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PREDICTING OF REFRIGERANT LEAKAGE IN A CONDITIONED ROOM: A NUMERICAL STUDY LEAKS DISTRIBUTION R-32 REFRIGERANT IN A/C SPLIT UNIT

Rizki Muliawan[a]*, Ari Darmawan Pasek[b]

[a]Department of Refrigeration and Air Conditioning, Politeknik Negeri Bandung, 40012, Bandung, Indonesia
[b]Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung, Bandung, Indonesia

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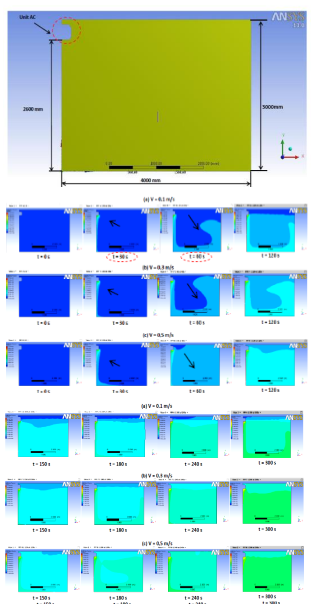
*Corresponding author
rizki.muliawan@polban.ac.id

Graphical abstract



Abstract

Hydrocarbon Refrigerant R-32 called difluoromethane is one alternative solution used for Air Conditioning (A/C) unit split, but the weakness is flame property. This study investigates and analyzes flammable refrigerant difluoromethane distributions in the room affected by the A/C unit's leakage. It discusses the distribution of flammable refrigerant R-32 (difluoromethane) in an air-conditioned room. The simulation uses three variations of mass flow rate (leakage) and three airflow rate variations: low, medium, and high cold airflow velocity. Numerical calculations are used in CFD ANSYS FLUENT software with a model developed by Species Transport, SIMPLE algorithm, solver using pressure-based, mesh type is the dominant quadrilateral (rectangle). Turbulent modeling uses K-Epsilon standards. CFD analysis in the transient system condition results from numerical simulation, indicating that the leak will run out after 180 seconds with 0.005 kg/s (0.5 m/s). The moderate leak rate of 0.002 kg/s for R-32 is 450 seconds (7.5 minutes). The slower 0.001 kg/s with 0.1 m/s airflows for the R-32 ends after 900 seconds (15 minutes). The air and flow mass flow can affect the distribution and directly difluoromethane to the conditioned room. The effect of airflow rates and positioning holes in the concentration leaks is also analyzed when the unit's refrigerant leak is indoors as the air conditioner works.

Keywords: CFD ANSYS Fluent, Difluoromethane, Distribution, AC Split, Leakage

1.0 INTRODUCTION

The development of refrigeration system technology currently leads to the potential for savings and is environmentally friendly. The greenhouse effect and the potential for global warming are among the issues that are clearly in sight. R-22 and R-410 are better to work fluid in unit *A/C* unit; however, Global Warming Potential (GWP) and Ozone Depleting Potential (ODP) values are still high at 1700 and 675 respectively [1,2,3]. The related parties have done various ways of solving the problems mentioned above, one way and an alternative that can be done is to develop a working fluid or what is commonly called a refrigerant. Refrigerant is one of the most important working fluids in the refrigeration system. Air conditioning applications, for example, A/C split which are widely used in homes or residential [4,5]. The alternative that is now widely used is environmentally friendly refrigerants (does not cause global warming and depletion of the ozone layer) and is energy efficient [6]. Hydrocarbon refrigerants are a plausible (make sense) alternative to be developed today due to energy-saving and environmentally friendly technical reasons. In addition to its advantages, there are also weaknesses of this refrigerant, and the most concern is the flammability aspect. Refrigerant hydrocarbons (HC), developed and will be used, are difluoromethane (R-32) [7].

The challenge is that many alternative refrigerants are flammable and registered under Standards ISO 817 (2014) and ASHRAE 15 & 34 standard (2013) for assigning reference numbers, safety classifications, and refrigerant concentration limits to refrigerants. Lower Flammability Limit and Upper Flammability Limit are two amounts defined to identify conditions where the ignition can occur at certain temperatures and pressures [8]. In Table 2, we can see the properties of the R-32 refrigerant; the main drawback of this refrigerant is flammability when the R-32 refrigerant is used for split air conditioners. Therefore, it is crucial to managing appropriate management according to the procedure when repairing if a leak occurs in the unit means catastrophic leaks [8], as shown in Figure 1 schematic diagram of the A/C unit. Thus, there have been several studies, both numerically and experimentally, to investigate the risk of flammable refrigerant leaks from a different system.

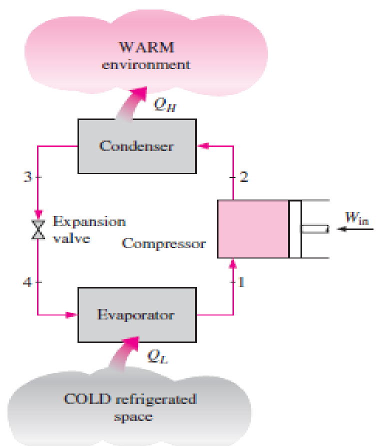


Figure 1. Schematic diagram of the vapor compression unit [19]

This study discusses the leakage of flammable Difluoromethane refrigerants from the A/C unit indoors [2]. When the air conditioner unit is in the room, the evaporator is assumed to experience a sudden leak [1]. Numerical analysis is an effective tool for this purpose as a refrigerant in the room's mass measurement is very difficult. Numerical simulation of flammable liquid cooling leak class 2L in the residential space to assess the feasibility of using these refrigerants in HVAC Systems [9]. In this study, diffusion phenomena in case of leakage of refrigerant in the large space of the room air conditioner (RAC), the variable refrigerant flow (VRF), and cooler were digitally analyzed. Based on the calculation results, refrigerant concentration distribution, volumes, and positions of the flammable regions and their time changes were determined. For RAC, the calculation results were verified using the results of a refrigerant leak experience.

