

# Design and Experimental Research on Active Safety Protection System for Staying in Solar Children Cars

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**Abstract.** When the engine stalls, the automobile air-conditioning system stops working, and the vehicle rapidly warms up under the influence of factors such as sun exposure and space sealing. The concentration of air pollutants in the vehicle also increases, which greatly reduces the comfort of the car. If there is a child left in the car, it even caused a safety accident. In order to improve comfort and safety of automobile, a safety protection system is developed, which can intelligently monitor the temperature and carbon dioxide concentration in the vehicle and the forced ventilation function. A portable device is added on the basis of the original air conditioning system. When the detection module detects the temperature or carbon dioxide concentration in the vehicle reaches the setting limit, the warning device is activated to enter the warning state. When the air quality in the vehicle deteriorates further, the forced ventilation will start to realize safety protection and intelligent adjustment of air comfort in a car.

## 1. Introduction

The popularity of automobiles has brought convenience to people's lives, but at the same time, automobiles have also given people some security risks. Compared with adults, children's physical and psychological immaturity are even more harmful to safety hazards and hidden dangers.

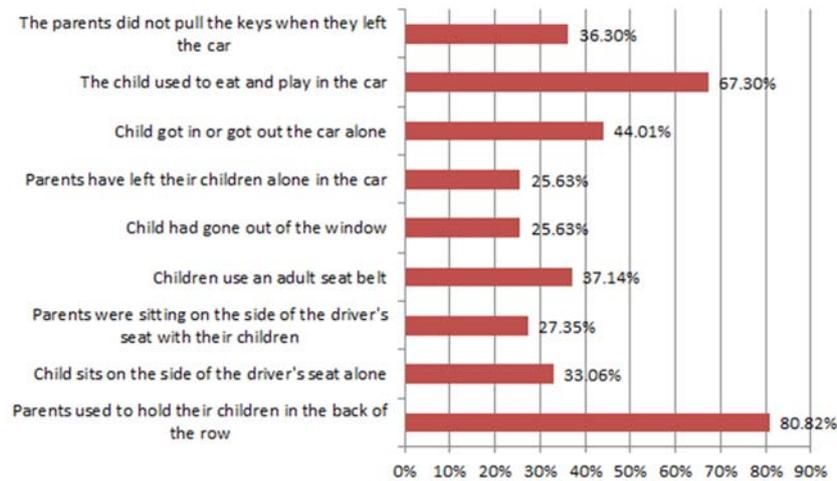
## 2. Children's safety hazards in the car

The survey [1] shows that the public's awareness of children's car safety risks is relatively weak. As shown in Figure 1, 36.30% of parents did not pull keys when they left the car, and 25.63% of parents tried to keep children alone in the car. The car is a closed space. The temperature inside the sealed car must be different from the temperature outside the car. As shown in Figure 2, the in-vehicle temperature test was conducted at a relatively constant ambient temperature. The results showed that when the outside temperature reaches 31°C, the temperature inside the sealed car will rise to 40 to 45°C within 10 minutes, and will reach 55°C [2] within 55 minutes. The results of the statistics and classification of non-traffic accident injuries in children's vehicles in the United States by the Kids and Cars organization of the United States for the ten years from 2001 to 2010 show that [3] children's car suffocation deaths accounted for 58%, much higher than other injuries, as shown in Figure 3.

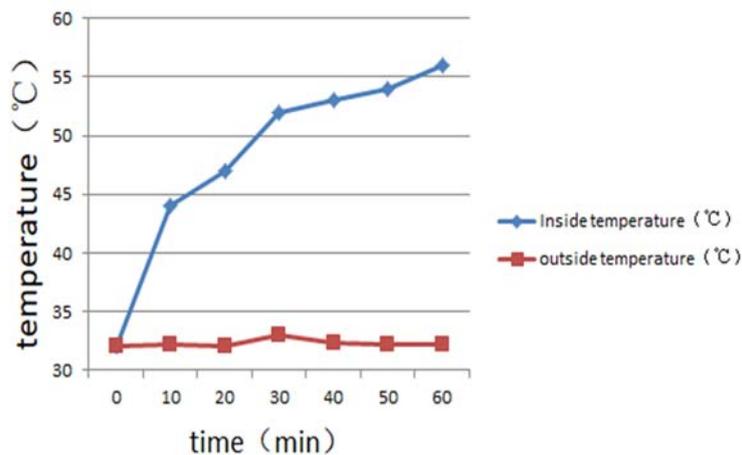
When children are trapped in the car, excessive temperatures in the car can cause children to lose water and accelerate salinity loss, which can lead to heat stroke and may cause symptoms such as heat stroke and heat collapse. When the child's body temperature reaches 42°C, the child has a great chance



