EFFECT OF NANO PARTICLES ON AIR CONDITIONING COMPRESSOR PERFORMANCE

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ABSTRACT

Nano particles are found to attract the attention in the recent years due to their diverse uses. Addition of metal or non-metal oxides to a base fluid leads to a different working fluid called NANO FLUID. Addition of Nano particles lead to change in both transport and thermal properties for fluid. In a traditional air conditioning system, there will be certain amount of lubricating oil that is carried away by the refrigerant in the compressor. So certain amount of lubricating oil circulates along with the refrigerant in the air conditioning circuit. If the solubility of lubricating oil in the refrigerant is low, there is a danger of accumulation of lubricating oil in the condenser. If the solubility of lubricating oil in the refrigerant is high, refrigerant washes away all the lubricating oil in the compressor and there is a danger of abrasion in the compressor. There is a danger of sedimentation of Nano particles in compressor if it is not dispersed properly in the oil. If the Nano particles are not correctly dispensed, there is a danger of their interference with environment. Nano particles are found to hinder the growth of plants. They are carcinogenic and hence care should be taken to handle them judiciously. Economic issues regarding the usage of Nano particles have also to be considered as they are quite expensive.The refrigerant used in the air-conditioning setup that is used for testing is R-410a. The refrigerant R-410a is azeotropic suggesting that the phase change temperature does not remain constant as in the case of traditional refrigerants. Temperature of the refrigerant (R-410a) decreases during the phase change. The refrigerant used in the air-conditioning setup that is used for testing is R-410a. The refrigerant R-410a is azeotropic suggesting that the phase change temperature does not remain constant as in the case of traditional refrigerants. Temperature of the refrigerant (R-410a) decreases during the phase change. Nano particles added to the lubricating oil clog the surface asperities thus decrease the sliding friction between the surfaces. Clogging of the surface asperities also found to decrease the nucleate boiling heat transfer characteristics. Addition of Nano particles also found to enhance the critical heat flux of the refrigerant. Literature studies show that Thermal conductivity of Nano fluid is greater than that of base fluid. Also viscosity of Nano fluid is greater than that of the base fluid. These are the uses of Nano particles. Nano particles also have certain disadvantages.

INTRODUCTION

There is an increase in energy utilization in recent years. So there has been a desire to decrease the energy utilized by different appliances used in daily life. Nano particles are found to attract the attention in the recent years due to their diverse uses.

Addition of metal or non-metal oxides to a base fluid leads to a different working fluid called NANO FLUID. Addition of Nano particles lead to change in both transport and thermal properties for fluid. In a traditional air conditioning system, there will be certain amount of lubricating oil that is carried away by the refrigerant in the compressor. So certain amount of lubricating oil circulates along with the refrigerant in the air conditioning circuit. If the solubility of lubricating oil in the refrigerant is low, there is a danger of accumulation of lubricating oil in the condenser. If the solubility of lubricating oil in the refrigerant is high, refrigerant washes away all the lubricating oil in the compressor and there is a danger of abrasion in the compressor. Therefore, for the proper functioning of the appliance using the given refrigerant and lubricating oil, they must be compatible with each other. For the refrigerant and lubricating oil to be compatible, polarity of both refrigerant and lubricating oil must be same. This ensures optimal solubility of lubricating oil in the refrigerant. Nano particles added to the lubricating oil clog the surface asperities thus decrease the sliding friction between the surfaces. Clogging of the surface asperities also found to decrease the nucleate boiling heat transfer characteristics. Addition of Nano particles also found to enhance the critical heat flux of the refrigerant. Literature studies show that Thermal conductivity of Nano fluid is greater than that of base fluid. Also viscosity of Nano fluid is greater than that of the base fluid. These are the uses of Nano particles. Nano particles also have certain disadvantages.

There is a danger of sedimentation of Nano particles in compressor if it is not dispersed properly in the oil. If the Nano particles are not correctly dispensed, there is a danger of their interference with environment. Nano particles are found to hinder the growth of plants. They are carcinogenic and hence care should be taken to handle them judiciously. Economic issues regarding the usage of Nano particles have also to be considered as they are quite expensive.