Mathematics studies on gas diffusion started in the 1950s until the 1960s, and thus of development, thousand of mathematical models have been developed—the mathematical models are based on theoretical and experimental data on target different application requirements. Empirical models, Gaussian models, box models, surface models, and since the 1970s, with computer development and processing capacity continues to increase, along with the development of estimated calculation methods such as the element method; Finite Element Method, Method Finite Difference (FDM), and the Finite Volume Method [2,9]. The conservation equations (the continuity mass, the momentum, the energy). The difluoromethane leakage software process was simulated in this article using CFD theory and ANSYS fluent to study the difluoromethane HC diffusion law [10,12].

2.0 METHODOLOGY

To achieve the goals, a step process flow of research methodology was developed, as shown in Figure 2.

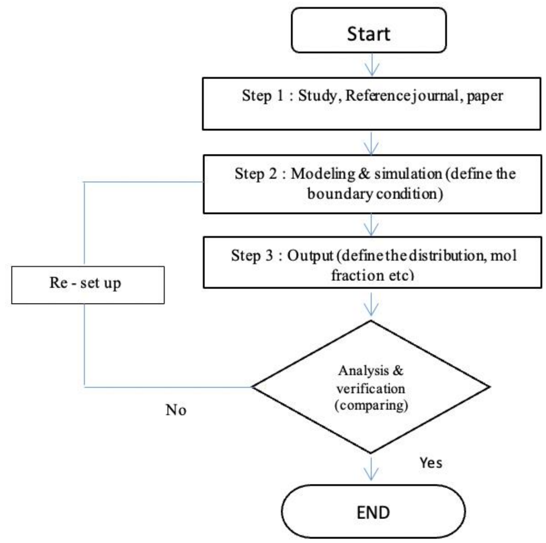


Figure 2. Steps in the flow chart of research methodology

2.1 Numerical Modeling

2.1.1 Leakage Modeling

The problem is similar to buoyancy jet diffuse; suddenly leaks in the Air Conditioning or catastrophic, the working fluid refrigerant goes through inlet the Air Conditioning unit entered to channel in the room space. The air at the same time suddenly output (Air Conditioning of fan) emits cold air on the entrance channel above because of the difference between the density of the refrigerants and the air. The mixing process between refrigerants and air is finally being fulfilled. The conservation equation of continuity conservation, transportation species, and others. The mixing process between refrigerants and air occurs instantly, following the case study of diffuse floating jet spray with different densities [3,4].

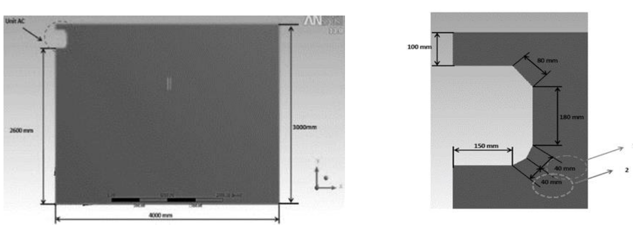
1. Depending on the split wall unit A/C, the initial charge refrigerant's in the system are limited [3].
2. Leakage of the refrigerant at the entrance (boundary conditions limits) to the entry of gas or vapor (steam), disperse flammable in a uniform flow [3].
3. The mass flow is a constant leak over a particular time and is analyzed by transient or unstable conditions (leak function of time).
4. The prediction of the duration of the concentrate after the refrigerant has been run out is limited to a given interval of time, with the analysis at a particular moment of separation between the refrigerant and the air remaining stagnant and constant by the time (steady-state) [3,5,6,7].
5. The boundary conditions of the simulated room wall (ideal isothermal), without heat flow or a rate of heat generation, without slip, not porous, a zero speed, gradient, and zero concentration temperature, and they are isolated where the ventilation and losses are ignored [3,5,6]

2.2 Modeling (Geometry room)

The model and simulation using fluid ANSYS, and geometric modeling must be made, then several simulation parameters must first be determined. The CFD Ansys Workbench Fluent Version.13 software is composed of creating a geometry, creating a mesh or grid, configuring problematic conditions, as well as solutions and results.

This is because it makes it easier to work on and geometric models are not too complicated, and the author is more familiar with direct modeling in the ANSYS Workbench. In the ANSYS Workbench, a Design Modeler (DM) functions to create a geometric model, then performs meshing on the model and defines the model's operating field. Various parameters in FLUENT must be determined before the computer can perform the iteration process. Parameters that must be determined include solver formulation, boundary conditions, turbulence model, material properties, and operating conditions.

