A Study on Discharge Characteristics from the Nozzle Orifice Attached to a Modularized Fire Extinguishing Gas-Agent Container Horizontal Position

Kim, Yun Zeung[1], Yoon, Myong O[2], Kim, Sang Wook[3]

[1]*HANSHIN Construction CO,. Ltd, 65-32,Jamwon-dong, Seocho-gu, Seoul 147-907,Korea*

[2]*University of seoul, Director, Urban Safety & Security Research Institute, Dr.Eng. Korea*

[3]*Fire Research & Technology Station, President, Korea*

Abstract

The conventional fire extinguishing gas-agent system has configuration in which the gas-agent comes out of a cylindrical container having vertically settled shape. However, in this research a horizontally installed container of piping shape having a cylinder of the same shape with a cylinder valve and a discharge nozzle was used, and the relationship between orifice size of nozzle and discharge rate of gas-agent was investigated through various experiments including the measurement of discharge rate under different ambient-temperature conditions. In such experiments, HCFC Blend A was used without super-pressurization by nitrogen. From this research, it was observed that legal discharge duration of 10 seconds can be met if the relatively large size of the valve and the nozzle orifice were properly selected. This research outcomes proves that a new method will be more effective, more economical and safer than the conventional method.

1. Introduction

In the conventional gaseous agents fire extinguishing system, vertical type agents-storing container is preserved in a room exclusively used for fire fighting, and a flooding agents-transferring pipe must be installed between a discharge nozzle installed in a room to be protected and a storage container. Besides that, the conventional system, for deciding the diameter of a pipe even at the time of design, essentially requires a troublesome process, computing process which uses an exclusive program. Especially, in the case of a user who is not familiar with the use of the proper program or inferior program, the investment of a high-priced equipments will be useless and it is difficult to achieve the purpose of fire fighting. Actually, the end users distrust the conventional gaseous fire extinguishing system, so that the Korea Fire Equipment Inspection Corporation requires that the experiment for reliance of such program should be mandatory carried out. By the way, the fire extinguishing system, the subject of this study, is the one in which a container valve and a discharge nozzle are installed in a pipe type agents-storing container which is only filled with agents and installed horizontally in the upper part (or in a ceiling) of the room subject to protection, so that agents can be discharged only by steam pressure of agents. In this case, different from the conventional system, agents are directly discharged from a pipe type storage container without installing a

Corresponding Author- Tel.: +82-2-3392-3114; Fax: +82-31-272-2457
E-mail address: kimyzz@hanmail.net

separate agents-transferring pipe, so it is deemed possible not only to propose a new fire extinguishing system, if discharge of agents is possible within legally stipulated time. It reduces a computing process, as well, Therefore, we intended to conduct a research on the possibility of and problems in actual application of this system by measuring and analyzing the relation between the orifice size of a discharge nozzle and discharge rate by temperature through experiments. In this research, HCFC Blend A, now widely used in the fire fighting, was used as agents for this research.

2. A theoretical prediction

Before experiments, following theoretical situation is predicted in relation to physi -cal characteristics of HCFC Blend A.

1) HCFC Blend A includes following four organic materials.

①Chlorotetrafluoro-ethane : HCFC-124 (C_2HClF_4) : 9.5%(mass percentage)

②Chlorodifluoro-methane : HCFC-22 ($CHClF_2$) : 82%(mass percentage)

③Dichlorofrifluoro-ethane : HCFC-123 ($C_2HCl_2F_3$) : 4.75%(mass percentage)

④Isopropenyl-1-methylcyclohexan: $C_{10}H_{16}$: 3.75% (mass percentage)

$C_{10}H_{16}$ has very low volatility and exists in a liquid state under the atmospheric pressure and normal temperature. That is, as matter not belonging to liquefied gas, its saturated vapor pressure is very small enough to be disregard. However, the remaining three organic matters which belong to liquefied gas under the normal temperature present strong vapor when exposed to the air.

By the way, the above four constituents have 100% miscibility from each other, because they are essentially compounds that belong to Hydrocarbon series or, in the case of $C_{10}H_{16}$, are matters made by a part of hydrogen combined with hydrocarbon being substituted by Halogen element (chlorine, fluorine, etc.).

