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JOHN F. KENNEDY SPACE CENTER
UNIVERSITY OF CENTRAL FLORIDA

STUDY AND DEVELOPMENT OF AN AIR CONDITIONING SYSTEM OPERATING ON A MAGNETIC HEAT PUMP CYCLE

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Ms. Kari Baird's enthusiasm and helpfulness was very much appriciated.

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ABSTRACT

This report describes the design of a laboratory scale demonstration prototype of an air conditioning system operating on a magnetic heat pump cycle.

Design paramters were selected through studies perfromed by using a KSC System Simulation Computer Model.

The heat pump consists of a rotor turning through four magnetic field area created by permanent magnets. Gadolinium was selected as the working material for this demonstration prototype. Rotor was designed to be constructed of flat parallel disks of gadolinium with very small space in between. The rotor rotates in an aluminum housing. The laboratory scale demonstration prototype are designed to provide theoretically an efficiency of 62% of Carnot cycle and a Coefficient of Performance of 16.55.

SUMMARY

The objectives of the project are: (a) to complete the design of a laboratory scale demonstration magnetic heat pump prototype utilizing a KSC System Simulation Computer Model, (b) to provide engineering drawing of the prototype, and (c) to evaluate the design and begain fabrication of the demonstration prototype.

The heat pump consists of a rotor turning through four magnetic field area created by permanent magnets. Permanent magnets are selected for its considerably less expensive than with superconducting magnets for demonstration purposes. Rotor was designed to be constructed of flat parallel disks of gadolinium with very small spaces in between. Gadolinium was selected as the working material for its convenient room temperature Curie point of 293K. Parallel flat plates provide good heat transfer and maximize the ratio of heat transfer coefficient to pressure drops. The rotor rotates in an aluminum housing. Aluminum is nonmagnetic. The laboratory scale demonstration prototype was designed to provide theoretically an efficiency of 62% of Carnot cycle and a Coefficient of Performance of 16.55.

I. INTRODUCTION

The use of Freon gas-cycle to provide refrigeration and space heating has broad application in industry and for domesticluse in this country. Research has shown that the release of Freon into the atmosphere will deteriorate the ozone layer in the earth's atmosphere. As a result, research has begun to try to limit or eliminate the use of Freon for refrigeration purposes. One alternative to consider is the magnetic heat pump.

NASA Kennedy Space Center has initiated the development of an air conditioning system operating on a magnetic heat pump cycle. The project is being managed by Mr. Frand S. Howard of DM-MDE-11. The preliminary study of a laboratory scale demonstration prototype has been completed. The design and fabrication of this prototype is proposed to be continued during the 1991 NASA/ASEE Summer Faculty Fellowship Program.

1.1 Concept Description

Many configurations of magnetic heat pump have been studied; they are rotory, reciprocating, and those in which working material is stationary and the magnetic field is switched on and off. Studies have shown rotary recuperative devices to have significant advantage over the others.

The rotory magnetic heat pump consists of a rotor of magnetic working matrial with flow passages to allow heat transfer fluid to move through the rotor in thermal contact with the magnetic material. The rotor moves in a housing with ports for fluid to enter and exit the system as shown in Fig, I. The cycle executed as follows:

(1) Fluid is pumped into the housing at point 1. Fluid flow through rotor to point 2 and 4 with most fluid flows to 2.

(2) Fluid entering at 3 flows to 4 and 2 with most fluid flows to 4.

(3) Between 1 and 2 rotor becomes magnetized and heats up. Fluid flowing between 1 and 2 with the rotor removes most of the heat of magnetization of the working material and transferred to the load.

(4) In the constant magnetic field region from 2 to 3 working material is cooled against colder fluid entering at 3.

(5) From 3 to 4 working material demagnetizes while absorbing heat from the fluid.

(6) The rotor traveling from 4 to 1 is heated by fluid flowing from 1 to 4.

(7) Recuperative heating of the working material from 4 to 1 and recuperative cooling

from 2 to 3 are essential for obtaining large temperature lifts with an efficient magnetic cycle.