The refrigerant used in the air-conditioning setup that is used for testing is R-410a. The refrigerant R-410a is azeotropic suggesting that the phase change temperature does not remain constant as in the case of traditional refrigerants. Temperature of the refrigerant (R-410a) decreases during the phase change.

LITERATURE REVIEW

[1]Srikhirin P, Aphornratana S, Chungpaibulpatana S. A review of absorption refrigeration technologies. Renew Sustain Energy Rev 2001;5(4): 343–72[1] they given initialisation of work that Absorption refrigeration was discovered by Nairn in 1777, though the first commercial refrigerator was only built and developed in 1823 by Ferdinand Carré, who also got several patents between 1859 and 1862 from introduction of a machine operating on ammonia–water. By 19th century, systems operating on ammonia–water found wide application in residential and industrial refrigerators. Systems operating on lithium bromide–water were

commercialized in the 1940's and 1950's as water chillers for large buildings air conditioning.

Horuz I. An alternative road transport refrigeration. Tr. J. Of Engineering and Environmental Science 1998;22:211-222. [2]conducted experimental investigation into the effect on the performance of the IC engine of introducing the VAR system into the exhaust system and also the provision of appropriate off-road/slow running cooling systems, in order to take account of the reduction in exhaust gas flow in slow running traffic or stationary situations or when the vehicle is parked and cooling is still required. Built-in eutectic plates could provide temporary cooling under such conditions. Such plates could be recharged by redirecting the cooling effect from the main body to the eutectic plate during off-load periods of continuous full-load travel.

Alam [3] Shah A. A proposed model for utilizing exhaust heat to run automobile air-conditioner. The 2nd Joint International Conference on Sustainable Energy and Environment 2006. studied the possibility of operating a triple fluid vapour absorption system using engine exhaust power. From the analysis it was concluded that there is a possibility of operating a triple fluid system using engine exhaust power.

[4]S.U.S. Choi, ASME, 99(1995) showed that the addition of a small amount of nanoparticles (less than 1% by volume) to base fluid would increase the thermal conductivity of the fluid up to approximately two times. But thermal conductivity having the most important property is not easy to determine accurately by a single formula, but there are some experimental relations that could be used to estimate it. With increase in temperature, there is increase in thermal conductivity but there is abnormal behavior of the thermal conductivity at high temperatures which is related to the solubility of the nanoparticles. In the nanometrical size range, kinetics of dissolution of particles is enhanced due to the small size according to the Kelvin equation.

Eastman JA, Choi US, Thompson LJ, Lee S. "Enhanced thermal conductivity through the development of nanofluids. Mater Res Soc Symp proc 1996;457:3-11[5] concluded that report that thermal conductivity of ethylene glycol of nanofluids containing 0.3% volume fraction of copper particles can enhance thermal properties by 40% compared to that of EG (Ethylene Glycol) base fluid.

Z. Zhang and Q. Que, Wear 209, 8 (1997).[6] In automobile lubrication nanoparticles dispersed in mineral oils were reported to be effective in reducing wear & enhancing load carrying capacity [41]. Recently lots of researchers show their interest to enhance the tri biological properties (such as load carrying capacity, wear resistance and friction reduction) of nanoparticle suspended lubricants. The vehicle life time as well as the performance will be increased by using the nanoparticle suspended lubricants. Osorio et al. investigated the tribological properties of CuO suspended lubricant.

[7] Wang X, Xu X, Choi SUS: Thermal conductivity of nanoparticle-fluid mixture. J Thermophys Heat trans 1999, 13:474-480 due to the low pressure operation compared

with a 50/50 mixture of ethylene glycol and water, which is the universally used automotive coolant. The nanofluids has a high boiling point, and it can be used to increase the normal coolant operating temperature and then reject more heat through the existing coolant system and also contributed to a reduction in friction and wear. It is conceivable that greater improvement of savings could be obtained in the future but with time nanofluids degrade radiator material and Erosion of radiator material will be there. Choi studied on the development of energy efficient nanofluids and smaller and lighter radiators. A major goal of the nanofluids project is to reduce the size and weight of the HV cooling systems by >10% thereby increasing fuel efficiency by >5%. Nanofluids enable the potential to allow higher temperature coolants and higher heat rejection in HVs. A higher temperature radiator could reduce the radiator size by perhaps 30%.