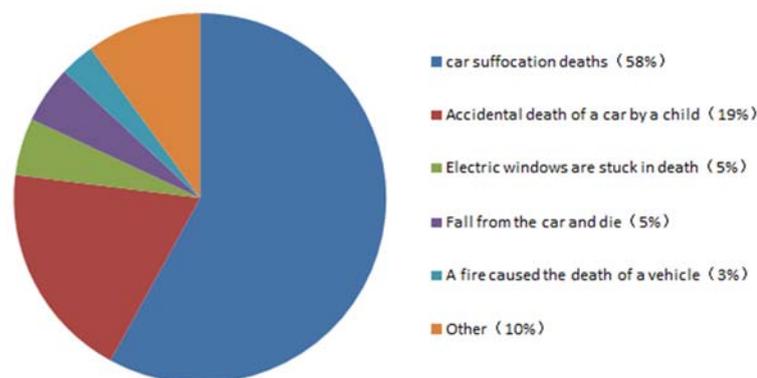
of death [4]. As of July 12, 2016, a two-year-old girl in Jinzhou, Hebei Province, was forgotten in the school bus for 9 hours. She died after being rescued. At 1 pm on August 25 of the same year, a man in Wuxi, Jiangsu Province, forgot his son in the car for five hours. Eventually the boy died.



**Figure 1.** Survey on children's riding behavior in China



**Figure 2.** Temperature change test results in a car



**Figure 3.** Children's non-traffic accident injury type in a car

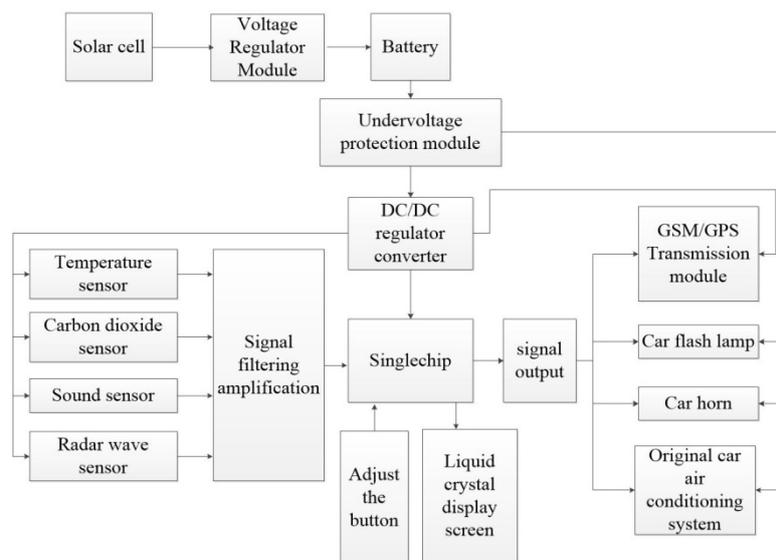
### 3. Active safety system r&d purpose of children's trapped in-vehicle

Vehicle active safety devices are mainly used to prevent safety accidents during driving, such as the Antilock Brake System, the Electrical Power Steering, and the Electronic Stability Program. There is not much concern about the safety of cars and people in the parked state. This research assumes that the vehicle is parked, and adds sensors, controllers, and power supply systems to the original vehicle's air-conditioning system. The self-designed portable controller performs closed-loop control of the original vehicle's actuators and additional actuators to achieve the function of children's active protection.

