# Research of Energy Efficiency of Chillers Using Intermediate Refrigerant

K.A.Movsisyan[1)*]

[1)*] National University of Architecture and Construction of Armenia, Yerevan, Republic of Armenia, e-mail: karen.movsisyan1999@gmail.com, ORCID: https://orcid.org/0009-0004-4232-1803

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## *Abstract*

*The purpose of the study is to study the operating principle of refrigeration machines with an intermediate heat exchanger, to consider the most suitable types, in particular for use in the Republic of Armenia. Currently, such refrigeration units that carry out a cooling cycle with an intermediate heat exchanger have become widespread. The use of systems with an intermediate refrigerant allows you to turn off the refrigerant circuit during the cold season, and transfer heat directly to the environment through an additional heat exchanger for the intermediate refrigerant, which in turn leads to energy savings. The article examines the cycles of refrigeration units operating with an intermediate refrigerant, with the supply of an intermediate refrigerant to the condenser, to the evaporator, both together and without an intermediate refrigerant. The most energy-saving and energy-efficient of them are calculated, in particular, for the hot, temperate and cold regions of Armenia. The results are presented in the form of graphs.*

**Keywords:** *intermediate refrigerant, heat pump unit, evaporator, condenser, shell-and-tube heat exchanger, plate heat exchanger*

## 1. Introduction

In the article, as intermediate refrigerants are used water, aqueous solutions of sodium and calcium salts, ethylene glycol and propylene glycol. Production processes that require year-round heat removal at relatively high temperatures (0°C and above) are: storage of fruits, vegetables and other food products, chemical production, cooling of digital technologies, etc. Operation of the chiller system during transitional periods of year, when the outdoor temperature is lower than the temperature of the cooling space; in addition to the fact that the system is operating, significant difficulties arise during the operation of the system (decrease in equipment condensation pressure, increase in oil viscosity, wet operation of the compressor, etc.) [1]: The use of systems with an intermediate refrigerant makes it possible to turn off the refrigerant circuit during the cold season, and transfer heat directly to the environment through an additional heat exchanger of the intermediate refrigerant. In other words, to realize the so-called cold savings [1]. Thus, using the laws of thermodynamics help us to understand that this solution not only leads to significant savings in the economy and life of the compressor, but also simplifies the operation of the system.

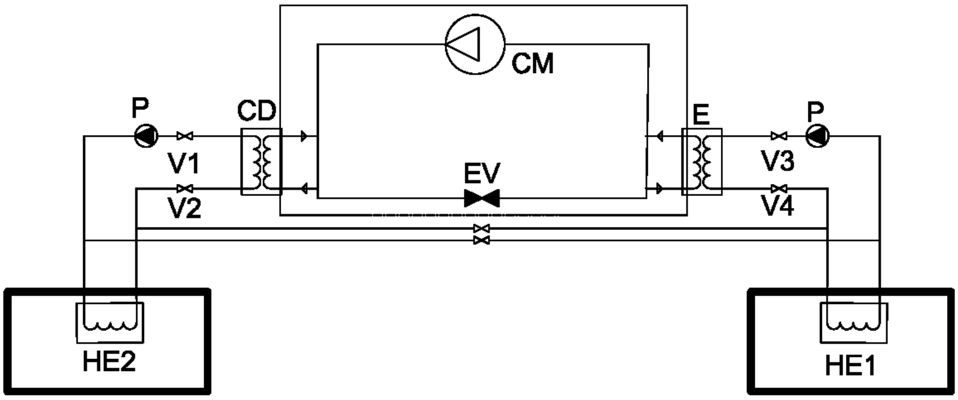
## 2. Materials and Methods

Options for cooling systems with an intermediate heat exchanger, which have a year-round application, where the operating temperature is greater than 0oC, are shown in Fig. 1 b, c. The refrigerant cycle is delimited by markings and includes a compressor (KM), a condenser (KD), a expansion valve (EV) and an evaporator (E) [2-6].

