International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 • Website: www.ijfmr.com • Email: editor@ijfmr.com

Optimization and Control of Regeneration Drier Air Inlet Temperature Using Pec Chiller (Pre-Evaporative Cooling Chiller) At Jsw Vijayanagar Metallics Limited

Bolisetti Ratna Rohini[1], Mrs. P. Rajeswari[2], Mr. Gondela Rakesh[3]

[1]M.Tech. Student, Mechanical Engineering, Sanketika Vidya Parishad Engineering College
[2]Associate Professor, Mechanical Engineering, Sanketika Vidya Parishad Engineering College
[3]Master Technician, Rashtriya Ispat Nigam limited

Abstract
Reliable temperature control is critical to the uninterrupted operation of a cryogenic air separation plant (ASU). The present work evaluates a modification for controlling regeneration drier inlet conditions during high-ambient summer operation by integrating a Pre-Evaporative Cooling Chiller (PEC chiller) with the existing cooling arrangement. The design replaces approximately 25 °C cooling-tower water supplied to the relevant cooling duty with chilled water at 12 °C and increases the E07 water flow from 40 to 45 m³/h. Design-basis calculations from the project data show a 50 m³/h chiller-side flow equivalent to 13.89 kg/s and a measured/design operating temperature reduction from 22.1 °C to 10.8 °C corresponding to a cooling capacity of 656.8 kW (about 187 TR). Using an assumed COP of 5.0, the corresponding compressor power is 131.4 kW and condenser heat rejection is 788.2 kW. A modified cooling analysis further gives 163 kW heat removal in E60, 232.1 kW refrigerant-stage duty, and 395.6 kW total duty for cooling water from 10.8 °C to 4 °C. The pipeline design for 50 m³/h recommends a DN 100 (4 in.) line with insulation and aluminium cladding. The preliminary execution cost for the 2 km pipeline installation, excluding the cost of the pipe itself, is ₹62.48 lakh including 10% contingency. The proposed modification is intended to maintain the regeneration drier inlet air below the critical 25 °C operating limit and thereby improve summer reliability, process stability, and avoidance of ASU shutdowns. The reported performance is design/simulation-based; final validation requires plant trial data after implementation.

Keywords: Cryogenic air separation unit, regeneration drier, PEC chiller, chilled-water pipeline, cooling capacity, E07, energy optimization, plant reliability.

I. INTRODUCTION

Cryogenic air separation plants operate at very low temperatures and depend on reliable removal of heat, moisture, and other contaminants before air enters the cryogenic section. The project considers the regeneration drier section of an industrial ASU, where summer ambient conditions can increase cooling-water temperature and adversely affect the temperature of air entering the drier.

The uploaded project presentation identifies the central problem as insufficient summer cooling when cooling-tower water temperature rises. The proposed engineering modification is to supply PEC-chiller-cooled water at 12 °C instead of approximately 25 °C cooling-tower water and to increase the E07 water flow from 40 to 45 m³/h. The intended operational result is improved temperature control, more reliable regeneration, improved moisture removal, and reduction of ASU trips associated with high drier inlet temperature.

The work is significant because moisture entering a cryogenic section may cause freezing and pipeline choking, while hydrocarbon contamination creates additional process-safety concerns. Therefore, maintaining stable pre-purification and regeneration conditions is essential for reliable production of oxygen, nitrogen, and argon.

II. OBJECTIVES AND RESEARCH GAP

The objectives are: (i) to optimize regeneration drier air inlet temperature by using PEC-chiller-cooled water; (ii) to increase E07 cooling-water flow from 40 to 45 m³/h; (iii) to improve summer reliability and cooling performance; and (iv) to reduce ASU shutdown risk caused by high drier inlet temperature.

The literature summary in the supplied presentation focuses mainly on exergy analysis, process integration, and energy optimization of cryogenic ASUs. The present work addresses a practical plant-level cooling-control application: integration of a PEC chiller with the regeneration drier cooling path. The proposed work therefore connects process reliability with a direct thermal modification at the equipment and piping level.

