Performance Evaluation of Household Refrigerator Using Different Concentration Of R290 With R134a

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Abstract- *Air, ammonia, carbon dioxide and water and HC are the only refrigerants with zero ODP and negligible GWP and low environmental impact and now R134a is widely used refrigerant in domestic refrigerator. An experimental performance study is done on the base refrigerant (R134a) and mixture of it with HC 290 for various composition ratios and loading conditions. This paper investigated experimental results of R134a and the mixtures of R134a/R290 at three different concentrations (60/40, 70/30 and 80/20 mass %). Experimental results showed that all of the alternative refrigerants investigated in the analysis have a higher performance coefficient (COP) than HFC134a for evaporating temperatures ranging between −30 °C to 12 °C. Refrigerant blends of HFC134/HC290 (80/ 20 by wt. %) instead of HFC134a are found to be replacement refrigerants among other alternatives. Also we can conclude that R134a/R290 (80/20 wt %) has the maximum average performance coefficient of the system of about 4.28%. The average power consumption of the system using R134a/R290 (80/20 wt. %) has found to be lower than other refrigerant blends about 4.02 %.*

Keywords- Refrigerant blends, Hydrocarbon, COP, Exergy loss, etc.

I. INTRODUCTION

Vapor compression refrigeration (VCRS) in which the refrigerant goes through phase change process called VCR system. Oil refineries, petrochemical and chemical processing plants, and natural gas processing plants are among the many types of industrial plants that often utilize large vapor-compression refrigeration systems. Refrigeration may be defined as lowering the temperature of an enclosed space by removing heat from that space and transferring it elsewhere.

Thermal properties of HCs are similar to that of refrigerants, like propane and R-12 & R-22. Since the discovery of the depletion of the earth ozone layer cause by CFCs and HCFCs and as the result of the 1992 united nation environmental program meeting, the out of CFCs- 11 and CFCs- 12 use mainly in conventional refrigeration.

Jose V. H. D'Angelo, et. al. [1], provides comparative study on the vapor injection system using mixture of R290/ R600a. The performance of the vapor injection cycle achieved 16-32 % higher than that of vapor compression cycle. A. S. Dalkilic, et. al. [2], works on the VCR system. He observed that, the performance coefficient values of system obtained in case of superheating/ sub cooling than that of Non-superheating/ sub cooling case. I. L. Maclaine- cross [4], works on the energy saving by hydrocarbons in the refrigeration and air- conditioning unit. According to study, hydrocarbons save over 20% of energy consumption. S. Wongwises, et. al. [5], presents an experimental analysis of hydrocarbon mixtures to replace R134a. The energy consumption was reduced by 4.86% in the mixture of propane/butane (60/40 %) compared to R134a. J. U. Ahamed, et. al [7], review on exergy analysis of VCR system. By using nano lubricants the energy efficiency of the compressor can be improved by some extents and they reduce the friction coefficient. J. A. Shilliday [9], deals with energy and exergy analysis of R744, R404A and R290 refrigeration cycles. The sub-cooling effect of heat exchanger increasing the cycle COP by about 5%. N. Austin et. al. [11], works on the optimization of performance using hydrocarbon mixture (propane-butane) at different concentration. It is found that the performance of the system with hydrocarbon refrigerant mixture has increase by about 7.6 %.

II. EXPERIMENTAL SET UP

This experimental work with blends of single Hydrocarbon (R290) with base refrigerant (R134a) which is used as refrigerant in 165 litre gross capacity refrigerator design by Godrej, from which we can find and study the refrigerator performance and exergy loss parameter. The performance of the system at ideal condition is given to be 1.2. This experiment is retrofitted only with the charge of refrigerants.

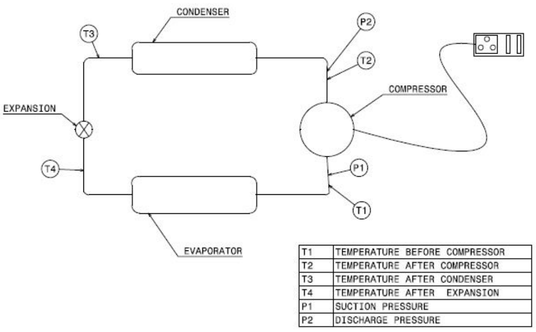

Figure 1: Experimental schematic of VCR system

Figure 1 depicts the experimental schematic of VCR system. The setup consists of single stage VCR system with hermetically sealed compressor. Set up is provided with necessary instruments for suction pressure, compressor pressure, Wattmeter for power supply measurement to the compressor and load and multi-point temperature indicator to record temperatures at different sections.

