Innovation Of A Flame Freeze Connector Tool For Extinguishing Fire In Forest Fires Using The VDI 2221 Method

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Abstract

Forest fires in Indonesia have become a case that occurs every year. The National Disaster Management Agency estimates that 99 percent of forest and land fires occur on land. The largest forest and land fires in Indonesia occurred in 1997-1998, with an area of burned land of 9.2 million hectares. Annual forest fires in Indonesia not only harm the ecology and society in various ways, but also harm external parties. The impact of forest fires that occur every year has raised concerns for many parties, both regionally and internationally. Environmental and economic approaches are very important in efforts to rehabilitate forests destroyed by fire. The basis for making a Flame Freeze Connector for fire emissions in areas where fires occur which require continuous spraying of air onto burning land. The VDI 2221 approach was used in this design to optimize the materials, technology and economics of the tool. The design results show that the Flame Freeze Connector works from all components that form a unified product that can extinguish fire with flame freeze (fire poison). The result is a flowing water discharge of 23.3 m^3/s, where the greater the rotation speed of the feeding pump, the greater the water discharge produced which affects the pressure.

Keywords
VDI 2221, Product Design, Fluid, Bernoulli's law

1. Introduction

Forest fires in Indonesia have become a case that occurs every year. The National Disaster Management Agency estimates that 99 percent of forest and land fires occur on land. Humans are the cause, while the influence of nature is only 1% (Ellyvon 2019). This behavior will be detrimental to humans because if nature is damaged then humans cannot use it; This illustrates the existence of reciprocal interactions between humans and nature or the environment Mulyana, E 2019).

The relationship between humans and their environment is circular. Every human activity can have an impact on the environment (R. and Y. Sopiana 2021). The largest forest and land fires in Indonesia occurred in 1997-1998, with an area of burned land of 9.2 million hectares (R. S. Septianingrum 2018). In 2015, forest and land fires occurred again in Indonesia and destroyed 2.64 million hectares of peatland.

Annual forest fires not only harm the ecology and society in various ways, but also harm external parties (Cochrane, M 2003). The impact of forest fires that occur every year has raised concerns for many parties, both regionally and internationally (S. Rusadi and Yuslaini Nina 2021). Forest fires are caused by several factors on purpose Certini, G 2005). Environmental damage will caused bad environmental in the forest ecosystem, including animals, biota that are important for human's survival, medicinal plants, resin, wood, fruit, etc (Wanaswara 2019). Environmental and economic approaches are very important in efforts to rehabilitate forests destroyed by fire (Yuniawati and Suhartana 2013).

1.1 Objectives
The objective of this research is to designed a Flame Freeze Connector to extinguish fires in areas where fires occur**.**

2. Literature Review
2.1 VDI 2221
The VDI 2221 method has advantages at the conceptual design stage, identifying the elements that make up the technical system will be produced, whose functions must be carried out by each element so that the system as a whole. Applications for these system components are referred to as subfunctions, and interactions between one subfunction and another are combined and changed (Ulrich, K. T and S. D. Epinger 2001). The VDI 2221 approach helps with the planning process. A product can maximize designer productivity to identify the best solution to a design problem (R. Majid 2021).

2.2 Product Design
The design form is the initial form, and those meet the requirements according to the specifications are selected based on performance, technical and economic aspects. The initial concept chosen will be developed into a definitive layout, that is, the type of design that meets needs and expectations. (Cupu Dedi Rosa Putra and Syamza Nanda 2021). The design include technical drawings, detailed technical drawings, component lists, material specifications, operating systems, tolerances and other references that make a prototype.

2.3 Fluid
Substances classified as fluids are capable of moving when a force is applied. Liquids are not static; they can take on new forms. Based on The Shape of the object through which it passes, liquids can form a wide variety of solids. Static pressure, dynamic pressure, total pressure, fluid velocity, and shear stress are examples of fluid flow properties (Nasution, 2008).

2.4 Bernoulli's Law
This law states that at any location along a current line, the amount of pressure (p), kinetic energy per unit volume, and potential energy per unit volume have the same value. Bernoulli's law states that the sum of pressure (p), kinetic energy per unit volume (½ rv2) and potential energy per unit volume (rgh) have the same value at any point along a current line (Giancoli, D.C 2001).

3. Methods
Methods are the processes that researchers take to gather information. The research method provides an overview of the study design, including required procedures and steps, research time, data sources, and problem-solving approaches. The flowchart of the methods can be seen in Figure 1.

