GUJARAT TECHNOLOGICAL UNIVERSITY

MECHANICAL (CRYOGENIC ENGINEERING) (10)
ADVANCED CRYO COOLER
SUBJECT CODE: 2731002
M.E. 3rd SEMESTER

Type of course: Major elective

Prerequisite: Nil

Rationale: Student should have basic idea about the thermodynamic cycle of the cryo cooler.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks						Total Marks
				Theory Marks		Practical Marks				
L	T	P	C	ESE (E)	PA (M)	ESE (V)		PA (I)		
						ESE	OEP	PA	RP	
3	2#	2	5	70	30	20	10	10	10	150

Content:

Sr. No.	Content	Total Hrs	% Weightage
1	**Cryo coolers:** Classification of cryo coolers, Working of cryo coolers, Selection of cryocooler and comparison of different types of cryo coolers, Ideal working Cycles, Important parameters –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 cryo coolers, Different types of at exchangers, Applications of Cryo coolers – military, environmental, commercial, medical, transportation, energy, police and security.	2	20
2	**Gifford McMahon Cryo cooler:** Advantages and disadvantages of G-M cryo cooler, Design of two stage G-M cryo cooler ,Efficiency of pressure oscillators, 4K operation, improved valve timing, Application of GM Cooler.	1	15
3	**Stirling Cryo cooler:** First order analysis Stirling cycle, Second order analysis, Third order analysis , Loss analysis, Comparison of Stirling and Carnot cycle, Design and optimization of Stirling Cryo coolers, Performance and reliability improvement of low cost Stirling cooler, Analysis of Stirling Cycle, Multi stage Cryo cooler, hybrid cooler, Miniature Stirling cryocooler, Linear compressor design.	3	10
4	**Pulse tube Cryo coolers:** Advantages and disadvantages of pulse tube cryo cooler, 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 behaviour of PTR, Valve timing effect on	3	20

	Performance of 4K pulse tube cryo cooler. Low vibration flexure bearing compressor, Miniature 50 k to 80 K 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, Co-axial PTR for high Tc- SQUID, 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, High frequency pulse tube cryo cooler with base temperature below 20 K, Performance of single stage pulse tube, Some of the phase shifting types of two stage G-M type pulse tube refrigerator, Small He3 PTR Multi stage pulse tube cooler 4 K technology.		
5	**Space pulse tube Cryo cooler development :** Miniature pulse tube cryo cooler for space, High frequency pulse tube cooler, High performance cryo cooler compressor, Vibration reduction in balanced linear compressor, G-M type pulse tube cryo cooler.	1	5
6	Regenerator material analysis and material development Ductile, High heat capacity magnetic regenerator alloy material, Manufacturing considerations of rare earth powder used in cryo cooler.	1	5
7	**Dilution Refrigerator:** Electrically driven 4 He circulating dilution refrigerator, Progress on microgravity Dilution refrigerator	1	5
8	**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 cryo cooler operating with mixed gas.	2	10
9	**Magnetic refrigerator:** Magnetic refrigerator –Its development and its utility in magnetic hydrogen liquefier.	1	5
10	Government Cryo cooler development program Military space cryogenic cooling requirement, Linear drive Cryo cooler for weapon system, Cryo cooler reliability.	1	5

Reference Books:

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

Course Outcome:

After learning the course the students should be able to:

Miniaturization of pulse tube cooler, Recent advances –Mixed refrigerant, Sorption compressor, Electrochemical compressor. Student should be aware of government space programme.

Important design parameters and technical parameters of different cryo coolers, Student will learn about cryo cooler selection. Different new regenerator material ,Miniaturization of stirling cryo coolers, Linear compressor design, Applications of different geometry of pulse tube cryo coolers, Thermoacoustically driven pulse tube refrigerator, Different methods of analysis, Phasor analysis , Oscillating flow behaviour of PTR, Valve timing effect on Performance of 4K pulse tube cryo coolers , Miniature 50 k to 80 K 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, Co-axial PTR for high Tc- SQUID, Characteristics of Double inlet PTR, High frequency pulse tube cryo cooler with base temperature below 20 K, Numerical and experimental study of Rotary valve for pulse tube, Multi stage pulse tube cooler 4 K technology.

List of Experiments:

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

Design based Problems (DP)/Open Ended Problem:

Student should critically study two research papers on any one topic and should prepare report and make presentation

Major Equipment: Pulse tube cryo coolers, G.M.Cryo cooler, Stirling Cryo cooler

List of Open Source Software/learning website: NPTEL