NANO FLUID PREPARATION USING TWO-STEP METHOD

Two-step method is the most widely used method for preparing Nano fluids. Nanoparticles used in this method are first produced as dry powders by chemical or physical methods. Then, the Nano sized powder will be dispersed into Mineral oil in the second processing step with the help of intensive magnetic force agitation and ultrasonic agitation. The schematics of magnetic stirrer and magnetic beads are shown in the figures:

Figure: Magnetic stirrer

Lubricating oil with Nano particles is placed in a beaker on the stirrer with a magnetic bead in it.

Figure: Different Magnetic Beads

Two-step method is the most economic method to produce Nano fluids in large scale, because Nano powder synthesis techniques have already been scaled up to industrial production levels.

Due to the high surface area and surface activity, nanoparticles have the tendency to aggregate. The important technique to enhance the stability of nanoparticles in fluids is the use of surfactants. However, the functionality of the surfactants under high temperature is also a big concern, especially for high- temperature applications. Effects of Nano particles on air-conditioning cannot be isolated if surfactants are used.

Amount of lubricating oil used for the

experiment is 650ml and the amount of TiO_2 Nano particles used is 0.2772 grams and the amount of Al_2O_3 Nano particles used is 0.1126 grams.

SPECTRAL ABSORBENCY ANALYSIS

Spectral absorbency analysis is an efficient way to evaluate the stability of Nano fluids. In general, there is a linear relationship between the absorbency intensity and the concentration of nanoparticles in fluid. Experiments evaluated the dispersion characteristics of TiO_2 and Al_2O_3 suspension using the conventional sedimentation method with the help of absorbency analysis by using a spectrophotometer after the suspension deposited for 24 h and 7 days. If the Nano materials dispersed in fluids have characteristic absorption bands in the wavelength 190–1100 nm, it is an easy and reliable method to evaluate the stability of Nano fluids using UV spectral analysis. The variation of particle concentration of Nano fluids with sediment time can be obtained by the measurement of absorption of Nano fluids, because there is a linear relation between the nanoparticle concentration and the absorbance of suspended particles. The outstanding advantage comparing to other methods is that UV spectral analysis can present the quantitative concentration of Nano fluids. It is believed that the stability of Nano fluids was strongly affected by the characteristics of the suspended particles and the base fluid such as particle morphology.

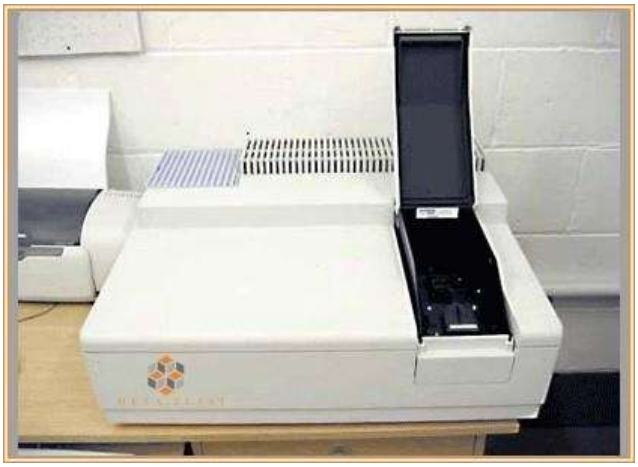


Figure: Photospectrometer

Thermal Conductivity Analysis

Thermal conductivity of Nano fluid is investigated by "**Thermal Conductivity Of Liquid And Gasses Apparatus**".