The room's whole geometry modeling is using the CFD ANSYS Workbench Version.13 programs from the ANSYS design modeler to make rooms 2D, the meshing process with ANSYS Meshing CFD ICEM. Solver with Ansys fluid up to the final post-processing then used to Post CFD devices. The modeling made in this simulation is a 2-Dimension of the surface of the lateral room.



a b

Figure 3. The geometry of the a) room b) Unit of A/C

The refrigerant leak simulation in the air conditioning unit in a room uses a 2D (two-dimensional) analysis method. The 2D model was chosen because the room system's geometry that is supposed to accumulate (leakage) is relatively easier and more simple. Figure 3 shows the room's simulated geometry in the form of a simple square block (fitted with A/C). According to the author (red: researcher) himself, the room geometry's simplicity makes the results be simulated between 2D and 3D will not be much different. 2D models are more advantageous from a computational perspective, considering the number of grids or meshes is less than 3D models so that calculations in the iteration process can be done faster with lower computer memory consumption; besides that, the analysis results from 2D will be easier than 3D simulation models.

According to figure 3 The room geometry model is assumed to be a standard room L (length) x W(width) x H (height) is (4-meter x 4 meters x 3 meters) with an area of 4 meters x 4 meters = 16 m2 and has a volume of = 48 m3, as for the use of space with these dimensions is usually for small family rooms, prayer rooms, apartments or hotel rooms. To calculate the air conditioner load, a quick count method (rule of thumb) is used where the area (A) 4-meter x 3 meters will be equivalent to 1 PK on A/C [14].

Geometric scheme of space (2D) to simulate. The step before modeling the leakage in the room is to determine the dimensions and shape of the room to simulate. The geometry of the room for the simulation in this study used several hypothesis parameters shown in Table 1 as follows.

Table 1. Geometry Modeling Parameters [5,6]

Room Geometry	
P (Parameter)	D (Dimension) (mm)
H (Height)	3000
L(Length)	4000
W(Width)	4000
Outlet of A/C	80
Inlet 1 of Air Conditioning	40
Inlet 2 of Air Conditioning	40

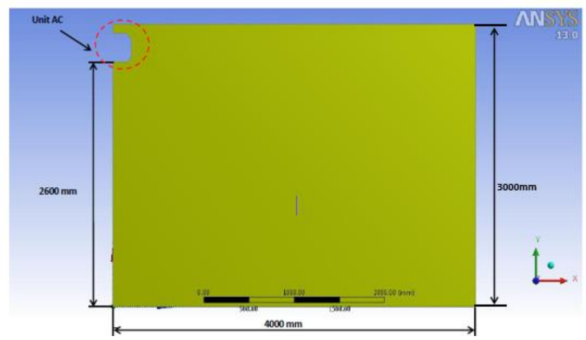


Figure 4. Geometry room

Description

The flammable refrigerant R-32 leaks from the A/C device in the room were investigated in this analysis [3]. The evaporator is thought to provide a sudden flight while within the A/C unit. Then, as with the buoyancy jet diffuse problem, there is a source of unexpected leakage in the A/C device. As the A/C device in the room leaks, coolant escapes through the inlet channel A/C in the room. With the density disparity between the refrigerant and the air, the air suddenly exits the fan A/C and exhales through the air damper on the inlet channel above. Unit A/C R-32 is refrigerant oil, and its properties are mentioned in Table 2.

Table 2. Properties of refrigerant [1,2,3,11]

Physical Properties	Unit	R-290	R-32
Molar mass	g/mol	44,0	52.0
Normal boiling point	°C	-42	-52
Critical Temperature	°C	96,7	78,1
ODP	-	0	0
GWP	-	3	675
LFL	% Vol	2.1	14.4
UFL	%Vol	9.5	29,3
BV	cm/s	38.7	6,7
MIE	mJ	0.246	
Heat of Combustion	MJ/kg	50,4	9,4
Burning Velocity	cm/s	46	6,7
Flammability Class	-	3	2L
Toxicity	-	A	A
Life	Years	*Some days*	5
Cond.Pres.	Mpa	1,53	2,80

Mix/Blend	-	*Single*	*Single*

The contour of concentration will be shown from simulation CFD Ansys Fluent Version 13. The differential equation of heat transfer and fluid mechanics is solved. *The governing equation of Computational Fluid Dynamics (CFD)*, was:

(1) Mass conservation or continuity equation

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial t} + \frac{\partial(\rho v)}{\partial t} + \frac{\partial(\rho w)}{\partial t} = 0 \quad (1)$$

(2) Momentum conservation equation

$$\rho\frac{\partial u}{\partial t} + \rho u\frac{\partial u}{\partial x} + \rho v\frac{\partial u}{\partial y} + \rho w\frac{\partial u}{\partial z} = -\frac{\partial \hat{p}}{\partial x} + \mu\left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right] \quad (2)$$

$$\rho\frac{\partial v}{\partial t} + \rho u\frac{\partial v}{\partial x} + \rho v\frac{\partial v}{\partial y} + \rho w\frac{\partial v}{\partial z} = -\frac{\partial \hat{p}}{\partial y} + \mu\left[\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right] \quad (3)$$

$$\rho\frac{\partial w}{\partial t} + \rho u\frac{\partial w}{\partial x} + \rho v\frac{\partial w}{\partial y} + \rho w\frac{\partial w}{\partial z} = -\frac{\partial \hat{p}}{\partial z} + \mu\left[\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right] \quad (4)$$

(3) Energy conservation equation

$$\frac{\partial(\rho e)}{\partial t} + \frac{\partial(e V_i)}{\partial x_i} = -\frac{\partial(\rho V_i)}{\partial x_i} + \frac{\partial(\tau_{ij} V_j)}{\partial x_i} + \frac{\partial}{\partial x_i}\left(k\frac{\partial T}{\partial x_i}\right) + s_E \quad (5)$$

(4) Species equations

$$\frac{\partial}{\partial t}(\rho Y_i) + \nabla\cdot(\rho\vec{v}Y_i) = -\nabla\cdot\vec{J}_i + R_i + S_i \qquad 1 \le i \le n-1 \quad (6)$$

Where :

ρ = Mass density
t = time
x,y,z = Coordinates of direction in x,y,z
u,v,w = velocity of components in u,v,w
T = Temperature
m = mass
A = Area
τ = stress
v = volume

3.0 RESULTS AND DISCUSSION

Analysis of numerical study simulation results using CFD Software ANSYS FLUENT version 13.0. Concentration is a measure that describes the amount of substance in a mixture divided by the total volume of the mixture. There are four kinds of quantitative descriptions of concentration: mass base concentration, molar concentration, total concentration, and volume concentration. The term concentration can be applied to any mixture but is most often used to describe the solution's solute amount [4,15,18].

