PIPELINE LENGTH EFFECT ON THE THERMAL PERFORMANCE OF SPLIT AIR CONDITIONING SYSTEM +

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Abstract :

The objective of this paper is to study the effect of pipeline length on the thermal performance of split air conditioning with cooling capacity of 2 TR, which was used to cool a special room of 3*4*2.8m, insulated internally by insulation layer made of Polystyrene. Three lengths of pipeline 3,4 and 5m were used for compression of thermal performance, pressure gauges and thermocouples are used at identified locations, in each of entrance and exit of(condenser, evaporator, capillary tube and compressor), the period of system operation was limited until the difference between indoor and outdoor temperatures reached 10^{o}C. The results show that the pipeline length of 3m gives the best results in term of thermal performance which higher than thermal performance (COP) of pipeline 5m by 15%.

Keywords: Pipeline length, spilt air conditioner, thermal performance.

تأثير طول الانبوب على الاداء الحراري لمنظومة تكييف الهواء المنفصل

كمال جلال توفيق

المستخلص :

يهدف هذا البحث الى دراسة تأثير طول الانبوب لمنظومة تكييف الهواء من النوع المنفصل على الاداء الحراري وذلك باستخدام مكيفة هواء سعة 2طن منصوب لغرض تكييف غرفة معزولة من الداخل بمادة عازلة من الستايروبور بأبعاد 3×4×2.8م. لأجل مقارنة الاداء الحراري استخدمت ثلاث اطوال من الأنابيب لربط الجزء الداخلي بالجزء الخارجي للمنظومة وهي 3، 4 و5 م. تم استخدام مقايس الضغط ومزدوجات الحرارية عند النقاط التي تم تحديدها عند الدخول و الخروج لكل من (المكثف والمبخر والأنبوب الشعري والضاغط)، كما تم تحديد فترة تشغيل المكيف لحد الحصول على فرق بين درجتي الحرارة الداخلية والخارجية بعشر درجات مئوية. تبين من النتائج ان انبوب بطول 3م يعطي نتائج افضل من حيث الاداء الحـــراري والذي هو اكبر من الاداء الحراري لانبوب 5م بنسبة 15%.

كلمات دالة : طول الانبوب ، مكيفة هواء منفصل ، الاداء الحراري.

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Introduction:

Refrigeration is a process in which work is done to move heat from one location to another. The work of heat transport is traditionally driven by mechanical work, but can also be driven by heat, magnetism, electricity, laser, or other means. Refrigeration has many applications, including, but not limited to industrial freezers, cryogenics, and air-conditioning. Heat pumps may use the heat output of the refrigeration process, and also may be designed to be reversible, but are otherwise similar to refrigeration units. Refrigeration and air conditioning system are used to cool products or a building environment. There are several types of air conditioning system available for use:

a) Air conditioning (for space or machine).
b) Split type air conditioners.
c) Fan coil units in a large system.
d) Air handling units in a large system.

Split type air conditioning units are usually used for small and medium size residential building, also used in hotels, and government buildings recently in Iraq, that is divided to two parts, outdoor part is called (condensing unit) and indoor part is called fan coil unit. The split type air conditioner based on the vapor compression refrigeration.

Yumoto et al.,2006[1] developed an experimental study on a split air conditioning to evaluate the performance under the actual condition in Japan, by two methods , one is measurement of a total energy consumption under fluctuation condition and the other is starting performance. From the results, they suggested that it is necessary to establish the evaluated method under actual condition. Ali and Usama,2007 [2] developed a theoretical and experimental studies on environmental effect on the performance of a vapor compression refrigeration system in air conditioning, by using R22 as circulating refrigerant. The result shows the (COP) was not effected greatly by the variation of humidity contain, but it vary inversely with dry bulb temperature. Tarred and Salim,2009[3] studied experimentally the use of R407C alternative to R22 in window type air conditioning. From the results they obtained, the COP of the system is reduced by 71% when alternative refrigerant is used. Takuya and kametani2010[4] studied the performance of a split air conditioner system based on a variable mass flow rate of the refrigerant by using two variable speed compressors. Researchers reached to develop an empirical relations of mass low rate of the refrigerant when each compressor works on its own, and both compressors works with each other. Jassim,2011[5] developed a practical study to improve the performance of condenser of split air conditioner by using evaporative cooling. The results of this study showed the value of COP of the system is increased by 73% and power consumption decreased by 18%. Elsayed and Hariri,2011[6] studied the effect of condenser air flow rate on the performance of split air conditioner by using variable speed condenser fan controlled with outdoor temperature via (PID) controller. They showed that the reduction in compressor power consumption is done by 10% by increasing the condenser air flow rate by 50%.