Graphs: Thermal conductivity graph:

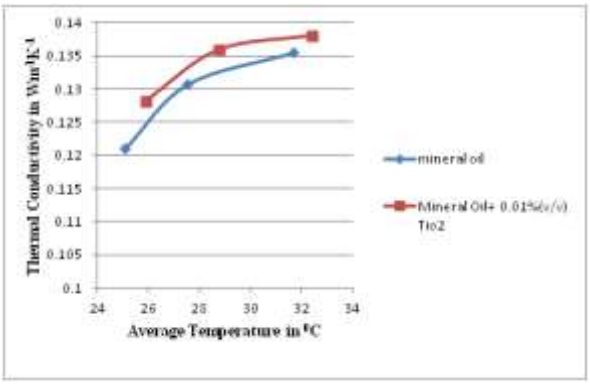


Figure: Thermal Conductivity of Mineral Oil (vs) Nano Fluid (Mineral Oil + 0.01 % (v/v) TiO_2 Nano particles)

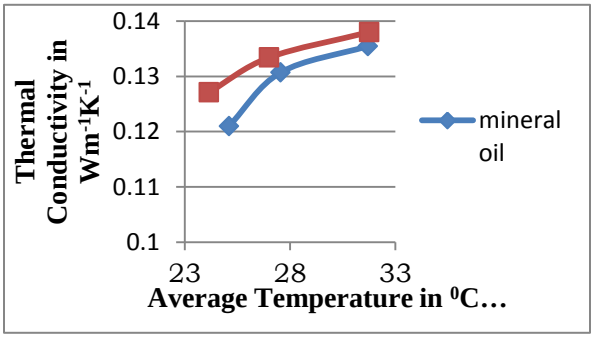


Figure: Thermal Conductivity of Mineral Oil (vs) Nano Fluid (Mineral Oil + 0.01 % (v/v) Al_2O_3 Nano particles)

Where the values on X-axis denote the temperatures in degrees Celsius and the values on Y-axis denote Thermal conductivities in Watt per meter per Kelvin.

From the above graphs, it ias observed that there is increase in Thermal conductivity of Nano fluids as compared with the base fluid. Literature studies have shown an increase in Thermal conductivity by the addition of Nano particles to Ethylene Glycol/water.

Performance Tests On Air-Conditioner Compressor Setup

Figure: Experimental Air-conditioning compressor equipment

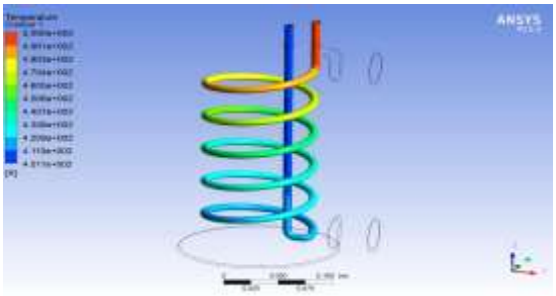
The Nano lubricant prepared above is tested in the compressor of air-conditioning test facility in M/S TECUMSEH. The equipment is run till the time steady state is reached or heat balance is attained. The refrigerant used is R-410a. Apparatus are available to maintain the same temperature all over the room. Thermocouples are provided to ensure the required conditions are maintained in the test setup.

Apparatus is provided to measure the power input to the compressor and temperatures at different places in the conditioned space.

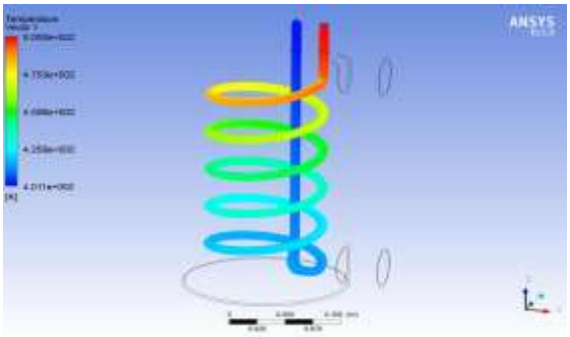
Figure : Compressor test cabin

Case study:-2 CFD study by using FLUENT software

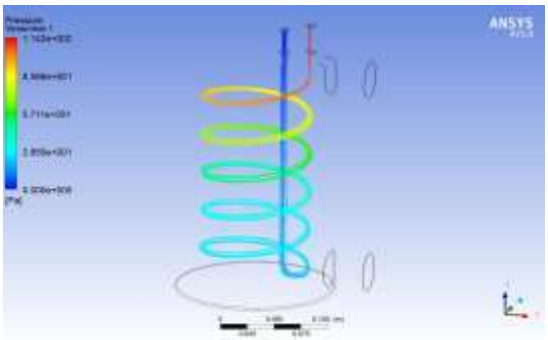
For nano fluid(Mineral oil+ 0.02%(v/v) Al_2O_3 Nano Particles



