Experimental Investigation of Joule – Thomson Effect

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Abstract- *The Joule – Thomson effect describes the temperature change of a real gas or liquid when it is forced through a valve or porous plug while keeping them insulated so that no heat exchange takes place with the environment. The gas cools when the gas temperature is below inversion temperature and vice versa. At present, industries are using bigger cooling and liquefaction systems, so it is becoming a burden for the industries for procuring and maintaining the Joule – Thomson coefficient and the low efficiency of the system. The project is to study the present system and making it compact without affecting the overall efficiency of the system.*

Keywords- Air Compressor, Needle Valve, Dryer, Temperature Indicator, etc.

I. INTRODUCTION

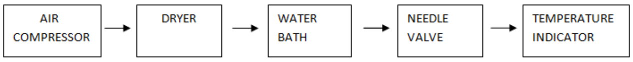
The Joule–Thomson effect describes the temperature change of a real gas or liquid when it is forced through a valve or porous plug while kept insulated so that no heat is exchanged with the surrounding. This procedure is called a throttling process or Joule–Thomsonprocessroom temperature all gases except hydrogen,helium and neoncoolupon expansion by Joule-Thomson process. These three gases experience the same effect but only at low temperatures.

The throttling process is commonly exploited in thermal machines such as refrigerators, air conditioners, heat pumps, and liquefiers. Throttling is a fundamentally irreversible process. The throttling due to the flow resistance in supply lines, heat exchangers, regenerators, and other components of (thermal) machines is a source of losses that limits the performance.

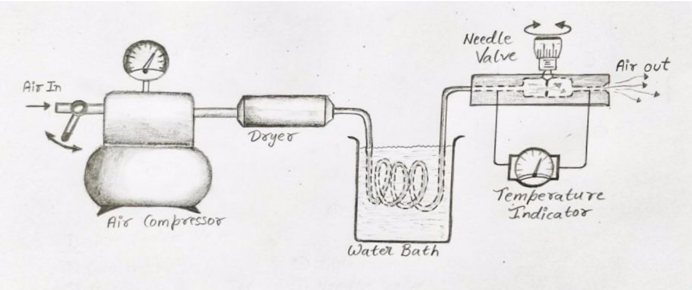
The effect is named after James Prescott Joule and William Thomson, 1st Baron Kelvin, who discovered it in 1852. It followed upon earlier work by Joule on Joule expansion, in which a gas undergoes free expansion in a vacuum and the temperature is unchanged, if the gas is ideal.

II. EXPERIMENTAL SETUP

BLOCK DIAGRAM



SKETCH OF THE APPARATUS



III. APPARATUS REQUIRED

Air Compressor: The model of the air compressor used in the experiment is DA7001. The maximum pressure it can withstand is 8 bar. The capacity of the air tank is 30L. The gross weight of the air compressor is 33kg.

Needle valve: A needle valve is a type of valve having a small port and a threaded, needle – shaped plunger.

It allows precise regulation of flow,although it is generally only capable of relatively low flow rates. It works as an expansion device for the experiment.

Temperature Indicators: These are installation instruments which can process signals from temperature sensors and show them on the display. Temperature indicators enable easy and economic valuation of resistance sensors, such as Pt100or different thermo element types.

These sensors can be directly connected to temperature indicators to avoid the installation of a transducer.

Thermocouple Wires: These are attached to the inlet and outlet of the needle valve. A thermocouple is an electrical device consisting of two dissimilar electrical conductors forming electrical junctions at differing temperatures

A thermocouple produces a temperature-dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature. Thermocouples are a widely used type of temperature sensor.

Water Bath: It is used to maintain the ambient temperature at the inlet of needle valve.

The air from the compresor is circulated inside the water bath through the coils at room temperature and passed for further process. The water bath works as a heat exchanger.

InsulationMaterials: Insulation is the reduction of heat transfer between objects in thermal contact or in range of radiative influence.

Thermal insulation can be achieved with specially engineered methods or processes, as well as with suitable object shapes and materials.

Electrical Switch:A switch isan electrical component that can "make" or "break" an electrical circuit, interrupting the current or diverting it fromone conductor to another.

The mechanism of a switch removes or restores the conducting path in a circuit when it is operated.

Dryer: The dryer is used to soak the moisture coming out of the air compressor.

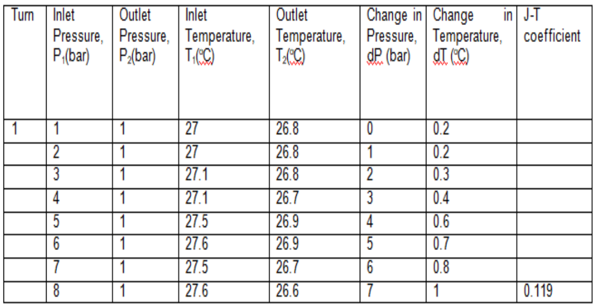
The model used is DML 304 called by the name Hermetic filter dryer. The net volume of the dryer is 0.224L. The maximum pressure it can withstand is 46 bar.