Chen et al.2012[7] offered a comparative study, two condenser units were used as outdoor in split air conditioner system without any change in other elements. The comparison between baseline condenser and liquid-vapor separation condenser(LSC). The results showed that the unit employing the LSC can supply equivalent cooling capacity and ERR value as the unit with baseline condenser when refrigerant charging amount was 80.3% of the baseline one and also the cooling capacity and EER value in LSC unit were found more sensitive than that

baseline unit at undercharge condition, but they can keep relative steady at overcharged condition.
Yan et al.2012[8], developed a model to study the effects of refrigerant pipeline length on the operational performance of a dual evaporator air conditioning system. They obtained that the change in the length of refrigeration of pipeline up to 20m causing reduction in value of COP by 7.7%.
The aim of this paper is to study the effect of pipeline length between indoor and outdoor units on the performance of split type air conditioning system, and the selected length of pipelines were (3,4,and 5)m, used in (2TR) HAAS split air conditioner model under controlled environment (outdoor condition at 33-35^{o}C DBT and indoor 27^{o}C DBT). Table (1) gives the technical specification of HAAS split air conditioner

Experimental Work:

1. Installation a split air conditioning system in its location and selecting seven nodes on discharge and section pipelines at each node, a thermocouple of type k was inserted to measure temperature of circulating refrigerant with bourdon gauge to measure refrigerant pressure, as shown in fig.(1).
2. Connecting indoor and outdoor units by pipelines (3m length).
3. Evacuation process must be done before the suction and discharge valve service are opened to insure purity of circulating refrigerant from humid air inside pipeline and evaporator.
4. The system was set on 27^{o}C DBT
5. The period of experimental is limited by 1 hr.
6. Set of reading data from measuring apparatus may be recorded at every 15min.
7. Before stopping the unit, all circulating refrigerant stored in outdoor unit by closing discharge service valve firstly and after a few minute the suction service valve must be closed, after insuring the pipelines and evaporator reached to pressure of -76 cm Hg.
8. The pipelines are changed to (4 and 5)m respectively, and procedures are repeated from item 3 to item 7 for each length.