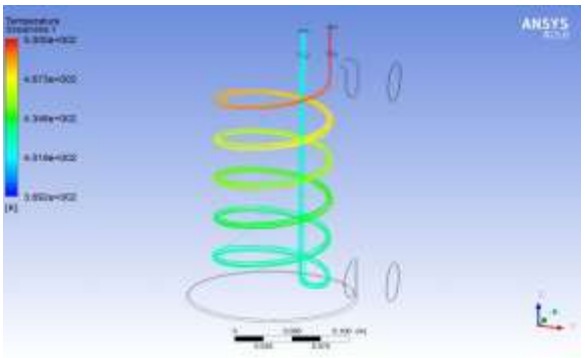
Temperature contour



Temperature vector



Pressure streamline



Temperature streamline

Results obtained from nano fluid(Mineral oil+ 0.02%(v/v) Al_2O_3 Nano Particles

shell_inlet 300.00015
shell_outlet 344.28268
tube_inlet 499.93713
tube_outlet 402.49203

For (Mineral oil)

Results obtained from (Minerals)

shell_inlet 300.00015
shell_outlet 344.28268
tube_inlet 499.93713
tube_outlet 402.49203

RESULTS AND DISCUSSIONS

- Thermal conductivity of Nano particles mixed in lubricating oil is found to be greater than that of the base fluid. This result agrees with that of the results obtained in literature. This is to be expected as thermal conductivity of metals/ metal oxides nano particles is higher than the base low thermal conductivity mineral oil.
- Analysis of dispersion characteristics of nanoparticles in lubricating oil using spectrophotometer shows that the Nano fluid is not stable and nano particles form sediments on the 1st day and 7th day, this is perhaps the reason we got only slight improvement in EER as nanoparticles had settled in the crank casing of the compressor. In order to overcome the problem of sedimentation of nano particles, surfactants can be used in lubricating oil.
- Compressor performance tests indicate that increase in EER is 0.1% when TiO_2 Nano particles are mixed with Mineral oil and 1.5% decrease in EER, when Al_2O_3 Nano particles are mixed with Mineral oil which is not encouraging. So, further experimentation is required with higher concentrations of nanoparticles with smaller sizes of Nano particles; surfactants can also be added to the Nano Fluids and EER checked.
- FLUENT software results also shows that the mixing of nano fluid particles are getting better results compared to mineral oil.

Tecumseh Products India Pvt.Ltd,Hyderabad

Calorimeter Test Results

Cal-2 Q.F:7.3- 01-15

TEST DOCUMENTATION

TEST PURPOSE	DEV SAMPLE	REPORT NO.	C12081016- L3
		PROJECT NO.	
BILL OF MATERIAL	BS12081016	MODEL NO.	RNB5528BXC
COOLING METHOD	425 CFM	DISPLACEMENT CC/REV	28
SERIAL NUMBER	146417	MOTOR MANUFACTURER	TPIPL HYD
CODE DATE		MOTOR SPECS.	PSC
REFRIGERANT	R410A	PHASE	Single Phase
REQUESTING ENGINEER	M.P.REDDY	FREQUENCY Hz	50
TESTED BY	MD.GHOUSE	CUSTOMER NOTFN. NO.	
TEST NAME	ASHRAE-R410a	TEST NUMBER	5548

TEST MEASUREMENTS

PRESSURES	ACTUAL VALUE		SET VALUE	
	BAR (A)	PSIA	BAR (A)	PSIA
SUCTION PRESSURE	9.9382	144.14	9.954	144.37
DISCHARGE PRESSURE	33.862	491.13	33.86	491.10
CAL. OUT PRESSURE	9.912	143.76		

DEV SAMPLE(TEST WITH) MINERAL OIL + TITANIUM DI -OXIDE.

