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Designing a Lowering Temperature Safety Device for Vehicles, Based on TRIZ Su-Field Analysis

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Abstract

There have been many reports from around the world of people dying inside overheated airtight vehicles. If the inside temperature could have been lowered in time, some of these tragedies would almost certainly have been avoided. In this study, a new, feasible problem-solving process based on a TRIZ Su-Field analysis model is constructed. The Su-field analysis enables the author to generate ideas to solve the overheated vehicle problem. A set of innovative safety device designs for vehicles that are going through a systematic application process is proposed. Based on this work, several patents were generated which include: Shaking-induced air-flow security device for kindergarten buses (R.O.C., I.P.O., Patent No, I295249); Sound-induced air-flow security device for kindergarten buses (R.O.C., I.P.O.; Patent No, I298300), Tread-induced Security Device for Vehicles (R.O.C., I.P.O., Patent No. I306067); and Induction air-flow safety device for vehicles (R.O.C., I.P.O., Patent No. M346545).

Keywords: Fatally hot airtight vehicle, Induced lowering temperature safety device, Patents and awards, Su-Field analysis.

1. Introduction

1.1 Aims and Motivation of the Research

Following the rapid pace of economic development, the automobile has become a major form of everyday transportation as well as an universal necessity. However, the steep increase in the numbers of cars has also brought a marked rise in traffic accidents and in the casualty toll. Traffic accidents figure in the top ten leading causes of death and are a cause of much personal and social woe and national economic damage.

Automobile tragedies are generally the result of careless behavior. There have been, for instance, many cases around the world of young children being locked in hot airtight vehicles, resulting in fatal accidents. Newspapers in Taiwan report that, between 1995 and 2005, designated vehicles taking children to and from kindergartens were involved in an average of 4.4 case of annual traffic accident statistics. The average Number of people for serious injury and death among children was 4.5 people annually. Between 1992 and 1999, there was a series of 10 serious kindergarten vehicle accidents that took 27 lives and the average of deaths and injuries per accident was 2.7 and 13.3, respectively. A number of young children suffered asphyxia and dehydration in kindergarten vehicle accidents in April of 1996 in Pintung, and in May of 2004 and September of 2005 in Taichung. In a similar case, a seven-year old boy and a five-year old girl were trapped and death in their father's car in 1999 in Miaoli County. In November of 2006 in Hsinchu, a two-year old child walking near a kindergarten bus, out of the driver's line of sight, was killed when the bus crashed. In 2003, in the United States, there were many reported asphyxia deaths of young children left alone in overheated cars. In 2007, in Guangdong Province, China, there were four school vehicle asphyxia fatalities, and in 2007, a two-year old child died from the same cause in Fukuoka, Japan.

In the past, when kindergarten vehicle tragedies of this kind happened in Taiwan, the people found at fault were punished, some were imprisoned, a number of kindergarten and day-care establishments were closed down and sums of compensation between NT$8,350,000 and NT$9,200,000 were agreed on.

The fact that, in 1996, 2004, and 2005, three children died each year from asphyxia and dehydration in kindergarten vehicle accidents highlights the pressing need for providing vehicles with appropriate security devices. The aim of this research, therefore, is to use a TRIZ Su-Field analysis model to design such devices and to provide the basic concepts for developing patents.

It is apparent from the above discussion that there are many big, unanswered questions concerning safety and kindergarten vehicles that must be faced and answered. It is very important to prevent such things happening again. There have been only few studies in this area of research. Therefore, the target here is the development of appropriate patents and improved rescue alarm devices.

2. Literature Review

2.1 Vehicle Safety

The automobile industry has witnessed frequent upgrades and development of vehicles, with overall enhancement of vehicle functions. However, there has also been a tragic increase in automobile accidents, making the search for effective prevention an issue of vital concern. Chai (2004) states that the goal of active vehicle management is to minimize the danger and damage of automobile accidents, the consequent loss of life and limb and the waste of social resources. The aim also is to make driving safer on different roads in different environments, while providing users with vehicles equipped with desired functions. Vehicle safety must be checked more frequently and strictly.

The Taiwan Government Institution of Transportation recognizes the importance of safe driving and the need for strengthening transportation laws. For this reason, "The Safety Inspection and Certification System for Vehicles by Type" for large-size automobiles was introduced on October 26th, 1996 and was extended to other vehicle types in succeeding years (Tseng, 2003).

