@aast.edu.

flake (scale) ice is widely used for fisheries applications. Compared to block ice, these characteristics allow for faster uniform cooling and higher packing density, making flake ice especially appropriate for vessels with limited hold volume (Piñeiro et al., 2004, Singha et al., 2025, Widell and et al., 2023, Widell et al., 2023). By removing the need to transport drinkable water and by taking advantage of the on-board availability of source water, at-sea production from seawater offers practical advantages over freshwater-based systems (Fu et al., 2024, Garcia and Semedo, 2024, Meng et al., 2024, Semedo and Garcia, 2025). However, the use of seawater presents design challenges related to salt inclusion, freezing point depression, and corrosion management.

Industrial scraped-surface evaporators and commercial seawater flake-ice machines are available for marine use, but many of them are still too big, expensive, and energy-intensive for small fishing boats. Standard industrial designs also don't always handle the motion, limited electrical capacity, and tilting (roll/pitch) that are typical of small boats (Liu et al., 2025, Witanowski, 2024, Xia et al., 2023, Yan et al., 2021). Therefore, compactness, low electrical demand, corrosion-resistant materials (like marine-grade stainless steels), and mechanical arrangements that enable stable ice production under vessel motion and seawater temperatures that can reach 30–34 °C in tropical regions must be given top priority in practical onboard designs.

Recent technical advances relevant to a low-cost maritime flake-ice maker include improved understanding of ice-slurry and flake heat-transfer/ and viscosity characteristics, optimized scraped-surface geometries and scraper speeds for stable crystal formation, and validated options for lower-GWP, (Global Warming Potential), refrigerants and compact vapor-compression configurations suitable for small compressors and limited power budgets (Altinkaynak, 2021, Mellari, 2023b, Widell and et al., 2023, Yıldırım et al., 2023). Integrating these developments permits a simplified design approach that aims to reach evaporator surface temperatures near −28 °C for continuous flake formation while using seawater-cooled condensers, stainless-steel evaporator drums, and refrigeration components selected for marine survivability.

1.1. Importance of Onboard Ice Production for Small-Scale Fisheries.

Because small-scale fishing vessels must promptly cool after catching to prevent microbiological activity and biochemical spoiling, onboard ice production is crucial. Compact ice-making devices have a significant role in lowering post-harvest losses and enhancing quality in artisanal fisheries, particularly in tropical and subtropical regions where fresh-catch temperatures rise quickly, according to recent research on fisheries.

1.2. Flake and Slurry Ice Thermal and Operational Benefits.

Because of its enormous surface-area-to-volume ratio, capacity to pack around fish, and quick thermal contact, flake ice offers superior cooling efficiency. In comparison to conventional block or cube ice, flake/slurry ice systems can prolong freshness retention periods by several days, according to experimental experiments conducted in 2023–2024 (Widell and et al., 2023). This is especially true for pelagic species with significant metabolic heat after capture. These results support the technical preference for flake ice in aboard applications where quick chilling is essential.

1.3. Commercial Seawater Flake-Ice Machines: Constraints and Performance.

A thorough market analysis of commercially available seawater flake-ice machines revealed stainless steel (304/316L) drum or scraped-surface evaporators, seawater-cooled or air-cooled condensers, with capacities ranging from 0.5 to 5 tons/day. Price ranges between US$3,000 and US$29,000, depending on capacity, condenser type, and marine-grade corrosion protection, according to recent catalog data from key suppliers (2023–2025) (Widell et al., 2023).

Among the main restrictions on small fishing boats are:

- Exorbitant initial costs, particularly for complete marine-grade installations with 316L stainless-steel evaporators (Widell et al., 2023).
- Electrical power limitations, as many units need a three-phase supply of 380–440 V (Fu et al., 2024, Meng et al., 2024).
- Intolerance to marine motion and vibration, as most commercial units are built to operate on land.
- Maintenance issues brought on by corrosion, fouling, and conditions with high salinity (Witanowski, 2024, Xia et al., 2023).

Table 1 provides an overview of typical commercial models.

Table 1: Commercial Seawater Flake-Ice Makers' Sample Specifications based on supplier data 2023?2025.