Analysis of the simulation results will be carried out using qualitative descriptive analysis, given the difficulty to perform quantitative analytical calculations (quantitative calculations) with manual calculations and the high cost of directly testing (research) with real experiments. This problem is used as a model for research using the numeric software CFD ANSYS Fluid Version.13 to simplify calculations and predict the distribution of refrigerant concentrations in the room [16,17].

The simple quantitative analysis of the flammable refrigerant leak prediction is carried out to strengthen the discussion regarding several variations carried out in this study, namely in the form of data obtained from the iteration of the CFD ANSYS FLUENT version.13 software, which is then processed and described into a function graph of the variation of parameters. Sensitive, which affects the level of distribution of refrigerant leakage in the room.

Besides, to be a comparison result of the simulations obtained, verification and validation of several calculation parameters were taken from several journals and experimental results. This is done with the intention that the numerical assessment that the researcher has done is close to and the results of the simulation are correct [19,20].

3.1 Comparative Analysis of Sensitivity of Several Parameter Variations for R-32

Several variations in airflow velocity that are useful as fresh air entering the room, can affect the distribution of refrigerant leakage shown in the mole contour of refrigerant fraction R-32 (CH_2F_2), where the split wall A/C unit has an initial refrigerant charge of 0.9 kg of refrigerant, the leakage rates of 0.001 kg/s at the position of placing the air conditioner on the floor of 2.6 meters. Airflow rate (ventilation rate) variation parameters that are simulated include the variation in airflow velocity which is assumed to be used in this simulation, which is 0.1 m/s (0.003675 kg/s), 0.3 m/s (0.011025 kg/s) and 0.5 m/s (0.018375 kg/s).

The explanation of the phenomenon that occurs regarding the effect of the varied parameters is explained as follows:

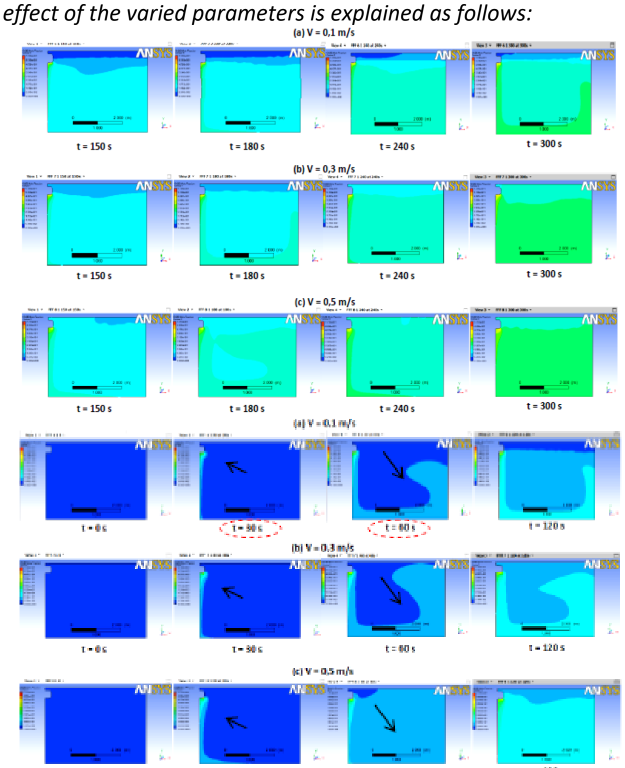


Figure 5. The concentration of R-32 with a leak rate of 0.001 kg/s with variations in airflow speed at the time (t = 0s - 1800s)

The distribution in Figure 5 with a leakage speed of 0.001 kg/s and the airflow change speed at the time (t = 0S - 1800). In figure 5, obviously, at the time of t = 0 s, the Air Conditioning unit has not happened at all; After the first t = 30 seconds, the leak starts slowly and finally starts to finish in the room. The surprising effect is the gravitational acceleration due to differences in density called the buoyancy effect among refrigerants and the air achieved with the initial impact of airflow speed. Fig. 4 at that time, t = 60 seconds and t = 120 seconds, hydrocarbons are precise indoors. After 1500 seconds to t = 1800 seconds, difluoromethane hydrocarbon is stagnant on the ground.