III. EXISTING AND PROPOSED COOLING ARRANGEMENT

In the existing arrangement, the cooling duty is associated with the plant cooling system and E07. The design problem arises when cooling-tower water temperature increases during summer. The proposed arrangement introduces the PEC chiller as a lower-temperature water source and modifies the flow path so that chilled water can support the relevant E07/E60 cooling duty.

The principal design change is summarized by two operating parameters: water supply temperature is reduced from approximately 25 °C to 12 °C, and E07 water flow is increased from 40 to 45 m³/h. The lower water temperature increases the available driving temperature difference for heat transfer, while the increased flow improves water-side heat-capacity rate.

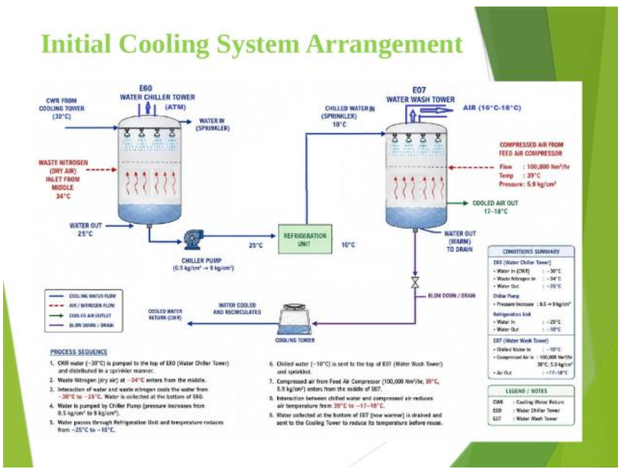

Fig. 1. Existing cooling arrangement reproduced from the project presentation.

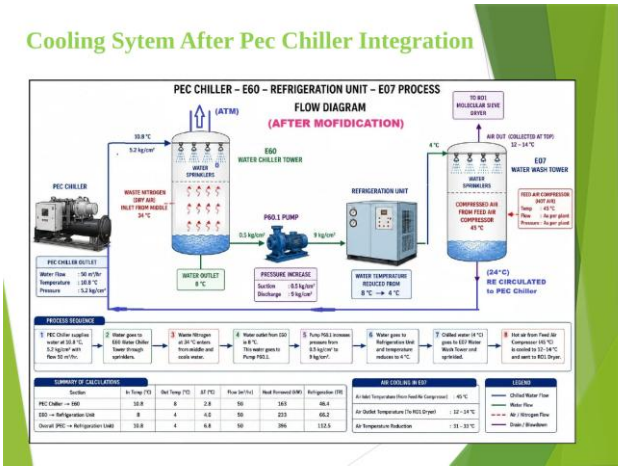

Fig. 2. Proposed PEC-chiller integration reproduced from the project presentation.

IV. DESIGN AND PERFORMANCE CALCULATIONS

A. Chiller operating data

The project operating data for the PEC chiller are: evaporator inlet water temperature 22.1 °C, evaporator outlet water temperature 10.8 °C, evaporator inlet pressure 5.5 kg/cm², evaporator outlet pressure 5.2 kg/cm², condenser inlet temperature 31.2 °C, condenser outlet temperature 34.8 °C, condenser inlet pressure 2.0 kg/cm², condenser outlet pressure 1.5 kg/cm², and water flow rate 50 m³/h.

B. Mass-flow conversion

For water density of approximately 1000 kg/m³,

$\dot{m} = (50 \times 1000) / 3600 = 13.89$ kg/s.

C. Evaporator temperature difference and cooling capacity

$\Delta T\_evap = 22.1 - 10.8 = 11.3$ °C.

Using $\dot{Q} = \dot{m}\, Cp\, \Delta T$ and $Cp = 4.187$ kJ/(kg·°C),

$\dot{Q} = 13.89 \times 4.187 \times 11.3 = 656.8$ kW.

D. Refrigeration capacity

$TR = \dot{Q} / 3.517 = 656.8 / 3.517 \approx 186.7$ TR, reported as approximately 187 TR.