Figure 2: Control panel of system

Figure 2 shows the control panel of the system on which all the necessary instruments are mounted for the data measurement. The instruments used in the experimentation are all calibrated by the manufacturer. The compound and simple pressure gauges are mounted on the control panel to measure suction and compression pressure respectively.

The pin and pencil type thermocouples is used to measure the temperature at different sections of the system with the accuracy of (+-) 1^0C. Total 7 thermocouples are used for temperature measurement at different sections. The 4 thermocouple are mounted on the inlet and outlet of compressor and evaporator and one is for atmospheric temperature measurement, and two for freezer and cabinet temperature measurement. The compound and simple type pressure gauges are used with the accuracy of (+-) 1 Psi and the wattmeter is used for the measurement of power supplied to the compressor and to control the load power given to the system which is also capable to capture the data of voltage and current supplied to the system.

III. RESULTS AND DISCUSSION

The pressure–temperature relationship in the cycle for condensers and evaporators depends on the composition of refrigerant mixture. The performance is affected by the pressure alterations while the ratios of the blend vary at the given temperature. For that reason, the proportion of the components in the mixture is one of the significant factors in the cycle.

The performance of the system is discussed by considering the effect of refrigerating effect, pressure ratio, power consumption per ton of refrigeration, variation of evaporator and condenser temperature, etc. The power consumption of the system was studied under the influence of the evaporator temperature and time. The exergy destruction of the each component is studied with respect to time and total exergy destruction is discussed with change in evaporator temperature. By studying the all these parameters, following results were obtained_

A. Performance Analysis

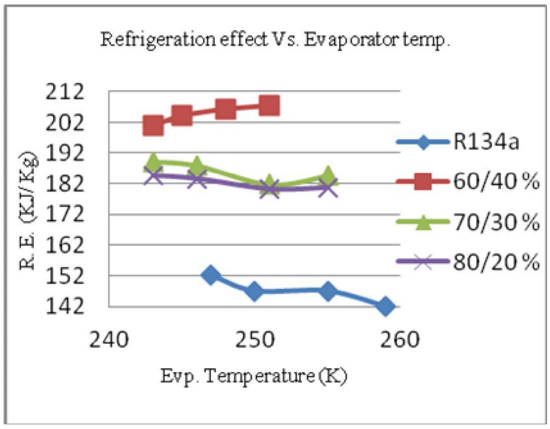

Figure 3: Refrigeration effect with evaporator temperature

Figure 3 shows the variation of refrigerating effect with respect to evaporator temperature. Change in evaporator temperature of the system is directly proportional to the refrigeration effect. The refrigerating effect of the system at each condition is decreases with respect to increase in the evaporating temperature. The major cause of decreasing the RE of the system is varying load condition after specific time. The average minimum refrigerating effect is given by pure R134a of about 147 Kj/ Kg. The average refrigerating effect of

R134a/R290 (80/20 wt. %) is found to be 19.37% higher than R134a.

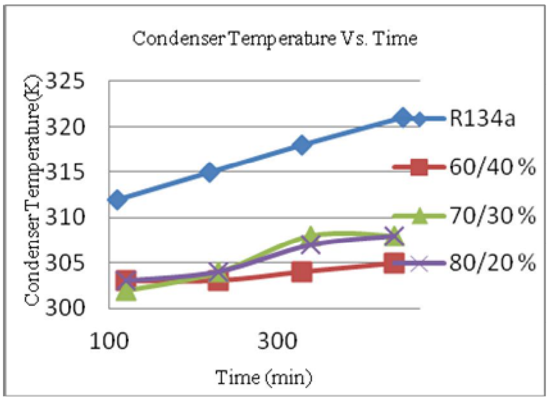

Figure 4: Condenser temp. change with time

Figure 4 shows the variation in condenser temperature of the system with respect to time. Peak up and peak down in the condenser temperature is directly or indirectly related to the performance of the system. As a result, the system performance decreases by increase in the condenser temperature. The result of R134a/R290 (60/40 wt %) proves the theoretical principle behind the increasing power consumption and lowering the performance of the system. The reduction in the percentage of condensing temperature using R134a/R290 (80/20 wt %) are found to be 3.46% respectively which helps to reduce power consumption.