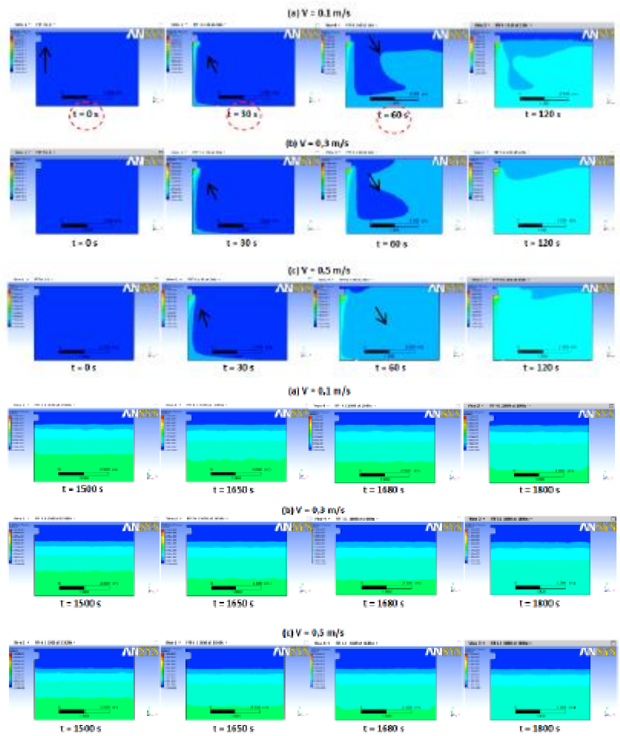
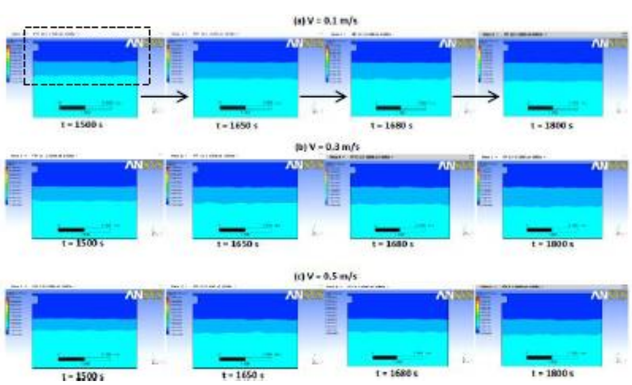


Figure 6. The concentration of R-32 with a leak rate of 0.002 kg/s with variations in airflow speed at the time (t = 0s - 1800s)

If compare Figure 5 and Figure 6 on t = 60 seconds the distribution of hydrocarbon is faster at a velocity of 0,5 m/s and 0,002 kg/s of leakage rates.



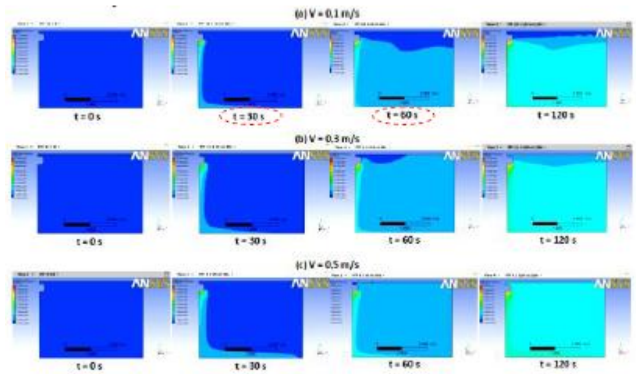


Figure 7. The concentration of R-32 with a leak rate of 0.005 kg/s with variations in airflow speed at the time (t = 0s - 1800s)

Table 3 shows the time prediction when the refrigerant R-32 is released into the room building.

Table 3. The depleted refrigerant estimated

	Leaks (kg/s)		
	0.001	0.002	0.005
time (second)	900s	450s	180s

The leakage rate of the mass refrigerant variation is 0.001 kg/s, 0.002 kg/s and 0.005 kg/s. Then three airflow variations are a cold cool speed of 0.1 m/sec, 0.3 m/s, and 0.5 m/s after the installation node in the AC unit room at 2.6 m. The result of a numeric simulation, the leakage speed of 0.001 kg/s with an airflow of 0.1 m/s for the R-32, will end after the release of 900 seconds (15 minutes), on the R-32 emptied after 180 seconds (3 minutes) at the leak rate of 0.005 kg/s. For the average leakage rate of 0.002 kg/s for R-32 after 450 seconds (7.5 minutes) and Figure 8 graphic of the mole R-32 fraction from time (seconds). After time t = 60 seconds after the influence of turbulence, the effect because of the re-circulation of the air in the air conditioning unit. The last effect is the effect of the separation between the air and the cooling layer. See Figure 4 to Figure 7 of time t = 1500s to 1800s. The difference between the air (above) and difluoromethane below is clear, later stagnation is collected near the ground. The results of the refrigerant description the speed of the airflow is faster than 0.5 m/s and the slow period of the gas diffusion process is 0.1 m/s and an average of 0.3 m/s.

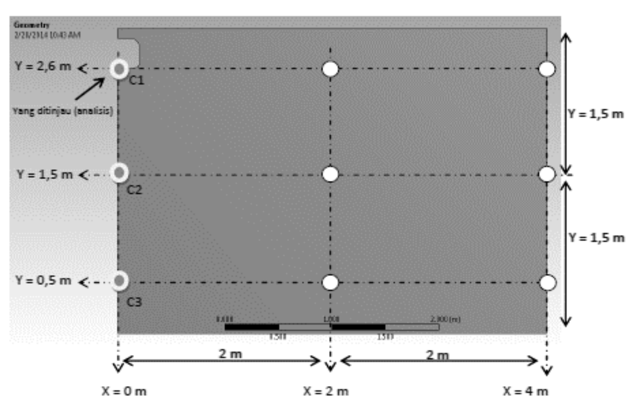


Figure 8. Longitudinal section – coordinate analysis of point

3.2 Comparison of HFC-32 Mole Fraction Against Time on x-y Plane Coordinates with x = 0 m and y coordinate = 2.6 m

The comparison in that position shows that the effect of rates of leakage. Three difference rates and three speed of fan below in figure 9 can be explained