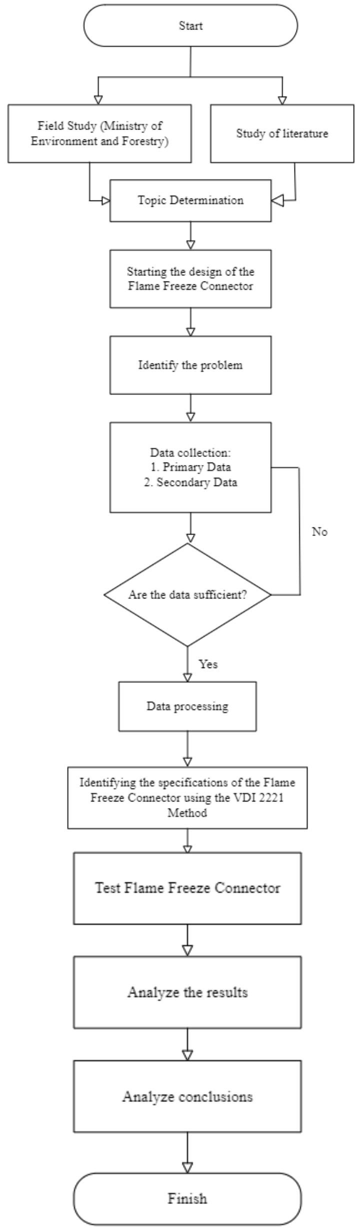

Figure 1. Flowchart of Methods

4. Data Collection

Table 1. Calculation Data of Water Discharge and Hydraulic Power

Water Discharge Velocity (v)	Cross-Sectional Area (A)	Density (ρ)
180 lpm	$0.09m^2$	1100 kg/m^3

Table 2 a. Calculation Data of Water Discharge and Hydraulic Power

P_1	ρ_1	v_1	h_1	g	P_2	ρ_2	v_2	h_2
$1{,}8x10^5$	$1.100\ kg/m^3$	5.54 m/s	0,4m	$9{,}8\ m/s^2$	-	$1.100\ kg/m^3$	0.69 m/s	0,05m

5. Results and Discussion

In designing products, the VDI 2221 method is used to ensure that the design meets various aspects, such as convenience, practicality, ease of use, maintenance, repair, and safety.

Table 2 b. Initial Specifications

Aspects	**D/W**	**Specification**
Function	D	Extinguish fire using flame freeze on fire land
Assembly	D	Tools can be disassembled easily
Energy	W	Use can be done efficiently
Geometry	D	Flame freeze liquid capacity <20L
Force	W	Tool weight does not exceed 5 Kg
Material	D	Using galvanized
	D	Using *stainless steel*
	D	Using brass
Maintenance	D	Maintenance is easy to carry out and inexpensive
	D	Easy tool cleaning process
	W	Material tools easily available
Operation	W	Tool operated by two operators
	W	No special skills are required in using the tool
	D	Safe when used
Cost	W	Affordable Production Cost
	W	Affordable for the lower middle class

After identifying the initial specifications, the next step is to design the sub solution principles then determine the combination of sub-function solution principles to determine the components that will be used in the manufacture of Flame Freeze Connector. The table combinations of sub-function solution principles can be seen in Table 3.

Table 3. Combination of Sub Function Solution Principles

No	**Solution Principle/Sub Function**	**Description**	**1**	**2**	**3**
1	Sock Connection	Make	Galvanized	Brass	Stainless Steel
2	*Pressure Gauge*	Buy	Stainless steel	Black steel Brass	Iron
3	Connector	Make	Stainless steel	Brass	Steel
4	Lid Container	Buy	Plastic	PVC	HDPE
5	Hose	Buy	Rubber	Vinyl	PVC

Description:

Combination 1
Combination 2
Combination 3

With the principles of the table above it will be obtained several combinations, namely:

a. C1: 1-1, 2-1, 3-2, 4-1, 5-1
b. C2: 1-2, 2-3, 3-1, 4-2, 5-2
c. C3: 1-3, 2-2, 3-3, 4-3, 5-3

The next step is to choose the best combination of the three available alternatives. The concept selection process is done through the selection diagram, which can be seen in Table 4.

Table 4. Selection Diagram

INDUSTRIAL ENGINEERING	**Solution variation selection table for Flame Freeze Connector**
Selection Criteria + Yes - No ? Lack of information ! Check the specification	Decision Sign Solution Variant (SV) + Solution sought - Delete Solution ? Collect Information ! View Specifications

Variants of Solution Principles

- A: according to the overall function
- B: according to the wish list
- C: within the limits of production costs
- D: knowledge of the concept adequate
- E: according to the wishes by the designer
- F: Safety requirements

	A	B	C	D	E	F	Description	SV
C1	+	+	+	+	+	+	Appropriate	+
C2	+	-	+	+	-	+	Inappropriate	-
C3	+	-	-	+	+	+	Inappropriate	-

From the analysis of the selection diagram in Table 4, it can be concluded that combination 1 is the best choice for designing Flame Freeze Connector.