1.2 TRIZ Su-Field analysis model

Su-Field analysis is a basic concept used to symbolize a technical system and to identify its completeness and effectiveness. Recognized as one of the most valuable contributions of TRIZ, Su-Field analysis is used to not only model a system in a simple graphical approach and to identify problems, but also to offer standard solutions to improve the system.

According to TRIZ, the rationale of creating a Su-Field model is to set up a system with the ultimate objective of achieving a function. This normally consists of two substances and a field, as shown in Figure 1. The term S2 represents an object that needs to be manipulated, and the term S1 represents a tool that acts upon S2. Both substances can be as simple as a single element or as complicated as a big system with many components, each of which can also be explained by individual Su-Field models. The field is the energy required that will enable the interaction between the substances. The states of substances can be typical physical forms (e.g., gas, liquid and solid), interim forms or composite forms (e.g., aerosol, power, porous). Likewise, the field can refer to a broad range of types of energy such as mechanism, chemistry, physics, acoustics, optics and radiations.

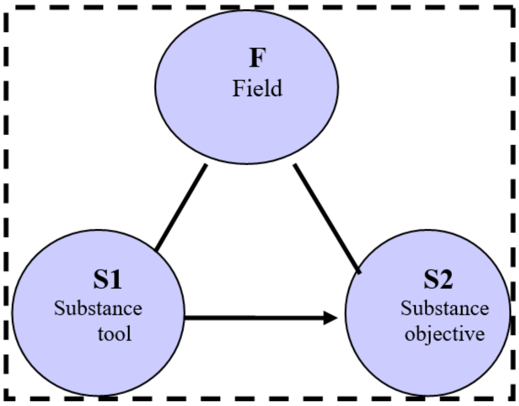

Figure 1 Basic Substances-Field Triangle Model

Genrich Altshuller and his colleagues, the creators of TRIZ, graphically represent a Su-Field model as a triangle. This is a simple and ingenious way to explain a technical system. Given the assumption that the field is generated by a hidden substance, the triangle can be simplified into a dumbbell shape with the field indicated above the arrow and the relationship indicated beneath the arrow, as shown in Figure 2. There are five main types of relationship between the substances: useful impact, harmful impact, excessive impact, insufficient impact and transformation. Among these relationships, useful and harmful interactions are the most common.

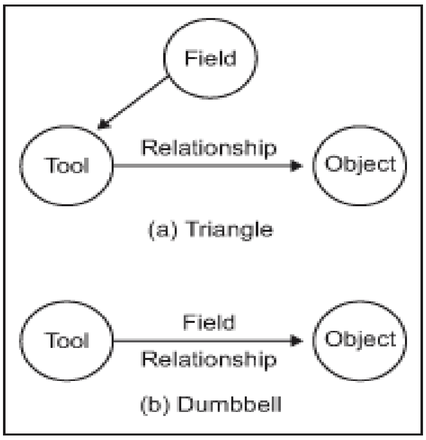

Figure 2. Basic Triangle and Dumbbell Su-Field Model (Mao *et al.*, 2007).

The Su-Field model is a fast and simple analytic tool for identifying problems in a system and for providing insights that help with the evolution of the system. Once a model is created, Su-Field analysis is used to determine if any of the three elements of the model is missing, or if there are any undesired effects in the system. Then, the analysis indicates the direction for improving the system. A complex system can be modeled using multiple, connected Su-Field models. Generally, there are four types of basic Su-Field models: (1) an effective complete system, (2) an incomplete system that requires completion or a new system, (3) a complete system that requires improvement to create or to enhance certain useful impacts and (4) a complete system that requires the elimination of some harmful or excessive impacts. (Terninko, 2000; Mao, et al., 2007)

3. Innovative Concept for a Safety Device in a Vehicle

3.1 Su-Field analysis

3.1.1 Case analysis of problems

Below, four cases are provided, and their problems are analyzed and summarized afterward:

1. Children suffered asphyxia and dehydration in kindergarten buses in April of 1996 in Pintung, and in May of 2004 and September of 2005 in Taichung (all Taiwan).
2. Four children suffered asphyxia on school buses in 2007 in Guangdong Province, China.
3. In 2003, in the United States, a number of children left alone in cars died from asphyxia because of the high temperature inside.
4. In 2007, a two-year old child on a bus suffered asphyxia in Fukuoka, Japan.

