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A Study on Air Conditioning in Personal Protective Equipments

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ABSTRACT

In recent years, it was witnessed how important PPE kits are. Ever since the emergence of Coronavirus cases, the importance and dependence on the PPE kits has increased. Study encountered lots of problems; majority of them are related to heat. Problem can be solved by air conditioning. Our goal is to achieve air conditioning with safety by aligning it with HEPA filter, to make it portable, reusable, flexible in different working areas. This will provide air to the wearer, reduce temperature, humidity, and will also suspend the ingress of microbes. Proper study would be carried to record change in temperature and humidity and observe the microbial growth, after applying the air conditioning unit. Research would help us to understand the difference created by such system. Study shows that the difference created in terms of the Temperature and humidity. Air Conditioning Unit works with HEPA (High Efficiency Particulate Air) filter of efficiency of 99.97%. Generated data would be analyzed and would help us to understand the ability of such system to work with PPE.

Keyword*: PPEs, Temperature, Humidity, Air Conditioning Unit, HEPA.*

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INTRODUCTION

Hazard like mechanical, chemical, biological, heat, optical, radioactive etcetera.[1] Hazard is basis of potential harm or damage on someone or something. [2] For example: Infection from COVID-19 virus is a hazard and it is a biological hazard. PPE kits have always helped humankind to not only protect it from hazards but also to study, understand, and overcome various life threatening situations. Over the years humans have developed various kinds of PPE kits based on the type of hazards. Hazard assessment is a very significant step as it deals with understanding the hazard, its risk and properties. Understanding hazards eventually helps us to select which type of PPE kits are suitable to use during that particular hazard. Later on the training can be provided to understand the PPE, how to use that PPE kit, what are the limitations of it and what are the precautions that are needed to be taken based on the PPE kit. [1]

As per current circumstances, we are dealing with a biological hazard that is COVID-19 or so called Coronavirus disease, it is an infectious disease; it is caused by a virus called SARS-CoV-2. It was observed that the virus can be transmitted by the mouth and nose of the infected person in the form of the droplet when sneezing or coughing. It was advised by the WHO (World Health Organization) that respiratory safety precautions must be followed like sneezing with a flexed elbow, wearing masks, maintaining distance of 1-2 meter approximately with other individuals and washing hands as well as sanitizing it with alcohol based solution. Get vaccinated. [3] Later this disease took the shape of a pandemic. It was observed [4] that, the virus transmitted through inhalation of it that is mainly minute droplets that contains virus, virus deposition on mucous membranes (cavities of the body are lined with this membrane) that are open to exterior (mucosa of nasal cavity and mucosa of mouth) and touching that open to exterior mucous membrane with hands that are contaminated by virus makes transmission successful. [5] [6] Research reflected various controversies around transmissions of respiratory viruses. Study states that there are many challenges to be properly aware of the spread of Covid-19 but there are enough reports that states that the spread of this virus can be done via:

(a) Direct contact (person to person)

(b) Indirect contact (3rd object is intermediate between source and sink)