E. Coefficient of performance and compressor power

The project calculation assumes a typical water-cooled chiller COP of 5.0. Therefore,

$W = \dot{Q} / COP = 656.8 / 5 = 131.4$ kW.

The condenser heat rejection becomes

$\dot{Q}\_H = \dot{Q}\_L + W = 656.8 + 131.4 = 788.2$ kW.

F. Pressure drops

Evaporator pressure drop = 5.5 − 5.2 = 0.3 kg/cm².

Condenser pressure drop = 2.0 − 1.5 = 0.5 kg/cm².

These values provide a compact thermal and hydraulic basis for assessing the PEC-chiller operating point.

Parameter	Symbol	Value
Water flow rate	$\dot{V}$ / $\dot{m}$	50 m³/h / 13.89 kg/s
Evaporator inlet temperature	T_ei	22.1 °C
Evaporator outlet temperature	T_eo	10.8 °C
Evaporator ΔT	ΔT_e	11.3 °C

Condenser inlet temperature	T_ci	31.2 °C
Condenser outlet temperature	T_co	34.8 °C
Condenser ΔT	ΔT_c	3.6 °C
Cooling capacity	Q̇_L	656.8 kW
Refrigeration capacity	TR	≈187 TR
Compressor power	W	131.4 kW
Condenser heat rejection	Q̇_H	788.2 kW
COP (assumed)	COP	5.0
Evaporator pressure drop	ΔP_e	0.3 kg/cm²
Condenser pressure drop	ΔP_c	0.5 kg/cm²

TABLE I. PEC CHILLER PERFORMANCE SUMMARY

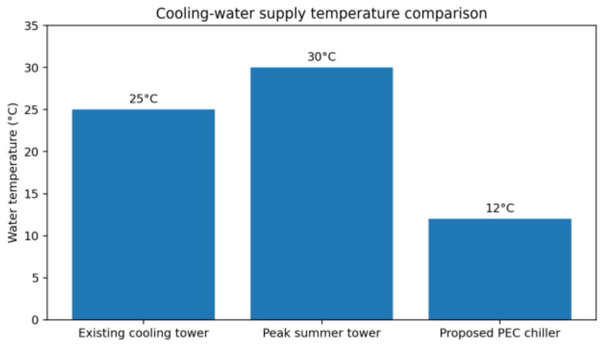

Fig. 5. Comparison of existing, peak-summer, and proposed PEC cooling-water supply temperatures.

V. MODIFIED COOLING DUTY ANALYSIS

The modified design data in the project evaluate water cooling and refrigerant duty after the proposed modification.

A. E60 cooling duty

Water is considered to cool from 10.8 °C to 8 °C. Thus,

$\Delta T\_E60 = 10.8 - 8 = 2.8$ °C,

$\dot{Q}\_E60 = 13.89 \times 4.187 \times 2.8 \approx 163$ kW.

B. Refrigerant-stage cooling duty

For water cooling from 8 °C to 4 °C,

$\Delta T\_ref = 4$ °C,

$\dot{Q}\_ref = 13.89 \times 4.187 \times 4 \approx 232.1$ kW.

The corresponding refrigeration capacity is approximately

$TR\_ref = 232.1 / 3.517 \approx 66.0$ TR.

C. Total cooling from PEC outlet to refrigeration outlet

For cooling water from 10.8 °C to 4 °C,

$\Delta T\_total = 6.8$ °C,

$\dot{Q}\_total = 13.89 \times 4.187 \times 6.8 \approx 395.6$ kW,

$TR\_total = 395.6 / 3.517 \approx 112.5$ TR.

D. Air-temperature reduction target

The project design notes an air inlet temperature of approximately 45 °C and an intended outlet temperature range of 12–14 °C. Using an average target of 13 °C,
$\Delta T\_air = 45 - 13 = 32$ °C.
This illustrates the magnitude of cooling improvement intended for summer operation.