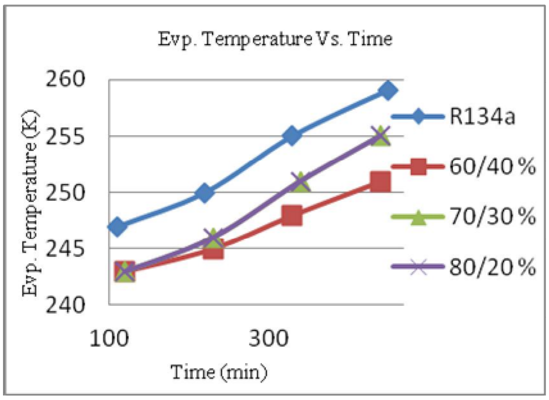

Figure 5: Variation of evp. Temperature with time

Increase in the evaporator temperature is directly related to the refrigeration effect which helps to improve the performance of the system. When the temperature of evaporator is increases then RE is also increase. Figure 5 shows the variation of evaporator temperature with the variation of time. The system using R134a gives the highest evaporator temperature at 150 W load conditions. But as the load increases the power consumption is also increases. The percentage decrease in the evaporator temperature in the mixture using 80/20% of R290 is 1.58%.

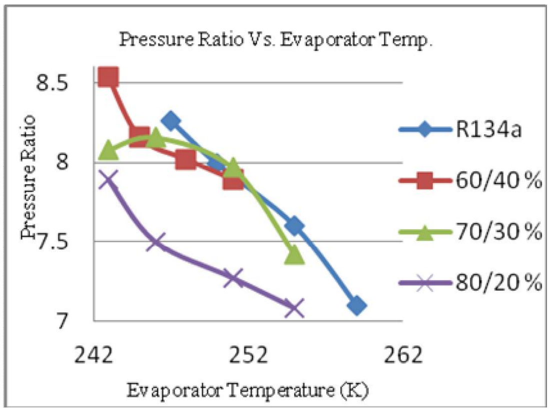

Figure 6: Change in pressure ratio with evp. Temperature

Figure 6 describes all the related variation in pressure ratio of the base refrigerant and its mixture with hydrocarbon (R290) with change in evaporator temperature. Small leakages, resistance to flow of refrigerant, etc are the main cause of pressure drop. And the drops in pressure cause reduction in the refrigeration effect which is directly related to the system performance. The pressure ratio of the mixture of R134a/R290 (60/40 by wt %) has found to be maximum pressure ratio of about 8.15 which is 5.53% higher than R134a. the mixture of R290 in the % of 80/20 % has the lowest pressure ratio values as compared to the R134a.

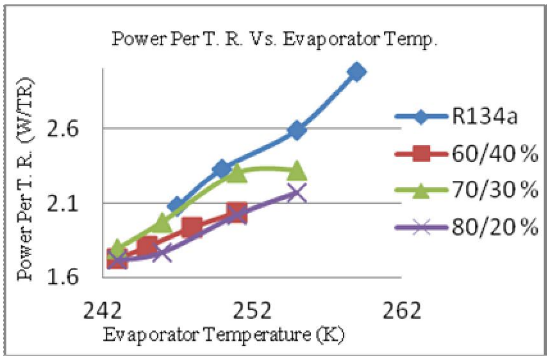

Figure 7: Power per TR with evaporator temperature

It is the power required to extract the heat to achieve 1 ton of refrigeration effect. Variation of the load is one of the greatest measures of the increasing power consumption in the system. The changes in power needed for refrigeration with evaporation temperature is shown in figure 7. Pure refrigerant (R134a) requires maximum power consumption as compared to other refrigerants mixture. The avg. minimum power consumption per T. R. is 1.92 W/TR which is 22.62% lower than pure R134a. This effect is achieved by using the mixture of, R134a/ R290 (80/20 wt %) which is 4.02% lower than the power consumption of R134a.