### 4. Active safety system design of children's trapped in-vehicle

#### 4.1. Overall design

Active safety devices for children staying in vehicles are mainly composed of four parts: power supply part, information acquisition part, information processing part and actuator part. The power supply part is in charge of providing energy for the entire system; the information acquisition part collects the information from the vehicle through the sensors and sends it to the information processing part; the information processing part processes the received information and sends the working signal according to the set program to the actuator part. The actuator part starts the corresponding actuator according to the work signal. Each part contains many large and small components, there are external components and the parts comes with the original car, Figure 4 is a schematic diagram of active safety devices for children's trapped in-vehicle.



**Figure 4.** Schematic diagram of active safety devices

This device is roughly divided into 8 kinds of working conditions. As shown in Table 1, in the 8 working conditions, the 7th working condition is in an optimal state and the system is in a standby state. The 1st, 2nd, 5th, and 6th working conditions can effectively work for a long time due to solar battery replenishment. The 3rd, 4th and 8th working conditions, lack of solar cell replenishment, the working time will be shortened accordingly, so the system design focuses on solving the problems in the 3rd, 4th and 8th working conditions, such as adding backup power, using low power components and so on.

**Table 1.** 8 working conditions of system

number	temperature	With or without direct light	Air quality
1	high	with	good
2	high	with	bad
3	high	without	good
4	high	without	bad
5	low	with	good
6	low	with	bad
7	low	without	good
8	low	without	bad

#### 4.2. Power supply part design

When the child is stranded, the car is in the off state. The device is designed to combine the solar battery with the original car battery for power supply. Under sunlight, the solar battery is used to charge the original car battery. The battery provides the operating voltage for the various parts of the system and achieves target adjustment. In order to allow solar cells to fit better with the car and meet the streamlined body design, solar cells are required to have a certain softness. The device is designed with a CIGS thin film battery with a flexible capability as a substrate and using CIGS as the main photoelectric conversion material. CIGS thin-film battery has the advantages of high absorption coefficient, large grain size, long working life, low consumption of raw materials, large output current, and good stability [5]. It meets the need for long-term operation of the device, and its structural parameters are shown in Table 2. The appearance is shown in Figure 5 [6].

**Table 2.** Structural parameters of CIGS flexible solar thin film cell

Electrical performance					
category	unit	model			
		FLEX-02 340W	FLEX-02 350W	FLEX-02 360W	FLEX-02 370W
Rated power	[W]	340	350	360	370
Aperture power	[%]	0.148	0.153	0.157	0.161
Output power tolerance	[W]	+10/-0			
Maximum power voltage	[V]	30.5	31	31.6	32.2
Maximum power current	[A]	11.23	11.33	11.43	11.52
Open-circuit voltage	[V]	38.3	38.8	39.3	39.8
Short-circuit voltage	[A]	12.97	12.99	13.02	13.04
Maximum series fuse rating	[A]	25			
Physical characteristics					
category	Detail				
Material technology	CIGS				
length	2598mm				
width	1000mm				
thickness	17mm (0.7in), 2.5mm (1in)				
No glue weight	5.1kg				
glue weight	6.2kg				
weight/m <sup>3</sup> (no glue)	2.0kg/m <sup>2</sup>				
weight/m <sup>3</sup> (with glue)	2.4kg/m <sup>2</sup>				