Manufacturer/ Source	Model Capacity	Evaporator Material	Condenser Type	Power Requirement	Approx. Price (USD)	Source
ICESTA Marine Series	1 ton/day	316L Stainless	Seawater-cooled	380 V / 3-phase	8,500–12,000	(Widell et al., 2023)
Focusun FIM-Series	1–2 tons/day	304/316 SS	Air-cooled	380–440 V	6,800–15,000	(Garcia and Semedo, 2024)
Alibaba Supplier (Generic Marine Unit)	0.5–1 ton/day	304 SS	Air or seawater	Customizable	3,200–6,000	(Fu et al., 2024)
Amazon Commercial Ice Machines	150–300 kg/day	Standard SS	Air-cooled	220–240 V	1,200–2,800	(Xia et al., 2023)
BestBuy Commercial Flake Ice Systems	200–450 kg/day	Stainless	Air-cooled	220 V	2,500–4,000	(Xia et al., 2023)

Source: Authors.

Note: Compared to land-based flake-ice units, marine-grade units with seawater-cooled condensers are usually heavier and more expensive.

1.4. Technical Perspectives from Current Refrigeration Studies.

Guidelines relevant to seawater flake-ice manufacturers are provided by recent research (2023–2024) on compact refrigeration systems:

i. Scraped-surface evaporator design: Research shows that varying the angle of the scraper blade, the contact pressure, and the speed at which the drum rotates improves flake uniformity and lowers compressor load (Singha et al., 2025, Widell and et al., 2023).
ii. Refrigerant selection: While R404A remains dominant in commercial marine units, several studies evaluate low-GWP substitutes (R448A, R449A) capable of maintaining evaporator temperatures as low as −28 °C under marine thermal load conditions (Liu et al., 2025, Yan et al., 2021).
iii. Heat-exchanger optimization: Marine studies emphasize the importance of 316L stainless-steel seawater-cooled condensers, corrosion protection via sacrificial anodes, and periodic descaling to maintain heat-exchange efficiency (Garcia and Semedo, 2024, Yan et al., 2021). These engineering findings align well with design objectives of cost-optimized compact systems.

1.5. Field Deployment Evidence & Socio-Economic Applications.

Recent fisheries development projects (2023–2024) in Southeast Asia and North Africa deployed small marine flake-ice machines to artisanal communities. Reports highlight significant reductions in spoilage rates, improved market value of fish, and enhanced flexibility for longer fishing trips (Bjorndal et al., 2014, FAO and INFOFISH, 2008, Mellari, 2023b, Mellari, 2023a). These deployments confirm both the technical feasibility and economic value of compact onboard ice makers.

1.6. Identified Research Gap.

Although several seawater flake-ice machines are commercially available, there is a lack of low-cost, small-capacity, motion-tolerant designs specifically engineered for:

- Vessels under 12 meters.
- Tilt angles up to 15–20°.
- Limited electrical supply (single-phase or small generators).
- Simplified maintenance capabilities.

This research addresses that gap by designing a low-cost, seawater-adapted flake-ice maker tailored to small fishing vessels, optimized for cost, energy consumption, and marine durability.

2. Methodology and Design.

The process is intended to produce a seawater flake ice maker that can be installed on small fishing boats and is the most affordable, high-quality, and user-friendly. This is accomplished by comparing commercially available components and doing heat calculations using the COOLPACK software.

2.1. Design and Calculation of the Refrigeration Cycle (Using COOLPACK).

Thermal calculations and determining the refrigeration cycle ideal performance will be done using the COOLPACK program.

i. Cycle Configuration and Parameters.

   Cycle Selection: A basic Vapor Compression Cycle will be designed, incorporating a compressor, a seawater-cooled condenser, an expansion valve, and a scraped-surface evaporator drum.

