GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Engineering

Level: PG

Branch: Cryogenic Engineering

Subject Code : ME02074041

Subject Name : Advanced Cryocoolers

w. e. f. Academic Year:	2024-25
Semester:	2
Category of the Course:	PCC

Prerequisite:	Basic knowledge of Cryogenic Refrigeration Systems

Course Outcome:

On successful completion of the course, the students will be able to

No	Course Outcomes	RBT level
1	Learn about various cryocoolers, their selection, design parameters and applications.	Apply
2	Have in-depth knowledge of Pulse tube cryocoolers, different geometries for different temperature ranges and their applications.	Understand
3	Gain knowledge of heat exchangers used in cryocoolers and recent regenerative materials.	Apply
4	Learn about cryocoolers used for very low temperature application	Apply
5	Summarize various applications of cryocoolers	Analyze

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE (E)	PA / CA (M)	PA/CA (I)	ESE (V)	
3	0	2	4	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1	**Cryocoolers:** Classification and working of cryocoolers, Thermodynamics of cryocooler,Ideal working Cycles- Regenrative and Recuperative cycles. Selection and comparison of different types of cryocoolers, Important parameters	3	5

	– mass, volume, vibration, acoustic noise, electromagnetic interface, operating life, technical parameters - cooling effect, compressor power requirement, cooling water requirement, service requirement of compressor, Vibration control, Steady flow and oscillating flow cryocoolers		
2	**Heat Exchanger in cryocoolers and regenerative materials:** Different types of heat exchangers used in cryocoolers, Design of Recuperative and Regenerative heat exchangers. Regenerators for very low temperature application, Hausen Regenerator, performance parameters - Reduced-Length, Reduced-Period Method, Heat Pipes in cryocoolers. Regenerator material analysis and material development, High heat capacity magnetic regenerator alloy material, Manufacturing considerations of rare earth powder used in cryocooler	5	10
3	**Vuilleumier Cryocooler:** Thermodynamic aspects, cycle of operation, heat transfer losses, VM coolers variations, accessories and components, Spilt Vuilleumier cryocooler**.**	5	10
4	**Gifford McMahon, Solvay and Postle Cryocooler:** Multiple Expansion G-M cryocooler, Combined G-M and JT expander, Advantages and disadvantages of G-M cryocooler, Design of two stage G-M cryocooler, Efficiency of pressure oscillators, 4K operation, improved valve timing, Application of GM Cooler.	5	15
5	**Stirling Cryocooler:** First order analysis Stirling cycle, Second order analysis, Third order analysis , Loss analysis, Comparison of Stirling and Carnot cycle, Design and optimization of Stirling Cryocoolers, Performance and reliability improvement of low-cost Stirling cooler, Analysis of Stirling Cycle, Multi stage Cryocooler, hybrid cooler, Miniature Stirling cryocooler, Linear compressor design.	5	15
6	**Pulse tube Cryocoolers:** Advantages and disadvantages of pulse tube cryocooler, Geometry of pulse tube U-tube, co-axial, in-line, two stage pulse tube refrigerator design, Thermoacoustically driven pulse tube refrigerator, Different methods of analysis, Phasor analysis, Oscillating flow behavior of PTR, Valve timing effect on Performance of 4K pulse tube cryocooler. Low vibration flexure bearing compressor, Miniature 50K to 80K space application of PTR, Experimental characteristics of PTR, Effect of D.C. flow, Active phase control of Stirling type PTR, Expansion efficiency considering shuttle heat transfer, Characteristics of Double inlet PTR, Experimental study and analysis of components of orifice pulse tube refrigerator Theoretical model of G-M type pulse tube refrigerator, Performance of single stage pulse tube, some of the phase shifting types of two stage G-M type pulse tube refrigerator, Small He^3 PTR Multi stage pulse tube cooler 4 K technology, Space pulse tube Cryocooler development.	9	20

7	**J-T Cooler:** Advantages and disadvantages of J-T cooler, Recent advances – Mixed refrigerant, Sorption compressor, Electrochemical compressor, Mixture properties, Cool down characteristics miniature J-T cooler , Liquefaction of nitrogen using mixed refrigerant, Further development ,Liquefaction of other gases, Modern trends in throttle cryocooler operating with mixed gas.	5	10
8	**Very Low Temperature Cooling System, Dilution Refrigerator:** He^3 refrigerators, $He^3 – He^4$ Dilution refrigerators, Progress in microgravity Dilution refrigerator, Pomeranchuk cooling, Magnetic Refrigerators - Its development and its utility in magnetic hydrogen liquefier.	5	10
9	**Applications of Cryocoolers** – military, environmental, commercial, medical, transportation, energy, police, and security.	3	5
	Total	**45**	**100**

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
20	**40**	**30**	**10**	**0**	**0**

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

References/Suggested Learning Resources:

(a) Books:

1. Cryocoolers by G. Walker
2. Cryocoolers Volumes (Proceedings of International Cryocooler conference)
3. Journal 'Cryogenics' published by Elsevier available at www.sciencedirect.com
4. Advances in Cryogenic Engineering. (Proceedings of International Cryogenic Engineering Conference)

(b) Open-source software and website:

1. Cryogenic Engineering by M D Atrey (NPTEL) nptel.ac.in/courses/112/101/112101004/

Suggested Course Practical List:

1. Comparative study of important and technical parameters of different Cryocoolers.
2. Preparation of theoretical model for generalized design of cryocoolers.
3. Detailed study (Design aspects) of cryocoolers for different applications.
4. Detail study of properties of different recent regenerator materials.
5. Study of analysis of Stirling cryocooler
6. Study of theoretical model of G-M type pulse tube cryocooler.

7. Comparative study of different geometry of pulse tube refrigerators.

Suggested Activities for Students: Students are required to download 3-5 research papers from reputed international journals on the recent advancement in the areas of cryogenics. They need to go through the same and prepare a review for the research papers.

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