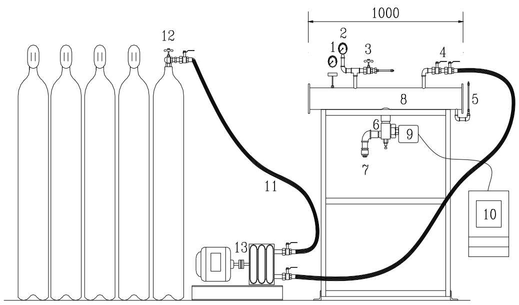
2) Because the remaining three matters except $C_{10}H_{16}$ among the constituents of HCFC Blend A become liquid under the normal temperature, each constituent will have its inherent saturated vapor pressure (property as function of only temperature), but if a container is filled with HCFC Blend A so that a liquid phase may exist in the container, each constituent will show saturated vapor pressure property (proper -ty of different size from vapor pressure of each constituent) composite formed by three constituents which belong to liquefied gas, and the saturated vapor pressure property composite showed will naturally vary with component ratio (mixing ratio) of three constituents (liquefied gas). That is because the volatility of each constituent is different from each other and the partial pressure of each constituent has functional relation with the mole fraction of the constituent in the liquid.

3) If the mixing ratio (mass ratio) of the liquefied constituents of HCFC Blend A contained in a container is under a certain condition, the vapor pressure in the container will be the function of only temperature. In fact, it is known that it has certain vapor pressure of 8.3㎏/㎠(=118.05psig) at 20℃ .

4) It is estimated that the specification of the container valve to be used in an experiment process, a discharge nozzle without built-in orifice, the connection pipe between a container valve and a container, and the connection pipe (including related components) between a container valve and a discharge nozzle are fixed, the discharge rate of HCFC Blend A at the set temperature under such fixed condition will usually show a steady average value.

3. Experimental method and device

3.1 Method of injecting extinguishing agents



Division	Name
1	Thermometer
2	Oil pressure gauge
3	Ball valve for gas(for air exhaust):Spec. 20mm
4	Ball valve for gas(Intake for agents injection) : Spec. 20mm
5	Water gauge (Transparent urethane pipe)
6	Exhaust valve (Container valve) 32 mm
7	Nozzle (12mm× 6hole, 60˚ angle)
8	Pipe type container(KSD3562,sch #40) : Spec. (100 ¢ × 1000L)
9	SOLENOID VALVE
10	Fire alarm (P type 1 class)
11	Agents-transferring hose(High pressure hose)
12	Cylinder(60 kg/BT, HCFC Blend A)
13	Agents-transferring pump (plunger pump), 1595 psi (pressure)

Fig.1 Diagram of experiment device

(1) We put an experimental storage tube which is not filled with agents on a digital scale to measure weight(W_1).
(2) Connect one end of high pressure hose, in the both ends of which a ball type switch valve is installed, to injection inlet of the storage tube and connect another end to outlet of plunger pump (Maximum exhaust pressure is 1,595 psi (112.14 kg/cm^2). And connect one end of another high pressure hose having the same structure to intake of above pump and connect another end to switch valve of a agents storage container. Under the condition in which the hose is connected like this, we measured the weight(W_2) indicated in the digital scale, that is, the weight applied to the scale plus the weight of a storage tube, with the hose hung on the scale.
(3) While the pump is in operation, we filled the storage tube until the digital scale indicates the value more than W_2 by 11.4kg. There is no rapid increase in pressure during the charge process. Because the storage tube was not completely filled with liquid agents.