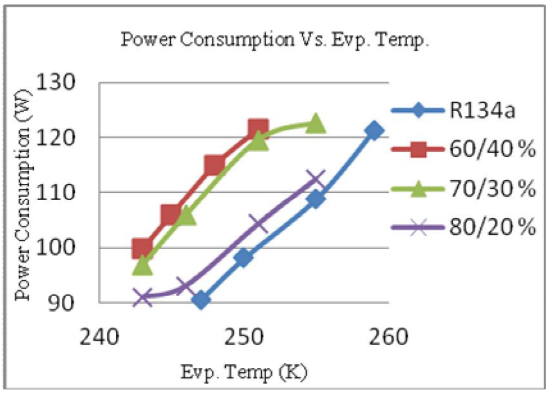

Figure 8: dependency of power consumption on evaporator temp.

Figure 8 and figure 9 shows the dependency of power consumption of compressor with time and evaporator temperature, for the evaporator temperature ranging from - 30 0C to 12 0C. Refrigerants at various concentrations, R134a, R134a/R290 (60/40 wt. %) and R134a/R290 (70/30 wt %) has much higher values of compression work than R134a/R290 (80/20 wt %). The average power consumption of compressor work is reduced by 4.02 % in R134a/R290 (80/20 wt %) than R134a. The major cause of increasing power consumption of compressor in all the cases (Figure 8 and 9) is the increase in load given to the system with respect to time.

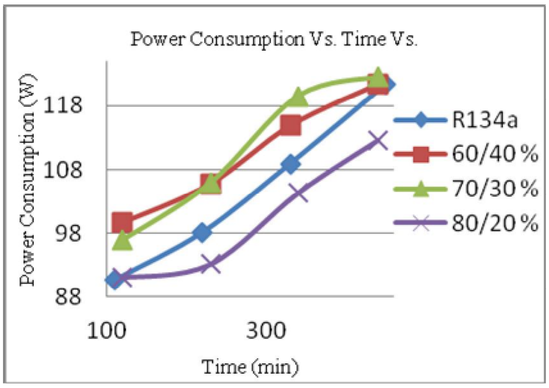

Figure 9: Dependency of power consumption with respect to time change

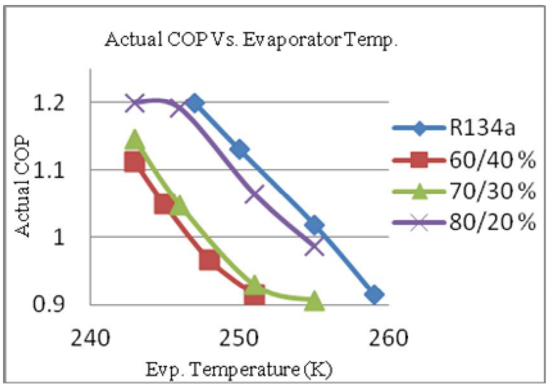

Figure 10: Variation of actual COP with respect to evaporator temperature

Figure 10 shows the coefficient of performance (COP) for R134a and alternative refrigerant for various evaporating temperature. In addition to this, the coefficient of performance (COP) has some alterations with the decrease or increase in the components' ratios in the composition due to the changes in the thermodynamic physical properties of the refrigerant mixture as the composition of the mixture varies. All the performance coefficients (COP) of the alternative refrigerants tested are found to be lower than those of R134a with the exception of R134a/R290 (80/20 wt. %) for the final steady state conditions. The average coefficient of performance of the mixture R134a/R290 (80/20 wt %) are found to be 4.28% higher than R134a.

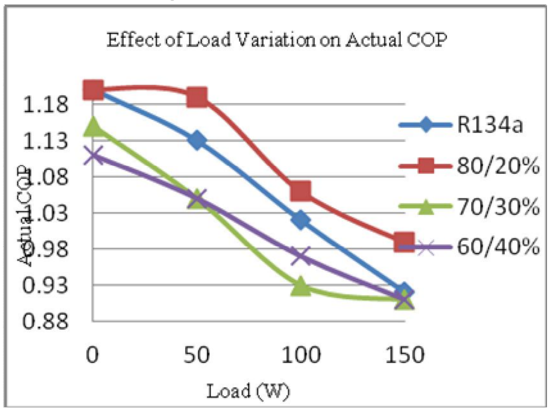

Figure 11: Effect of Load variation on actual COP

Figure 11 shows the variation of COP along with load at different concentration using R290 in the blends. The variation of concentration of R290 is limited to 40% because of the high pressure of R290 than R134a. The mixtures of other concentrations are lowering the performance of the system because of increase in the concentration of R290. The results shown in the figure 11 concludes the best refrigerants of R290 mixture which provides the maximum performance of the system of about 4.22 % higher than R134a using 80/20 % concentration.