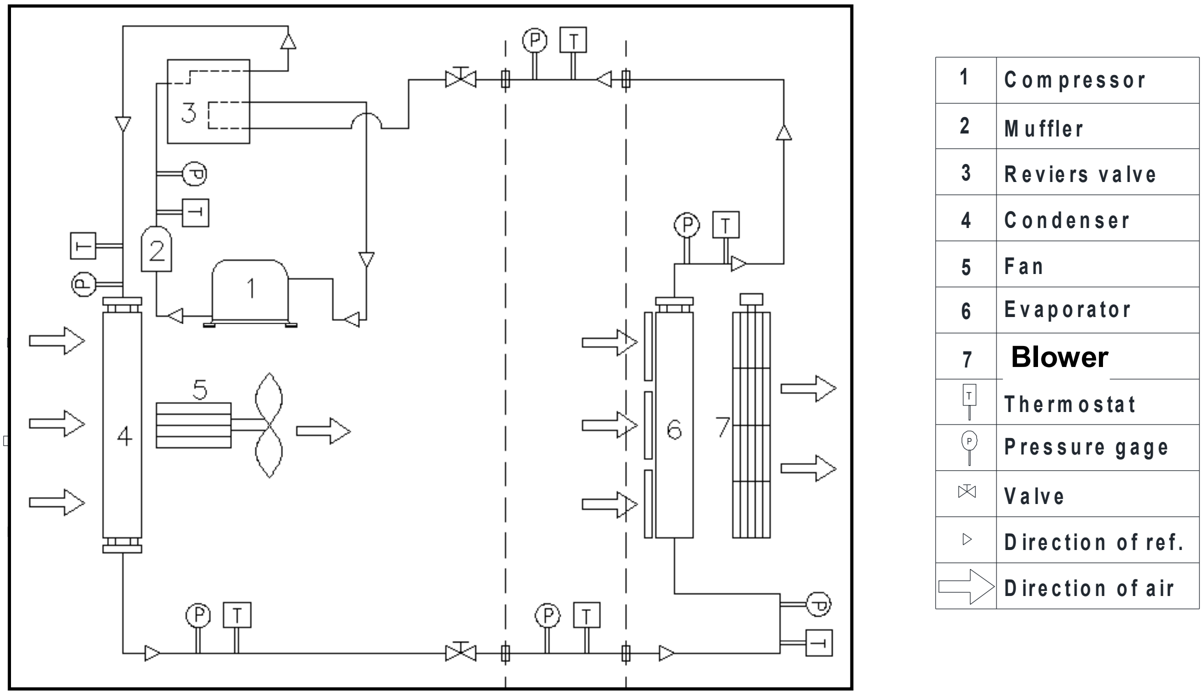

Figure (1): A schematic view of the experimental apparatus

Theoretical Background :

The pressure-enthalpy (p-h) diagram is the most common graphical tool for analysis and calculation of the heat and work transfer and performance of a refrigeration cycle. Fig(2) shows a standard vapor compression refrigeration cycle, and consist of four refrigeration processes[9].

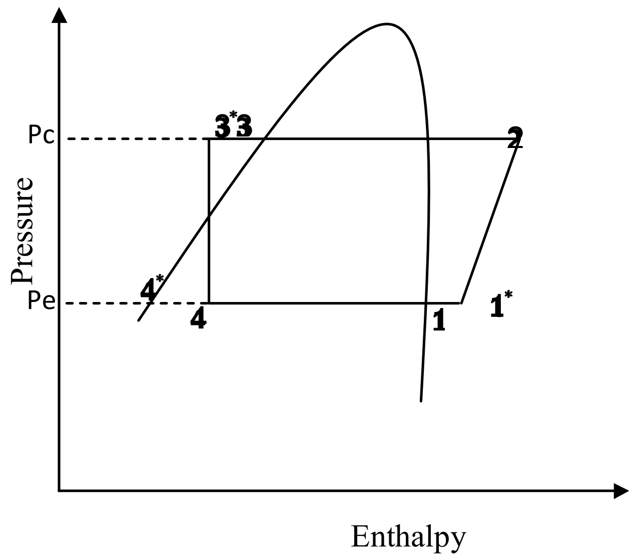

Fig.(2) Basic refrigeration cycle on *p-h* diagram[9]

1. Isothermal evaporation process ($4\text{-}1^*$) – the refrigerant evaporates completely in the evaporator and produce refrigeration load of the cycle, and its estimated by:

$$Q_{evap} = \dot{m_r}(h_1 - h_4) + \dot{m_r}\, cp_g(T_1 - T_{1^*}) \quad \ldots\ldots(1)$$

where h_1, h_4 are enthalpy of refrigerant at state points 1 and 4 respectively (J/kg), $\dot{m_r}$ is mass flow rate of a refrigerant (kg/s) and cp_g is a specific heat of a refrigerant (J/kg.^{o}C).