(c) Droplet transmission (droplet in air consist of infectious microbes due to coughing sneezing)
(d) Airborne transmission (microbes in air)
There has been controversy between droplet transmission and airborne transmission, therefore it's recommended to wear full body covering without omitting any unit of kit. N95 masks are very effective in this intense situation. [7]
The best way to prevent biological hazard is to eliminate the source of it but if the contact can be restricted then Personal Protective Equipments are used. [8] Stated in their study that PPE kits are specialized clothing consists of a face shield, goggles, mask, gloves, gown, shoe cover and head cover. This pandemic also created another problem as study done by [9] revels that everyday millions of PPE kits are used and discarded. These growing numbers of discarded PPE kits are creating disposal problems and stress on the environment. It was concluded that a decentralized system is preferable because it's flexible I.e. It has shown moderate and low pollution level.
It has been reported that the person that wears the PPE kits experience a fair amount of the issues mostly due to heat. [10]Authors created questionnaires and surveyed HCWs (Doctors, nurses, paramedical staff) in India; their data shows the problems related to PPE kits. Every single person has reported that the biggest problem is sweating. Suffocation, breathlessness, fatigue, headache, scars on skin and vexation are other problems reported by HCWs. Our body constantly releases heat this heath increases the heat stress. Heat stress further results in physiological response that is sweat, difficulty in breathing. The combination of things mentioned earlier leads to decline in productivity of healthcare workers or any other PPE wearers. To eliminate above mentioned problems the idea of air conditioning in PPEs emerged. During initial research it was found that [11]designed cooling system for PPE kits to reduce sweat, temperature and humidity. It was executed and evaluated based on the humidity and temperature levels. Model used 2 PC fans and 3 Li-Ion batteries; battery dies in 5 hours after continuous power delivery. Their results showed that the temperature and humidity levels were decreased after installation of fans.Goal is not only to make an air conditioning system but also to make it safe (using HEPA filter), applicable (Ability to attach itself to PPE on will), portable, inexpensive and reusable. The ACU was designed with the mindset to create such product. Another aspect is to find that even if the system is fabricated, will it really be effective. Therefore, laboratory data collection will be carried out. Study will help to find out whether the inclusion of a High Efficiency Particulate Air Filter is effective or not. The pair of brushless DC (Direct Current) motors with fans will be used to direct air in the suit; the main objective is to reduce the heat and breaking down the stable condition inside the suit. The ACU (Air Conditioning Unit) will be powered by a 4x 3.7V batteries with the aid of delay relay integrated circuit. Later air will pass through the HEPA filter and then inside PPE. Temperature and humidity will be monitored and microbial sample would be collected and observed. Study is being carried out to understand whether it's applicable and safe enough for real world use and last but not least what will be the limitation of this system.

MATERIAL AND METHOD

MATERIALS

(A) Structural: Plastic containers, Sun board, Foam, Paper, Plastic gland, Belts, Buckles, Wire tubes, Plastic mesh, Lock ties, Screws, Double sided tapes, Abrotape, Transparent tape, Adhesive, Aluminium foil and Pipes (flexible)
(B) Technical:12v Brushless DC motor x2, Wires, Connectors, Delay relay circuit (for Delay), Li-ion battery 3.7v 3000Mah x4, Battery management system 4S, Battery cradle 4 bay, Switch, Temperature and humidity sensor, Balanced charger and Battery indicator 4S
(C) Clothing: PPE kit
(D) Laboratory requirements: LAF, Petri plates, Nutrient solution and Incubator

METHOD

An experiment starts with identification of problems which are related to PPEs. After understanding problems which were mostly related to heat, designing of Prototype 1 was initiated. A very basic prototype was designed and fabricated. The parts that were used to carry out pilot study were limited to six (BLDC) Brushless Direct Current Motor with fans aligned with HEPA Filter (High Efficiency Particulate Air filter). The fabricated unit was lined with Velcro so that it could easily mount with PPE. BLDC motors with fans Specifications were 12V (Volts) 0.22A (Amperes) seven blades and HEPA filter was effective to filter out small particles larger than 0.3 microns in diameter. The fundamental prototype was powered by AC (Alternating Current) adapter whose output was 19.5V (Volts) and 3.33A (Amperes). Prototype 1 was used for studying whether system like this can actually provide air inside PPE kits when aligned with HEPA filter. The Next prototype {Prototype 2 = Air Conditioning Unit (ACU)} was developed with the mindset to check all the objectives that were predefined. The second fabricated prototype unit consists of

more components. The components include two BLDC motors with fan (12V, 0.22A and 7 blades), HEPA Filter (H13 grade), DC delay relay circuit (6-30V), four Lithium-ion batteries (18650, 3.7v and 3000 mAh), BMS 4S (Battery Management System) and Battery indicator 4S. All of these components were adjusted inside the plastic container to make it compact and portable. Air could be directed inside PPE with the help of flexible Plastic pipe and the ACU (Air Conditioning Unit) could be attached to PPE with the help of Cable gland PG-25. To carry around ACU easily, it was fabricated in a way that Wearer can carry it just like bag with the help of 2 adjustable straps. The most Significant thing which is data collection method was then designed. The data collection was carried out in exceedingly straightforward way. The temperature and humidity were collected with the help of Temperature and humidity sensor probe (installed inside the PPE). The data will be recorded, quantified and expressed with the help of the tables and graphs which will provide the basic idea about the trend of temperature as well as humidity. Qualitative data would be recorded and observed in the form of the microbial growth. The observation would be simply limited to observation as the goal of the system is just to ensure that no microbes should be observed from the outlet of ACU. (ACU will not be inside LAF, only its pipe will be inside it for air delivery) Quantitative and Qualitative data would be interpreted based on the observation and graphical analysis to reach conclusion, whether system like this can work and what will be the limitations if not?