From the combination diagram obtained design results that can be seen in the figure below.

Figure 2. Product Design of Flame Freeze Connector

In the process of forming a prototype, it takes Make-or-Buy decision analysis to consider what components will be made and purchased. Make or Buy analysis can be seen in Table 5.

Table 5. Make-or-Buy Analysis

Component Name	***Make or Buy***
Sock Connection	*Make*
Pressure Gauge	*Buy*
Hose Niple	*Buy*
O Ring Seal	*Buy*
Niple Branch 3-Y	*Buy*
Lid Container	*Make*
Double Niple	*Buy*
Ball Valve	*Buy*
Hose Clamps	*Buy*
Cable Ties	*Buy*
Hose	*Buy*

After analyzing the Make or Buy decision the next step is to make a Bill of Material to determine what components will be used in the process of making Flame Freeze Connector which can be seen in Figure 3.

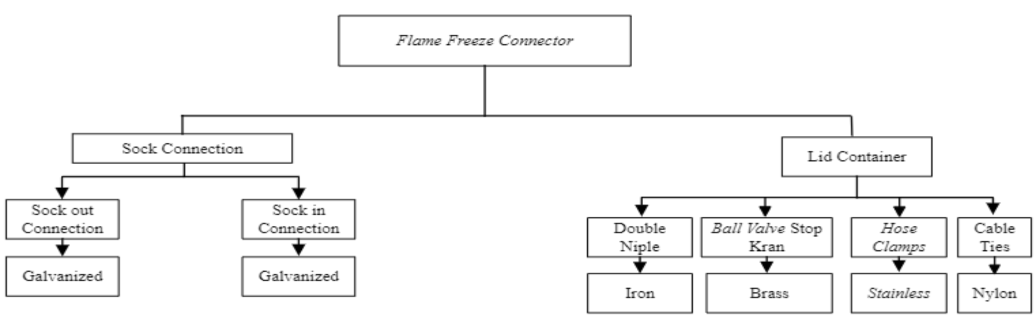

Figure 3. Bill of Material

After creating a Bill of Material that will be the main component and support the formation of The Flame Freeze Connector prototype, the next step is to create an Assembly Process Chart to assemble the tool. The Assembly Process Chart can be seen in Figure 4.

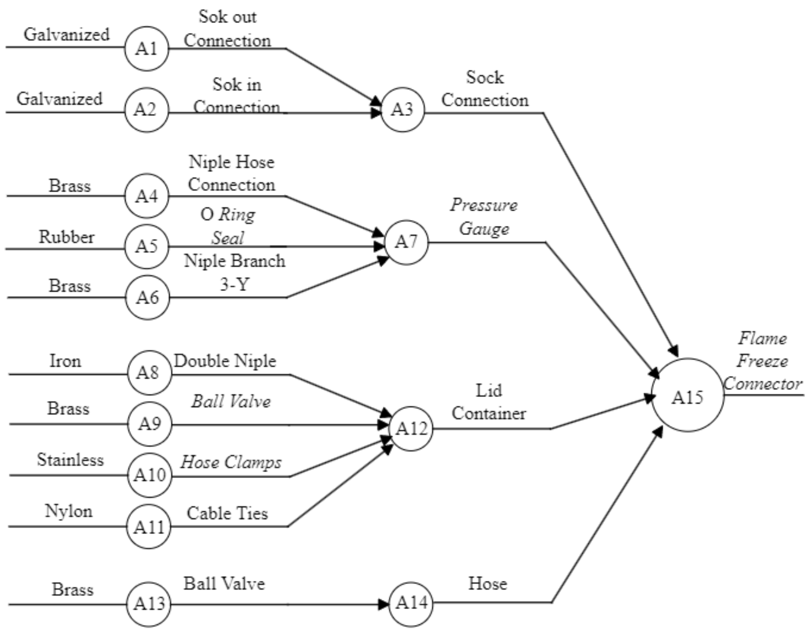

Figure 4. Assembly Process Chart

The Assembly of Flame Freeze Connector is carried out in 4 stages. The first stage is to assemble the sock connection, the second stage is to assemble the pressure gauge to attach it to the sock connection, the third stage is assembling the container lid to close the container that will be used to drain water to the adapter/sock connection, and the last is to assemble the hose as a water facility to flow to the adapter and then the suction hose. The end of the assembly is the product Flame Freeze Connector. The results of The Flame Freeze Connector design can be seen in Figure 5.