A KSC System Simulation Computer Model and other documentations and data were utilized to the design of the laboratory prototype.

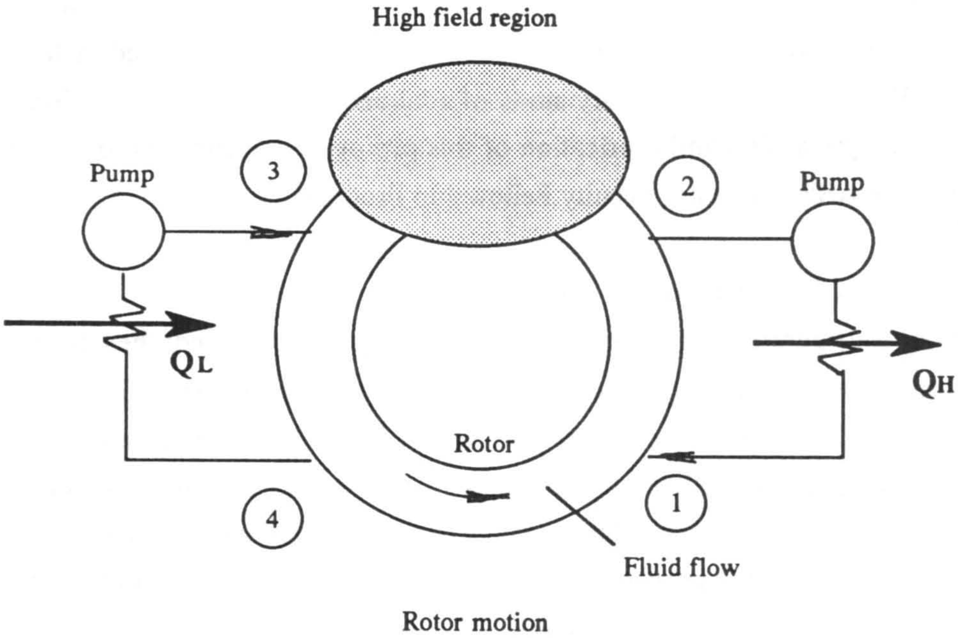


Fig. I Flow Schematic

II THE DESIGN OF HEAT PUMP PROTOTYPE

The design of the magnetic heat pump laboratory demonstration prototype configurations are basically done by utilyzing a KSC system simulation computer model.

2.1 The KSC System Simulation Computer Model

Structured programming

Forty separate subroutines for the following functions:

- Refrigerant entropy calculation and table building
- Refrigerant entropy from calcualated table
- Recuperator fluid data
- Heat transfer correlations
- presure drop correlations
- Adiabatic temperature rise
- Data impuit and output
- Plotting and iteration control

2.2 Use of the System Simulation Computer Model

This model is an interactive computer progaram to simulate the performance of a rotor recuperative magnetic heat pump. The computer prompts for data to define the heat pump configuration. After all data values are entered, the program prompts for the name of file containing entropy data. This file contains entropy data for various working materials and MAPS of magetic field profiles to allow simulation of heat pump with any circumferential field variation. The program also prompts for the name of a file containing recuperator fluid data. The current file contains data for several recuperator fluids. The program will print out a summary of heat pump configuration and performance. The computer will then ask for increment rotation time. This is useful for comparing one heat pump to another since each may have optimum performance at different speeds. If rotation time increment are given, a plot file will be created and an efficiency versus power density will be plotted. After runs for speeds entered are completed other variables can be changed until desirable configurations of the magnetic refrigerator found by computer iterations.

2.3 Data Input and Results of Design

Data Input:

Core Material: GDTC293
Recuperator Material: Water
Core Type: Plate
Rotor OD: 0.1524m
Rotor ID: 0.1379m
Core Hight: 0.0254m
Plate Thickness: 0.762D-04
Plate Spacing: 0.127D-03
Source Temperature: 282K
Delivery Temperature: 293K
High Field: 1
Low Field: 0
Rotation Time: 8 Sec.
Cycle/Revolution: 4

Anticipated Results:

COP W/0 Cryocooler: 16.55
Efficiency: 62.15 %Carnot
Power Density: 354.16 W/Kg
Fluid Flow Rate: 0.46701E-01 Kg/s

2.4 The Design

The laboratory scale demonstration prototype is intended to demonstratrate high efficiency greater than 50% of Carnot cycle, and to verify that the design concept is physically operable.