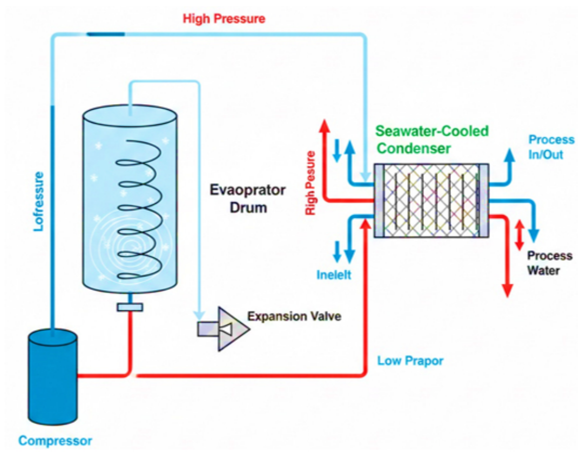
   Refrigerant Selection: Referencing the literature which mentions R404A and its low GWP alternatives like R449A (Liu et al., 2025), both will be input into COOLPACK to compare their Coefficient of Performance (COP) and energy efficiency. The goal is to reach an evaporation temperature near –28 °C.

- Temperature Determination:
  - Evaporation Temperature (T_{evap}): Set between –28 °C and –30 °C for continuous flake formation.
  - Seawater Condensing Temperature (T_{cond}): Considering the maximum tropical seawater temperature of 34 °C, the condensing temperature will be set higher, typically 38 °C to 42 °C, allowing for the necessary temperature difference (LMTD) in the heat exchanger.
  - Cooling Capacity Required (Q_{evap}): The target ice production capacity (0.5 ton/day or 500 kg/day) will be converted into refrigeration capacity (in kW) using the heat balance equation:

$$
\begin{aligned}
Q_{\text{evap}} \quad = \quad & \dot{m}_{\text{ice}} \Big[C_{p,\text{water}} \left(T_{\text{in}} - T_{\text{frz}}\right) + L_{\text{fusion}} \\
& + C_{p,\text{ice}} \left(T_{\text{frz}} - T_{\text{ice}}\right) \Big] \\
& + \text{Losses}
\end{aligned}
$$

  where T_{frz} is the freezing point of seawater (depressed below 0 °C due to salinity).

Figure 1: Schematic Diagram of the Low-Cost Seawater Flake Ice Maker Refrigeration Cycle.



Source: Authors.

ii. COOLPACK Simulation.

T-s and P-h cycle simulations will be carried out using COOLPACK Cycle Analysis module.

COOLPACK Outputs of Interest:

- Coefficient of Performance (COP): To choose the best refrigerant and assess cycle efficiency.
- Compressor Volumetric Displacement: To determine the proper compressor size based on the refrigerant computed mass flow rate.
- The seawater-cooled condenser size is determined by the Condenser Heat Load.

2.2. Selection and Standardization of Materials (Material and Codes).

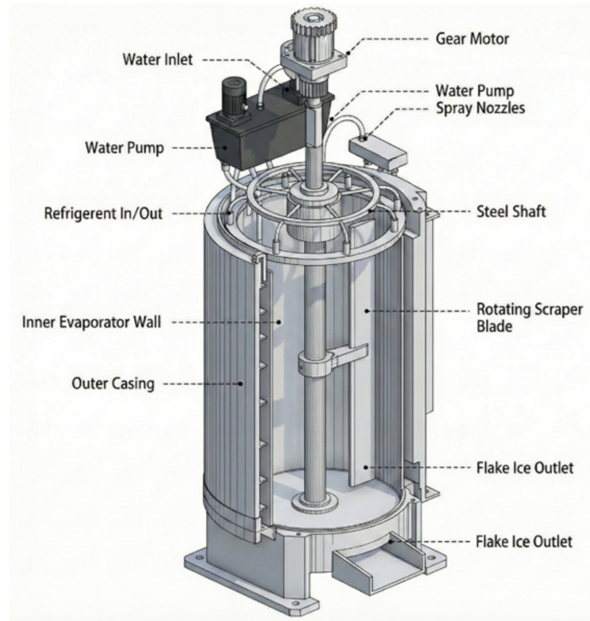
To reduce corrosion and attain long-term dependability in the challenging marine environment (Mellari, 2023a, Piñeiro et al., 2004):

- Evaporator Drum: Where there is no direct contact with seawater or ice, non-contact support structures may use less expensive 304 stainless steel, but the evaporator drum surface will be made of 316L stainless steel.
- Seawater Condenser: To withstand biofouling and corrosion from the seawater, a heat exchanger composed of titanium, cupro-nickel, or premium 316L stainless steel will be chosen.