IV. EXPERIMENTAL PROCEDURE

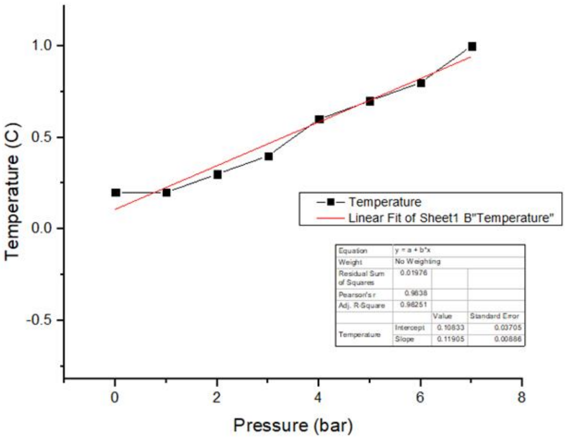
- Air compressor and temperature indicator should be switched ON.
- The number of turns in the needle valve should be 1.
- The right valve of the air compressor and the valve of the tube inserted in water bath should be opened completely.
- When the pressure of the air in the air compressor reaches to 1bar, left valve of the air compressor should be used to maintain the pressure at 1bar itself. (Here 1bar is the inlet pressure and the outlet pressure will be the atmospheric pressure that is 1 bar and this outlet pressure will be same for all the readings)
- At this maintained temperature of 1bar, both the inlet and outlet temperatures should be noted down which is shown by the temperature indicator using the switch.
- After this the position of the left valve should be changed so that the pressure startsincreasing.
- The first set of readings should be taken for pressure values ranging 1bar - 8bar.
- Similarly, the second set of readings should be taken for pressure values ranging 1bar - 8bar but the number of turns in the needle valve should be 2.
- Set of readings should be ranging from 1 - 8 turns of the needle valve.
- After the readings are taken, a graph should be plotted between dTvsdP for each set of reading.
- The slope of these graphs give the value of Joule - Thomson Coefficientμ_{JT} .

V. EXPERIMENTAL OBSERVATION:

Turn 1:



Turn	Inlet Pressure, P_1(bar)	Outlet Pressure, P_2(bar)	Inlet Temperature, T_1(°C)	Outlet Temperature, T_2(°C)	Change in Pressure, dP (bar)	Change in Temperature, dT (°C)	J-T coefficient
1	1	1	27	26.8	0	0.2	
	2	1	27	26.8	1	0.2	
	3	1	27.1	26.8	2	0.3	
	4	1	27.1	26.7	3	0.4	
	5	1	27.5	26.9	4	0.6	
	6	1	27.6	26.9	5	0.7	
	7	1	27.5	26.7	6	0.8	
	8	1	27.6	26.6	7	1	0.119



VI. LITERATURE REVIEW

➢ The Joule-Thomson Effect in Petroleum Fields: II. CO_2 Sequestration, Wellbore Temperature Profiles, and Thermal Stresses and Wellbore Stability

Abstract

The significance of Joule-Thomson effect in petroleum industry applications has extensively been documented in the literature. In the first part of an extensive literature survey conducted on the significance of Joule-Thomson effect in petroleum fields YadaliJamaloei and Asghari, 2015, this effect was presented in well testing, in multilateral/slanted wells, in drilling/completion/production operations, and in hydrate formation. In this article, the second part of this comprehensive review is presented, which consists of Joule-Thomson effect in CO_2 injection into depleted natural gas reservoirs, in prediction of wellbore temperature profiles, and the influence of thermal stresses resulting from this effect on the wellbore stability. It is expected that this article will serve as a reference tool for the engineers interested in the Joule-Thomson effect in petroleum fields.

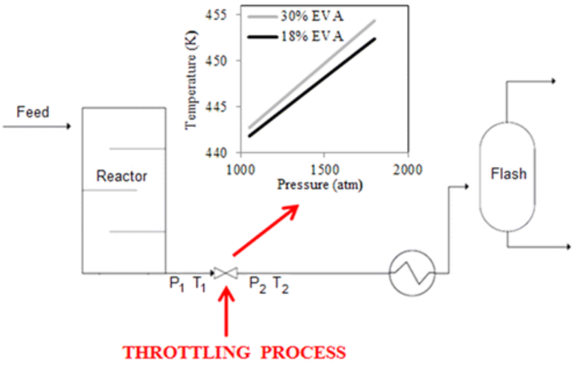
➢ Prediction of final temperature following Joule-Thomson expansion of nitrogen gas