2.4.1 Design Parameters

Design parameters were selected by using the KSC system simulation computer model. The working material is gadolinium. Gadolinium is used because its room temperature Curie point of 293 K is convenient and because gadolinium is malleable and well characterized thermodynamically. The heat pump consists of a rotor turning through four permanent magnets. Working material executes four complete thermodynamic cycles each revolution instead of one as illustrated in Fig. I. Permanent magnets are used because demonstration of the heat pump with permanent magnets is considerably less expensive than with superconducting magnets. Peak fields are about 1.0 T. The rotor is constructed of flat disks of gadolinium with very small gaps in between. Actual disk and gap thickness were selected by using the computer model. Rotor disks are parallel to the plane of rotation because they are simpler to manufacture and assemble. The magnetic field is applied parallel to plates to minimize the demagnetization field of the magnetic working material. The width of the rotor is designed to be only 1/4 inch to minimize the permanent flux gap. The stacked hight of gadolinium disks is one inch. Rotor turns in an aluminum housing that provids bearing races and flow ports. Aluminum is used because it is nonmagnetic and easy to machine.

The sketch of magnetic heat pump, pictorial sketch of magnetic heat pump housing, prototype assembly sketch, and selected drawings are shown in the list of illustrations section.

III CONCLUSION

This design is intended to demonstrate anticipated efficiency of the laboratory scale prototype and to verify the design is physicslly operable. It is not a device designed for practical services. Permanent magnets (peak field strength are about 1 Tesla) are selected for its less expensive than superconducting magnets (peak field strength are about 7-9 Tesla) for demonstration purposes.

The laboratory scale demonstration prototype will be fabricated and tested at Kennedy Space Center. Analysis of test results are not available at the present time.