Figure 5. Flame Freeze Connector Design Results

Figure 6. Installation of Flame Freeze Connector with Pump and Suction Hose

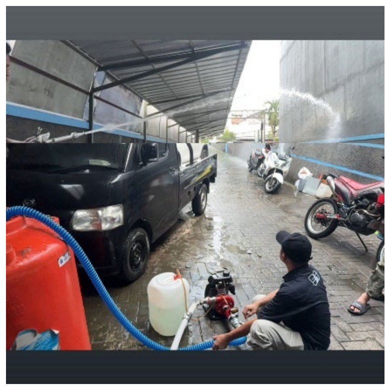

Figure 7. Flame Freeze Connector Test Results

After testing the Flame Freeze Connector design, it was concluded that the product works well, the purpose of creating this tool is to help firefighters extinguish fires more quickly and efficiently using flame freeze (fire poison). The distribution of liquid from the container and through the adapter that becomes the connecting bridge can unite the liquid with water to produce foam. By showing the results of the foam that blends with the water can be stated, that Flame Freeze Connector is successfully designed.

5.1 Numerical Results

$v = 180\ lpm$

$v = 10{,}8\ \mathbf{m^3/h}$

To get the results of the calculation of water discharge the next step can do the calculation with the following formula.

$Q = v.A$

Description:

Q = water discharge volume ($\mathbf{m}^3/\mathbf{s}$)

v = water flow velocity (m/s)

A = cross-sectional area (m^2)

So that the results of the calculation of water discharge *volume* data are as follows.

$Q = v.A$

$Q = 10.8\ \mathbf{m^3/h}\ x\ 0.09m^2$

$Q = 0.972\ \mathbf{m^3/h}$

Examples of calculations and formulas for Hydraulic Power are as follows.

$P = Q.\rho.g.h$

Description:

Q = water discharge volume ($\mathbf{m^3/s}$)

$\rho\ = density\ (kg/m^3)$

$g = gravity(\ m/s^2)$ (9,8 m/s^2)

$h\ =\ head\ pompa\ (m)$

So that the results of the calculation of hydraulic power data are as follows.

$P = Q.\rho.g.h$

$P = 0{,}972\ m^3/s$. 1100 kg/m^3 9,8 m/s^2 . 0,08m

$P = 0.838$ kW

From the data listed in the data collections, it can be seen that it is P_2 we don't know the result, so we have to calculate the data to find the result of P_2. The calculation result is as follows.

$$P_1 + \frac{1}{2}.\rho_1.\ v_1{}^2 + \rho_1.g.h_1 = P_2 + \frac{1}{2}.\ \rho_1.\ v_1{}^2 + \rho_2.g.\ h_2$$

$$P_1 + \frac{1}{2}.\rho_1.\ v_1{}^2 + \rho_1.g.h_1$$

$$1{,}8\text{x}10^5 + \frac{1}{2}.\,1.100\ \text{kg/m}^3.\,5{,}54\ \text{m/s}\ +\ 1.100\ \text{kg/m}^3.\,9{,}8\ \text{m/s}^2.\,0{,}4\text{m}$$

$$P_2 + \frac{1}{2}.\ \rho_1.\ v_1{}^2 + \rho_2.g.\ h_2$$

$$\text{P2} + \frac{1}{2}.\,1.100\ \text{kg/m}^3.\ 0{,}69\ \text{m/s} + 1.100\ \text{kg/m}^3.\,9{,}8\ \text{m/s}^2.\,0{,}05\text{m}$$

$$= 1{,}8\text{x}10^5 + 21.192{,}38 =\ P_2 + 262.392$$

P_2 = 182.092,999

P_2 = 1.82 bar.

The final result of the calculation that has been carried out is that the final pressure (P_2) 1.82 bar or 1,82 x10^5 Pa. When compared to the known initial pressure, it can be concluded that the resulting pressure is still constant. 1,8 x10^5 Pa it can be concluded that the resulting pressure is still constant. The effect of pressure and velocity variations in the calculation, it can be observed how variations in pressure, velocity, and altitude at various points in the fluid flow contribute to the total energy. A decrease in pressure can be offset by an increase in velocity or a change in altitude, according to the principle of Bernoulli's Law.