* Abstract

This paper shows a theoretical prediction of the final temperature T_a which can be obtained using the Joule-Thomson (J-T) effect by expanding nitrogen gas across a throttling valve to 0.101 MPa. An iteration method using the J-T coefficient μ is first used to predict T_a. The Benedict-Webb-Rubin (BWR) and Redlich-Kwong (RK) equations are used to determine the specific volume and the derivatives of properties, respectively. Values of T_a can be well predicted by a five-step expansion simulation, except for cases where the isenthalpic lines to 0.101 M Pa cross a region around T = 120–160 K and P = 6.0 M Pa. In this region, calculated μ are lower than the experimental data. By equalizing the value of enthalpy after expansion to that before expansion and using the Peng-Robinson (PR) equation to calculate the departure function, the values of T_a can also be well predicted by the second method, except for $P_{b> 3.5\,MPa}$ in the cases where T_b = 170 and 150 K.

➢ Joule–Thomson Effect in Mixtures Containing Polymers and Copolymers

➢



The objective of this study is to evaluate the Joule–Thomson effect, which occurs at a valve due to the throttling process for mixtures containing polymers and copolymers. For economic and safety reasons, it is essential to know the temperature change in industrial processes due to the pressure drop in the valve. The modeling of this phenomenon in mixtures containing polymers and copolymers, however, remains a challenge for process engineers, and the literature rarely reports studies on the subject. This work proposes a model that can directly compute temperature due to the throttling process using the concept of residual enthalpy and the perturbed-chain statistical associating fluid theory equation of state, instead of solely computing the Joule–Thomson coefficient. Systems containing poly (ethylene-co-vinyl acetate) and low-density polyethylene were chosen as case studies because of the need for temperature control at the reactor outlet and separation processes. The model prediction was validated using industrial data, and deviations of approximately 2% between the model prediction and the experimental temperature indicate the efficiency of the proposed approach when describing the temperature due to the throttling of both systems that are being studied.

VII. APPLICATIONS

- Liquefy gases: In petro-chemical industries, the cooling effect is used to liquefy gases.
- Oil and gas fields: Used regarding horizontal or multilateral or slanted wells.
- Cryogenic applications: It is used for the production of liquid oxygen, Nitrogen and argon.
- Liquefiers: Joule – Thomson effect is used because at lower temperatures, the molecules move more slowly and occupy less space, leading air change phase to become liquid.
- Refrigeration: Joule – Thomson expansion is a valuable tool as it allows rapid cooling down to operating temperatures from room temperature.

VIII. SOCIAL RELEVANCE

- Reducing the usage and wastage of the natural resources (such as Helium, Nitrogen, etc.).
- Reducing pollution since air is used as the work input.
- Reducing the effect of ozone layer depletion by preventing the use of CFC gases.
- Reducing the cost by simple design and construction of the system and since system uses natural air as a work input.

IX. CONCLUSION

The experiment we conducted was for varying pressure from 1 atmospheric pressure to 8 bar and the temperature held constant at room temperature, for which the Joule – Thomson coefficient is found to be 0.1042.

The Joule – Thomson coefficient of air at 1 atmospheric pressure and 50 ^{0}C when computed is found to be 0.189, but the observed value found by Joule – Thomson was 0.204 and the same by Noell was 0.185[10].

REFERENCES

[1] M.J. Moran and H.N. Shapiro "Fundamentals of Engineering Thermodynamics" 5th Edition (2006) John Wiley & Sons, Inc.

[2] B. N. Roy (2002). Fundamentals of Classical and Statistical Thermodynamics. John Wiley & SonsISBN 0-470-84313-6.

[3] Hoover, Wm G, Carol G. Hoover and Karl P. Travis. "Shock-Wave Compression and Joule–Thomson Expansion." Physical review letters 112.14 (2014).

[4] A.T.A.M. de Waele, Basics of Joule–Thomson Liquefaction and JT Cooling, Journal of Low Temperature Physics, Vol.186, pp.385-403, (2017).

[5] R.G. Mortimer “Physical Chemistry”, Benjamin/Cummings, Redwood City, Calif

[6] Mamata Mukhopadhyay, “Fundamentals of Cryogenic Engineering”, 4th edition, PHI Learning.

[7] Er. R.K. Rajput, “Thermal Engineering”, 9th edition, Laxmi Publications.

[8] Beattie, J. A. and Bridgeman, O. C., J. Amer. Chem. Soc., 49, 1665 (1927).

[9] Taylor, H. S. and Glasstone, S. (eds.), "A Treatise on Physical Chemistry",vol. II, 187 ff. van Nostrand, Princeton, N.J. (1951).

[10] Oscar C. Bridgeman, The Joule-Thomson effect and heat capacity at constant pressure for air, Research laboratory of physical chemistry, Massachusetts Institute of Technology (1929).