3.2 Measurement of occurrence vapor pressure by temperature of agents

1) Measuring device
We decided, for measuring the occurring vapor pressure, to use an experiment device for emitting agents.
2) Measuring method
In measuring the occurring vapor pressure of the agents used in this research, we decided to use the pressure gauge installed in this experiment device by filling an experiment device so that liquid agents are partially filled with the device.
In this case, it is important to maintain the temperature of the experiment device itself, liquid agents and vapor in the device to raise precision degree of measurement. To do that, we manufactured separately Water Bath(1,500L x 500W x 500H x 3.2ton) covered with insulated materials 10mm thick and selected a method by which the temperature of the water contained therein was maintained at the set temperature and the experiment device was completely sunk into the water. In the above method, maintaining the temperature in the water bath as 20℃ for a long time (more than an hour), we observed the pressure gauge, obtained 117 psig. As a result of another measurement with the experiment device filled with different volume of agents, we obtained the same value, so we decided to confirm the above method. Provided that, according to literature, saturated vapor pressure is 118.05 psig at

20℃, so as causes for a minute error (118.05-117 = 1.05 psig), followings are considered.

① An error according to the precision degree of a pressure gauge and a visual error at the time of viewing the indicator
(Notes) As a result of an experiment by which the two pressure gauges (oil pressure gauge) prepared for this experiment replaced each other and were installed in the experiment device, we found out the two pressure gauges have the same performance. Therefore, we decided that the reliability of the pressure gauges is comparatively high.

② An error from the minute difference of mixing ratio which may occur in the process of a bulk type container (Storage capacity 1000kg) being filled with each constituent at the origin country of agents (China)

3.3 Measurement of discharge ratio by set temperature and by orifice

1) Measuring device
We manufactured a piping container for storing agents 1m long, using Sch. #40 black steel pipe with diameter of 100mm. A container valve was installed in the center of the black steel pipe and a discharge nozzle was installed in the end of the container valve through a connection pipe. Besides that, injection inlet, a pressure gauge, a thermometer and air outlet, etc. were installed. Also, a digital thermometer (Calibration before use) : One for measuring the temperature of the air and water which was subject to inspection and correction for a measuring instrument by an authorized agency. The type and specification of experiment devices and incidental instruments are as showed in Fig. 1.
2) Measuring method

① After we soaked an experiment device in the water bath which contained water of set temperature for more than an hour and then fixed the device to a support, we let agents discharge from a discharge device for a discharge experiment.

② A heater was used in order for the temperature in a laboratory to be equal to the set temperature, provided in case of the set temperature of 5℃ a laboratory was difficult to be kept cold, so we tried to reduce the fixing time by a support (Operation time: about four minutes) in order that the temperature of drugs in an experiment device might not be increased due to the open air. Considering the fact that the specific heat of liquid agents is 1,250J/kg., it is decided that the rise of temperature of agents during the operation time of four minutes was in fact very little enough to be disregarded. Because this agent is a matter having larger heat capacity than water.

③ At the time of measurement of the discharge rate, the set temperature was 20℃, 15℃ and 5℃.

④ At the time of the discharge rate, the charge amount of agents is 11kg.

⑤ With regard to measurement of the discharge rate, we measured discharge time by using stop watch, but in consideration of the error of a man's action, appointed the users of stop watch as one and the same person, and measured the error of a man's action through repeated rehearsals. (Result error: 0.2 seconds)

⑥ An orifice was set as 10mm, 12mm, 15mm, 18mm, 20mm and 24mm. In case of 24mm, the orifice was not inserted in the discharge nozzle, because the actual inner diameter of the outlet of exhaust valve and intake of a discharge nozzle were 24mm.

⑦ We decided not to make one container valve discharge agents more than twice.
3) Estimated details before this experimen
-t is conducted.
When we conducted test discharge of the agents put in a container before the main

experiment was conducted, it was observed that, as dark cloud type of discharge appears with start of discharge, the pressure slowly decreased but from certain pressure (60~ 70psig), the pressure suddenly decreased, when cloud type of discharge shape still continued but greatly reduced. The time elapsed during which such changed shape occurred was usually about 2~3 seconds. When the changed shape of discharge disappeared, there was no cloud type of shape and only weak sound at the time of gaseous discharge could be heard for about 1 second. Since most of agents are discharged for the relatively longest time in the early stage during which agents are strongly discharged, the time elapsed was deemed as the main discharge time, the weakened cloud type discharge was presumed to be a phenomenon by which liquid agents remaining in the tube which connects the container valve with the discharge nozzle is discharged for a short time. If so, the remaining discharge time was expected to be usually the same.