2. Isothermal compression process ($1^*\text{-}2$) – vapor refrigerant is extracted by a compressor and compressed isentropically from state 1^* to 2. The work input to the compressor is calculated as:

$$W_{comp} = \dot{m_r}(h_2 - h_{1^*}) \quad \ldots\ldots(2)$$

where h_2 is enthalpy of refrigerant at state 2

3. Isothermal condensation process ($2 – 3^*$) – Hot gaseous refrigerant discharged from the compressor is condensed the condenser into liquid, and the latent heat rejected to the ambient air. The condensing load of the condenser is estimated by:

$$Q_{cond} = \dot{m_r}(h_2 - h_3) + \dot{m_r} cp_l(T_3 - T_{3^*}) \quad \ldots\ldots(3)$$

4. Throttling process ($3^*\text{-}4$) – The liquid refrigerant flows through throttling device (capillary tube) , and its pressure reduced to the evaporating pressure. In this process, assuming that the heat gain from the surroundings is negligible:

$$h_{3^*} = h_4 \quad \ldots\ldots(4)$$

5. The value of COP of the refrigeration cycle is estimated by:

$$COP = \frac{h_1^* - h_4}{h_2 - h_1^*} \quad \ldots\ldots(5)$$

Through the throttling process, under constant enthalpy process, portion of the liquid is evaporated to cool the liquid down to the temperature at the evaporative pressure line ($1\text{-}\ 4^*$) the percentage of the flash gas is calculated as the follow:

$$\%\ of\ flash\ gas = \frac{h_4 - h_{4^*}}{h_1 - h_{4^*}} \times 100 \quad \ldots\ldots(6)$$

The remainder amount of the liquid excluding the flash gas in the evaporator is the useful effective liquid for refrigeration, the enthalpies difference between (1 – 4) is the “Net Refrigeration Effect (NRE)”. Therefore:

$$NRE = h_1 - h_4 \quad \ldots\ldots(7)$$

The amount of refrigerant flow required to absorb one (TR) through the evaporator is determined as follow:

$$\dot{m_r} = \frac{3.5}{NRE} \times TR \quad \ldots\ldots(8)$$

Results and discussion :

The purpose of air conditioning is to control the filtration, air movement, temperature and humidity of an atmospheric environment. The best efficiency of air conditioner is the required cooling load in minimum time. Figure (3) shows the time required to reach temperature difference $10^{o}C$ between outside and inside temperature for each pipe length, it shows that the temperature difference between outside and inside environment are affected by the pipe length. The temperature difference is inversely related to pipeline length, and the system with 5m pipe length is quicker than others to reach a temperature difference of $10^{O}C$. In the case of 5,4 and 3m pipeline length the system reached the higher temperature difference in (25, 28 and 33) min. respectively.

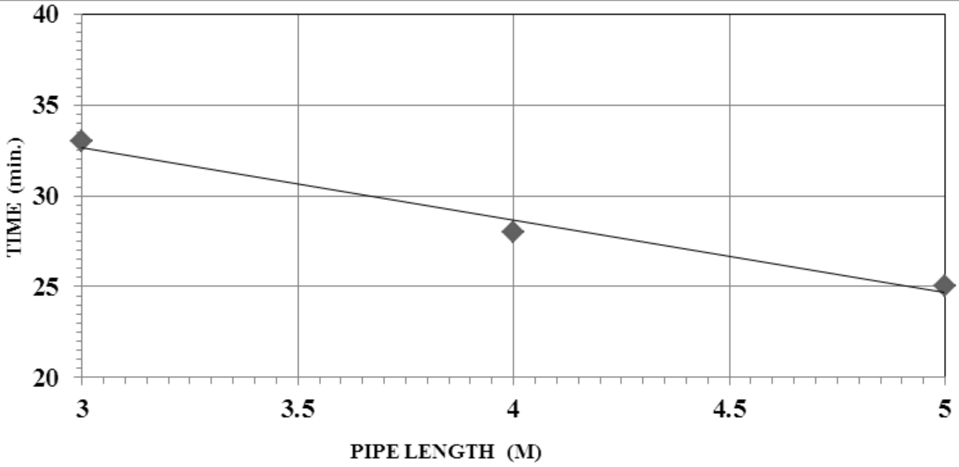

Figure (3) Time required to reach a temperature different between outdoor and indoor temperature to (10°C) for each pipe length

The effect of length on a pressure drop in each of suction and discharge pipelines was very little as shown in fig.(4), pressure drop is related proportionally to the pipe length.