Analytical Analysis of the Flake Ice Maker Operating System and Engineering Components.

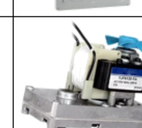
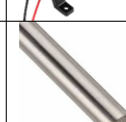
The flake ice maker employs an integrated mechanical cycle and a direct chilling mechanism to turn water into ice flakes.

Figure 2: Vertical Flake Ice Make Internal Structure.



Source: Authors.

Table 2: Prototype Key Components And Specifications.

Component	Maker / Model	Technical Specifications	Estimated Price in Egyptian Market (USD)	Component Image
Compressor	Tecumseh / THG1374YMS	R134a, 220V / 50–60Hz, LRA 10.5A, Thermally Protected (Brazil)	200 USD	
Condenser	Bundyweld / Series 4.76 mm OD	Static Wire-on-Tube, Natural Convection, R134a Compatible, Epoxy Coated	100 USD	
Expansion Valve	Danfoss T2 / TAE Series	Precision Copper, 0.8 mm ID, 2.5 m Length, Constant Pressure Drop	35 USD	
Evaporator	Vertical-Drum / VED-SS304	Double-walled Vertical Cylinder, SS304 Internal Surface, Polyurethane Insulation, High Heat Transfer Efficiency	150 USD	
Gear Motor	(Shaded Pole Motor) YJF6130	AC 220–240V / 50Hz, 20–26W, 0.35A, 2 RPM (Gearbox), Class H, BBRG, Thermal Protector	40 USD	
Water Pump	MAKA / CF-2203-1	12V DC (9–14.4V), 2.2A, 3.1 LPM (80 PSI), Auto Cutoff, BBRG, Thermally Protected	15 USD [alibaba.com]	
Main Shaft	MS-316-P25	Precision Ground SS316L, Ø25 mm, High Torque Capacity	4 USD /cm	

Source: Authors.

Water cycle: The pump draws water and distributes it evenly through spray nozzles to cover the evaporator wall.

- Instant freezing: Refrigerant (R134a) cools the evaporator wall, causing a thin coating of ice to form right away.
- Scraping procedure: To transform ice into flakes, the scraper is moved along the wall by the gear motor rotation of the steel shaft.
- Collecting: Ice flakes enter the collecting bin through the outflow and fall by gravity.
- Protection: For safe, continuous operation, motors and pumps are equipped with thermal protection.
- Thermal insulation: Heat loss is stopped by foam insulation and a cooling jacket.
- Protection: For safe, continuous operation, motors and pumps include thermal protection.
- Durability: In humid conditions, sealed ball bearings guarantee a long operational life.

2.3. *Thermal Load Estimation and Target Ice Capacity.*

The intended ice production rate is converted into the necessary refrigeration capacity using a first-principles heat balance. The ideal ice discharge temperature for sub-cooled flake ice is about −7 °C, while the freezing point of seawater is lowered to about −2 °C at a salinity of about 3.5%. The following is used to estimate the design cooling load:

$$\begin{aligned}\dot{Q}_{\text{load}} &= \dot{m}_{\text{ice}}\Big[c_{p,w}\left(T_{\text{in}} - T_f\right) + h_{\text{fus}} \\ &\quad + c_{p,\text{ice}}\left(T_f - T_{\text{ice,out}}\right)\Big] \\ &\quad + \dot{Q}_{\text{parasitic}}.\end{aligned} \quad (1)$$

where $\dot{m}_{\text{ice}}$is the ice mass production rate, $c_{p,w}$and $c_{p,\text{ice}}$are the specific heats of liquid water and ice, $T_{\text{in}}$is the inlet seawater temperature, $T_f$is the seawater freezing point, and $h_{\text{fus}}$is the latent heat of fusion. After taking into consideration transmission losses, heat leaks, and non-ideal operation, a 1.0 kW design point is chosen. Eq. (1) produces an ideal load of roughly 0.65–0.79 kW using a sample summer inlet temperature of 30 °C and a production rate of 5–6 kg/h.