PROCEDURE

Heat and stability (inside the PPE) are fundamental elements that results in heat stress. Our body constantly releases heat and PPE create stable condition; that is, air doesn't move much in PPEs after donning it. Difference created by ACU (Air Conditioning Unit) would be measured. Temperature and humidity inside the PPE would be recorded using temperature and humidity sensor Probe installed inside the PPE suit. Data of both temperature as well as humidity would be collected for 1 hour at the interval of 5 minutes, where ACU will be OFF During 1st 30 minutes. Similarly, ACU will be turned ON for next 30 minutes. (Total 1 hour, 30 minutes OFF and 30 minutes ON)Data will be recorded for 3 days with 2 collections per day. It is explained by flow chart below. Where D = Data, C = Collection, T = Temperature and H = Humidity. After recording data of temperature and humidity for each day, an overlay graph of both temperature and humidity would be plotted separately.

RESULT AND DISCUSSION

When planned data collection pattern was followed, it was observed that the temperature and humidity show downward trend when ACU was turned ON. The temperature was measured in degree Celsius (℃) and humidity was measured in Percentage (%).

It was noted that maximum value of temperature when ACU was OFF was 34.8 degree Celsius and lowest was 32.9 degree Celsius. Similarly, when ACU was ON the maximum temperature recorded was 34.6 degree Celsius and minimum was 28.5 degree Celsius. The maximum and minimum humidity when ACU was turned OFF was 84% and 49% respectively. When ACU was turned ON, the maximum and minimum humidity was 84% and 35% respectively. Refer table 1 and 2.

Table 1 Temperature overlay of every single day. m=minutes, T=Temperature℃, {Red (00:00 TO OO: 30) =ACU was OFF, Green (00:30 TO 01:00) = ACU was ON)

Time interval (m)	D1C1(T) ˚C	D1C2(T) ˚C	D2C1(T) ˚C	D2C2(T) ˚C	D3C1(T) ˚C	D3C2(T) ˚C
00:00	33.4	33.7	33.1	34.2	32.9	34.4
00:05	33.4	33.8	33.2	34.4	32.9	34.6
00:10	33.6	34.1	33.7	34.5	32.9	34.4
00:15	33.5	34.2	33.6	34.6	33.1	34.6
00:20	33.5	34.3	33.5	34.6	33.3	34.6
00:25	33.5	34.6	33.3	34.8	33.3	34.7
00:30	33.6	34.6	33.1	34.4	33.3	34.7
00:30	33.6	34.6	33.2	34.4	33.4	34.6
00:35	28.5	30.3	29.4	29.9	29.6	30.6
00:40	29	30.4	29.7	30.1	29.8	31
00:45	29.3	30.7	29.9	30.5	29.9	31.5
00:50	29.7	30.9	30	30.5	30.3	31.6
00:55	29.7	31.1	30.1	30.8	30	31.8
01:00	29.7	31.1	30.1	30.8	29.9	31.8

Table 2 Humidity overlay of every single collection. m=minutes & H=Humidity % {Red (00:00 TO OO: 30) =ACU was OFF, Green (00:30 TO 01:00) = ACU was ON)

Time interval (m)	D1C1(H) %	D1C2(H) %	D2C1(H) %	D2C2(H) %	D3C1(H) %	D3C2(H) %
00:00	76	69	49	80	79	80
00:05	79	76	56	82	80	81
00:10	81	80	74	83	80	82
00:15	82	81	78	83	81	83
00:20	82	82	80	83	82	83
00:25	83	83	80	84	82	83
00:30	83	83	82	84	83	84
00:30	83	83	82	84	83	84
00:35	77	54	45	54	51	49
00:40	42	47	43	50	47	40
00:45	36	43	42	43	45	38
00:50	36	40	42	40	41	38
00:55	35	39	39	41	42	38
01:00	35	41	40	43	44	39

Table no. 3 shows the difference between TEMPERATURES when ACU was turned ON. (For 30 minutes).