**Figure 5.** Appearance structure of CIGS flexible solar thin film cell

#### 4.3. Modified design of original vehicle battery circuit

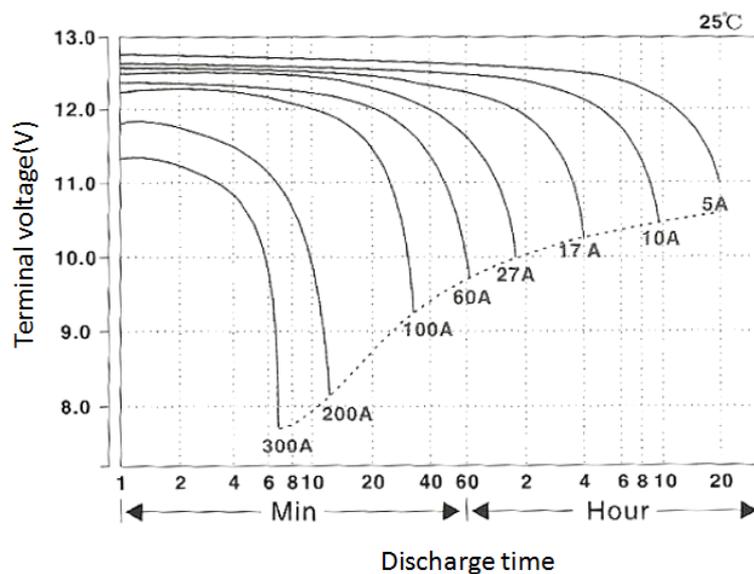
When the solar battery is in the condition of unable to receive light (rainy days, indoor parking, etc.), the original car battery provides operating voltage for the various components of the system with its own reserve of electrical energy, ensuring that the device can work normally for 12 hours under special circumstances. Cut off the power before the system consumes the battery power to reach the limit value, in order to guarantee the necessary electric energy when the car starts.

##### (1) Target value calculation of design

In order to facilitate the reliability evaluation of the design, the battery electric power allowance  $\Delta Q$  is defined as the electric power that the battery can supply to other electric equipment without affecting the normal start of the vehicle. The unit is kw/h. As shown in Figure 6, this is the discharge curve of the benchmark vehicle. The specific parameters of the battery are 12V/60AH/580CCA, and the minimum discharge voltage is 9.6V. The starter power of 1.6L displacement models is generally 1kw, so the operating current of the starter is:

$$I = \frac{P}{U} = \frac{1000W}{12V} = 83.3A \quad (1)$$

In order to ensure the normal operation of the starter, we can see from Figure 6, the battery voltage dropped to 11V, 100A curve, the battery has a strong current output capability, so set the discharge voltage to 11V stop working.



**Figure 6.** Discharge curve of standard car

### 1) Calculation of battery power allowance

Because the specific parameters of the battery are 12V/60AH/580CCA, the maximum electric power of the battery is

$$W_{max} = UI t = 12V \times 60A \times 1h = 0.72kw \cdot h \quad (2)$$

When the battery voltage is 11V, the battery capacity is about 60% of the capacity, so the remaining battery power is 40% of the battery's maximum power, that is,

$$\Delta Q = 40\% \cdot W_{max} = 0.4 \times 0.72kw \cdot h = 0.288kw \cdot h \quad (3)$$

Through calculations, the battery's maximum electric power margin is:

Calculating the working time of each gear of the blower under the rated electric power margin:

The rated voltage of the target model blower is 12V, the operating current of the second gear is 5.25A, the operating current of the third gear is 7.55A, and the operating current of the fourth gear is 11.25A. Therefore, the operating hours of the gears of the blower under the rated electrical power margin are as follows:

① the second gear: the power of the blower in the second gear is:

$$P_2 = UI_2 = 12V \times 5.25A = 0.063kw \quad (4)$$

So

$$t_2 = \frac{\Delta Q}{P_2} = \frac{0.288kw \cdot h}{0.063kw} = 4.57h \quad (5)$$

Through calculations, it can be seen that the selection of the second blower in the rated electric power remaining capacity lasts about 274 minutes.

② the third gear: similarly, the blower power in the third gear is:

$$P_3 = UI_3 = 12V \times 7.55A = 0.09kw \quad (6)$$

So

$$t_3 = \frac{\Delta Q}{P_3} = \frac{0.288kw \cdot h}{0.09kw} = 3.2h \quad (7)$$

Through calculations, it can be seen that the selection of the third blower in the rated electric power remaining capacity lasts about 192 minutes.

③ the fourth gear: similarly, the blower power in the fourth gear is:

$$P_4 = UI_4 = 12V \times 11.25A = 0.135kw \quad (8)$$

So

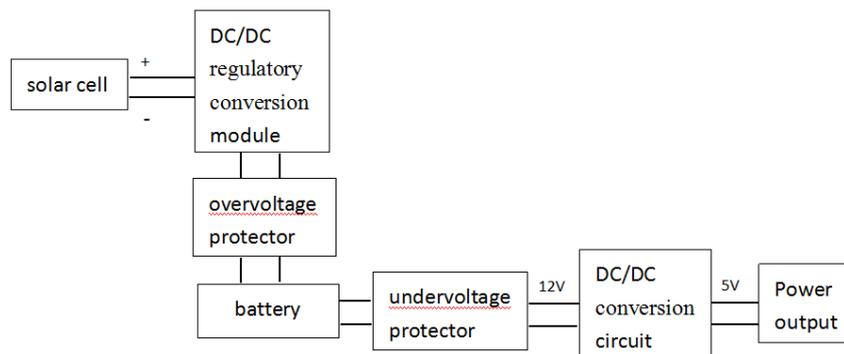
$$t_4 = \frac{\Delta Q}{P_4} = \frac{0.288kw \cdot h}{0.135kw} = 2.13h \quad (9)$$

Through calculations, it can be seen that the selection of the fourth blower in the rated electric power remaining capacity lasts about 128 minutes.

### (2) Modified design of battery circuit

As the characteristics of solar cells are easily affected by environmental factors, the main reason is that the greater the light intensity, the greater the open circuit voltage of the solar cells, and the non-linear relationship between the light intensity and the open circuit voltage [7]. If the solar battery is directly outputting the unstable voltage to the original vehicle battery, it will cause damage to the original battery, so it is necessary to install a DC/DC voltage stabilization conversion circuit to perform voltage regulation and voltage transformation on the output voltage of the solar battery; The battery capacity is limited, and the solar battery will continue to charge the battery when there is sufficient light. To prevent the solar battery from overcharging the original battery and damaging the life of the battery,

an overvoltage protector is needed. In the absence of sunlight, the battery will consume its own energy when it is not recharged by the solar battery. If the battery voltage is too low, it will cause problems such as the failure of the engine ignition other equipment. Therefore, it is necessary to install the undervoltage protector. When the battery is low voltage, the protector cuts off the system circuit to ensure that the other systems and equipment of the car can operate normally. Under normal circumstances, the output voltage of battery is 12V, and the rated voltage of the additional components and modules is 5V. It is necessary to install a DC/DC conversion module which can convert the 12V output voltage into 5V voltage for the additional system. The components and modules provide the normal voltage. Figure 7 is a modification design diagram of battery circuit and a physical map.



(a) Modification design diagram of battery circuit



(b) DC/DC conversion module map

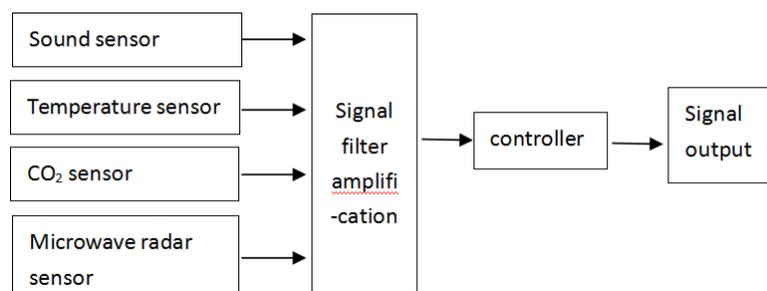


(c) overvoltage/undervoltage protector map

**Figure 7.** Modified design of battery circuit

*4.4. Information acquisition part design*

In order to accurately determine the interior environment of the vehicle, the information acquisition part need input information such as car sounds, children's movements, air quality, and temperature into the controller. The controller performs necessary calculations, comparisons and confirmations, and then sends control commands to drive actuators to implement actions, as shown in Figure 8.



**Figure 8.** Design diagram of information acquisition part

## (1) Hardware implementation

The hardware part is mainly composed of a sound sensor, a microwave radar sensor, a carbon dioxide sensor and a temperature sensor, and collects vehicle information from multiple angles to improve accuracy.