3.4 Experiment method

① Injection amount 11kg, Orifice10mm

Set temperature20℃, about 8 sec after discharge starts

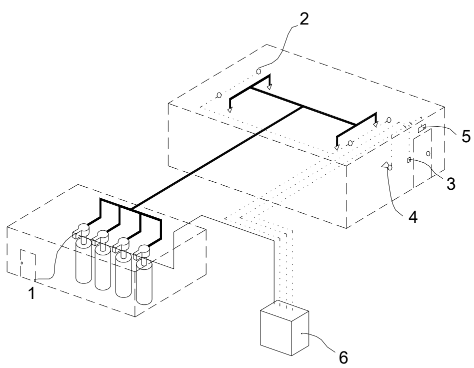
② about 19 sec after discharge starts

Fig. 2 Discharge test

3.5 Comparison of the conventional engineered-method gaseous fire exting -uishing system with the fire extinguishing system on which this study is conducted.

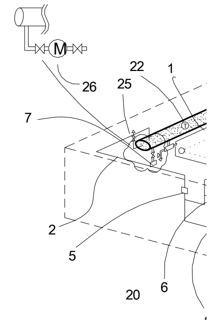
Table1. Comparison of gaseous fire extinguishing systems

Division	Conventional fire extinguishing system(Fig.3)	Fir extinguishing system on which this study is conducted(Fig.4)
Agents-storing method	Vertical type storage container (Usually inner volume of 68ℓ)	Pipe-type horizontally installed storage container (Inner volume is decided according to design)
Container valve	Installed in the top of a storage container	Installed in a pipe type storage container in the vertical direction
Where container is installed	A room exclusively used for fire fighting	The upper part of a room to be protected or in a ceiling
Operation method	Electric or fluid pressure method	Same as previous
Other	Nitrogen is constricted in a storage container	Only agents are injected



No.	Name
1	Solenoid driving type valve-opening device
2	Automatic fire alarm
3	Manually operated switch
4	Alarm device
5	Exhaust indication lamp
6	System control part

Fig.3 Diagram of Engineered method gaseous fire extinguishing system



No	Name	No	Name
1	First supply pipe	14	Control wire
2	Second supply pipe	15	Valve-opening device
3	Pressurized container	16	Discharge nozzle
4	Container valve	17	Storage tube
5	Automatic constant pressure device	18	Exhaust valve
6	Pressure switch	19	Liquid level sensor
7	injection inlet	20	Connection pipe
8	Alarm device	21	Pressure gauge(compound pressure gauge)
9	Automatic fire alarm	22	Thermometer
10	System control part	23	Water gauge
11	Exhaust indication lamp	24	Safety valve
12	Manually operated switch	25	Air-exhausting valve
13	Chamber	26	Oil gauge

Fig.4 Diagram of the fire extinguishing system on which this research is cond -ucted

4. Experiment result

4.1 Saturated vapor pressure

Table 2. Saturated vapor pressure by tem -perature

Temperature (℃)	20	17	15	14	10	7	5	4	0
Saturated vapor pressure (psig)	117	106	102	97	89	79	70	69	56

<Remark>

ⓐ The pressure of the experiment device was measured under the condition in which the device was sunk in water bath that maintained the set temperature. So, it appeared that there was no influence of the inside temperature of the laboratory.

ⓑ Dry ice was put to lower the temperature of water in the Water Bath to 4℃ and 0℃ .

4.2 Calculation of discharge time and rate of agents

Table 3. In case the set temperature is 20℃

Division	Diameter of Orifice(mm)					
	10	12	15	18	20	24
Amount of agents injection	11	11	11	11	11	11
Main discharge time(sec)	20.8 (21.8)① (19.3)②	13.1	8.0	7.2	6.4	6.2

Division	Diameter of Orifice(mm)					
	10	12	15	18	20	24
Injection amount of agents(kg)	11	11	11	11	11	11
Main discharge time(sec)	22.9	15.3	8.5	8.1	6.6	6.8
Remaining discharge time(sec)	2.97	2.67	2.34	2.28	1.97	1.93
Discharge rate (kg/sec) [Injection amount÷ Main discharge time]	0.48	0.72	1.29	1.36	1.67	1.62

<Remark>

ⓐ Main discharge time means the time during which fire extinguishing gas indicates normally strong discharge type.