Problems of the four cases: People outside the vehicle were not informed in time that at least one child was left alone in the closed vehicle. The condition of the closed vehicle was not a ventilative environment and/or the temperature was not controllable.

3.1.2 Demand function

There are three demand functions as shown below:

1. **The presence of the children was not noticed in time. Demand function**: Need to realize someone is still in the vehicle in time
2. **The vehicle is not ventilated. Demand function:** Need to ventilate
3. **The temperature inside is too high. Demand function:** Need to lower the temperature

3.1.3 Model of the problem

As Figure 3 shows, the airtight vehicle, identified as the tool substance, is represented by S1 and the people trapped in the vehicle, the objective substance, are represented by S2. If the temperature in S1 increases, S2 might suffer asphyxia and dehydration. The thermal field, identified as the fatally hot temperature, is represented by T1. S1 is harmful to S2. The model of the problems is given in Figure 3.

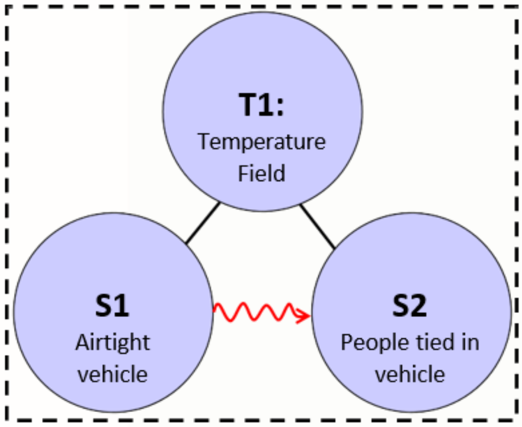

Figure 3. The Model of Problems of Young Children Who Died from Asphyxia and Dehydration n Kindergarten Buses.

3.1.4 Solution in the model

As for the Standard Inventive Solution 1.2 of Su-Field analysis, when a Su-Fields model has some harmful, unwanted, or unneeded functions, it is advised that the most efficient way to destroy the harmful, unwanted, or unneeded functions is to introduce a third substantial component that is a modification of one or both substantial components composing the given Su-Field. Figure 3 shows that S1 "airtight vehicle" is harmful to S2 "people tied in vehicle."

and thus avoid the possibility of people dying from excessively high temperature. T2 is induced by sensor S3. S2 induces (Mechanical field) sensor S3,

Figure 4 shows that the solution provided by the model is to apply the Standard Inventive Solution 1.2 of the Su-Field analysis; that is, to add the refined element, S3, to effectively eliminate harmful, redundant and unnecessary substances or fields. Therefore, this research adds the opposite thermal field T2 to lower the temperature between S1 and S2 which passes through a circuit (Electric field) to trigger safety device S4 (one or more of a variety of methods for lowering temperature) to lower the temperature inside the vehicle in time.

