THERMAL SYSTEMS

Service Technical Training

Rev 22 July 2014 MT

温控系统

技术培训

Rev 22 July 2014 MT

Administration

- **Sign the attendance roster;**

- **Coffee & lunch breaks;**

- **Switch cell phones off or to silent;**

- **For Health & Safety the use of cell phones is <u>not</u> permitted in the workshop area;**

- **Technicians are required to:**
  - Wear workshop clothing
  - Wear steel-toed cap safety footwear
  - Wear all necessary personal protection equipment
  - Keep all work areas clean, neat and tidy;

- **PowerPoint presentation is e-mailed.**

Health & Safety

- **Pedestrian Safety**
  - Traffic – mixed traffic (forklift, tug, tow motor, golf carts, bicycles, motor vehicles, etc)
  - Walk defensively – look before crossing an aisle:
    - Stop and look both ways
    - Stop at all blind corners and stop signs

- **Emergency Exits & Assembly Points**

- **Toilets/Washrooms**
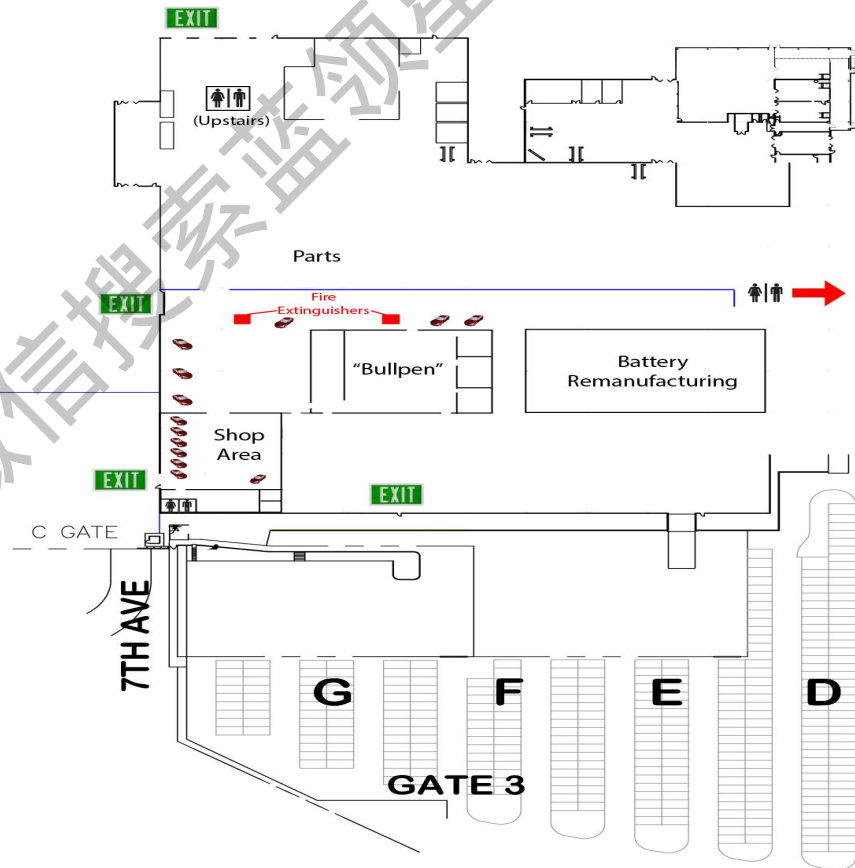
# Health & Safety

Plant Alarm Tones

Evacuation Procedures
- Evacuate from the closest exit
- Report to your meeting location for Roll Call

Tesla's Emergency Response Procedure
- **For emergencies such as:**
  - Fires
  - Medical Emergencies
  - Security Emergencies
  - Chemical Spills

- **Use a Manual Fire Box**
  - Call Extension 55500 from any Tesla Phone
  - Call (650) 681-5500 from your cell
  - Provide location (number found on columns)