2.4. *Refrigeration Cycle and Performance Metrics.*

A single-stage vapor-compression system utilizing R404A is the chosen cycle. For the prototype design, cycle state points were derived from COOLPACK cycle analysis. The liquid line is subcooled by 5 K at the condenser outlet, whereas the suction condition corresponds to −25 °C evaporation with 10 K superheat. Table 1 summarizes the important state characteristics, and the primary performance measures are calculated from:

$$q_e = h_1 - h_4, \qquad w_c = h_2 - h_1, \qquad \text{COP} = \frac{q_e}{w_c}. \quad (2)$$

Table 3: R404A cycle state points used for performance calculations.

State	P (bar)	T (°C)	h (kJ/kg)
1 (suction)	2.40	−15.1	361.58
2 (discharge)	18.60	69.5	418.01
3 (condensing, sat.)	18.60	40	—
4 (subcooled liquid)	17.96	34.2	253.44

Source: Authors.

From Table 3, the refrigeration effect is q_e= 108.14 kJ/kg and the specific compressor work is w_c= 56.43 kJ/kg, yielding COP= 1.73.

The corresponding heat rejection rate is $\dot{Q}_{\text{cond}}=\dot{Q}_e+\dot{W}_{\text{comp}}$, which is approximately 1.6–1.7 kW for a 1.0 kW evaporator load.

2.5. *Evaporator Drum and Heat-Transfer Sizing.*

With an inner freezing diameter of 150 mm and an outer shell diameter of 158 mm, the evaporator is a stationary vertical stainless - steel drum (SS304) that creates a 4 mm annular refrigerant gap to encourage high refrigerant velocity and boiling heat transfer. With active cooling length is 400 mm, giving an available heat-transfer area of $A_{\text{act}}=\pi DL\approx 0.188$ m^2.

A cylindrical thermal resistance network comprising refrigerant - side boiling, wall conduction, an ice-layer (fouling) resistance, and water-film convection is used to calculate the overall heat-transfer coefficient. The controlling relationship is:

$$\frac{1}{U} = \frac{1}{h_i} + \frac{\ln(r_o/r_i)}{k_{\text{ss}}} + \frac{\delta_{\text{ice}}}{k_{\text{ice}}} + \frac{1}{h_o}. \quad (3)$$

where $h_i$is the nucleate boiling coefficient for R404A, $h_o$is the falling-film coefficient for seawater, $k_{\text{ss}}$is the drum thermal conductivity, and $?_{\text{ice}}$is the average ice thickness between scraping events. Using a conservative design value of U, the required area follows from $\dot{Q}=UA?T_{\text{lm}}$. The fabricated drum area is approximately 2.5×the minimum required area, which provides robustness against oil fouling, scraper wear, and elevated ambient temperatures.

2.6. *Condenser, Expansion Device, and Seawater Hydraulics.*

A seawater-cooled coaxial condenser intended for tropical seawater input temperatures of 28–34 °C is used to achieve heat rejection. The condenser was sized for a condensing temperature of up to 45 °C and a fouling safety factor of 2.0 in order to maintain a sufficient driving temperature differential in the worst-case scenario. To provide turbulent, self-cleaning seawater flow while preventing erosion (small diameters) and sedimentation (large diameters), a 3/8-inch (9.52 mm) tube was used. A total coil length of roughly 6 m is used in the final prototype specification.

To offer steady superheat control when the ice layer thickens and the load fluctuates, a thermostatic expansion valve (TXV) was chosen rather than a capillary tube. A Danfoss T2/TES2 valve body with orifice No. 01 offers a nominal cooling capacity close to 1 kW based on R404A design settings (−25 °C evaporation and 45 °C condensing). To avoid liquid carryover, the overall superheat is adjusted to about 10 K and the static superheat is set close to 4 K.

Water distribution achieves an operating recirculation rate close to 150 L/h by using a corrosion-resistant submersible centrifugal pump (≈40 W) with throttling. Incoming makeup water in the sump is pre-cooled by the high recirculation ratio, which also prevents dry patches and guarantees a constant falling film.

2.7. Mechanical Drive System and Scraper Design.

To prevent corrosion and maintain food safety, the scraper is an inside spinning helical/auger blade made of stainless steel. A vector VFD controls the motor-gearbox set to change the ice thickness and drum speed without requiring mechanical changes. With an adjustable range of 4.5–14 rpm (10–30 Hz), nominal operating is roughly 7 rpm at 15 Hz.