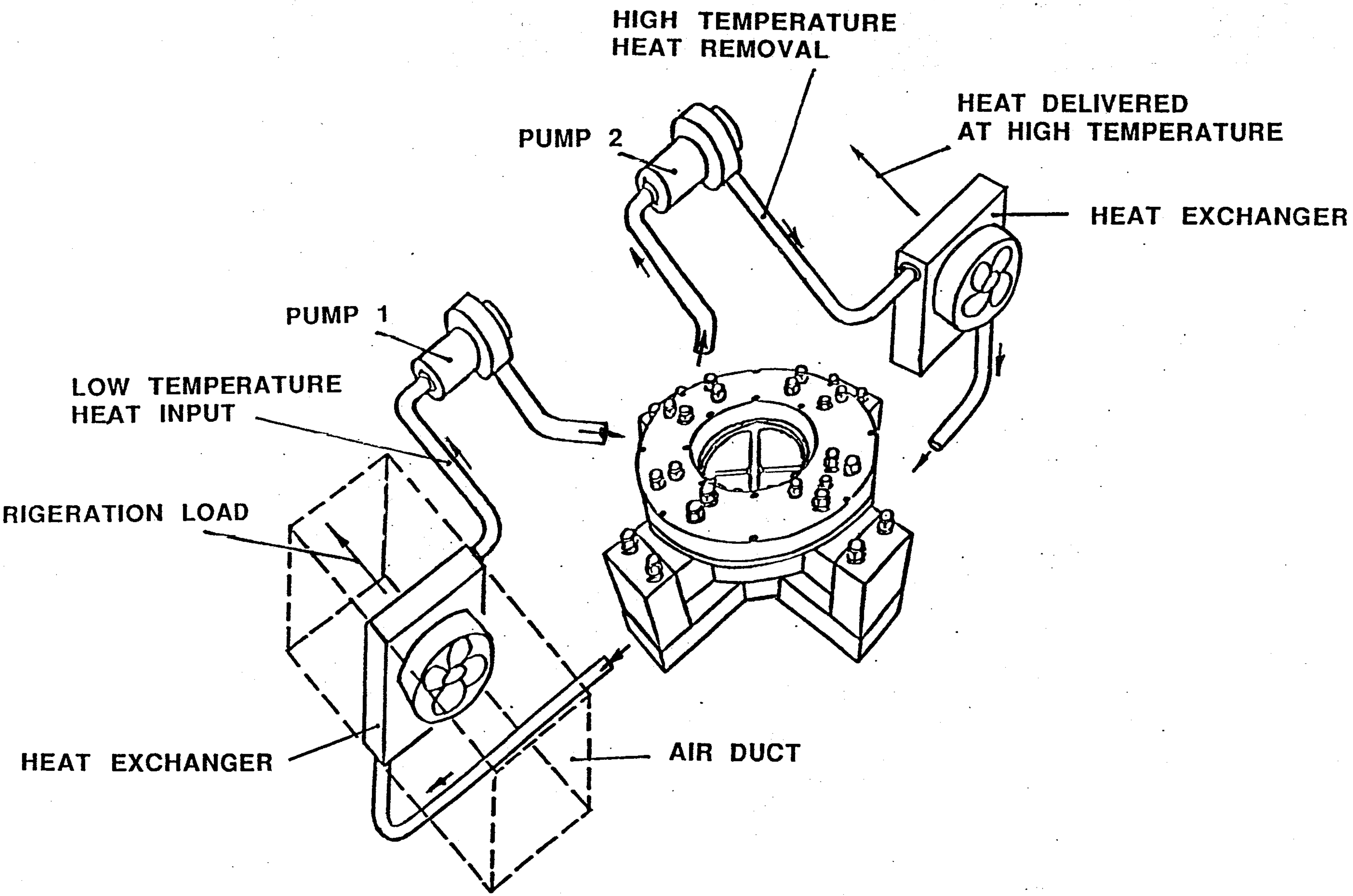


FIG 1 - SKETCH OF MAGNETIC HEAT PUMP

