Effect of leakage on refrigerant distribution in an air conditioned room using propane as working fluid

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Abstract. Propane R-290 as hydrocarbon refrigerant has more benefits from the aspect of thermophysical properties, but the only weakness from this refrigerant is flammable. The distribution prediction of R-290 leakage to an air-conditioned room. The study using numerical simulation of CFD ANSYS FLUENT V.13. The distribution of R-290 with a leakage rate of 0.001kg/s and an airflow of 0.1m/s will run out after 600s, with 0.002kg/s will run out after 300s and with 0.005kg/s and 0.5m/s will run out after 120s. The mass flow rate can influence the refrigerant distribution of leakage effect flowrate. Airflow can increase the dispersion of refrigerant gas and decrease the level of the refrigerant amount at any certain point in the room after the refrigerant charge is empty. This momentum effect was due to the impact of supply air initial velocity. The buoyancy effect was due to R-290 density is greater than the air makes the refrigerant flows downward, accumulated, and stagnant. Make sure that the contactor relays and other electrical tools have the position, $x=0 \text{ m} \leq x \leq 1 \text{ m}$ on $y= 0 \text{ m} \leq x \leq 26 \text{ m}$ and then $y= 1 \text{ m}$, $x= 0 \text{ m} \leq x \leq 4 \text{ m}$.

1. Introduction
In the present time, one of the most critical issues is the phase-out of refrigerants that have the potential of destroying ozone layer depletion and global warming. One alternative is the use of alternative refrigerant, natural, and environment-friendly refrigerants. The solution is the Hydrocarbon Refrigerant (HC), among which is being developed using to propane HC (R-290). With all the advantages in terms of thermophysical, technical possessed by HC. The main weakness of this HC refrigerant is flammable. Therefore, if the HC refrigerant used for Air Conditioning (A/C), it is necessary to handle proper management according to the procedure, if propane HC leak occurs in the unit. Studies regarding the simulation of leakage HC refrigerants of the A/C unit in the room [1-3]. The process of mixing between propane and air will ultimately meet the momentum conservation equation is mass multiplied by speed, mass conservation, and species transport [1-3].
2. Methodology

Performing studies by numerical software CFD ANSYS-Fluent Version 13, and Figure 1 represented the study method [4].

2.1. Modeling leakage
The problem lies in the diffuse buoyancy jet problem, there is an unexpected source of leakage instantaneous on the air conditioning unit (A/C). When there is a leakage in the A/C unit of the room, the refrigerant exits through the A/C inlet channel into the room. The air at the same time exit from the A/C fan exhales cold air on the inlet channel above it because of the difference in density between the refrigerant and air [2].

- Prediction length of time the distribution after the refrigerant runs out is limited [1-3,5].
- The separation of sedimentation between the refrigerants and the air has remained stagnant accumulated and has not been affected by time (steady-state) [1-3,5].
- The initial charge mass of the refrigerant in the system is finite, according to the type Split Wall A/C unit [2,3].
- Distribution of flammable refrigerant leakage with uniform to the room and refrigerant properties at the entrance boundary conditions inlet are gas vapor [2,3].
- The process of mixing between refrigerant and air takes place instantaneously, according to the case of diffuse buoyancy jet spray with a difference in density [3,6].
- Mass leakage flow rate is constant over a period of time and analyzed by un-steady or transient system conditions, leakage as a function of time [7].
- The boundary conditions of the wall room are the ideal boundaries. The wall boundary condition is set up to default condition. Ventilation and losses are ignored and adiabatic isothermal [3,5,7].

2.2. Room modeling
The model and simulate using ANSYS Fluent, the geometry model first created, and various simulation parameters are determined. Software ANSYS Workbench Fluent V.13 CFD, the sequence consists of making geometries, meshing or grids, setting up problem conditions, finally get the solutions and results. The whole process of creating a room geometry model using the ANSYS Workbench v.13 CFD...
program. Starting with the ANSYS Design Modeler for 2D room construction, meshing process with ANSYS ICEM CFD meshing, solver with ANSYS Fluent until the final post-processing process with CFD post. The model created in this study is a 2-D model of the surface of the side of the room.

2.3. **Room geometry schemes (2-D)**

The room geometry for simulation in this study shown in Table 1 and the model room building created in this study is a Two Dimensional (2-D).

| The Geometry of the room | Parameter | Dimension (mm) |
|--------------------------|-----------|----------------|
|                          | Length    | 4000           |
|                          | Width     | 4000           |
|                          | Height    | 3000           |
|                          | Inlet 1 air conditioning (A/C) | 40 |
|                          | Inlet 2 air conditioning (A/C) | 40 |
|                          | Outlet air conditioning (A/C) | 80 |

In ANSYS Design Modeler, enter the geometry dimensions of the room above. Then the results of the room shape can be seen in Figure 2 below.