Table 3 Temperature difference and average decrease in temperature (IV = Initial Value, FV = Final Value)

IV ˚C	33.6	34.6	33.2	34.4	33.4	34.6
FV ˚C	29.7	31.1	30.1	30.8	29.9	31.8
Difference	3.9	3.5	3.1	3.6	3.5	2.8
Average of the difference (average decrease in temperature)				3.4 ˚C		

IV – Initial value of temperature (˚C) (when ACU was ON)
FV – Final value of temperature (˚C) (when ACU was ON)
Table also shows the average decrease in temperature that is 3.4˚C
Table no. 4 shows the difference between HUMIDITY when ACU was turned ON. (For 30 minutes)

Table 4 Humidity difference and average decrease in Humidity (IV = Initial Value, FV = Final Value)

IV %	83	83	82	84	83	84
FV %	35	41	40	43	44	39
Difference	48	42	42	41	39	45
Average of the difference (average decrease in humidity)				42.83%		

IV – Initial value of humidity (%) (When ACU was ON)
FV – Final value of humidity (%) (When ACU was ON)
Table also show the average decrease in humidity that is 42.83%
When developed prototype (ACU {Outside LAF}) was used to direct air on nutrient agar plate (in LAF); the plate was observed with grown microbial colonies after incubation.
ACU has limitations like low battery life and low air flow due to less clearance between filter and fans, other suspected reason is the density of HEPA filter. ACU has gaps. System like ACU needs to construct in clean room (no contamination room) with high precision machinery.