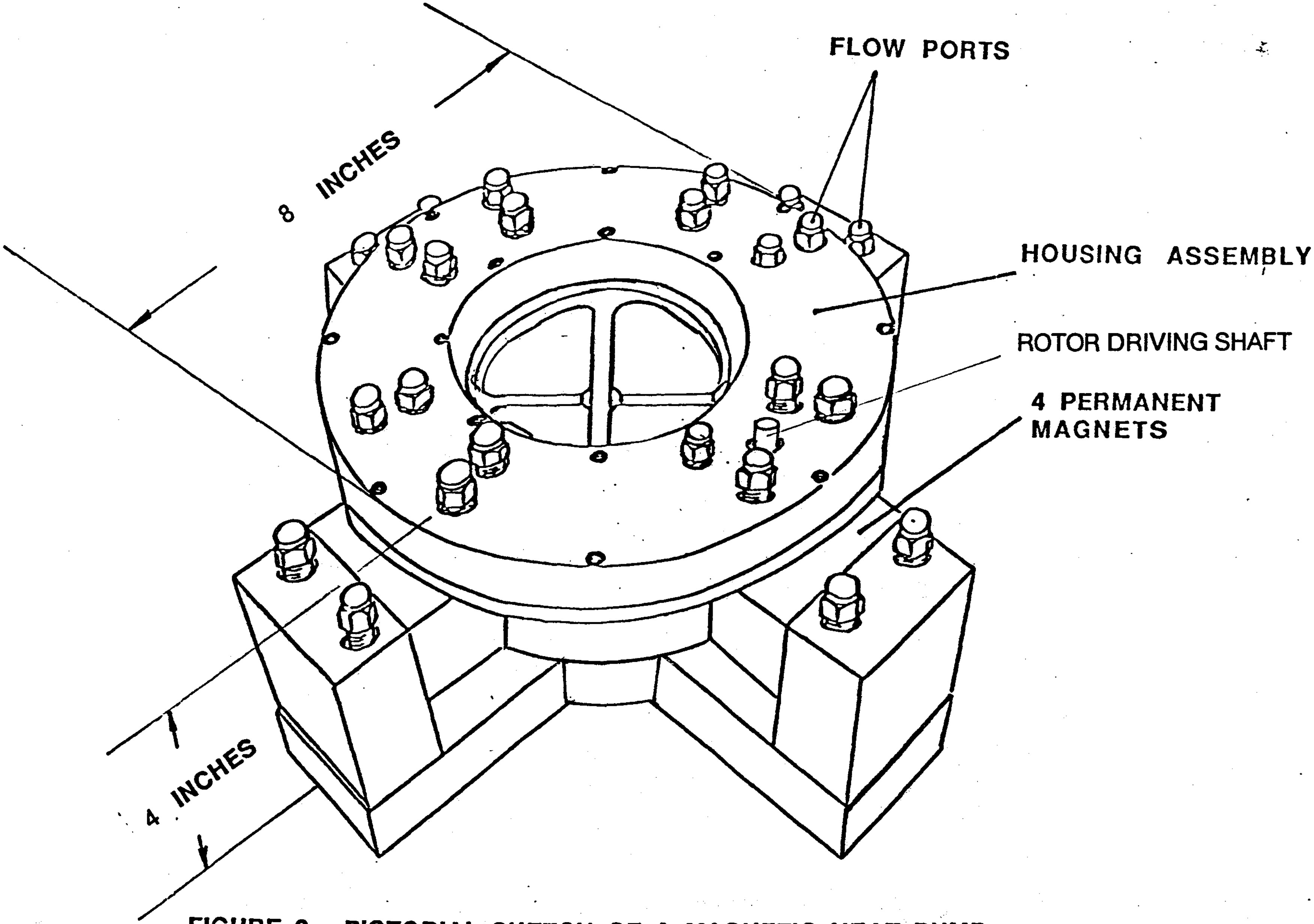


FIGURE 2 - PICTORIAL SKETCH OF A