## (2) Software implementation

The system needs to have air filtration and purification, children's staying warning and parking high temperature cooling function, and the realization of these functions requires a set of procedures to analyze the signal of the information acquisition part and control the actuators in stages. In order to realize the above functions, the singlechip is used as the carrier to control the blower, the external circulation motor, and the short message sending module through an independently designed program and circuit, and the carbon dioxide concentration data visualization and threshold adjustment functions are added. The procedure is as follows:

```
voidproc ()
{
    if(co2>=co2_s)    //if the current carbon dioxide exceeds the threshold
    {
        led_2=0;    //corresponding indicator light
        led_1=1;
        alarm_1=0; //relay pull-in
    }else            // or else
    {
        alarm_1=1; //relay disconnected
        led_2=1;
        led_1=0;    //corresponding indicator light
    }
}
```

According to the implementation of the preceding hardware circuit, the blower is in series with the relay, and the closure of the relay connect the power to achieve ventilation. The carbon dioxide threshold used in the system can be debugged by the user, so programming is done through the C++ language:

```
voidkey()
{
    if(!key_1)    //judge if the button is pressed
    {
        delay(1000); // button delay and debounce
        if(!key_1) //judge if the button is pressed again
        {
            time=0;
            while(!key_1) //Judge if the button is released
            {
                proc();
                show();
            }
            if(co2_s<5000) co2_s++; //Perform the function of the corresponding key
            H=co2_s/256;
            L=co2_s%256;
            SectorErase(0x2000); //save the upper limit
            byte_write(0x2000,H); //high bit
            byte_write(0x2001,L); //save low bit into EEPROM
        }
    }
    if(!key_2)    //judge if the button is pressed
```

```

{
    delay(1000);    //button delay and debounce
    if(!key_2)     //judge if the button is pressed again
    {
        time=0;
        while(!key_2) //Judge if the button is released
        {
            proc();
            show();
        }
        if(co2_s>1) co2_s--; //Perform the function of the corresponding key
    }
    H=co2_s/256;
    L=co2_s%256;
    SectorErase(0x2000); //save the upper limit
    byte_write(0x2000,H); //high bit
    byte_write(0x2001,L); //save low bit into EEPROM
}
}
}

```

#### 4.5. Actuator part design

According to the design goal of the system, the system requirements for the actuator part can realize ventilation, high temperature cooling, early warning of children staying. Under the requirements of the system, the original car's blower, external circulation motor, flashlight, anti-theft horn and additional SMS sending module were selected. Through the combined work of different actuators, the basic functional requirements of the system are achieved. At the same time, four of the five actuators are owned by the original vehicle, making the most of the original vehicle equipment, simplifying the system structure, reducing the difficulty of layout, and saving design cost.

The SMS sending module requires simple structure, good signal, low power consumption, etc. Under the requirements of the system, the SIM900A mini-message sending module was selected. The module size is 24\*24\*3mm, and the current is less than 18mA under standby condition. It can directly connect with the single chip, and can achieve low-power transmission for voice, SMS, data and fax information. Figure 9 shows the SIM900A SMS sending module.



**Figure 9.** Message sending module

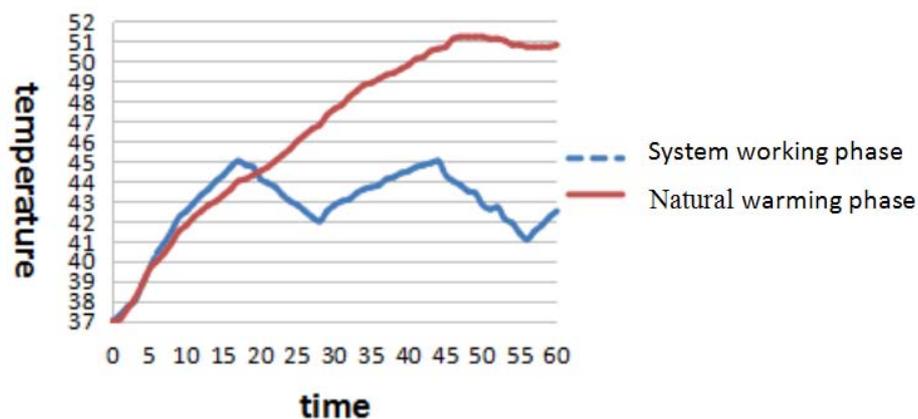
## 5. Experimental study of system

Test subject: One standard car; one tester. Test main instrument: thermal thermometer, internal temperature (-30°C to +50°C), external temperature (-50°C to +70°C). Resolution: it is 0.1°C when the temperature is more than -20°C, and it is 1.0°C when the temperature is less than -20°C; the accuracy has an error of ±1°C. According to the test requirements, it is necessary to measure the changes in the temperature and carbon dioxide concentration in the vehicle. The system is aimed at the overall air environment and temperature in the vehicle. The influencing factors such as the ambient temperature

inside the vehicle, the position of the air outlet and return air inlet in the cab are neglected, the measuring points are arranged just below the information collection part, which is just below the roof light.