ⓑ Remaining discharge time means he time which follows the completion of main discharge time and during which weakened discharge type is indicated.

ⓒ The parenthesized value is the measurement value of discharge experiment conducted by using the two container valves and agents amount which remained after completion of 18 times of main experiment. Among them, the parenthesized value of number ① was the value when 8kg agents are injected in a small container and the parenthesized value of number ② was the value when 8kg agents are injected in medium-sized container.

ⓓ The same container valve was twice used. Accordingly, in case one container is firstly used, it corresponds to 10mm, 15mm and 20mm of orifice diameter.
The same applies to other experiment for which different temperature was set.

Division	Diameter of Orifice(mm)					
	10	12	15	18	20	24
Remaining discharge time(sec)	2.65 (2.70)① (2.56)②	2.02	1.75	1.70	1.56	1.50
Discharge rate (kg/sec) [Injection amount ÷ Main discharge	0.53 (0.50)① (0.57)②	0.84	1.38	1.53	1.72	1.77

Table 4. In case the set temperature is 15℃

<Remark>

ⓐ The room temperature in the day showed the range of 14℃~ 18℃, so there was almost no difference with the set experiment temperature.

Table 5. In case the set temperature is 5℃

Division	Diameter of Orifice(mm)					
	10	12	15	18	20	24
Injection amount of agents(kg)	11	11	11	11	11	11
Main discharge time(sec)	27.5	17.7	9.4	8.3	7.3	7.3
Remaining discharge time(sec)	3.60	3.34	3.00	2.75	2.40	2.45
Discharge rate (kg/sec) [Injection amount÷ Main discharge time]	0.4	0.62	1.17	1.33	1.51	1.51

<Remark>

ⓐ The set temperature was very low (5℃ while the room temperature in the daytime usually showed the range of 5℃ ~ 20℃, so we urgently reduced the time during which the experiment device was supported by a supporter(An average of less than 4 minutes was required).

5. Analysis of characteristics of experiment data

5.1 Correlation between the temperature and saturated vapor of agents

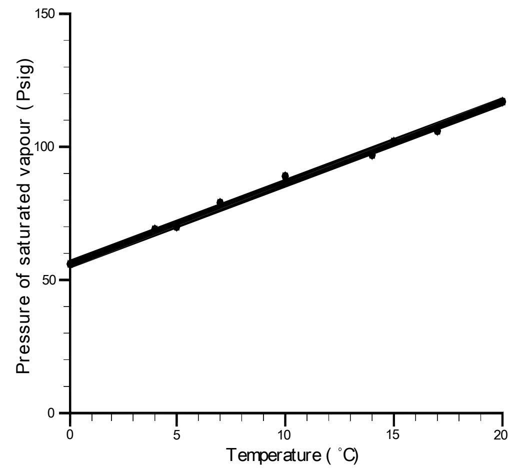
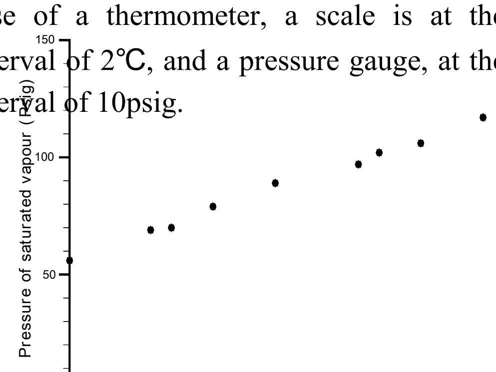


Fig.5 Correlation between the t emperature and saturated vapor pressure of agents

In order to understand the change trend according to the temperature of saturated vapor pressure, we showed the correlation between temperature and saturated vapor pressure as following graph with temperat -ure indicated on the horizontal and saturat -ed vapor pressure on the vertical.
The straight line indicated in this graph was intended to have an approximate access to pressure distribution points**.(Fig.5)**
It can be verified from above graph that there exists linear correlation between saturated vapor pressure and temperature. It appears that the visual error in viewing by naked eye the scale of the pressure gauge greatly influence the measurement error. Because in case of a thermometer, a scale is at the interval of 2℃, and a pressure gauge, at the interval of 10psig.