MAGNETIC HEAT PUMP HOUSING ASSEMBLY

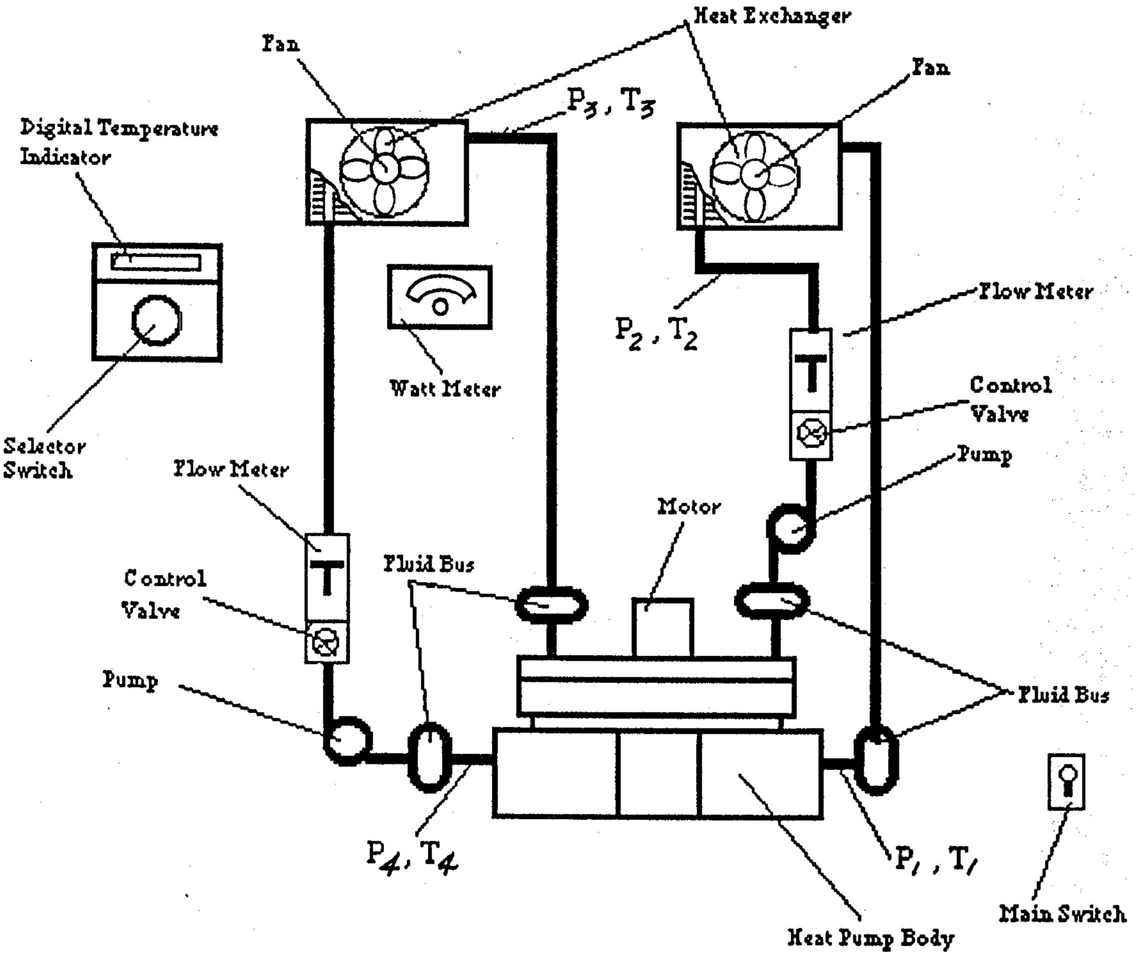