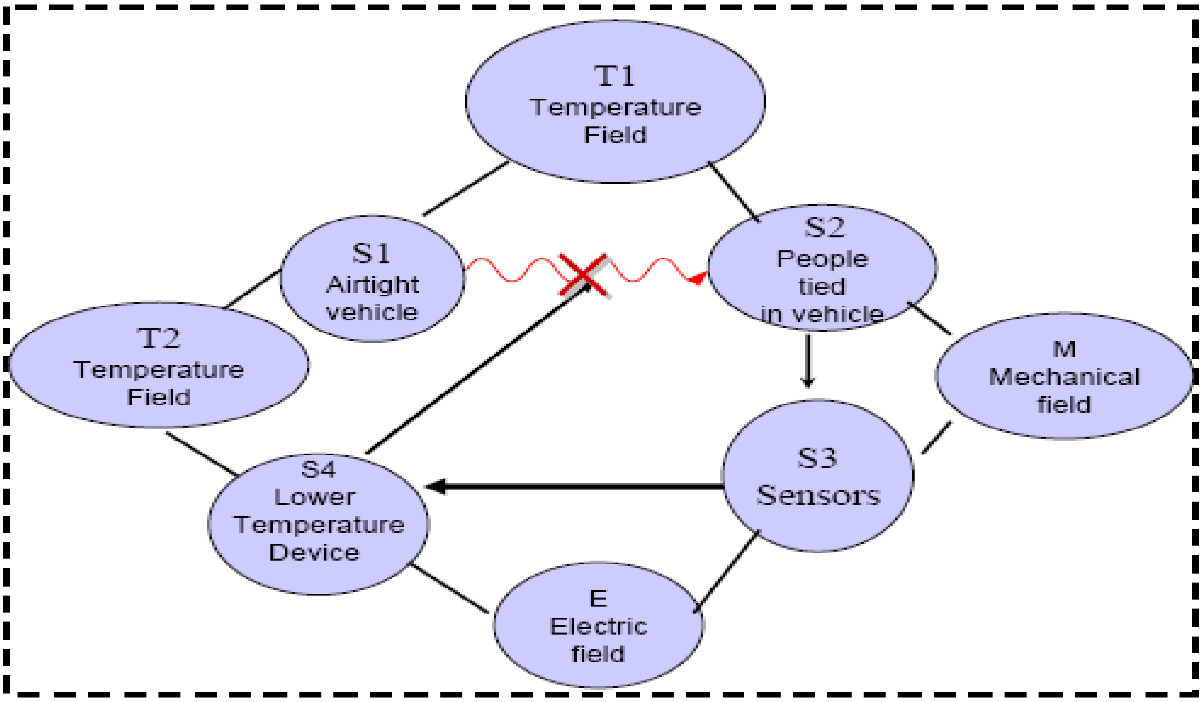

Figure 4. The Model of Solutions of Young Children Who Died from Asphyxia and Dehydration in Kindergarten Buses.

3.2 Safety device design for kindergarten buses

The design covers two groups of devices. The first is comprised of sensors such as those that detect movement (shaking or vibration), sound, tread, or detect by microwave, supersonic, infrared rays sensor or the variation of atmosphere, CO2 concentration. The second is comprised of security devices such as those that could open a window or switch on the air conditioning or the fan to lower the inside temperature. The device could also be a sensor linked to an alarm. Other examples include viewing or detecting devices, such as a camera linked to a monitor that allows the driver to determine who or what is present in the vehicle, or a device that alerts the driver when the vehicle is overloaded. For example, when the vehicle is parked with its doors locked, the safety system turns on. Any noise made by a child left inadvertently on the bus will trigger the safety device, which will in turn open at least one window. A patent search is underway at present to avoid violating any intellectual property rights during the process of innovation analysis. The information collected and analyzed in Table 1 is undergoing a Taiwan patent search in the Intellectual Property Office, Republic of China. The information shows the relationship between the safety device and sensors for kindergarten vehicles. In Table 1, "V" stands for "able to be researched and developed," and "X" stands for "someone's patents." Through a systematic process, a set of innovative designs is proposed. Table 1 shows the relationship between safety devices and sensors for kindergarten school buses.

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Table 1. The Relationship between Safety Devices and Sensors for Kindergarten School Buses.

		Safety Device			
		Open Side Window (vent hole)	Open Electric Fan	Air Conditioning	Sunshade
Sensors	Shake	V	V	V	V
	Sound	V	V	V	V
	Pulling rings	X M293866	V	V	V
	Tread	V	V	V	V
	Microwave	V	V	V	V
	Air pressure	V	V	V	V
	supersonic	V	V	V	V
	Infrared rays	V	V	V	V
	CO_2 Concentration	X M298200	V	V	V
	Complex	V	V	V	V
	Monitor	X I294848	V	V	V

3.2.1 Lowering the temperature

Figure 5 shows a safety device in a kindergarten bus. When the engine is switched off, and the vehicle is parked and locked, a sensor inside is activated. So, for example, any noise made by a frightened child left inadvertently in the vehicle will trigger the sound-induced security device. Or, if the child beats the windows or crystalloid windows, the shaking-induced security device is triggered. When either or both of these safety devices are triggered, a control window or vent hole opens, or the air conditioning or an electric fan switches on to circulate air/lower the temperature, thus prolonging life and increasing chances of rescue for those trapped in the vehicle.