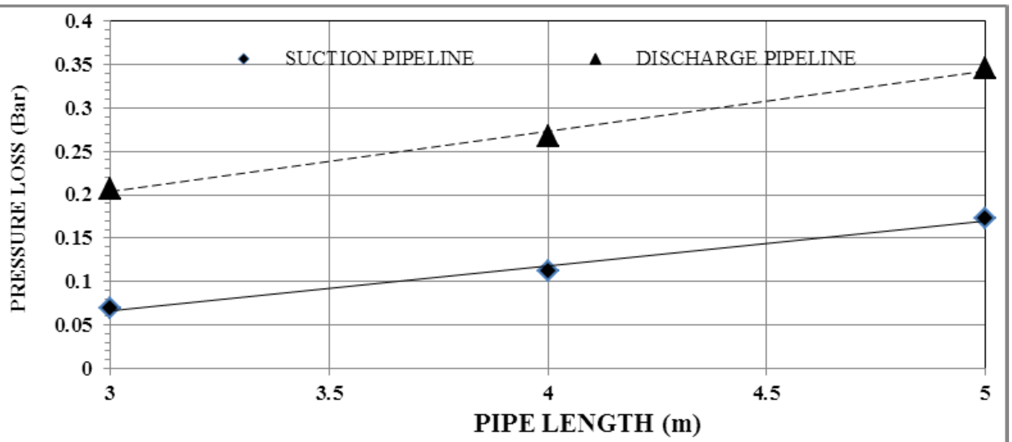

Fig.(4) Pressure drop as a function of pipeline length

Where the higher values of pressure drop were obtained in discharge pipeline, because the refrigerant flow in this pipe is in liquid state . Fig.(5) shows that the value of COP decreased as a the length of the pipeline increased. The maximum value of the COP at pipeline length of 3m, was about 4, but this value is reduced upon increasing pipe length the reduction in COP over 5m was 15%.

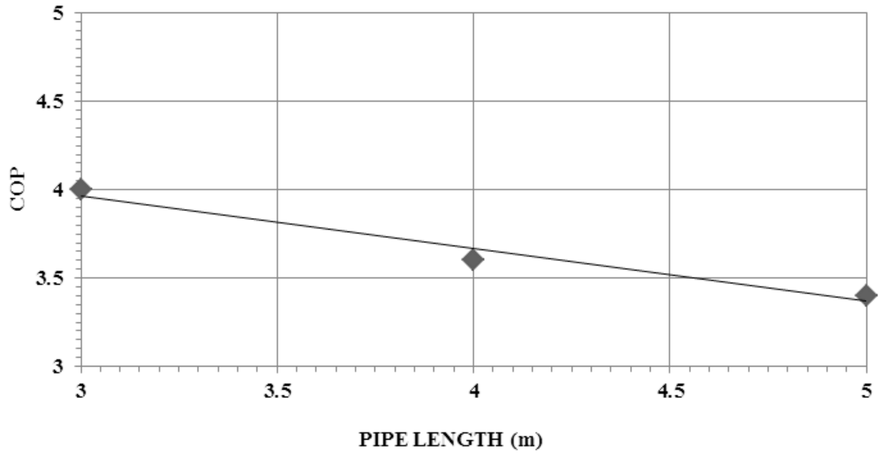

Fig.(5) Relation between COP and pipeline length.

After expanding the liquid refrigerant through a capillary tube, the refrigerant changed into a mixture of flash gas and liquid, and any reduction in the amount of flash gas is considered as a positive case to improve a refrigeration load of the cycle, while the percentage of the flash gas depended on the pipeline length as shown in fig.(6), The percentages of flash gas changed from 34.7 to 24.7% , when pipeline length was changed from 3 to 5m.