Recycling
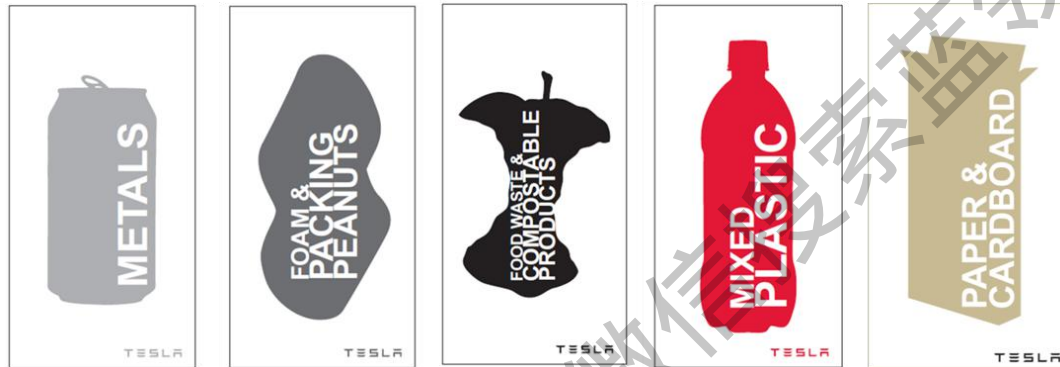
We collect 5 commodities:
1. **Metals** (light gray) (Soda cans, Food tins, Food trays);
2. **Foam and Foam Products** (Dark Gray) (Foam packing peanuts, Styrofoam trays and containers);
3. **Food Waste and Compostable Products** (Black) (All of our napkins, cutlery, coffee cups, and soda cups are compostable).;
4. **Mixed Plastic** (Red) (Drink bottles, plastic cups and containers)
5. **Cardboard and mixed paper** (Light brown) (Small boxes and other paper packaging);
6. All **office paper** should be placed in the confidential shred containers located near each copy machine.

INTRODUCTIONS

- Name
- Service Center
- Date Started with Tesla Motors
- Brand experience

介绍

- 姓名
- 维修中心
- 何时加入特斯拉
- 品牌经验

Course objectives

- **Material**
  - Develop an understanding of thermal components.
  - Basic understanding of operation.
  - HVAC system (cabin).
  - Thermal management system (PT and battery loops).

- **Tasks to learn**
  - Coolant purge
  - Coolant drain and fill
  - AC evacuation and charge
  - AC fill without Toolbox
  - Louver test
  - Thermal test
  - Cabin HVAC signals
  - Thermal system signals
  - Vehicle signals

课程目标

- **材料**
  - 了解温控系统部件。
  - 基本理解原理。
  - HVAC 系统 (乘客厢).
  - 温控管理系统 (驱动单元和电池冷却回路)。

- **学习任务**
  - 冷却液排气
  - 冷却液加注和排放
  - 空调抽空和加注
  - 空调没有Toolbox加注
  - 风门
  - 乘客厢 HVAC信号
  - 温控系统信号
  - 车辆信号

Course Content

Day 1
- Safety
- Thermal systems Introduction
- System overview
- Purpose

HVAC System (refrigeration loop)
- Interface
- HVAC Components
- HVAC Modes
- HVAC Service Functions
- HVAC Function test theory

LAB
- Worksheet
- Perform Performance test
- Review worksheet

Day 2
Review day 1

Thermal Management System
- Components
- System operation/ Logic
- Service function
- Coolant Drain procedures
- HV Battery removal and installation procedure
- HV Battery shipping documentation

LAB
- Worksheet
- HV Battery removal & install
- HV Battery coolant drain/fill
- Review worksheet
- End Test

课程内容

第一天
- 安全
- 温控系统介绍
- 系统概括
- 目标

HVAC 系统（制冷剂循环图)
- 控制页面
- HVAC 零部件
- HVAC 模式
- HVAC 服务功能
- HVAC 功能测试原理

实操
- 工作单
- 性能测试
- 回顾工作单

第二天
回顾第一天内容

温控管理系统
- 部件图
- 系统操作/逻辑
- 服务功能
- 冷却液排放流程
- 高压电池的拆卸和安装流程
- 高压电池运输文件

实操
- 工作单
- HV 电池的拆卸和安装
- HV 电池的冷却液排放和填充
- 回顾工作单
- 课后测试

Thermal / HVAC System Introduction

Introduction

- The Model S is equipped with one the most advanced Thermal Systems available for an automobile today.

- The Model S thermal system is not only comprised of the HVAC system, but also for powertrain thermal management system.
  - ➢ Think of it as combining a I.C. cooling system with the HVAC system.