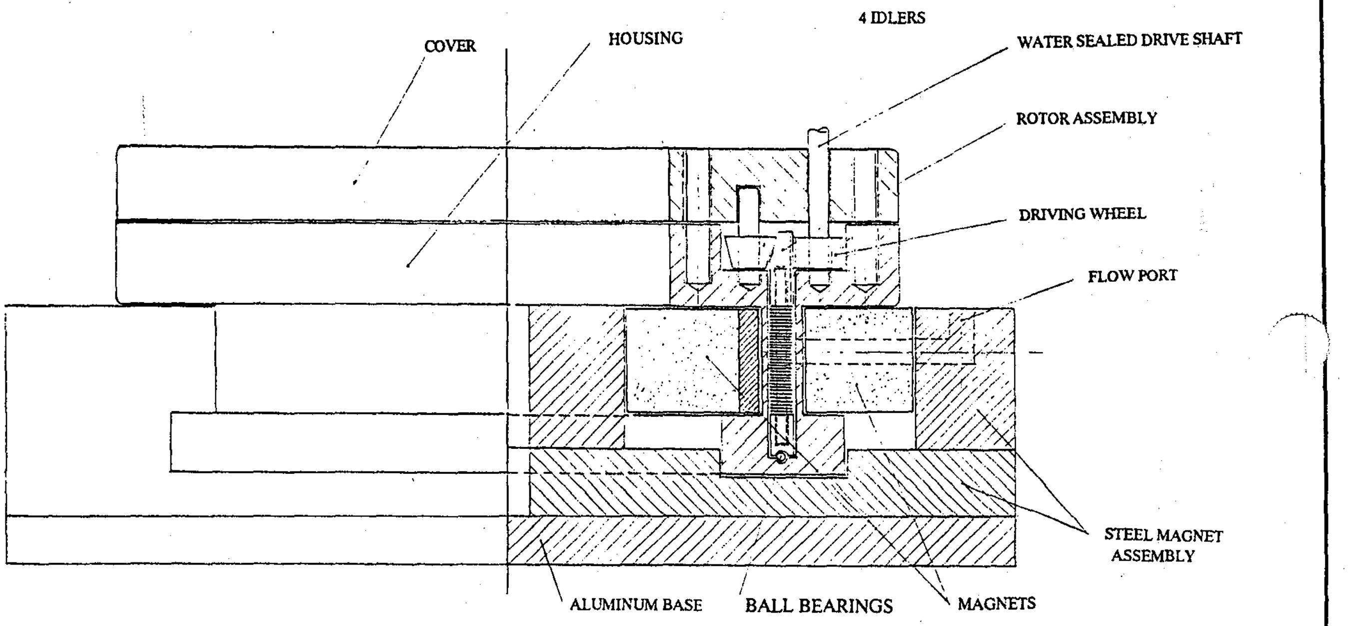
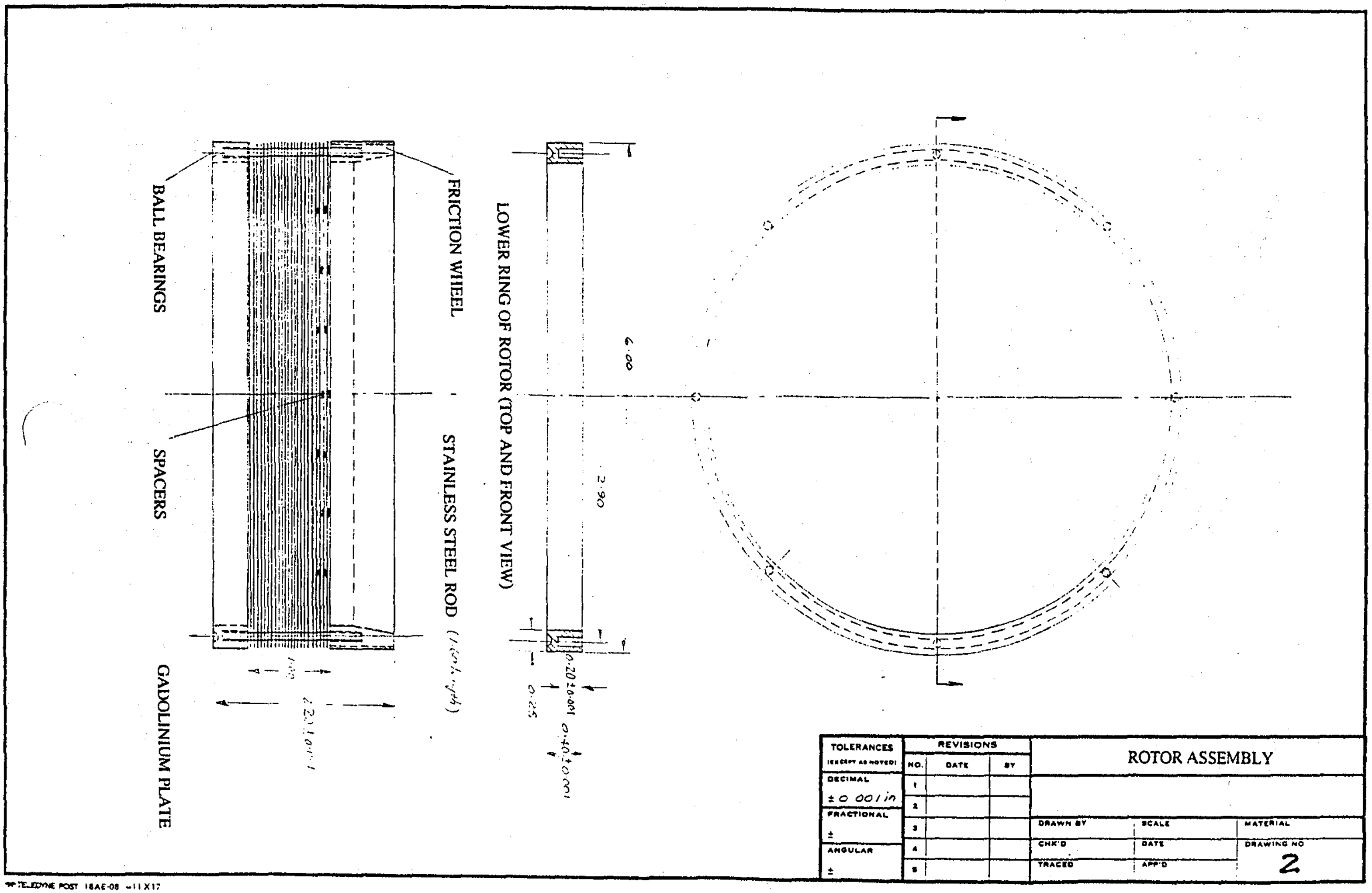