Also, with regard to measured data, the saturated vapor pressure is 56psig(3.94 kg /cm^2) at 0℃, which is never low pressure. It is deemed that, if the diameter of an orifice and the size of a container valve increases under this pressure,

5.2 Analysis of correlation between discharge rate and orifice diameter

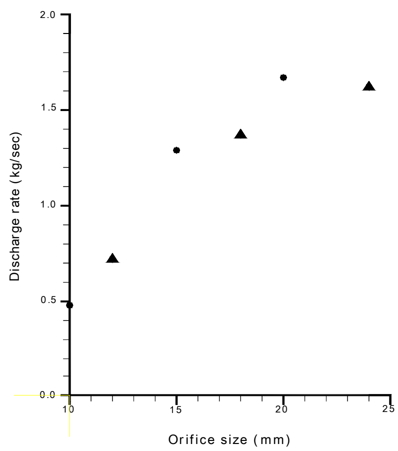


Fig.6 In case the set temperature is 20℃

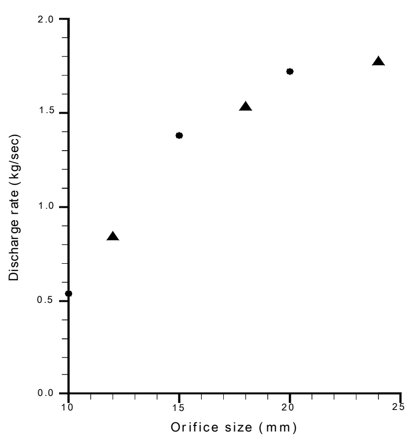


Fig.7 In case the set temperature is 15℃

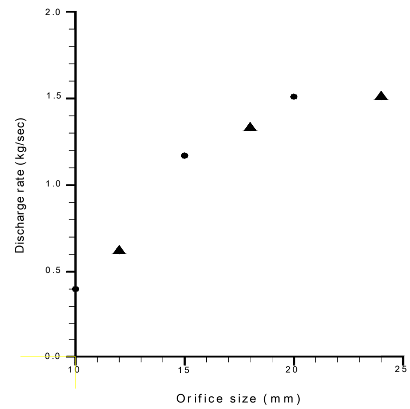


Fig.8 In case the set temperature is 5℃

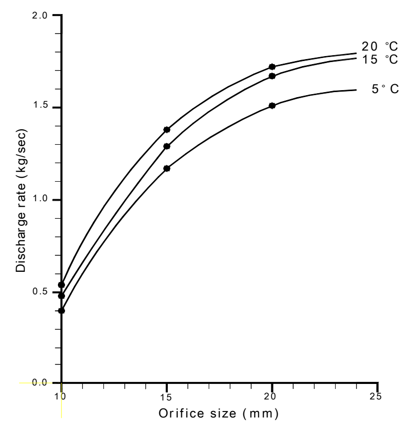


Fig.9 Indication of solid line of Fig. 6~8

① By making plotting on a graph, you can not only easily grasp the correlation between orifice diameter and discharge rate but understand the trend of change. Accordingly, it was possible to indicate following graph by plotting discharge rate according to orifice diameter by the set temperature. (In this case, the horizontal meant the diameter of an orifice and the vertical meant discharge rate).

As compared with the above three measurement diagrams, distinct common points are found.

As a result of examination of measurement data showed in a circle (●) and a triangle(▲), it was found all of them represent zigzag patterns. Especially, in case of an orifice of 24mm aperture, discharge rate decreased compared with 20mm, which is theoretically impossible. The fact that can't be overlooked from the above three cases in cause analysis was that agents were discharged with same container valve reused when the aperture of the orifice was 12mm, 18mm, 24mm showed in a triangle (▲).