![Figure 2. Detail geometry room.](image)

The Table 2, simulation numerical in three variations (low, medium, and high) airflow rates.

| No. | Velocity air flow rate (m/s) | Mass flow (kg/s) (m³/min) Cfm |
|-----|------------------------------|-------------------------------|
| 1   | 0.1                          | 0.025                         | 1.5 | 0.003675 |
| 2   | 0.3                          | 0.075                         | 4.5 | 0.011025 |
| 3   | 0.5                          | 0.125                         | 7.4 | 0.018375 |

Table 3 shows that the simulation by three variations (low, medium, and high) of leakage rates.
Table 3. Leakage rate variations [3,4,8].

| No. | mass flow (kg/s) |
|-----|-----------------|
| 1   | 0.001           |
| 2   | 0.002           |
| 3   | 0.005           |

3. Results and discussion

The results are described by contours of the mole fraction propane and time. The qualitative data for Split Wall Air Conditioning (A/C) on position 2.6 meter.

**Figure 3.** Difference in R-290 concentration with leakage rate of 0.001 kg/s and variation in airflow velocity at time (t = 0s - 1200s).

In Figure 3, it is clear that at time t = 0s, the A/C unit leakage has not occurred at all, after t = 30 seconds, the leakage starts slowly. The initial effect is the accelerating gravity effect, due to differences in density and buoyancy between the refrigerant and air in addition to the initial impact of the airflow velocity.

**Figure 4.** Difference in R-290 concentration with leakage rate of 0.002 kg/s and variation in airflow velocity at time (t = 0s - 1200s).
Figure 5. Difference in R-290 concentration with leakage rate of 0,005 kg/s and variation in airflow velocity at time (t = 0s - 1200s).

In Figure 3 to 5 shows that the concentration of R-290 refrigerant distribution, at any time and the difference in the rate of leakage and airflow in the A/C unit installation position (2.6 m). And we can compare Figure-3 to 5 at time t = 30 seconds that the rate of leakage affects the accumulation of refrigerant distribution in the room.

After time t = 60 seconds, the next effect is turbulence. This occurs due to air recirculation in the A/C unit. The last fact we call the impact concentration of sedimentation, separation between air and refrigerant layers. See Figure 3 to 5, at time t = 900s- the 1200s, clearly visible the difference between air (above) and R-290 refrigerant (below) and then accumulates stagnation close to the floor.

In Table 4 below, the distribution of refrigerant concentrations over a specified period of time. When the leakage rate is 0,001 kg/s with an airflow of 0,1 m/s for R-290, the refrigerant will run out after 600 seconds (10 minutes). For mid-leak, the leakage rate of 0,002 kg/s will run out after 300 seconds (5 minutes), and most quickly after time t = 120 seconds (2 min).

| Leakage Rate (kg/s) | time (s) | 0,001 | 0,002 | 0,005 |
|---------------------|----------|-------|-------|-------|
|                     | after 600s | after 300s | after 120s |

In figure 6, the results of the description refrigerant contour mole fraction-time, show that the airflow velocity will be faster at 0,5 m/s. And the gas diffusion disperses process period is the longest for 0,1 m/s and in the middle time of 0,3 m/s.
Figure 6. Mole fraction propane – time (s).

Figure 7, from the simulation results, it can be described that for propane R-290 (2,1% LFL). Make sure that switch and other electrical equipment are advised not to be placed in the position $x = 0 \ m \leq x \leq 1 \ m$ at $y = 0 \ m \leq x \leq 2,6 \ m$ and at position $y = 1 \ m$, $x = 0 \ m \leq x \leq 4 \ m$. The recommended that switch and other equipment in the shaded position distance at $x = 1 \ m \leq x \leq 4 \ m$, $y = 1 \ m \leq x \leq 3 \ m$ above so that the risk of fire does not occur or can be prevented and minimized.

4. Conclusion
The study aimed to simulate the distribution of Propane Hydro-Carbon (R-290) to the air-conditioned room in different leakage rates dan airflow rates, using the numerical software ANSYS-Fluent in the 2-D room building. As a conclusion from the simulation, the mass flow rate can influence the refrigerant distribution of leakage effect. Airflow can increase the dispersion of refrigerant gas and decrease the level of the refrigerant amount, at any particular point in the room after the refrigerant charge amount is over. This momentum effect was due to the impact of supply air initial velocity. The buoyancy effect was due to R-290 density is greater than the air makes the refrigerant flows downward, accumulated, and stagnant.
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