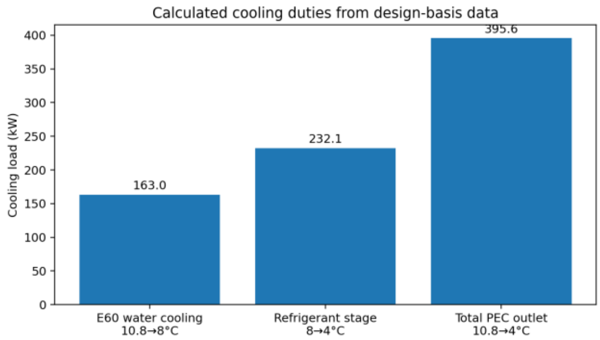

Fig. 7. Design-basis cooling duties calculated from the modified temperature ranges.

VI. CHILLED-WATER PIPELINE DESIGN

The pipeline design is based on a water flow rate of 50 m³/h, equivalent to 0.01389 m³/s. The selected design velocity is 1.5 m/s.
The required flow area is
$A = Q/v = 0.01389/1.5 = 0.00926$ m².
For a circular pipe,
$D = \sqrt{(4A/\pi)} \approx 0.1086 \text{ m} \approx 108$ mm.
The project therefore recommends a standard DN 100 (4 in.) line. Using an illustrative internal diameter of 0.102 m, the independent velocity check gives approximately 1.70 m/s, which remains within the stated recommended design range of 1.0–2.0 m/s. Final internal diameter and velocity should be confirmed against the selected pipe schedule and actual material specification.
Because chilled-water piping is exposed to condensation risk, the project recommends 25 mm minimum indoor insulation and 40–50 mm insulation for hotter outdoor exposure, with suitable closed-cell or wool insulation and approximately 0.8 mm aluminium cladding. The preliminary design recommends SCH 40, with final schedule selection subject to pressure rating and applicable piping standards.

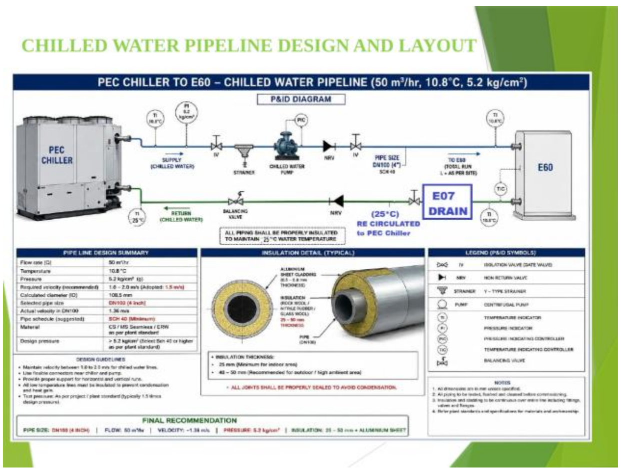

Fig. 3. Chilled-water pipeline design and layout reproduced from the project presentation.

VII. COST ESTIMATION

The preliminary execution estimate is based on a PEC-chiller-to-E60 pipeline length of approximately 2000 m, eight bends, and an elevation of approximately 12 ft (3.66 m). The cost estimate includes erection, welding, consumables, supports, insulation, aluminium cladding, equipment deployment, scaffolding, handling, testing, painting, and safety arrangements.

The itemized base execution estimate totals ₹56.80 lakh. Applying a 10% contingency of ₹5.68 lakh gives an estimated execution cost of ₹62.48 lakh. As stated in the project presentation, this estimate is for installation, insulation, and cladding activities and does not include the actual cost of the 2000 m pipe itself. The final capital estimate should therefore add pipe procurement, valves, instrumentation, tie-in shutdown costs, engineering, commissioning, and taxes as applicable.

The manpower plan is approximately 51–52 persons, with an estimated duration of 35–45 working days when two work fronts operate simultaneously.