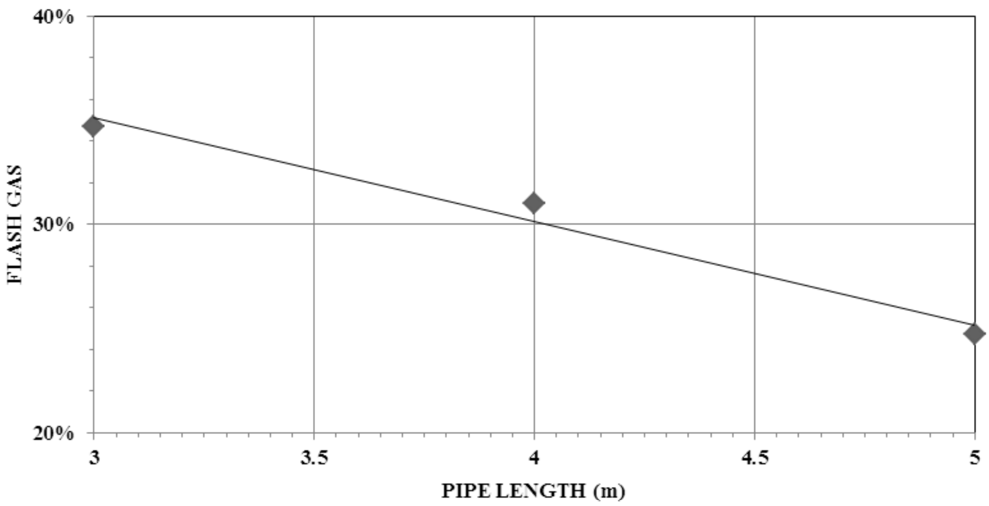

Fig.(6) Percentage of flash gases created in the refrigerant cycle

Fig (7) shows that amount of refrigerant was changed according to change of pipeline length in opposite form, where the maximum mass flow rate of the refrigerant occurred 3 m length and minimum amount was in case of 5m length, and this is due to extension of flow distance.

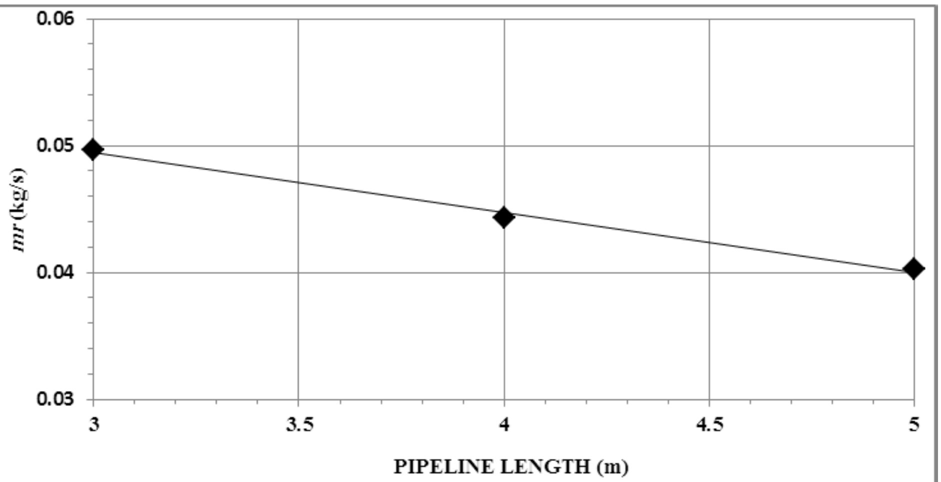

Fig.(7) Relation between mass flow rate and pipeline length

Conclusion:

The experimental results, showed that increasing pipeline to 5m caused reduction in each of COP, m_r, percentage of flash gas, and the period of system operation to are reach 10^oC. For this reason the split air conditioner will become more effective in operational performance. The effect of pressure drop of the system was very little, especially in suction pipeline.

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Table (1): Technical specification of HAAS split air conditioner

Model	SXSA24CV73
Supply (V-PH-Hz)	240 – 1 – 50
Current Cool	15A
Current Heat	11.8A
Test Pressure	High 300 Psig Low 150 Psig
Power input	Cool 24000 Btu/hr Heat 26000 Btu/hr
Comp. LRA	75 A
Refrigerant Charge	R22 1.830 kg