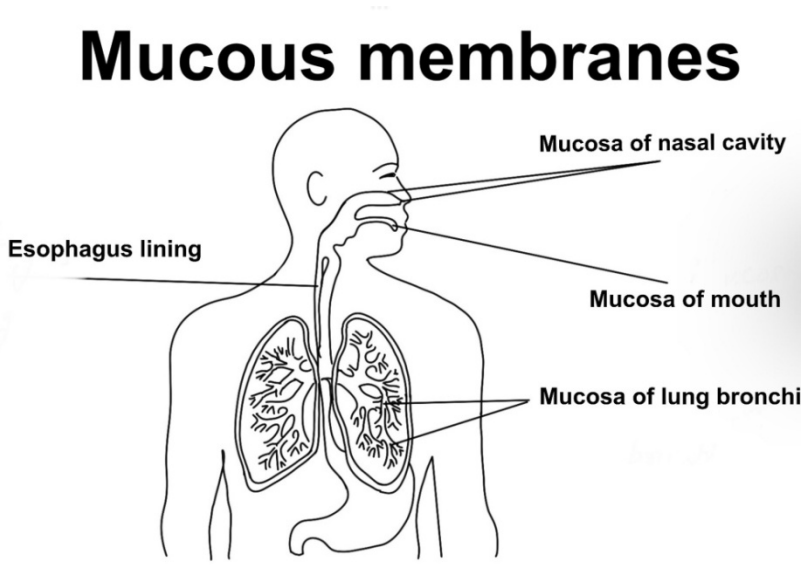

Figure 1: Body cavities lined by mucous membrane which are open to exterior

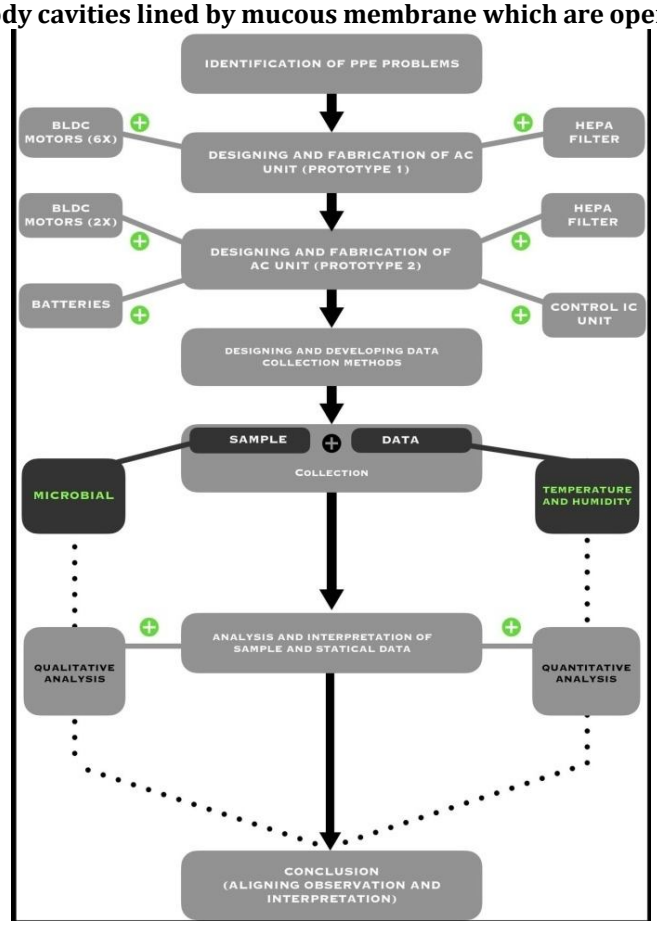

Figure 2: Methodology

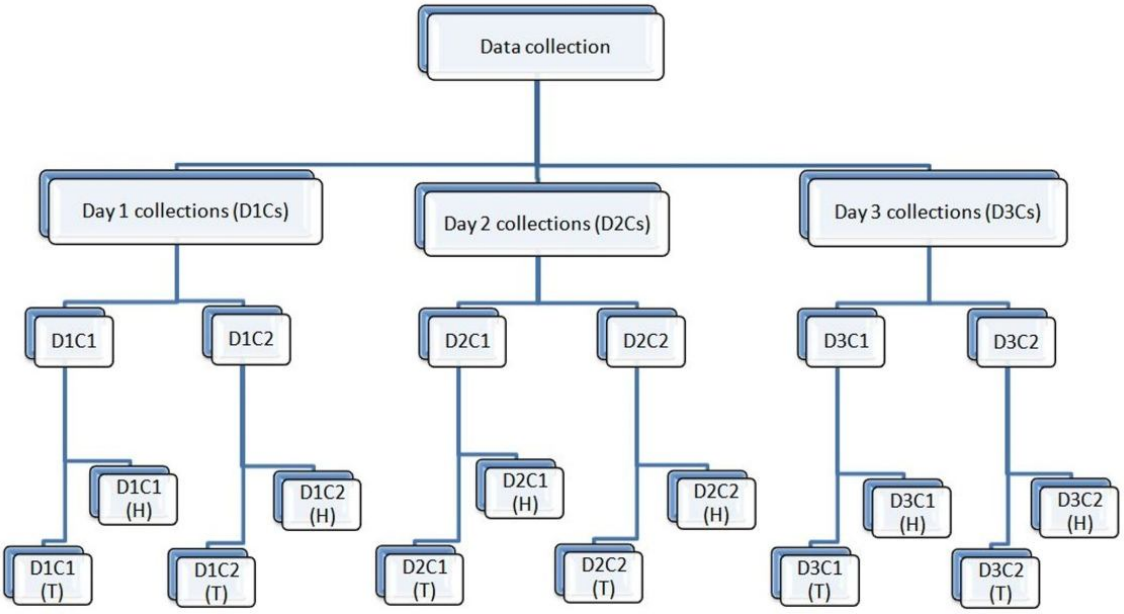

Figure 3: Procedure

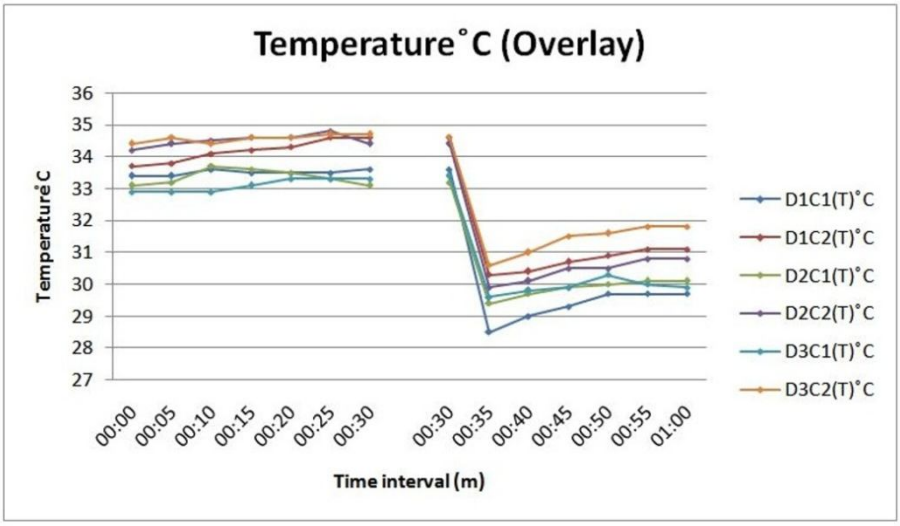

Figure 4: Temperature overlay graph

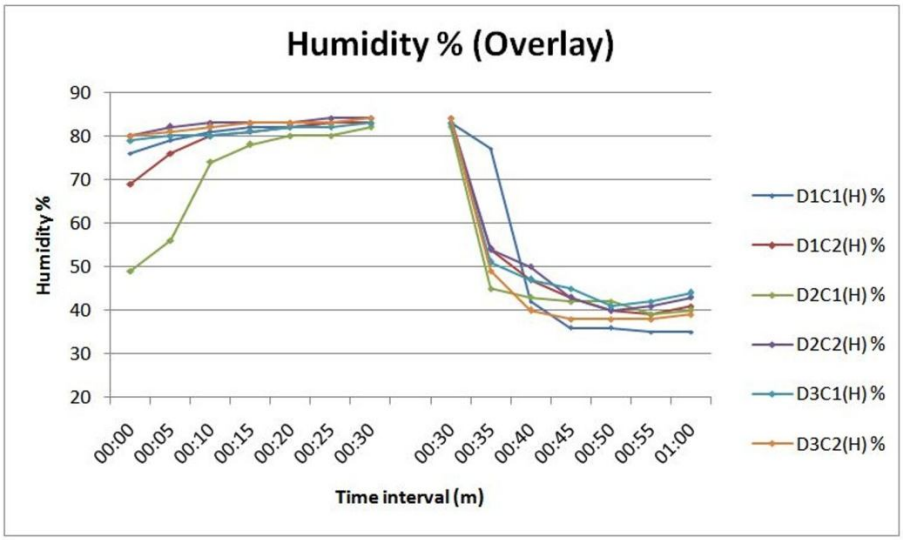

Figure 5: Humidity overlay graph

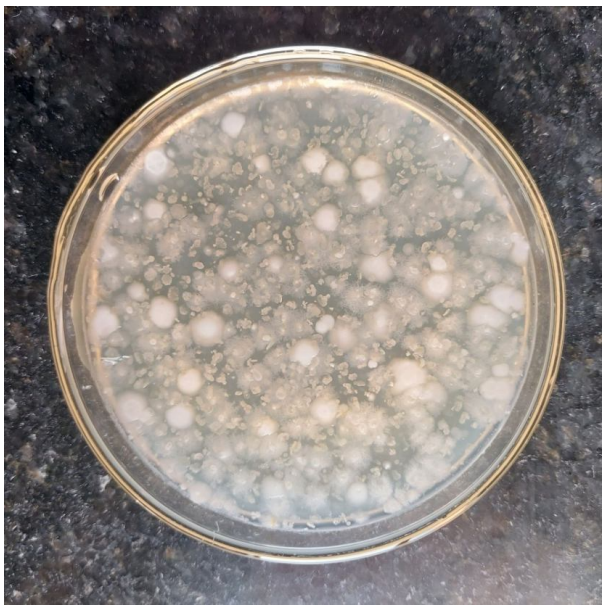

Figure 6: Microbial observation

Figure 7: Air Conditioning Unit attached to PPE kit.

CONCLUSION

Systems like this can work very well with PPEs as per above results but limitations like LOW battery life and air flow raises questions. Safety is a key aspect when dealing with contamination or hazard. Units like this needs to be constructed in proper clean room to be on safer side. Gaps are also major problem in unit which led to failure in microbial contamination test; precise machinery can sort this problem, 3D printing will absolutely work, working with lithium ion batteries is hard, risky and there is always possibility of harm.

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