Item	Amount (₹ lakh)
Pipe erection, alignment & fit-up	9.00
Welding & joint fabrication	7.00
Grinding/cutting/consumables	1.50
Pipe supports & clamps	3.00
Glass-wool insulation	10.00
Aluminium sheet cladding	11.00
Crane/Hydra deployment	4.80
Welding machines/tools	2.00
Scaffolding/working at height	2.50
Material handling/transportation	2.00
Testing & inspection	1.50
Painting/touch-up/misc.	1.50
Safety/PPE/temp. facilities	1.00
Subtotal	56.80
10% contingency	5.68
Estimated execution cost	62.48

TABLE II. PRELIMINARY PIPELINE EXECUTION COST

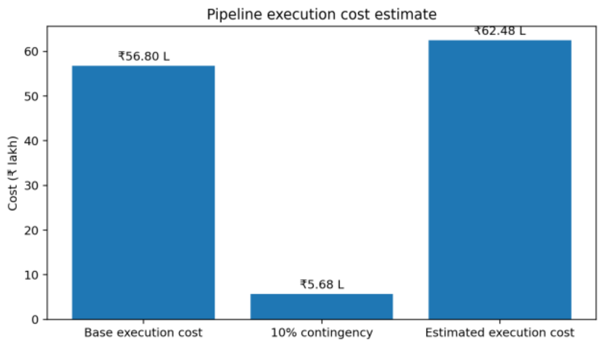

Fig. 8. Preliminary execution cost and contingency.

VIII. RESULTS, OUTCOME, AND DISCUSSION

The proposed design produces a substantial reduction in cooling-water supply temperature from approximately 25 °C to 12 °C, while increasing E07 flow by 12.5%. The temperature reduction increases the available thermal driving force and is expected to support stable drier inlet conditions during peak ambient periods.

The principal calculated chiller performance values are 656.8 kW cooling capacity, approximately 187 TR refrigeration capacity, COP 5.0 (assumed), 131.4 kW compressor power, and 788.2 kW condenser heat rejection. The modified-duty calculations give 163 kW for E60 cooling, 232.1 kW for the refrigerant stage, and 395.6 kW for the total 10.8-to-4 °C cooling duty.

The process outcome targeted by the project is to maintain the regeneration drier inlet air below the 25 °C operating limit referenced in the project material. This is expected to improve ASU reliability and reduce summer shutdown risk. However, the supplied final PPT explicitly labels the graphical results as simulation/design-basis data; therefore, these results should not be interpreted as post-implementation measured performance. A field trial should record ambient temperature, E07 inlet/outlet water temperature, water flow, drier inlet air temperature, chiller power, pressure drops, and ASU trip history before and after modification.

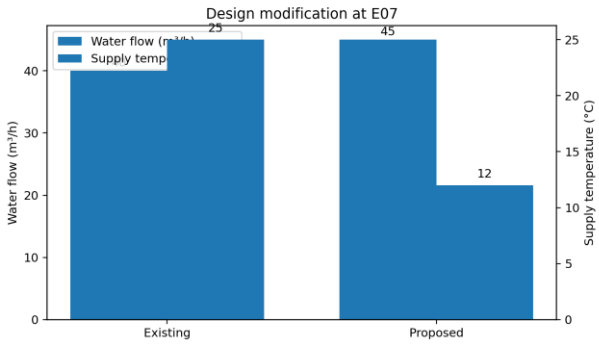

Fig. 6. Design comparison of E07 water flow and supply temperature.

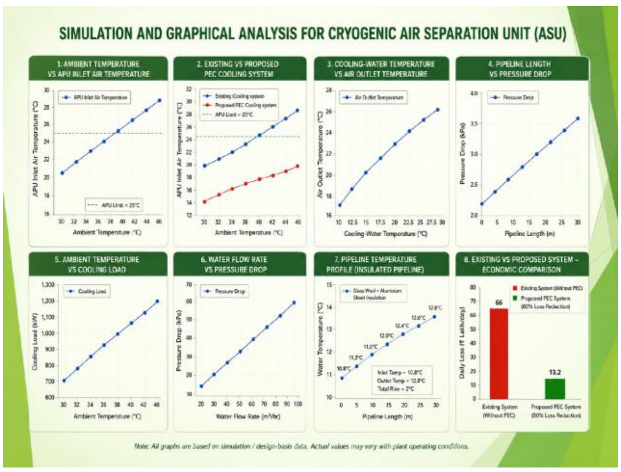

Fig. 9. Simulation and graphical analysis reproduced from the project presentation; actual values require plant validation.