- The HVAC and thermal management systems have several overlapping parts and functions and has 2 modules that control there operation (THC and RCCM).

- The Model S has a completely electric Thermal Management and HVAC system, with several HV components.

- This means that the Model S can control its Powertrain thermals as well as the HVAC system at any time without the "car running", or the driver present. This also means that it can run while inside/indoors because there is not I.C. engine or emissions while operating.

温控系统/HVAC 系统介绍

系统介绍

- 配备了车辆中最先进的温度管理系统

- 系统不仅是空调和暖风系统，更是动力单元的温度管理系统
  - 可以想象它是一个由类似发动机冷却系统和空调系统相结合的系统。

- 空调和温度管理系统有很多部件是交叉共用的，由2个模块来控制(THC 与 RCCM).

- Model S的温控系统是纯电动的，包含几个高压部件。

- 这意味着车辆任何时候都可以控制动力系统温控系统和空调系统，无论车是否运行，司机在不在。同时系统可以在室内运行，因为没有内燃机，车辆没有任何排放。
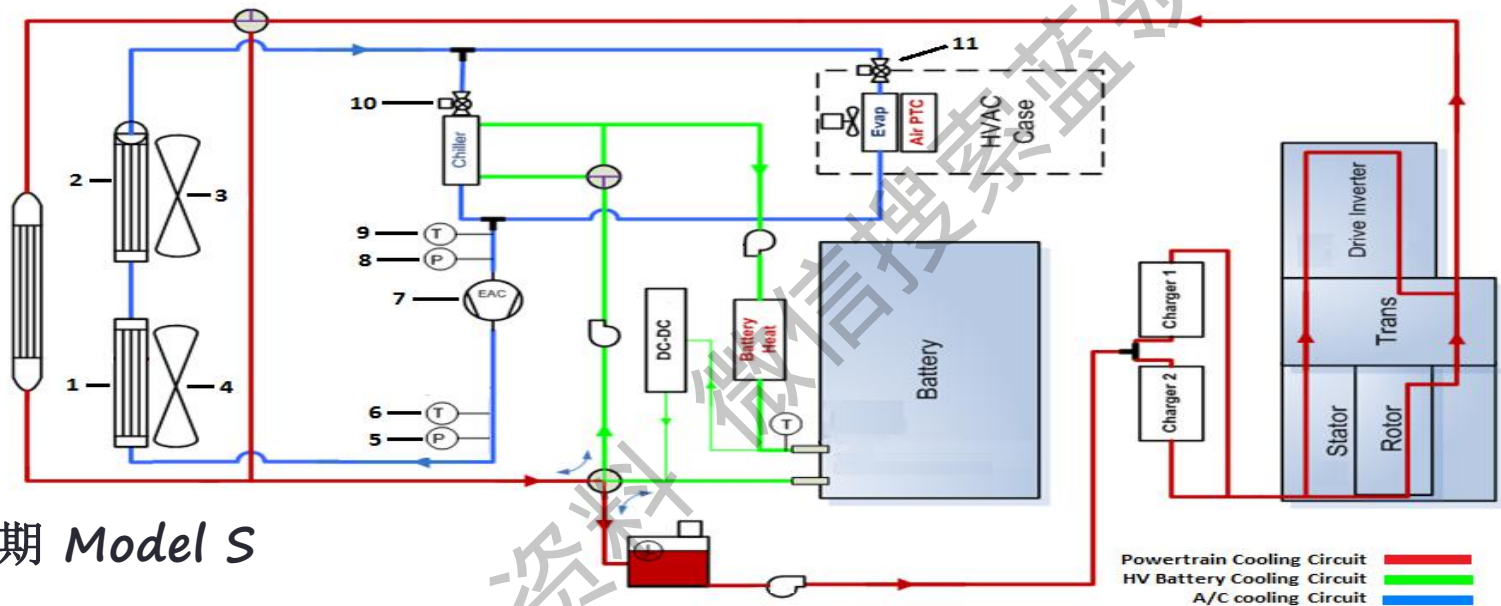
Thermal / HVAC System Introduction
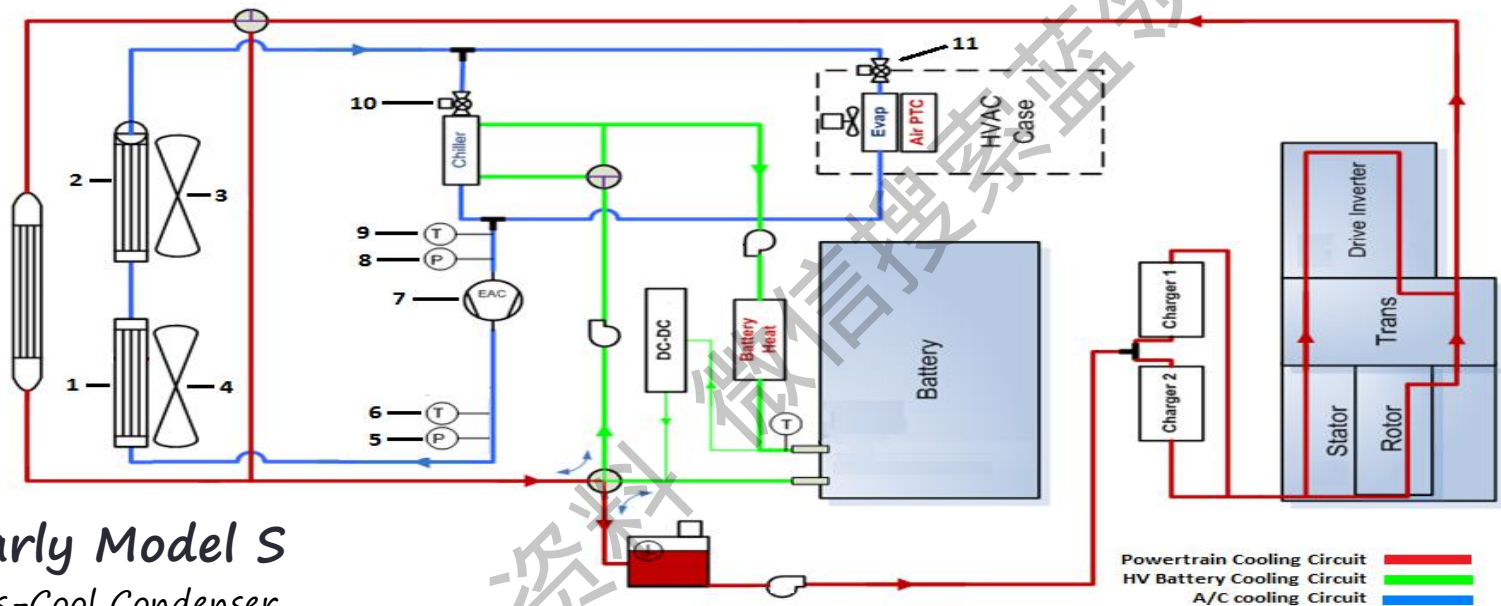
Early Model S