Comparison between and among the Fig.6~8 indicated in the above three measure -ment diagram gives distinct commonness. That is, as a result of investigation of the measured data indicated in a small circle(●), it was found out that they all showed zigzag pattern. Especially, in case of an 24mm-diameter orifice, the discharge rate reduced compared with 20mm. It is theoretically impossible to occur this phenomenon. Then what is the cause? The important fact in analyzing such cause in above three cases is that we reused the same container valve to exhaust agents in case when the diameter of the orifice was 12mm, 18mm and 24mm.

The discharge rate measured in case of 19mm, 15mm and 20mm orifice where the container valves were first used seemed to be relatively reliable. Therefore, we deemed it necessary to verify the trend of change by plotting the discharge rate in orifice diameter 10mm, 15mm and 20mm on a graph, so that we, as showed Fig. 9, connected three points

① / ②	8.6 %			9 %			10%		
	20	15	5	20	15	5	20	15	5
10 mm	14.6	12.7	10.4	13.9	12.4	9.9	12.4	11.0	8.8
15 mm	38.0	34.2	30.5	36.1	33.2	29.1	35.7	29.5	25.9
20 mm	47.3	44.3	39.4	45.0	43.0	37.5	40.1	34.6	33.4

(the discharge rates in orifice diameter 10mm, 15mm and 20mm) in a solid line by using a circular ruler. As a result of that, it appears there are similar points.

The total flow of each curve in the above **Fig.9** shows plenty of mutual commonness , and also shows the tendency that the increase speed in discharge rate becomes slower more or less despite the fact that the diameter of an orifice increases.

The curves in case of set temperature of 20℃ and 15℃ appears come nearer each other according to increase in the diameter of an orifice, however, comparing these two curves with the curve in case of set temperature of 5℃, it is possible to know the difference between discharge rates becomes larger according to the increase of the diameter of an orifice.

② **Table 3.** is the case where set temperature is 20℃ and the remaining discharge time when orifice diameter 10mm was used is 2.65 seconds, 2.70 seconds and 2.56 seconds, showing mutual similar values. From this, the estimation details before this experiment was conducted, that the occurrence of change situation like remaining discharge would be caused by the discharge of liquid drugs which exist the connection pipe between exhaust side and discharge nozzle of the container valve, appears considerably reliable.

③ **Table 6.** shows the size(volume) of the space, converted according to the discharge rate measured by set temperature, which can be protected by orifice diameter with regard to the space to be protected whose necessary fire extinguishing density is respectively 8.6%, 9% and 10%.

Table 6. The size of the space which can be protected by necessary fire extinguishing density(unit: m^3)

① Fire extinguishing density

② Set temperature

③ Diameter of orifice

Table7. Required amount of HCFC Blend A in case of total flooding system metric unit(calculated under atmospheric pressure)

Temperature(□)	Specific volume ratio m^3/kg	WEIGHT/VOLUME(kg/m^3) REQUIREMENTS FOR							
		8.6%	9%	10%	11%	12%	13%	14%	15%
-25	0.2192	0.4293	0.4513	0.5070	0.5639	0.6222	0.6818	0.7428	0.8052
-20	0.2236	0.4208	0.4423	0.4970	0.5528	0.6009	0.6683	0.7281	0.7893
-15	0.2280	0.4127	0.4338	0.4873	0.5421	0.5981	0.6554	0.7140	0.7740
-10	0.2324	0.4048	0.4255	0.4781	0.5318	0.5867	0.6429	0.7004	0.7593
-5	0.2368	0.3973	0.4176	0.4692	0.5219	0.5758	0.6309	0.6874	0.7451
0	0.2412	0.3900	0.4100	0.4606	0.5123	0.5652	0.6194	0.6748	0.7315
5	0.2457	0.3830	0.4026	0.4523	0.5031	0.5551	0.6083	0.6627	0.7183
10	0.2501	0.3762	0.3955	0.4443	0.4942	0.5453	0.5975	0.6510	0.7057
15	0.2545	0.3769	0.3886	0.4366	0.4856	0.5358	0.5871	0.6397	0.6934
20	0.2589	0.3634	0.3820	0.4291	0.4774	0.5267	0.5771	0.6288	0.6816
25	0.2633	0.3573	0.3756	0.4220	0.4694	0.5178	0.5675	0.6182	0.6702
30	0.2677	0.3514	0.3694	0.4150	0.4616	0.5093	0.5581	0.6080	0.6591
35	0.2722	0.3457	0.3634	0.4083	0.4541	0.5010	0.5490	0.5981	0.6484