The blade–ice contact area and the ice shear strength at below-freezing temperatures are used to estimate the scraping torque. The shaft is sized in torsion, and a conservative ice shear strength is used. The calculated torque safety factor is roughly 5.4, and the chosen solid SS304 shaft diameter is 20 mm. An additional forced-cooling fan is required to maintain thermal stability since low-frequency VFD operation diminishes the motor capacity for self-cooling.

3. Results and Discussion.

3.1. Optimized Refrigeration Cycle Performance.

The prototype cycle achieves a refrigeration effect of 108.14 kJ/kg and a COP of 1.73 under the design condition (−25 °C evaporation, 40–45 °C condensing), according to cycle analysis utilizing the state points in Table 4. The comparable compressor input for a 1.0 kW design evaporator load is roughly 0.58 kW, while the condenser must reject roughly 1.6–1.7 kW. These numbers correspond to the condenser size that the component design aims to achieve. When the drum speed is kept close to 7 rpm and the recirculation rate is throttled to about 150 L/h during prototype operation, stable flake formation is accomplished, resulting in an anticipated steady-state production of 5–6 kg/h (1 kilogram harvested every 10–12 minutes). Before the first complete kilogram is generated, there is a pull-down phase of roughly ten to twelve minutes, which is caused by the stainless drum cooling and the recirculating sump pre-cooling.

Table 4: Summary of key design and performance metrics.

Metric	Value
Evaporation temperature	−25 °C
Condensing temperature	40–45 °C
COP (R404A)	1.73
Design capacity	≈1.0 kW (5–6 kg/h)

Source: Authors.

Figure 3: Actual flake Ice Maker Prototype.

Source: Authors.

3.2. Design for Motion Tolerance and Marine Durability.

The prototype is designed for use in maritime environments, where traditional land-based ice makers may perform worse due to excessive salinity, fouling, and vessel motion. Corrosion resistance, motion tolerance, maintainability, and safe electrical operation are the major design considerations.

- Corrosion control: food-grade stainless steel is used for the ice-contacting drum and structural frame, while copper - nickel tubing and other corrosion-resistant materials are used for the seawater heat-exchanger surfaces, together with facilities for routine cleaning and descaling. Electrical fasteners and enclosures are chosen for saline, humid conditions.
- Motion tolerance: The vertical stationary-drum design lowers the possibility of leaks by doing away with rotational refrigerant seals. Under normal small-vessel pitch / roll conditions, Electrical and thermal safety: the refrigeration and drive systems are designed for operation from standard 220 V supplies or small onboard generators. Thermal protection is included for the compressor, motor, and pumps, and auxiliary motor cooling is implemented for low-frequency VFD operation.
- The suggested device can supply onboard flake ice without relying on shore ice logistics by combining a simplified scraped-surface evaporator, seawater cooling, and locally produced parts. This reduces melt losses and improves catch quality, which directly increases the sale value of fish for artisanal fleets. Local manufacturing also improves spare-part availability and reduces downtime caused by import delays.

Conclusions.

An engineering design and validation process for a small saltwater flake-ice maker that may be installed on small fishing boats was provided in this study. The evaporator and condenser were built to consistently provide a 1 kW-class cooling load in tropical seawater temperatures using a verified R404A vapor-compression cycle and cautious heat-transfer sizing. The scraper drive mechanical calculations showed a strong stainless-steel shaft choice and sufficient torque margin, allowing for steady operation over a useful speed range for regulating ice thickness.

i. Boost energy efficiency by reducing suction-line pressure losses in the evaporator circuit and preserving regulated superheat/subcooling.
ii. Choose marine-appropriate materials for seawater heat exchangers and have cleaning and anode procedures in place to lessen corrosion and fouling. Enhance operational resilience by using a stationary drum (no rotary seals), VFD-based speed control, and fail-safe thermal / electrical protections.

Overall, the proposed design offers a technically feasible and economically accessible pathway to onboard ice production, supporting improved cold-chain integrity and reduced post-harvest losses for artisanal fisheries.

References.