1. Gas-Cool Condenser
2. Sub-Cool Condenser
3. Sub-Cool Condenser Fan
4. Gas-Cool Condenser Fan
5. A/C Pressure Sensor (high pressure side)
6. A/C Temperature Sensor (high pressure side)

7. Electric A/C Compressor
8. A/C Pressure Sensor (low pressure side)
9. A/C Temperature Sensor (low pressure side)
10. Thermal Expansion Valve (Chiller)
11. Thermal Expansion Valve (Evaporator)

温控系统/HVAC 系统介绍

早期 *Model S*

1. 气态冷凝器
2. 副冷凝器
3. 副冷凝器扇
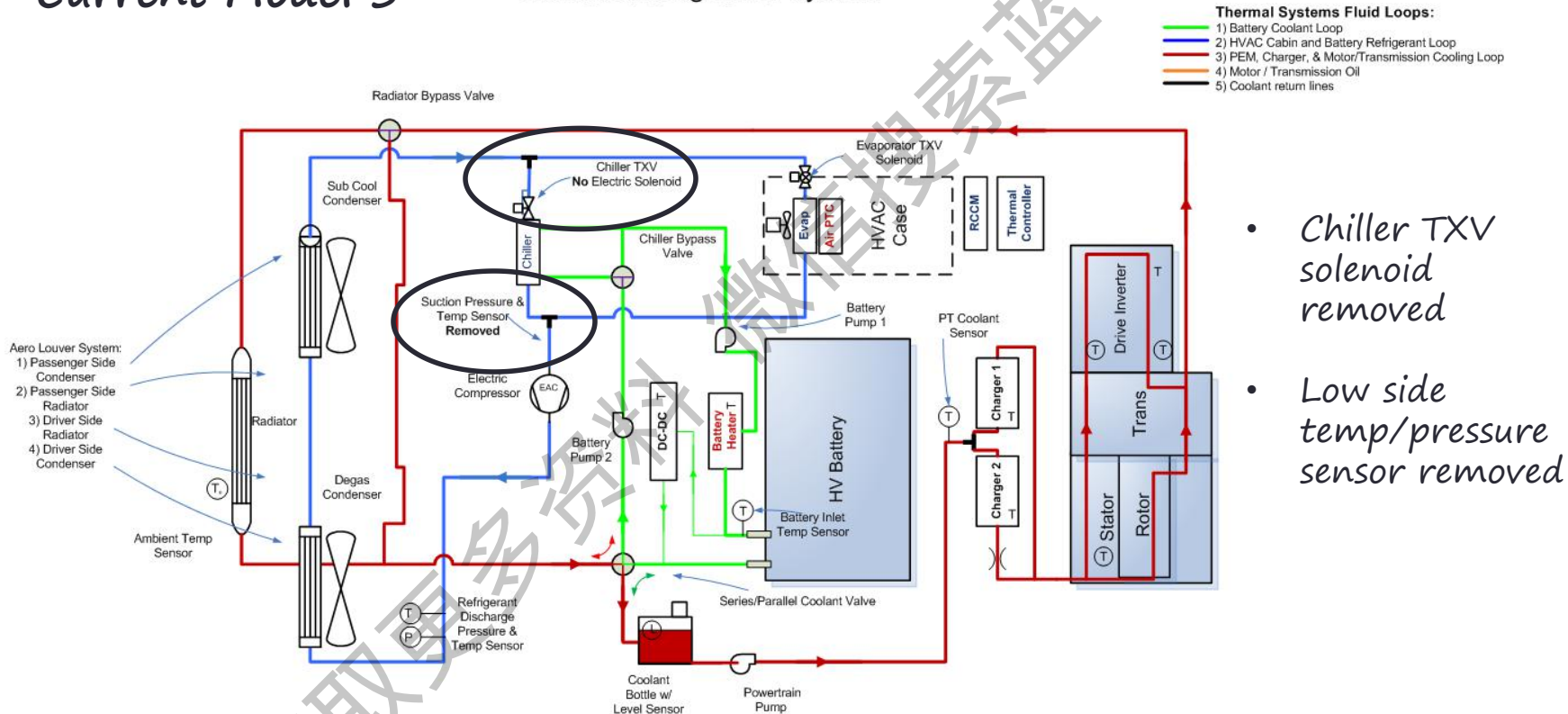4. 气态冷凝器扇
5. 空调压力传感器 (高压侧)
6. 空调温度传感器 (高压侧)