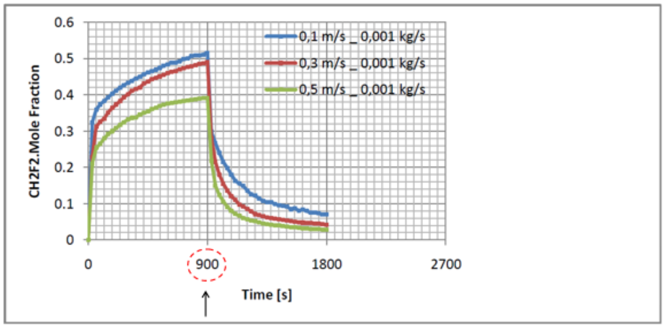


Figure 9. Comparison of CH2F2 Mole Fraction with Time at Plane Coordinates x = 0 m, y = 2.6 m at leakage rate 0.001 kg/s

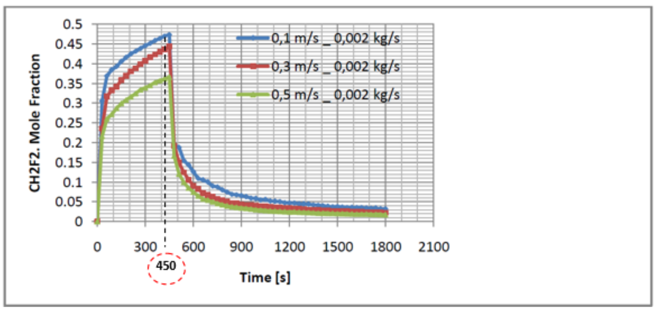


Figure 10. Comparison of CH2F2 Mole Fraction to Time at Plane Coordinates x = 0 m, y = 2.6 m at Leakage Rate 0.002 kg/s

The rate of leakage and the amount of airflow affects the accumulation and distribution of refrigerant in a room. Figure 10 explains this. The largest leakage rate occurs at (m) = 0.002 kg/s and at the largest fan speed V = 0.5 m/s. At this level of leakage, the refrigerant in the unit runs at a time after t = 450 seconds.

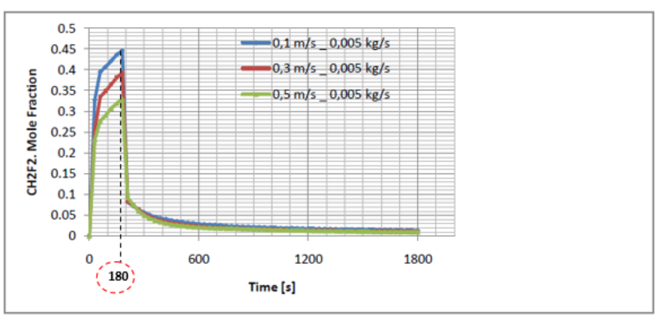


Figure 11. Comparison of CH2F2 Mole Fraction - Time on Plane Coordinates x = 0 m, y = 2.6 m at Leakage Rate 0.005 kg/s

The fastest leakage time occurs after t = 180 seconds at a leakage rate of 0.005 kg/s and at the speed of an A/C fan that is blowing air, namely v = 0.5 m/s, it can be seen in the graph of the function of the refrigerant mole fraction relationship to time in Figure 11 above.

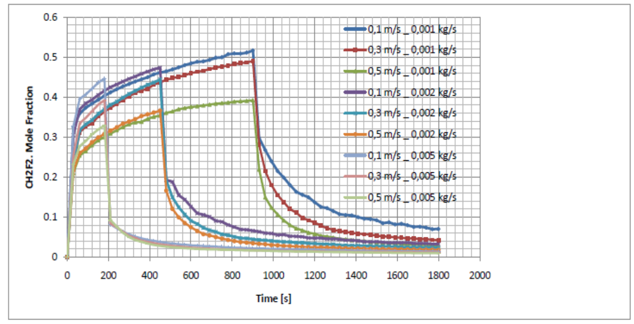


Figure 12. Comparison of several parameters varied for the R32

By comparing all the variations in Figure 12, the leakage occurs most rapidly when the airflow is at 0.5 m/s at a leakage rate of 0.005 kg/s, i.e. at the time after t = 180 seconds (3 minutes) for A/C Split Wall with Refrigerant R-32. This results from the impact of the initial velocity of the cold air (initial velocity) and the momentum effect [1,2,12].

3.3 Description Analysis of the Qualitative Prediction of the Flammability Assessment based on ASHRAE 34 Standard and EN-378 standards on Flammable Refrigerants (R-290 and R-32).

Quantitative predictions are analyzed based on the results of simple calculations given the difficulty of analyzing with certainty the point and time at which the area can be said to be easily flammable. By the description of the flammability assessment prediction, several aspects of value such as Lower Flammability Limit (LFL), Burn Rate (BV), Heat Of Combustion (HOC), and Minimum Ignition Energy (MIE), etc., are explained qualitatively. Because R-290 (HC) is included in the A.3 class category and R-32 is in the A.2L (slightly flammability) category.