O.C.R - 2.4%

TEMPERATURES	°C	°F	°C	°F
EVAPORATING TEMP.	7.1	44.9	7.2	45.0
CONDENSING TEMP.	54.5	130.2	54.5	130.2
DEGREE OF SUPERHEAT	27.9	50.2	27.8	50.0
DEGREE OF SUBCOOLING	8.4	15.2	8.4	15.2
RETURN GAS TEMP.	35.0	95.0	35.0	95.0
LIQUID TO EXPN. VALVE	46.1	115.0	46.1	115.0
CAL. OULET TEMP.	35.0	95.0	35.0	95.0
COMPR. CHAMBER AMB.	35.0	95.0	35.0	95.0
Top Shell	71.2	160.2		
Bottom Shell	54.5	130.2		
Middle at shell	78.9	174.0		
Discharge Line	87.6	189.6		

ELECTRICAL MEASUREMENTS

PARAMTER	ACTUAL VALUE		SET VALUE	
FREQUENCY	49.996	Hz	50	Hz
COMPRESSOR VOLTAGE1	220.26	Volts	220	Volts
COMPR. CURRENT1	10.772	Amp.		
COMPR. POWER	2304	Watts		
COMPR. PF, MEASURED	0.97			
CAL. HEATER ENERGY	6676	Watts		
RUN CAPACITOR USED	45MFD			
ECR	316.62	Volts		
ECH	245.26	Volts		
START WDG. CURRENT	4.7	Amp.		
MAIN WINDING CURRENT	8.52	Amp.		
MOTOR SPEED	2880	RPM		

REFRIGERATION RESULTS				
MASS FLOW RATE, CALC.	2.296	Kg/min	303.76	Lbs/hr
MASS FLOW RATE, MEAS.	2.300	Kg/min	304.34	Lbs/hr
MASSFLOW AGREEMENT	-0.19	%		
CORRECTED CAPACITY	6756.29	Watts	23072.72	Btuh
CORRECTED COMP. POWER	2304.18	Watts		
VOLUMETRIC EFFICENCY	88.49	%		
ISENTROPIC EFFICENCY	66.04	%	EER	10.01

DEVIATION ANALYSIS		NOMINAL	ACTUAL	DEVIATION
COMPR. POWER, Watts		2320	2304.18	-0.7
COMPR. CURRENT, Amp.		11.5	10.772	-6.3
CAPACITY, Btu/Hr		23400	23072.72	-1.4
EER (Btu/Wh)		10.10	10.01	-0.9

Winding Temperature 102.76°C Checked By

For Nano Fluid: Mineral oil + 0.01(v/v)% Al_2O_3:

Tecumseh Products India Pvt.Ltd,Hyderabad

Calorimeter Test Results

Cal-2 Q.F:7.3- 01-15

TEST DOCUMENTATION

TEST PURPOSE	Dev sample	REPORT NO.	C12081016-L4
		PROJECT NO.	
BILL OF MATERIAL	BS12081016	MODEL NO.	RNA5528BXC
COOLING METHOD	425 CFM	DISPLACEMENT CC/REV	28
SERIAL NUMBER	146417	MOTOR MANUFACTURER	TPIPL,HYD
CODE DATE		MOTOR SPECS.	PSC
REFRIGERANT	R410A	PHASE	Single Phase
REQUESTING ENGINEER	M.P.REDDY	FREQUENCY Hz	50
TESTED BY	R.CHANDRA	CUSTOMER NOTFN. NO.	
TEST NAME	ASHRAE-R410a	TEST NUMBER	5549

TEST MEASUREMENTS

PRESSURES	ACTUAL VALUE		SET VALUE	
	BAR (A)	PSIA	BAR (A)	PSIA
SUCTION PRESSURE	9.9364	144.12	9.954	144.37
DISCHARGE PRESSURE	33.854	491.01	33.86	491.10
CAL. OUT PRESSURE	9.912	143.76		

Tested with Al2O3 oil
Mineral oil+ Aluminium oxide.