B. Exergy Analysis

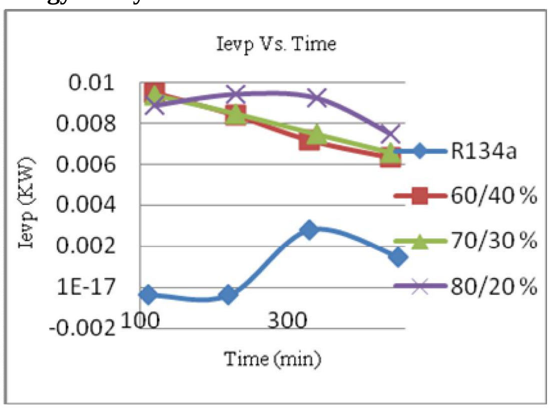

Figure 12: variation evaporator exergy loss with Time

In case of evaporator (Figure 12), R134a gives the best results of exergy destruction among all the refrigerants used. The average exergy destruction in the evaporator using R134a/R290 (80/20 wt %) as compared to the pure R134a is 89.34 % higher respectively. The mixture of R290 with R134a in the ratio of 80/20 wt % provides the maximum exergy destruction in the evaporator.

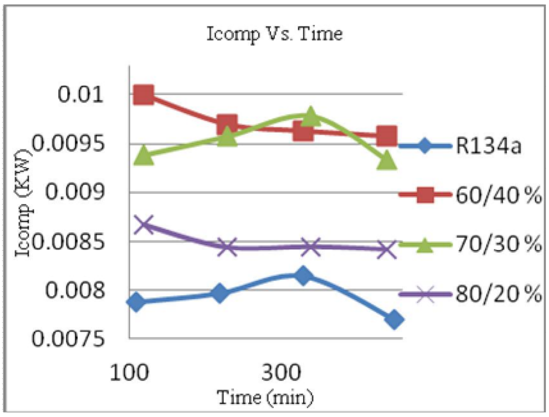

Figure 13: Exergy loss in compressor with time

The exergy performance of the pure R134a refrigerant trends the up and down as the load changes gradually. The system with condenser exergy loss is graph in the parameter of time and loss of exergy in condenser in figure 13. The exergy destruction in the compressor using the mixture of R290 with R134a is gradually in decreasing order. System consist of 20% of R290 performs better than the other mixtures. The mixture of R290 with the ratio of 60/40 wt % gives 18.49 % higher exergy destruction in the system as compare to R134a.

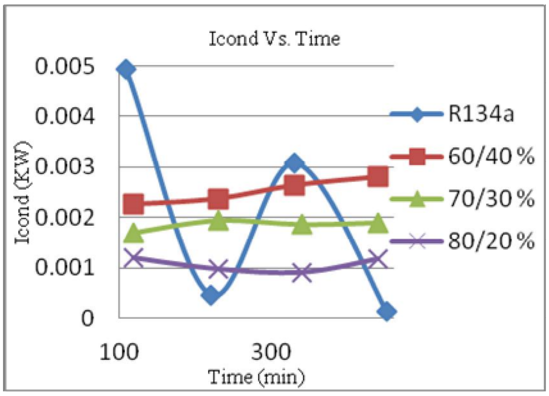

Figure 14: Condenser exergy loss with time

In condenser (figure 14) mixture of R290 with 20% concentration performs better than other refrigerant mixture. The destruction of exergy using R134a only is graphed up and down. Some alterations are occurred in the values of destruction of exergy in each refrigerant mixture. The destruction in exergy in case of R134a/R290 (80/20 wt %) is near about stable in whole run time and loading conditions of the system.