Altinkaynak, M. 2021. Exergetic performance analysis of low-GWP alternative refrigerants for R404A in a refrigeration system. International Journal of Low-Carbon Technologies, 16, 842-850.

Bjorndal, T., Child, A. & Lem, A. (eds.) 2014. Value Chain Dynamics and the Small-Scale Sector: Policy Recommendations for Small-Scale Fisheries and Aquaculture Trade, Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO & Infofish 2008. Present and Future Markets for Fish and Fish Products from Small-Scale Fisheries—Case Studies from Asia, Africa and Latin America. Rome, Italy: Food and Agriculture Organization of the United Nations.

Fu, H., Huang, S., Li, Y., Cheng, J., Guo, Y., Wang, K. & Sun, R. 2024. The research and application of technology and core components in commercial refrigeration and freezing systems: A review. Journal of Stored Products Research, 108, 102400.

Garcia, J. & Semedo, A. 2024. Sustainable CO? refrigeration system for fish cold storage facility using a renewable integrated system with solar, wind and tidal energy for Cape Verde—Analyzing scenarios. Sustainability, 16, 4259.

Liu, L., Chen, Y., Yan, H., Peng, S. & Pan, Y. 2025. Study on performance of seawater-based evaporative cooling integrated with desiccant wheel air-conditioning system for marine vessels. Applied Energy, 389, 125723.

Mellari, S. 2023a. Experimental investigation and modeling of the pressure drop of ice slurry flow in horizontal pipe. International Journal of Refrigeration, 147, 134-142.

Mellari, S. 2023b. Experimental investigation of ice slurry viscosity. International Journal of Air-Conditioning and Refrigeration, 31, 27.

Meng, X., He, Y., He, L., Zhao, C., Wang, L., You, W. & Zhu, J. 2024. A review of the energy-saving potential of phase change material-based cascaded refrigeration systems in the Chinese food cold-chain industry. Energies, 17, 4762.

Piñeiro, C., Barros-Velázquez, J. & Aubourg, S. P. 2004. Effects of newer slurry ice systems on the quality of aquatic food products: A comparative review versus flake-ice chilling methods. Trends in Food Science & Technology, 15, 575-582.

Semedo, A. & Garcia, J. 2025. Harnessing renewable energy sources in CO? refrigeration for eco-friendly fish cold storage. Processes, 13, 2847.

Singha, P., Das, C., Köster, L., Kochunni, S. K., Dasgupta, M. S., Widell, K. N., Bhattacharyya, S. & Hafner, A. 2025. Thermodynamic comparison of various refrigerants for an on-board R290 refrigeration system with economizer subcooling in small fishing boats. Thermal Science and Engineering Progress, 60, 103443.

Widell, K. N. & et al. Energy efficient and climate friendly refrigeration systems onboard fishing vessels. Proceedings of the 26th IIR International Congress of Refrigeration (ICR 2023), 2023 Paris, France. Paper 0450.

Widell, K. N., Svendsen, E. S. & Nordtvedt, T. S. Possibilities of ice slurry systems onboard fishing vessels. Proceedings of the 10th IIR Conference on Ammonia and CO_2 Refrigeration Technologies, 2023 Ohrid, North Macedonia. Paper 0017.

Wittanowski, Ł. 2024. Optimization of an organic Rankine cycle–vapor compression cycle system for electricity and cooling production from low-grade waste heat. Energies, 17, 5566.

Xia, X., Liu, Z., Wang, Z., Zuo, Q. & Sun, T. 2023. Energy, conventional and advanced exergy analysis for the organic Rankine cycle–vapor compression refrigeration combined system driven by low-grade waste heat. Applied Thermal Engineering, 220, 119650.

Yan, M., He, S., Gao, M., Xu, M., Miao, J., Huang, X. & Hooman, K. 2021. Comparative study on the cooling performance of evaporative cooling systems using seawater and freshwater. International Journal of Refrigeration, 121, 23-32.

Yildirim, R., KumaŞ, K., Akyüz, A. Ö. & Güngör, A. 2023. Numerical analysis of using R449A refrigerant alternative to R404A in cooling systems: 3E-analysis—Energetic, exergetic, and environmental. Politeknik Dergisi, 26, 1319-1325.