(1) LFL and UFL according to ASHRAE standard 34

LFL (Lower Flammability Limit) is the minimum concentration of a refrigerant in a homogeneous air-refrigerant mixture that can cause flame propagation at 21°C and 101 kPa (P ambient = 1 atm). The flammability of a substance is stated in the Flammable limit. LFL describes the composition of the fuel mixture least that can still ignite a fire, while the upper limit of flammability (UFL) is the composition of the most that can still ignite a fire.

Based on ASHRAE standard 34-2007 concerning the selection, planning, and safety classification of refrigerants, refrigerants R-290 and R-32 are classified by flame levels, namely:

Class 2: LEL or LFL > 0.10 kg/m^3 or 3.5% by volume at 21°C and 101 kPa and heat of combustion <19000 kJ/kg. By the classification category of Refrigerant R-32, including category A.2L where it has a maximum BV value of less than 10 cm/s according to Table 4 in Class 3: LEL or LFL < 0.10 kg/m^3 or 3.5% by volume at 21°C and 101 kPa and heat of combustion > 19000 kJ/kg for R-290. Following the Flammability Assessment Criteria based on standards (ASHRAE) 34 of 2007, concerning safety or safety class (ASHRAE) refrigerants are divided into several classes A3, A2, A2L.

Table 4. Refrigerant information for class A2 and A3 [1,2]

R No.	Safety Group	Name	Practical limit (kg/m^3)	Flammability			
				Lower limit LEL/LFL		Upper Limit	
				Kg/m^3	% v/v	Kg/m^3	% v/v
R-32	A.2	Difluoro methane	0.054	0.270	12.7	0.710	33.4
R-290	A.3	Propane	0.008	0.038	2.1	0.171	9.6

The prediction when the refrigerant reaches the LFL concentration in Table 5 is explained through a simple prediction calculation based on the ratio of the practical limit to the lower limit (LFL), obtained from the refrigerant properties in Table 4 above. A room can be said to be at risk of a fire if its LFL flammability limit levels have been met. For the R-290 (2.1% Vol ≈ 0.038 kg/m^3) and for the R-32 (12.7% ≈ 0.270 kg/m^3). If the LFL level has been reached, the room will easily ignite and burn (flame).

The results of simple comparison calculation values can be seen in Table 5 below. There are different results between LFL for refrigerant R-290 and R-32 with the same ratio level but in practice, it is different because of the R-32 load and the heavier density of R-290, so R-32 is less easy to use burning (flame) when referring to the properties and LFL earlier than R-290.

Table 5. Time of prediction

Refrigerant	*LFL ratio*	Amount charged	*LFL*	Leakage rates (kg/s)		
R-32	1 : 5	0.9 kg = 900 gr	180 gr	0.001	0.002	0.005
Predicted time to reach LFL				180 s	90 s	36 s
Refrigerant	*LFL ratio*	Amount charged	*LFL*	Leakage rates (kg/s)		
R-290	1 : 5	0.6 kg = 600 gr	120 gr	0.001	0.002	0.005
Predicted time to reach LFL				120 s	60 s	24 s

3.4 Autoignition Temperature

Autoignition means that the flammable substance reaches a condition (pressure and temperature) where the substance can burn itself without the need for ignition.

So based on this, the ignition point or autoignition temperature can be seen in Table 6. Autoignition point value. Temperature R-32 is greater (648 °C) when compared to R-290 (450 °C). The physical meaning of this is that with this minimum temperature the R-290 refrigerant will be flammable in a normal atmosphere without any external combustion source, compared to the R-32 refrigerant. This is also a factor in why it is difficult to manage if the R-290 leaks.

Table 6. Autoignition Temperature [1,2,3]

R No.	*Safety Group*	*Name*	*Auto Ignition Temperature °C*
R-32	A.2	*Difluoromethane*	648
R-290	A.3	*Propane*	450

3.5 Minimum Ignition Energy (MIE) dan Burning Velocity (BV)

Ignition rate and minimum energy of ignition as values for assessing the risk of fire spread. MIE is the minimum energy required to burn. The rate of combustion is a good indicator of the severity of the fire or the speed at which the explosion propagates.

Table 7. MIE Value of Some Refrigerants [1,2,3]

Refrigerant	*Minimum Ignition Energy (MIE)* (mJ)
R-32	30
R-290	0.25

The importance of the rate of combustion and related properties or properties such as Minimum ignition energy makes it possible to measure combustible materials and rank them from hardest to most flammable and allows taking appropriate steps to reduce the risk of flammability. So according to Table 7, the MIE value for Propane (R-290) and R-32 means that Propane is a refrigerant that is prone to an easy fire propagation rate compared to R-32 because it has a lower MIE, namely (0.25 mJ) compared to R-32 which is only 30 mJ. Similar to Minimum Ignition Energy, Burning Velocity R-290 is faster than R-32 which is 46 cm/s ~ 0.35 m/s. For R-32 because it is included in the A.2L category, it has a BV value ≤ 10 cm/s, namely 6.7 cm/s ~ 0.1 m/s.

3.6 The heat of Value / Heat of combustion (HOC)

The calorific value or combustion heat (HOC) is a property related to the severity of the risk if a fire occurs, the higher the calorific value the easier it is to burn. Table 8 shows the heating value (heat of combustion) of the R-290 is greater than the R-32, which means that the R-290 will burn more easily.