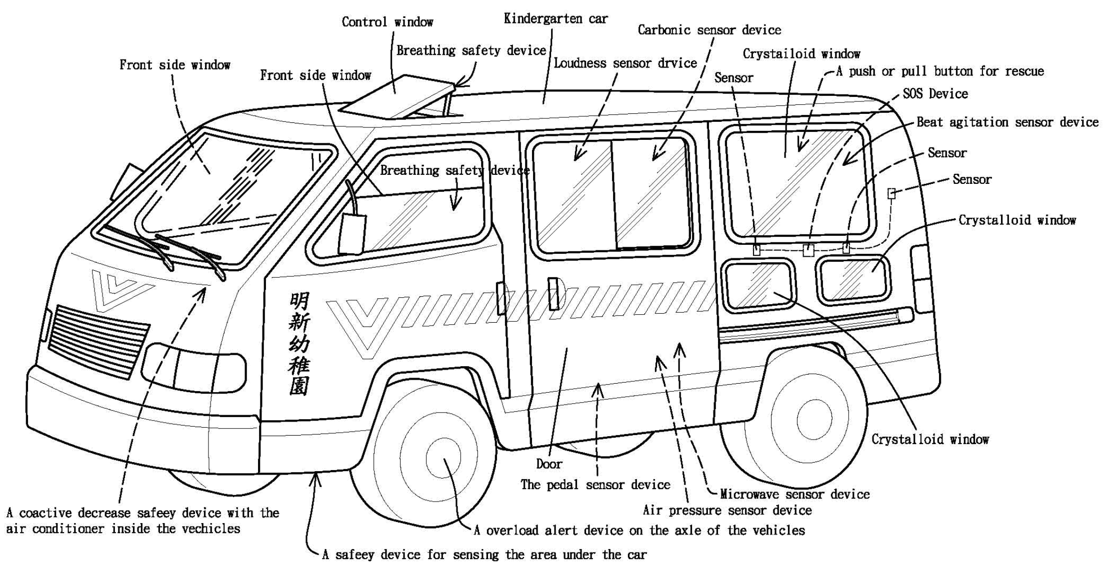

Figure 5. Young Children's Safety Device in Kindergarten School Buses.

3.2.2 Objectives for Safety Devices in Vehicles

These devices enhance and ensure the safety of children using kindergarten vehicles. In addition, they are suitable for usage in vehicles that carry seniors, pregnant women and disabled or mentally challenged people.

3.3 Present Achievements

The following detailed information relates to six safety device designs that have been approved or are awaiting the outcome of patent applications.

1. Shaking-induced air-flow security device for kindergarten buses (R.O.C., I.P.O., Patent No, I295249)

When the bus is parked and locked, the security device, powered by the car battery, is set on alert. Any movement made by a child inadvertently left on the bus will trigger the security device, which in turn will transmit a message to the person in charge and also open at least one window to allow ventilation.

2. Sound-induced air-flow security device for kindergarten buses (R.O.C., I.P.O., Patent No, I298300)

When the bus is parked with doors locked, the security device is set on alert. Any noise made by a child still on the bus will trigger the security device, which in turn will transmit a message to the person in charge and also open at least one window to allow ventilation.

3. Tread-induced security device for vehicles (R.O.C., I.P.O., Patent No. I306067)

This constitutes tread-induced security device for vehicles. It features a tread-conduction device and a rescue-signal device. The first part is comprised of a treadle with a spring on top of a conducting board. The items are electrically wired together and placed in the desired position in the vehicle. The whole device is in a box that is linked to the rescue-signal device by a circuit, and the device is powered by the vehicle. When the vehicle is parked with doors locked, the security device, powered by the car battery, is activated. With the vehicle doors closed and locked, anyone inside who steps on the treadle will trigger the conducting-board, which will trigger the rescue alarm and security device. The security device will then transmit a signal and also open at least one window. This will allow ventilation and alert people outside that someone inside the car needs help. Figures 6 and 7 shows geometry of treadle.

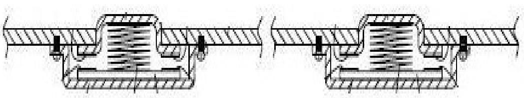

Figure 6. Treadle with a Spring without Someone Steps on-Car Floor Is Convex and with Electric Conductivity.

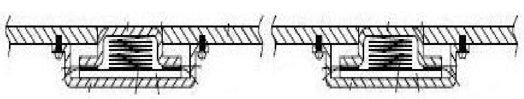

Figure 7. Treadle with a Spring with Someone Steps on-Car Floor Is Flat and without Electric Conductivity.