6. Conclusion

From the results of research on the Design of Flame Freeze Connector with VDI 2221 Method it can be concluded that:

1. The making of the Flame Freeze Connector aims to extinguish fires on land where fires occur which require continuous spraying of water by mixing liquid fire poison (flame freeze).
2. In the innovation carried out by researchers using the VDI 2221 Method to ensure that the Flame Freeze Connector design meets various aspects, such as comfort, practicality, ease of use, maintenance, repair, security, and safety.
3. The combination of component sub-functions consists of galvanized, stainless steel, plastic, brass, and rubber materials.

4. The components that make up the Flame Freeze Connector include a threaded seat, pressure gauge, connector, collection cap and hose.
5. Make or Buy analysis of the Flame Freeze Connector tool resulted in 2 components to be made, namely the seat / adapter and the container cap. The results of the Flame Freeze Connector operation map have a total of 21 operation processes and 4 inspection processes.
6. The results obtained from the calculation of water discharge data and hydraulic power are 0.972 m^3/h and 0.838 kW. The results of data acquisition are obtained from the results of density, cross-sectional area, and water flow velocity.
7. The results obtained from the volume of water discharge and hydraulic power show that water discharge affects the speed of water flow. Flow velocity can determine the extent to which water can produce hydraulic energy or form hydraulic power that can be utilized.
8. The calculation results with Bernoulli's Law show that the final pressure (P_2) is 1.82 bar or equivalent to 1.82 x 10^5 Pa. When compared to the previously known initial pressure, which is 1.8 x 10^5 Pa, it can be concluded that the resulting pressure remains stable. In this calculation, the influence of variations in pressure, velocity, and altitude at various points in the fluid flow contribute to the total energy generated.

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Biography

Alyssa Felicia Wijaya Yakup is an Industrial Engineering student at Tarumanagara University in Jakarta, Indonesia. She has been active in organizations at Tarumanagara University from 2021-2023. She is interested in photography, artificial intelligence, visual landscapes.

Frans Jusuf Daywin is a lecturer in the Department of Agricultural Engineering at Faculty of Agricultural Technology Bogor Agricultural University since 1964 conducted teaching, research, and extension work in the field of farm power and machinery and become a professor in Internal Combustion Engine and Farm Power directing and supervising undergraduate and graduate students thesis and dissertation and retired as a professor in 2007. In 1994 up to present as a professor in Internal Combustion Engine and Farm Power at Mechanical Engineering Program Study and Industrial Engineering Program Study Universitas Tarumanagara, directing and supervising undergraduate student's theses in Agricultural Engineering and Food Engineering Desain. In 2016 up to present teaching undergraduate courses of the introduction of concept technology, research methodology, and seminar, writing a scientific paper and scientific communication, and directing and supervising undergraduate student's theses in Industrial Engineering Program Study at the Faculty of Engineering Universitas Tarumanagara. He got his Ir degree in Agricultural Engineering, Bogor Agricultural University Indonesia in 1966, and finished the Master of Science in Agricultural Engineering at the University of Philippines, Los Banos, the Philippines 1981, and got the Doctor in Agricultural Engineering, Bogor Agricultural University Indonesia in 1991. He joined 4-month farm machinery training at ISEKI CO, AOTS, Japan in 1969 and 14 days agricultural engineering training at IRRI, Los Banos the Philippines, in March 1980. He received the honors "SATYA LANCANA KARYA SATYA XXX TAHUN" from the President of the Republic of Indonesia, April 22nd, 2006, and received appreciation as Team Jury from the Government of Indonesia Minister of Industry in Industry Start-Up 2008. He did several research and surveys in farm machinery, farm mechanization, agricultural engineering feasibility study infield performance and cost analysis, land clearing and soil preparation in secondary forest and Alang-alang field farm from 1966 up to 1998. Up till now, he is still doing research in designing food processing engineering in agriculture products. Up to the present he already elaborated as a conceptor of about 20 Indonesia National Standard (SNI) in the field of machinery and equipment.

Didi Widya Utama is a Lecturer in Mechanical Engineering. Currently he is an Assistant Professor and Deputy Head Mechanical Engineering Study Program. He graduated with his Bachelor's degree at Tarumanagara University, Jakarta - Indonesia. He got his Master's Degree at University of Indonesia, West Java – Indonesia, and he recently got his PhD at Kun Shan University, Tainan - Taiwan, in 2023. His research interest is mechanical design, mechatronics and robotics, industrial automation, CAD/CAM/CAE. His expertise includes, research in mechanics design and automation, Autodesk certified professional in design for manufacturing and CAD/CAM/CAE skills, technopreneurship expertise, program development and management, and quality education development.