FIG. 3 MODULE ASSEMBLY



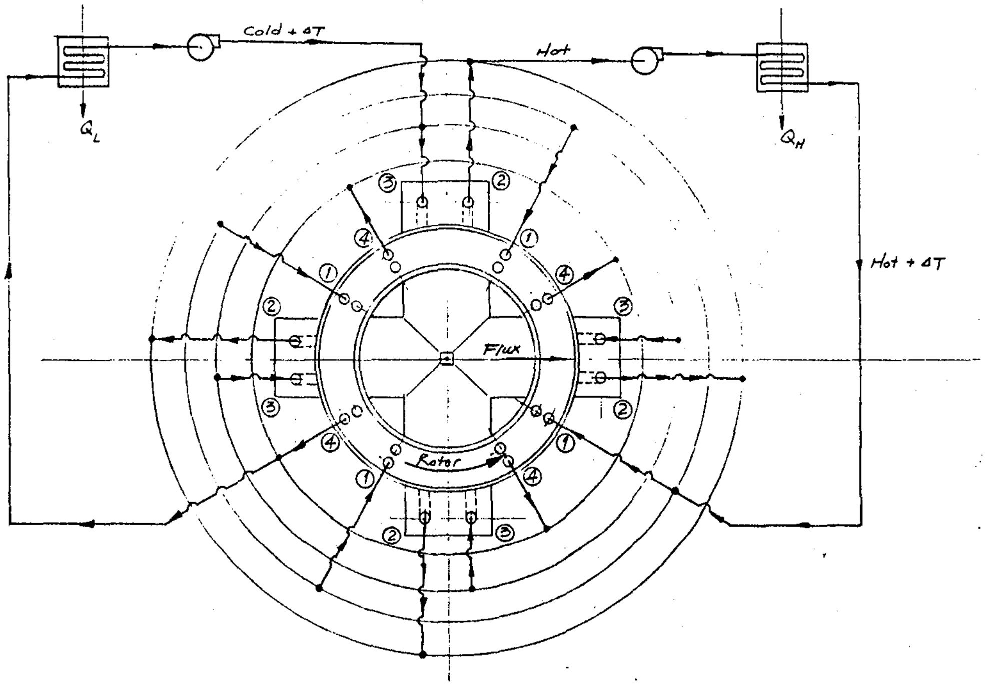
TOLERANCES (EXCEPT AS NOTED)	REVISIONS NO	DATE	BY	MAGNETIC HEAT PUMP ASSEMBLY		
DECIMAL ±	1					
	2					
FRACTIONAL ±	3			DRAWN BY	SCALE	MATERIAL
	4			CHK'D	DATE	DRAWING NO 1
ANGULAR ±	5			TRACED	APP'D	

TELEDYNE POST 18AE-08 —11 X 17



TOLERANCES (EXCEPT AS NOTED)	REVISIONS NO.	DATE	BY	ROTOR ASSEMBLY		
DECIMAL	1					
±0.001 in	2					
FRACTIONAL	3			DRAWN BY	SCALE	MATERIAL
±	4			CHK'D	DATE	DRAWING NO
ANGULAR ±	5			TRACED	APP'D	2

TELEDYNE POST 18AE-08 —11 X 17



TOLERANCES
(EXCEPT AS NOTED)
DECIMAL
±
FRACTIONAL
±
ANGULAR
±

REVISIONS		
NO	DATE	BY
1		
2		
3		
4		
5		

FLUID FLOW CHART

DRAWN BY
SCALE
MATERIAL
CHK'D
DATE
DRAWING NO. 3
TRACED
APP'D

TELEDYNE POST 18AE-08 -11 X 17

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