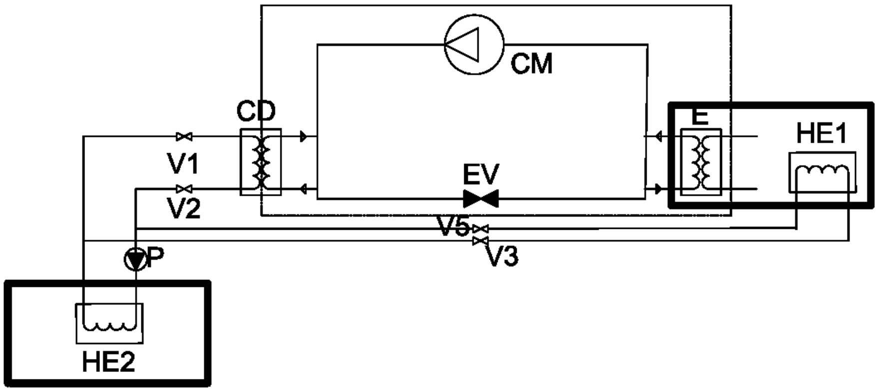
Let's consider the operation of a refrigerating installation consisting of an intermediate heat exchanger system in Fig. in c of 1. When the outdoor temperature is higher than the temperature of the space to be cooled, the intermediate coolente is supplied by the pump P to the evaporator, cools and passes to the heat exchanger HE1 for cooling the room (valves V3, V4, V5 are closed, V1, V2, V6 are open, Fig. 1, d).

The most interesting is the operation of the system in combined mode, when the intermediate coolant is cooled first in heat exchanger HE2, then in the evaporator (V6, V3 are closed, and the rest are completely or partially open) Fig. 1, c.

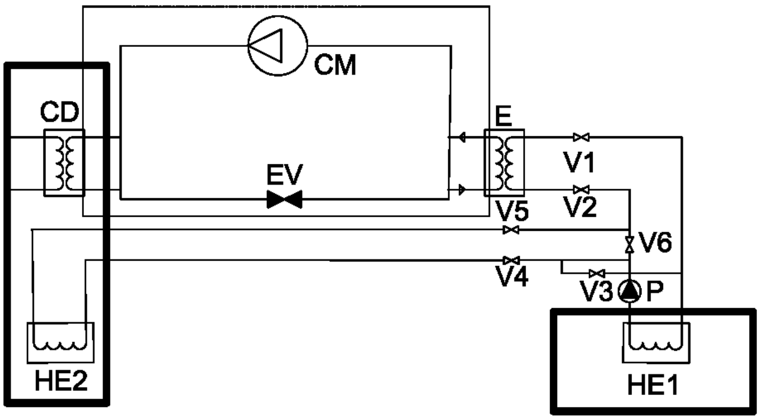
Systems with intermediate coolant also have significant operational advantages. Automatic control of such heat pumps is not particularly difficult. Due to the flexible and combined operation of system control units, it is possible to significantly reduce the volume of refrigerant in the system, which makes it possible to increase the environmental safety of the system and reduce investments in the event of high costs for new refrigerants. The diameters of main pipelines and the number of connecting seams are reduced, and it becomes easier to detect leaks in the system during operation. Returning oil to the compressor is more reliable. Finally, the operation of heat pumps is simplified when using non-aerotropic refrigerants such as R404a, R407c, etc.[7-10].



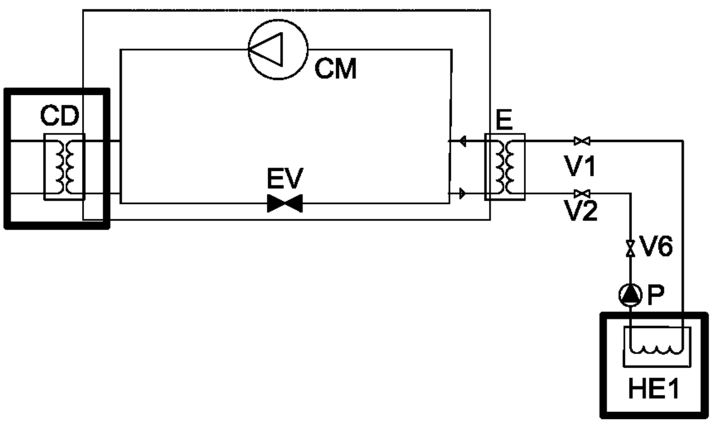

a) scheme of the system with intermediate refrigerant, circuit in a condenser and evaporator circuit




b)scheme of the system with intermediate refrigerant, circuit in a condenser circuit




c) scheme of the system with intermediate refrigerant, circulation in the evaporator cycle




d) scheme of the system with intermediate refrigerant, cooling cycle for the warm period of the year

Fig.1 Cycles of systems with intermediate refrigerant.

In traditional heat exchangers, the intermediate refrigerant-heat exchanger (shell-and-tube condenser and evaporator) temperature difference between the phase transition of the refrigerant and the temperature of the intermediate coolant is 6K. Additional losses of cooling capacity reach up to 23% and 7% in the case of using systems with intermediate coolant on the evaporator and condenser respectively (evaporation temperature t0=+5°C, and condensation temperature tk=+45°C). Comparison with traditional cooling systems showen in Fig.2.