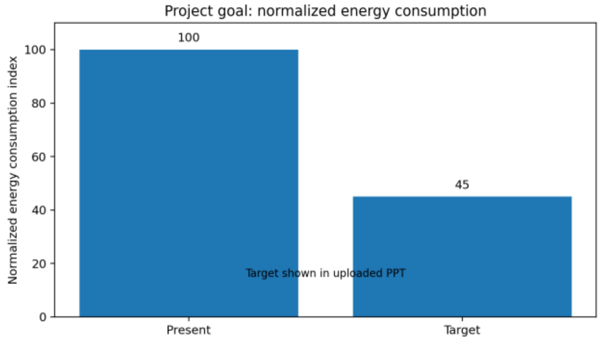

Fig. 10. Normalized present and target energy-consumption index as shown in the project goal slide.

IX. IMPLEMENTATION AND VALIDATION PLAN

A practical implementation sequence is: approval of modification, detailed data collection and literature review, drawing and material preparation, procedure preparation, trial implementation, and performance monitoring. Before permanent commissioning, the pipeline should undergo applicable inspection and pressure testing, insulation inspection, leak checks, and functional verification of pumps and chiller controls.

For validation, the recommended key performance indicators are: (i) drier inlet air temperature; (ii) E07 water supply and return temperature; (iii) water flow rate; (iv) chiller electrical power; (v) cooling capacity calculated from measured flow and temperature difference; (vi) evaporator and condenser pressure drops; and (vii) ASU trip frequency during comparable summer operating periods.

X. CONCLUSION

A practical cooling-system modification for a cryogenic ASU has been developed using the design data supplied in the final project presentation. The modification combines a reduction in cooling-water supply temperature from approximately 25 °C to 12 °C with an increase in E07 water flow from 40 to 45 m^3/h. The design-basis performance calculations indicate a PEC-chiller cooling capacity of 656.8 kW (approximately 187 TR), an assumed COP of 5.0, compressor power of 131.4 kW, and condenser heat rejection of 788.2 kW.

The modified cooling analysis indicates 163 kW E60 duty, 232.1 kW refrigerant-stage duty, and 395.6 kW total cooling duty for the stated modified temperature range. A DN 100 chilled-water line with appropriate insulation and aluminium cladding is recommended for the 50 m^3/h design flow. The preliminary installation, insulation, and cladding cost is ₹62.48 lakh including contingency, excluding the pipe procurement cost.

Overall, the design is technically oriented toward maintaining the regeneration drier inlet below the project’s 25 °C operating limit and improving summer ASU reliability. The next essential step is plant trial implementation and measured validation of thermal performance, energy consumption, and shutdown reduction.

REFERENCES

1. Hamayun et al., “Cryogenic air separation unit configurations using exergy analysis,” Energies, vol. 13, no. 23, p. 6361, 2020, doi: 10.3390/en13236361.

2. Young et al., "Design and evaluation of an energy-efficient cryogenic air separation unit," Industrial & Engineering Chemistry Research, vol. 60, no. 35, pp. 12801–12814, 2021, doi: 10.1021/acs.iecr.1c02818.
3. Bucșa et al., "Detailed exergetic analysis of an industrial cryogenic air separation unit," Processes, vol. 24, no. 2, p. 272, 2022, doi: 10.3390/pr10020272. (Bibliographic details reproduced from the supplied PPT literature-review slide.)
4. Mora et al., "Exergy-based multi-objective optimization of an industrial cryogenic air separation unit," Energy, vol. 268, p. 126654, 2023, doi: 10.1016/j.energy.2023.126654.