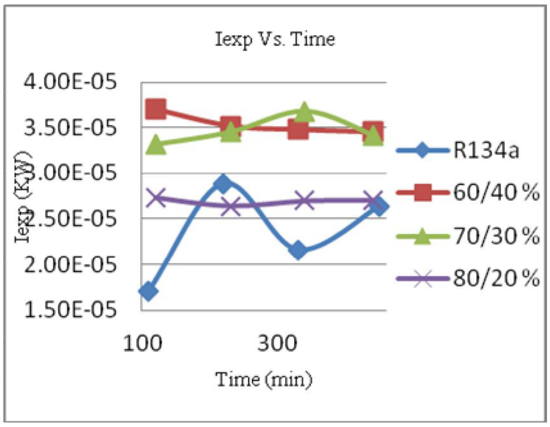

Figure 15: Expansion device exergy loss with time

Expansion device has lowest exergy destructive component of the system among all the other components (Figure 15). The range of the destruction for the expansion device changes from 1.5*E-5 to 3.55*E-5. Mixture R134a/R290 (80/20 wt %) and pure R134a provides best performance of expansion device with stability in the exergy loss with time. The mixture of R290 with R134a (60/40% and 70/30%) gives the highest exergy loss as compared to the mixture of 80/20%.

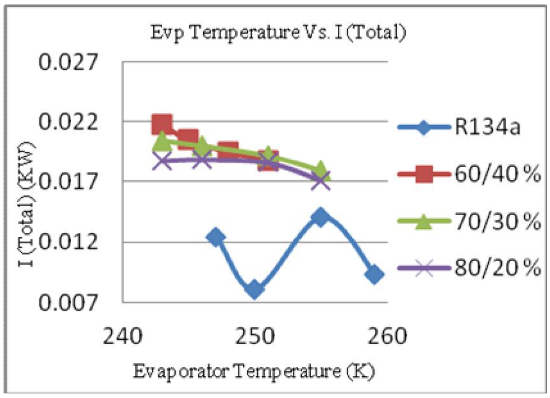

Figure 16: Total exergy loss with respect to Evp. Temp.

Total exergy destruction obtained from all runs is plotted versus time and evaporator temperature. Figure 16 and figure 17 provides a good sight to compare results and enables extraction of two important points.

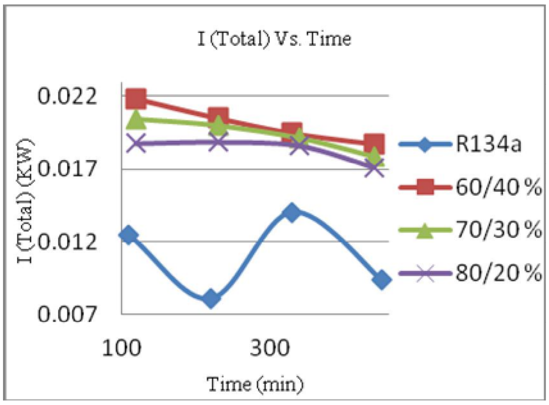

Figure 17: Total exergy loss with respect to time

The total exergy loss of the system using the mixture of R290 with R134a is much higher as compared to the base refrigerant (R134a). The mixture of R290 in the ratio of 80/20% is the slightly lower exergy destruction as compared to the other.

IV. CONCLUSION

In this study, a vapor-compression refrigeration system is used for the performance analysis of alternative new refrigerant mixtures of hydrocarbons (R134a/R290) as substitutes for HFC134a. After the experimentation and analysis, it can be concluded that-

1. The COP of the system decreases along with increase in evaporator temperature with respect to time change and load means the variation of evaporator temperature impacts on the all performance data (Refrigeration effect, COP, power consumption, ect.).
2. Refrigeration effect, condenser and evaporator temperature, power consumption, power per TR of the system using mixture of R290 is improved as compared to the results of R134a. Refrigeration effect has improved by 19.37% as compared to R134a using R290 in the ratio of 80/20 wt %.
3. R134a/R290 (80/20 wt %) has given the maximum average performance coefficient of the system of about 4.28 % higher than R134a.
4. The average power consumption of the system using R134a/R290 (80/20 wt %) has found to be lower than R134a of about 4.02 %.
5. The mixture using R290 (80/20 wt %) achieves 29.52 % less power consumption per TR as compared R134a.
6. The system using R134a has greatest value of Mass flow rate with respect to other refrigerant mixture. The mass flow rate of the system is reduced by 19.37 % using R290 in the ratio of 80/20 wt %.
7. Compressor has found to be the highest exegy destructive component of the system.

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