4. Induction air-flow safety device for vehicles (R.O.C., I.P.O., Patent No. M346545)

The induction air-flow safety device is comprised of a supersonic and/or infrared sensor in the vehicle. The sensor is linked to the SOS device, which is powered by the vehicle. After the power of the vehicle is turned off, the SOS device will be activated if the sensors are triggered by the rescue alarm and security device. The SOS device will open at least one control window or vent hole to allow ventilation and also to alert someone outside that someone inside the car needs help.

5. CO2 concentration-induced security device for vehicles (R.O.C., I.P.O., Application No. 095143243)

Situated inside the vehicle, the device is connected to a rescue signal device by a circuit, which is powered by the vehicle. If the CO2 concentration inside an airtight and locked vehicle exceeds a set limit, the CO2 induction device will be triggered, transmit a rescue signal, and open at least one window. This will allow ventilation and alert people outside that someone inside the car needs help.

6. A safety device to coactively decrease the temperature in vehicles (R.O.C., I.P.O., Application No. 097109945)

Linked to sensors inside the vehicle, the device serves as an SOS device. When the bus is parked with doors locked, the SOS device is activated as soon as any sensor detects that help is needed, and the SOS device activates another device to decrease the inside temperature.

7. Induction rescue device for vehicles (US, I.P.O., Application No. 12/385,646)

An induction rescue device for vehicles is comprised of at least one sensing element mounted in a vehicle. The sensing element is electrically connected to a mayday activation apparatus, which is powered by the power supply of the vehicle. Once the vehicle is turned off, if the sensing element senses that someone is trapped in the vehicle, it will activate a mayday activation apparatus and issue a mayday signal to the outside for help. The mayday will trigger at least one controlled vent to open and/or at least one coercive cooling-down apparatus to circulate the air in the vehicle and to cool the temperature. This would allow the trapped passenger to survive and alert people outside of the problem within the vehicle.

Table 2 shows the patent applications in this research.

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Table 2. The Patent Applications of this Research.

		Safety Device			
		Open Side Window (vent hole)	Open Electric Fan	Air Conditioning	Sunshade
Sensors	Shaking	I295249	097109945	097109945	US,12/385,646
	Sound	I298300	097109945	097109945	US,12/385,646
	Pulling rings	X	097109945	097109945	US,12/385,646
	Tread	I306067	097109945	097109945	US,12/385,646
	Microwave	M346545	097109945	097109945	US,12/385,646
	Air pressure	M346545	097109945	097109945	US,12/385,646
	Supersonic	M346545	097109945	097109945	US,12/385,646
	Infrared rays	M346545	097109945	097109945	US,12/385,646
	CO2 Concentration	X	097109945	097109945	US,12/385,646
	Complex	I295249	097109945	097109945	US,12/385,646
	Monitor	X	097109945	097109945	US,12/385,646

4. Conclusions and Suggestions

People in many parts of the world die in hot, airtight vehicles. The crucial cause is the extremely high temperatures that can be reached inside the vehicle. If the temperature can be lowered in time, such tragedies can be avoided.

In this study, a new, feasible problem- solving process based on a TRIZ Su-Field analysis model was constructed. The airtight vehicle, identified as the tool substance, was represented by S1; and the people trapped in the vehicle, identified as the objective substance, were represented by S2. If the temperature in S1 increased, S2 might suffer asphyxia and/or dehydration. The thermal field, identified as the fatally hot temperature, was represented by T1. S1 is harmful to S2. Therefore, the solution provided by the model was to apply transfer rule 4 of Su-Field analysis, add a refined element S3 (sensor) and thus effectively eliminate harmful, redundant and unnecessary substances or fields. The added opposite thermal field, T2, lowered the temperature between S1 and S2 and avoided fatalities caused by the high temperatures. T2 was induced by sensor S3. S2 induced (Mechanical field) sensor S3 to pass through a circuit (Electric field) and turn on the safety device, S4 (a variety of methods for lowering temperature), which then lowered the inside temperature in time.

This research used the systematic innovation method and provided several innovative designs for which patents were applied. Three invention patents and one new style patent have been received, and three invention patent applications are still being processed. This research suggests that researchers can use TRIZ Su-Field analysis to solve problems in engineering. Although the TRIZ Su-Field analysis, in principle, can be used to achieve solutions, feasibility and costs should still be considered.

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