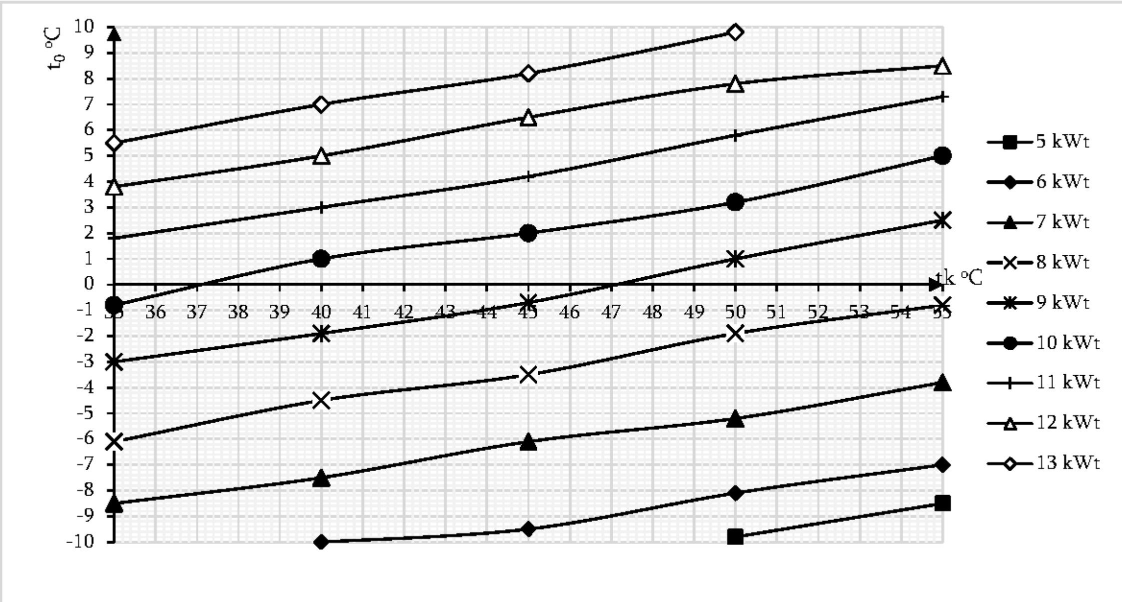



Fig. 2. Dependence of cooling capacity Qo kW on evaporation to and condensation tk temperatures

The use of efficient plate heat exchangers makes it possible to reduce the degree of incomplete recovery by up to 3°K, therefore the values of cooling capacity losses in intermediate heat exchange systems with plate heat exchangers (evaporator and condenser) are 12% and 3%, respectively. Experiment shows that an increase in hydraulic losses in plate heat exchangers does not significantly affect the efficiency of the cycle. On the other hand, their use significantly improves the volumetric and operational characteristics of the system [11, 12].

For a clearer understanding of the operation of systems with an intermediate coolant, parameters for calculating equipment characteristics using a plate heat exchanger on an evaporator are given. The cooling capacity of the equipment is assumed to be 10 kW at an ambient temperature of 25°C and a cooled environment of 18°C and working coolant is R22.

For calculations the following was taken:

1. 25% of the energy used by the compressor is spent on superheating the freon,
2. The compressor displacement coefficient was observed as a function of the refrigerant vaporization temperature and the suction superheat value.
3. The cost of electricity for the transportation of the intermediate heat carrier in the pipes is not taken into account, because the power of the pump is very small compared to the power of the compressor.
4. The energy saving of the cooling mode is taken into account when the outdoor temperature is below +1°C

## 3. Results and Discussion

Fig. Figures a, b, c of 3 show the calculated dependence of the used electricity on the external air temperature of the periods of the year (cooling savings in systems with an intermediate coolant) for 3 cities of Armenia:

1- Application of the intermediate coolant system on the evaporator-condenser
2- Applying the intermediate coolant system to the evaporator
3- Applying the intermediate coolant system to the condenser
4- the system without intermediate coolant