Considering the values showed in above **Table 3**, we consider that orifice diameter 20mm can apply practically. For example, with regard to the space to be protected which needs fire extinguishing density of 8.6%, in case 20mm orifice is installed in a discharge nozzle, space of 47.3m^3 per nozzle can be protected.

If the indoor height of this space is 2.5m, it means it is possible to protect by installing one discharge nozzle per area of 47.3/2.5=18.9m^2. The experiment data applied at the time of value calculation per fire extinguishing density of **Table 6.** was based on the main discharge time. Because the remaining discharge amount is within 5% excluding 95%, legal discharge amount.

6. Conclusion

(1) With regard to the systematic characteristics of the HCFC Blend A discharge facility for which the experiments are concentrated in this research, if we compare with the cabinet type package system which is the typical pre-engineered system, following points are considered to be the qualification that the system applied in this research seems to be the new pre-engineered system broke from the conventional discharge method of gas suppression agents and provides same function of the engineered system, typically for total flooding function.

①Siphon is not necessary in the pipe type horizontal cylinder.

②Nitrogen super-pressurization is not required.

③Discharge method is downward type on the contrary to the upward type from cylinder to cylinder valve in conventional system.

④Cylinder could be located in the upper space of the room thus can make conservation of the floor space.

(2) It is noticed that there is relatively linear relation between saturated vapor pressure and temperature of HCFC Blend A.

(3) With regard to the dependence between the orifice size and the discharge rate of the HCFC Blend A agent, the tendency of the variation could be noticed by plotting the experimental data on the graph. Discharge rates have been naturally increased in proportion to the size of the nozzle orifice as expected, however, the increments between both parameter have been further enlarged according to the ambient temperature increase.

(4) Referring to the figures and the tables, it

is judged there is strong possibility of the practical application in the case of orifice size 20mm and above. For instance, when 20mm orifice is used in the discharge nozzle for the protection space which requires 8.6% of gas concentration, 47.3m^3 of the space could be protected by one discharge nozzle. If the height of the compartment is 2.5m, then one nozzle can cover the area of 18.9m^2(47.3/2.5=18.9m^2). Accordingly it is judged that bigger size of the cylinder valve and discharge nozzle would be required for larger compartment.

(5) It is confirmed that the saturated vapor pressure, 8.3kg/cm^2 of HCFC Blend A at 20℃ which is the normal design tempera-ture for gas suppression system is a sufficient pressure in making agent discharge within the statutory discharge duration.

.(6) In both case of conventional system and new system based on this research, the usage of the cylinder valve should be limited to be used only once.

(7) On the contrary to the definitive necessity to utilize a computerized design with dedicated software for conventional engineered system, the design of the pre-engineered system of this research would not require the dedicated software, accordingly it could attribute in resolving the disbelief in design by users and would be one of the advantage in economic aspects as well.

Reference

1. NFPA 2001 Standard on Clean Agent Fire Extinguishing System 2000 Edition.
2. Australian Standard : Gaseous fire extinguishing systems Part5 : NAFS-Ⅲ Total flooding systems(AS 4214.5-1995).
3. Lee Soo Gyeong, Ha Dong Myeong, Oct. 1998. "Theory of general chemistry and organic matter", Book publisher Uije p.576 ~p.583.
4. Seo Jeong Il, Jan. 1979, "Industrial thermodynamics",Munundang,p.63~P.68
5. OLAF A. HOUGEN et al, 1962., "Chemical Process Principles, Part Ⅰ", Published by Wiley & Sons, INC, p. 79~ p.79.
6. Kim Taeman and other six persons, "Gerneral Physics", Hyeongseol Publishing Company, p.328(1986. 02 .20).