(1) Test results analysis of parking high-temperature cooling function

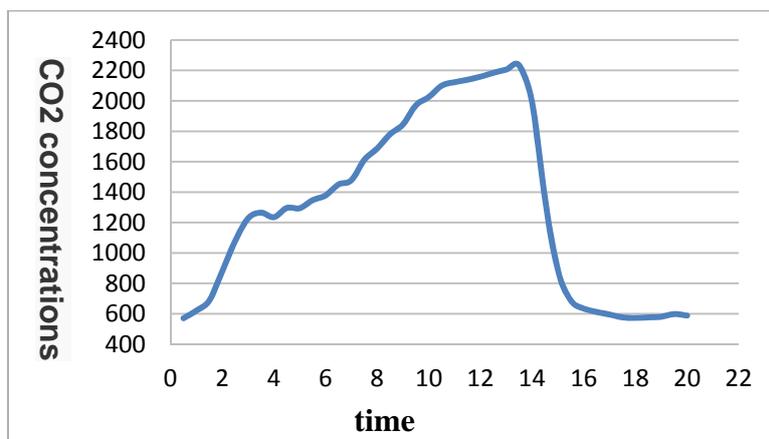
Fig. 10 is a curve diagram of the test data for parking high-temperature cooling function. The solid line in the figure is the temperature change curve of the car in the natural warming phase, and the dotted line is the temperature change curve in the working phase of the system. As shown in the figure, there are two changing ways in the natural warming period. Before 45 minutes, the curve rises with time. After 45 minutes, the temperature fluctuates around 51°C. In the test, the maximum temperature in the car reaches 51.2°C. For the temperature change curve of the system in working phase, the early 15 minute change trend is the same as that of the natural warming phase, both of which are tortuous rising. When interior temperature reaches the threshold of 45°C, the temperature starts to drop with the intervention of the system. The system stops working after 12 minutes, the temperature starts to rise slowly until the temperature in the vehicle reaches the threshold of 45°C. The system is again involved in the work. In the one-hour experiment time, the system works twice for a total of 24 minutes. The temperature dropped by an average of 3.5°C. Compared with the natural warming curve, the maximum temperature difference reached 9.2°C. After the system intervention, the car temperature rise trend slowed down.



**Figure 10.** Test data curve of parking high- temperature cooling function

(2) Test results analysis of air purification function

Fig. 11 is the test data curve of air purification function. As can be seen from the figure, a normal adult man breathes in a sealed car for about 10 minutes and the car's carbon dioxide concentration will increase from 600 ppm to 2000 ppm. At the same time, according to feedback from the testers, mild lethargy and nausea happened during the increase of the carbon dioxide concentration in the vehicle. When the carbon dioxide concentration exceeded the threshold of 2200 ppm, the system was involved in the work, the concentration of carbon dioxide in the car quickly decreased, and the adverse reactions of the testers gradually disappeared. During the six minutes of systemic intervention, the concentration of carbon dioxide returned to its initial state within the first 4 minutes, and it basically changed around 600 ppm in the last 2 minutes.



**Figure 11.** Test data curve of air purification function

## 6. Conclusion

During the test, the portable smart air-conditioning system was found to work about 2 times per hour, each time for 12 minutes. Therefore, in the case of the rated electric power margin and external power supplement, the blower can work intermittently 11.4 hours in the second gear, 8 hours in the third gear, and 5.3 hours in the fourth gear. It can effectively protect the children safety in the car.

## Acknowledgments

Wu Dongsheng (1980- ), male, Kaiping people in Guangdong, postgraduate, Master's degree, a lecturer at the Guangdong Industry Technical College, Research direction: Automotive electronic control technology, Automobile emission purification.

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