Fig. 3-a. In Yerevan, E-mail monthly energy costs for different cooling systems

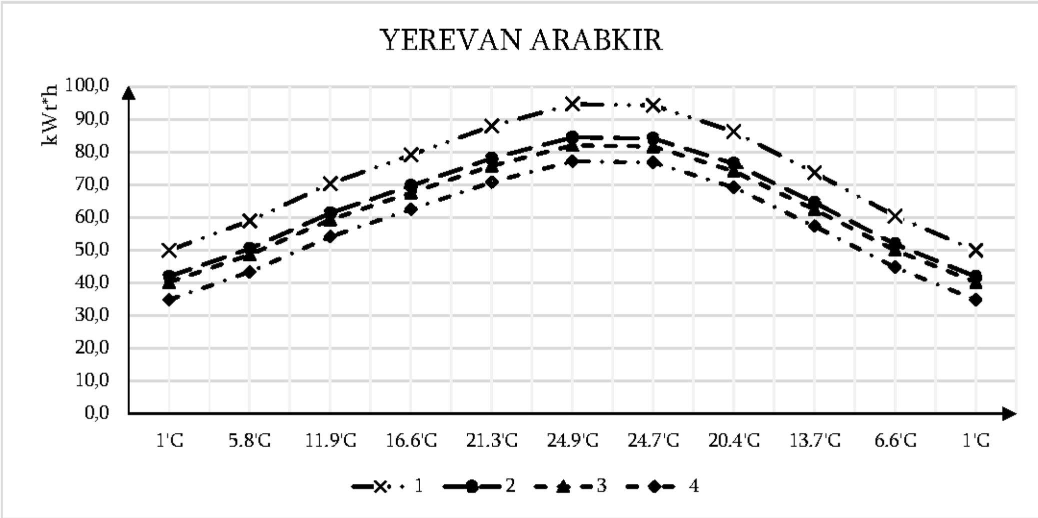



Fig. 3-a. Monthly electricity costs for different cooling systems in Yerevan

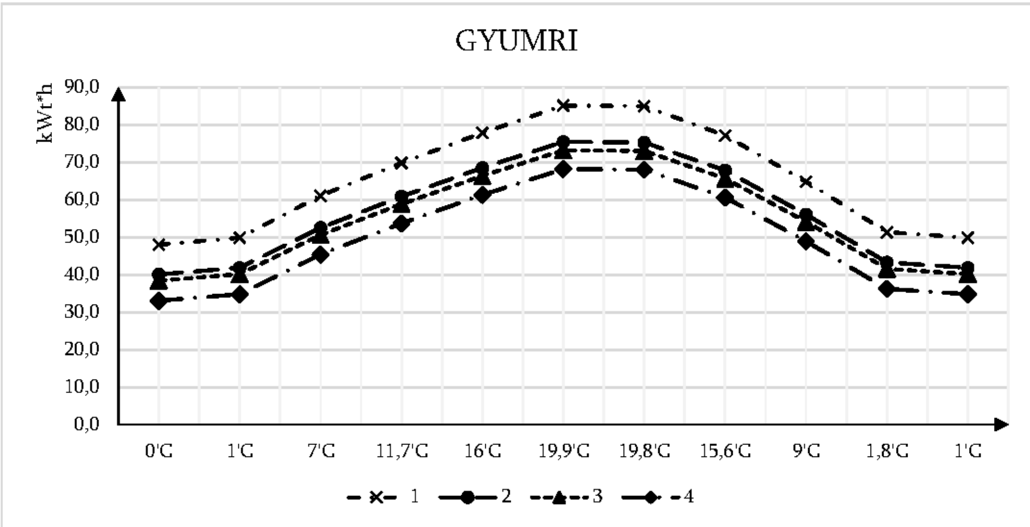



Fig. 3-b. Monthly electricity costs for different cooling systems in Gyumri,

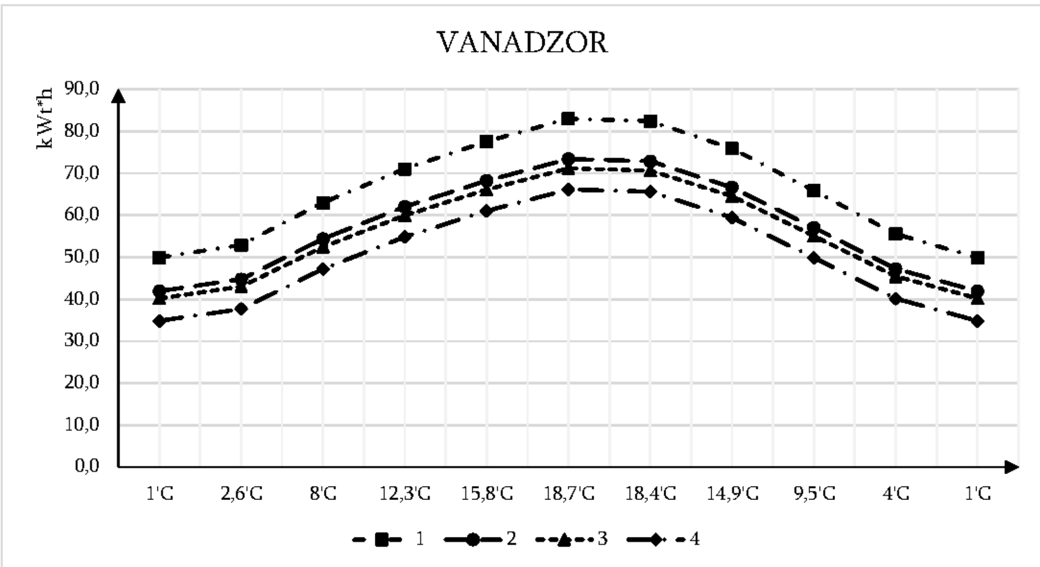
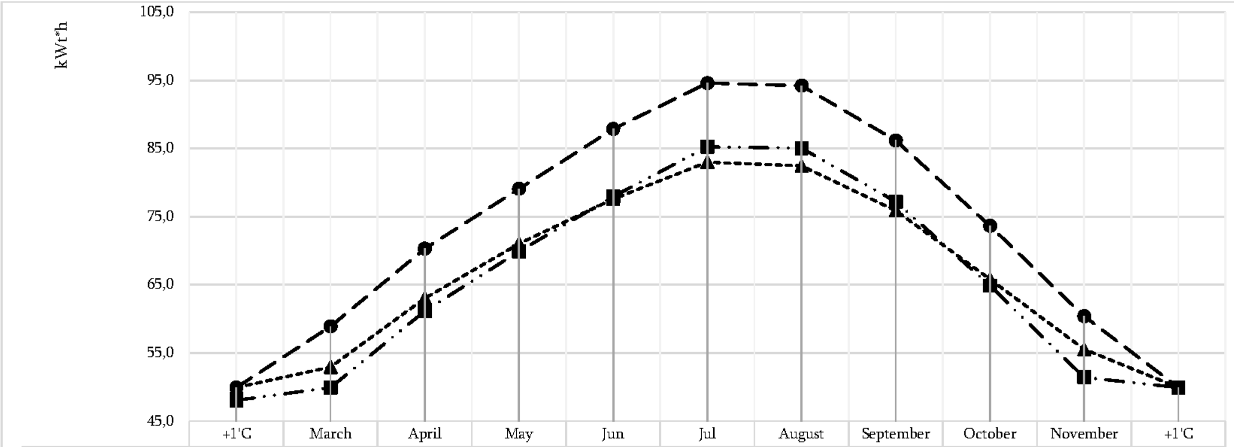



Fig. 3-c. Monthly electricity costs for different cooling systems in Vanadzor.

Fig. Figure 4 shows the calculated dependence of the electricity used in Yerevan, Gyumri and Vanadzor on the external air temperature of the periods of the year, the application of the intermediate coolant system on the evaporator-condenser.




| | +1'C | March | April | May | Jun | Jul | August | September | October | November | +1'C |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Yerevan Arabkir | 49,9 | 58,9 | 70,3 | 79,1 | 87,9 | 94,6 | 94,2 | 86,2 | 73,7 | 60,4 | 49,9 |
| Gyumri | 48,1 | 49,9 | 61,1 | 69,9 | 78,0 | 85,3 | 85,1 | 77,2 | 64,9 | 51,4 | 49,9 |
| Vanadzor | 49,9 | 52,9 | 63,0 | 71,1 | 77,6 | 83,0 | 82,5 | 75,9 | 65,8 | 55,5 | 49,9 |

Fig. 4. Monthly electricity costs for different cooling systems in Yerevan, Gyumri, Vanadzor,

The choice of cities is not random, because Yerevan is located in a warm climate zone, Vanadzor in a moderate climate zone, Gyumri in a cold climate zone [13].

Integrating the energy consumption for the whole year, a criterion is obtained that characterizes the efficiency of the use of the system with intermediate heat exchanger from the point of view of energy saving.

Tab. 1. Percentage Energy Savings in Different Types of Cooling Systems

| | IHE on the evaporator | IHE on the condenser | IHE on the condenser and evaporator |
|---|---|---|---|
| With shell and tube heat exchanger | -2.4% | +3.0% | -25.7% |
| With plate heat exchanger | +11.2% | +13.8% | +0.4% |

## 4. Conclusions

- It can be seen from Table 1 that systems with intermediate coolant with plate heat exchangers are becoming one of the most cost-effective cooling systems or heat pump.
- Air-conditioning and cooling systems with an intermediate coolant will be more efficient in production purposes, where we have positive temperatures all year round. The effectiveness of such systems is evident especially in countries with moderate and cold climates.

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