Table 8. Heating Value (Heat of Combustion) of some refrigerants [1,2,3]

Refrigerant	*BV* (cm/s)	*MIE* (mJ)	*HOC* (MJ/kg)
R-290	46	0.25-4000*	46.3
R-32	6.7	30-33*	9.4

4.0 CONCLUSION

The ANSYS-fluent software was used to simulate and predict the distribution of rooms with difluoromethane (R-32) air conditioning with leakage rate and airflow, in a 2-D digital construction room. After the amount of refrigerant charge is exhausted, the simulation concludes that the air stream will increase the refrigerant gas's dispersion and decrease the level of the amount of refrigerant. The impact of the initial effect on the air supply is responsible for the dynamics of this effect. The leakage effect's distribution may be affected by the mass flow.

The buoyancy effect is caused by the fact that R-32 has a higher density than air, causing the refrigerant to flow down, accumulate, and stagnate.

With environmental performance and excellent thermal properties, difluoromethane (R32) is an alternative refrigerant R-22, but its application is limited due to flammability. Due to internal security, this analyzes the leakage and diffusion of air conditioners mounted on the R32 wall in different conditions. The effect of airflow speed and position of the holes in the leakage of the concentration and distribution is also analyzed when the working fluid (refrigerant) leakage of the indoor unit when operating the A/C Unit. The results showed that the leakage rate decreased with the operating times. The process of refrigerant leaks under operating conditions can be classified into a faster leakage phase to slower leakage. As the working fluid (refrigerant) is leakage on the evaporator inlet tube, the leaks speed is higher than the evaporator outlet tube.

The simulation also analyzes the effect of the speed of the airflow on the distribution of concentration and obtained in different operating conditions means when R-32 leaks from different positions. Later, the security was evaluated when the R-32 leakage of air conditioning was running. Thus, the results show of the burning area only appears close to the leakage of the hole and a very short duration of the burns area. We can conclude that the risk of fire of the R-32 as an alternative refrigerant air was very low under general operating conditions. LFL flammability limit levels have been met. For the R-290 (2.1% vol ≈ 0.038 kg/m^3) and for the R-32 (12.7% ≈ 0.270 kg/m^3). If the LFL level has been reached, the room will light up, and it will be easily burned (flame).

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References

[1] Clodic D. 2010. Low GWP Refrigerants and Flammability Classification K06. International symposium on next generation air conditioning and refrigeration next Technology.2010. February 17-19 Tokyo. Japan.

[2] Yu-nong Li Jun-jun Tao, Yu-chon Han Xue Han. 2014. Numerical and Experimental Study on the Diffusion Property of Difluoromethane (HFC-32) in leakage. 71: 34-43.

[3] Wang Zhang and Zhao Yang Jin Li. 2013. Research on the Flammability Hazards of Air Conditioner using Refrigerant R-290. 36: 1483-1494

[4] Quangyi Liu and Hui Zhang Yi Liu Hong Huang. 2013. Influencing Factors of Flammable Refrigerants Leaking in Building Air Conditioning System. 62**:** 648-654.

[5] Yuebin Wu and Enlu Yu Ying Xu. 2007. Simulation and Analysis of Indoor Gas Leakage 1267-1271.

[6] Ryuichi Nagaosa and Aute C V Radermacher R. 2012. A Risk Assessment for Leakages of Flammable Refrigerant into a Closed Space 2240 : 1-10.

[7] Kataoka,O and Yoshizawa, M Hirakawa. 2000. Allowable Charge Calculation Methode for Flammable Refrigerants. 506**:** 383-390.

[8] A. Elatar *et al.*, "Evaluation of flammable volume in the case of a catastrophic leak of R-32 from a rooftop unit," *International Journal of Refrigeration.* 91: 39–45, 2018, doi: 10.1016/j.ijrefrig.2018.04.024.

[9] Goetzler, B., Guernsey, M., Faltermeier, S., and Droesch, M., 2016. AHRI Project No. 8016: Risk Assessment of Class 2L Refrigerants in Commercial Rooftop Units. Prepared for Air- Conditioning, Heating and Refrigeration Institute by Navigant Consulting, Inc.

[10] [10] Daikin E- Catalog of specification Daikin. Daikin Industries. Tokyo-Japan. 2022. Source: https://www.daikin.co.id/en/semua-e-catalogue

[11] ANSYS FLUENT v13. 2010. Ansys Inc, Theory Guide.

[12] Popovici CG, 2017. HVAC system functionality simulation using ANSYS-Fluent. 112**:** 360-365.

[13] H Haris. 2015. Numerical simulation of natural gas leakage from pipelines. 5: 893-896.

[14] L. Jia, W. Jin, and Y. Zhang, 2017, "Experimental study on R-32 leakage and diffusion characteristic of wall-mounted air conditioners under different operating conditions," *Journal of Applied Energy*, 185(81172625): 2127–2133, doi: 10.1016/j.apenergy.2016.01.041.

[15] Nagaosa, R. S., 2014. A new numerical formulation of gas leakage and spread into a residential space in terms of hazard analysis. *Journal of Hazardous Materials*, 271: 266-274.

[16] Colbourne, D., and Suen, K. O., 2003. Equipment design and installation features to disperse refrigerant releases in rooms—part I: experiments and analysis. *International Journal of Refrigeration*, 26(6): 667-673.

[17] R Muliawan, Effect of Leakage on Refrigerant Distribution in Air Conditioned Room Using Propane as Working Fluid," in Proceding ICIEVE UPI, 2020.

[18] Jia, L., Jin, W., and Zhang, Y. 2017. Experimental study on R-32 leakage and diffusion characteristic of wall-mounted air conditioners under different operating conditions. *Applied Energy,* 185(2): 2127-2133.

[19] Moran, M., J, Saphiro,"Fundamentals of Engineering Thermodynamics," Jhon Wiley & Sons, Inc. : London, 2011.