O.C.R - 1.7%

TEMPERATURES	°C	°F	°C	°F
EVAPORATING TEMP.	7.1	44.9	7.2	45.0
CONDENSING TEMP.	54.5	130.1	54.5	130.2
DEGREE OF SUPERHEAT	27.8	50.1	27.8	50.0
DEGREE OF SUBCOOLING	8.5	15.2	8.4	15.2
RETURN GAS TEMP.	35.0	95.0	35.0	95.0
LIQUID TO EXPN. VALVE	46.1	114.9	46.1	115.0
CAL. OULET TEMP.	35.0	95.0	35.0	95.0
COMPR. CHAMBER AMB.	34.9	94.9	35.0	95.0
Top Shell	71.3	160.3		
Bottom Shell	58.8	137.8		
Middle at shell	75.0	167.0		
Discharge Line	86.8	188.3		

ELECTRICAL MEASUREMENTS

PARAMTER	ACTUAL VALUE		SET VALUE	
FREQUENCY	50.006	Hz	50	Hz
COMPRESSOR VOLTAGE1	219.5	Volts	220	Volts
COMPR. CURRENT1	10.916	Amp.		
COMPR. POWER	2330	Watts		
COMPR. PF. MEASURED	0.97			
CAL. HEATER ENERGY	6642	Watts		
RUN CAPACITOR USED	45MFD			
ECR	316.28	Volts		
ECH	244.4	Volts		
START WDG. CURRENT	4.7	Amp.		
MAIN WINDING CURRENT	8.56	Amp.		
MOTOR SPEED	2860	RPM		
REFRIGERATION RESULTS				
MASS FLOW RATE, CALC.	2.284	Kg/min	302.18	Lbs/hr
MASS FLOW RATE, MEAS.	2.297	Kg/min	303.92	Lbs/hr
MASSFLOW AGREEMENT	-0.58	%		
CORRECTED CAPACITY	6721.90	Watts	22955.28	Btuh
CORRECTED COMP. POWER	2329.72	Watts		
VOLUMETRIC EFFICENCY	88.69	%		
ISENTROPIC EFFICENCY	64.98	%	EER	9.85

DEVIATION ANALYSIS		NOMINAL	ACTUAL	DEVIATION
COMPR. POWER, Watts		2320	2329.7	0.4
COMPR. CURRENT, Amp.		11.5	10.91	-5.1
CAPACITY, Btu/Hr		23400	22955.3	-1.9
EER (Btu/Wh)		10.09	9.85	-2.3

WINDING TEMPERATURE 106.7°C

Checked By

CONCLUSIONS:

- Spectroscopic analysis of nanoparticles added to lubricant oil shows that sediments start forming on the 7th day indicating that Nano particles are not fairly well dispersed in the base fluid. Surfactants may be added to enhance the dispersal level.
- Thermal conductivity of Nano fluids (TiO_2, Al_2O_3 Nano particles added to Mineral oil) is greater than that of the base fluid. This is to be expected as thermal conductivity of metals/metal oxides nano particles added is higher than that of the base mineral oil. This is consistent with literature which reports an increase in Thermal Conductivity when Nano particles are added to water/Ethylene Glycol.
- The reproducibility of the air conditioning test facility was checked by repeating one case twice. Results showed agreement of EER values within ± 0.1%. The Energy Efficiency Ratio for TiO_2 spiked lubricant increased by 0.1% and for Al_2O_3, spiked lubricant, EER decreased by 1.5%. It is concluded that significant results were not obtained. It is inferred that in order to get an increase in EER, the nano particles concentration has to be increased and size of nano particles has to be decreased and tests have to be conducted afresh.
- Also, care should be taken that lubricating oil left over in the crank case of the compressor housing after a particular experiment should be removed totally and filled afresh for next experiment, to avoid contamination.

SCOPE OF FUTURE WORK:

- Examine other Nano particles at higher concentrations and smaller sizes.
- Try out with surfactants added to the lubricating oil, to overcome sedimentation.

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