7. 电子空调压缩机
8. 空调压力传感器 (低压侧)
9. 空调温度传感器 (低压侧)
10. 膨胀阀 (冷却器)
11. 膨胀阀（蒸发箱）

车辆空调系统（蓝线）
电池温控系统（绿线）
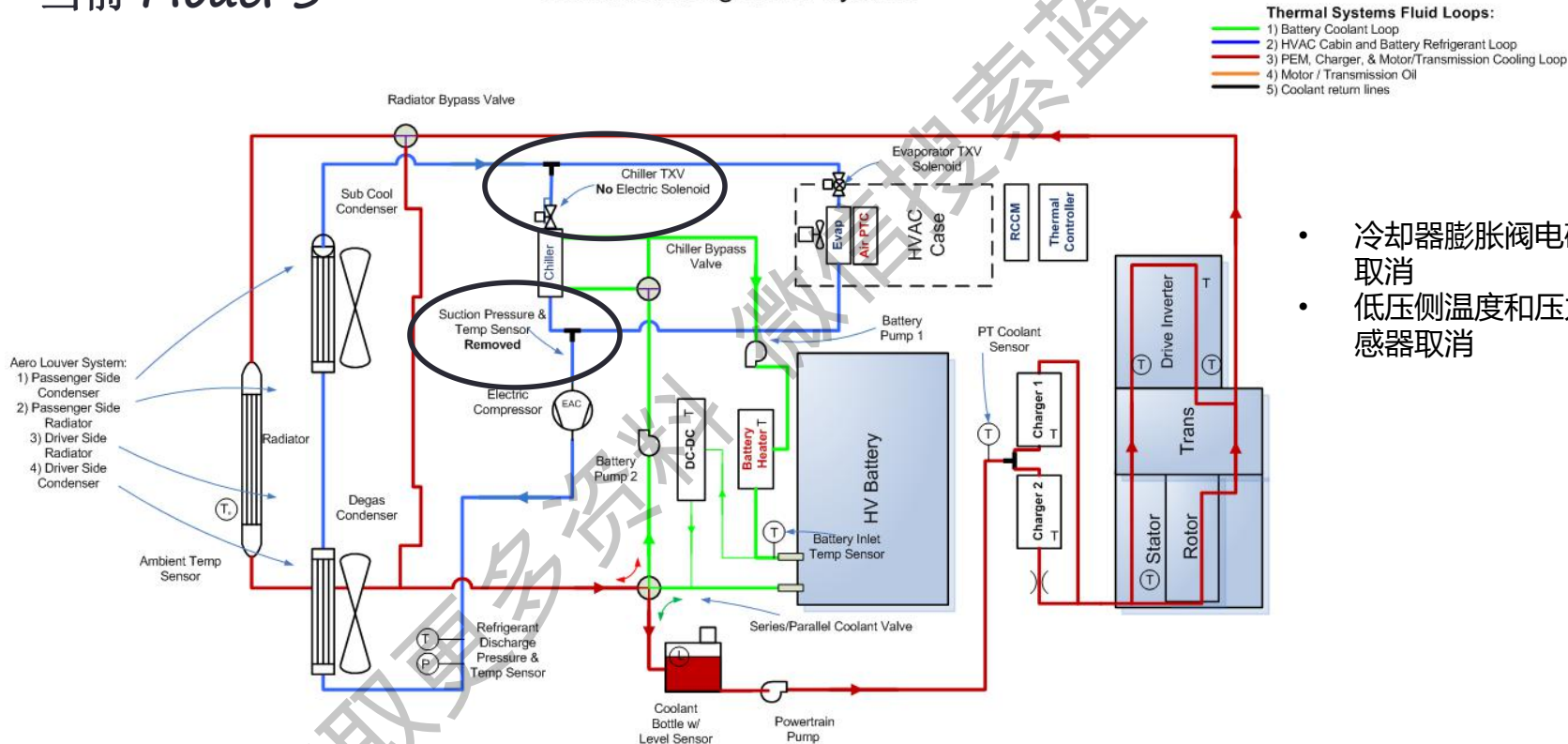**动力单元温控系统（红线）**

Thermal / HVAC System Introduction

Current Model S

Model-S
Thermal Management System

- Chiller TXV solenoid removed

- Low side temp/pressure sensor removed

温控系统/HVAC 系统介绍

当前 *Model S*

Model-S
Thermal Management System

Thermal Systems Fluid Loops:
1) Battery Coolant Loop
2) HVAC Cabin and Battery Refrigerant Loop
3) PEM, Charger, & Motor/Transmission Cooling Loop
4) Motor / Transmission Oil
5) Coolant return lines

- 冷却器膨胀阀电磁阀取消
- 低压侧温度和压力传感器取消

Thermal / HVAC System Introduction

What is the Big Difference?

- **Electric Cabin Heater**
  - ➢ No heater core
  - ➢ Gets hot faster then heater cores

- **Electric AC Compressor**
  - ➢ Not driven by belt
  - ➢ No AC compressor clutch

- **Electric coolant Heater**
  - ➢ Does not use I.C. engine to heat coolant
  - ➢ Can heat coolant faster and only when needed
  - ➢ Eliminates need for thermostat
  - ➢ Coolant is Not used to heat cabin heater
  - ➢ Coolant temp is electronically controlled

- **Refrigerant cooled coolant**
  - ➢ Chiller is cooled with R134 with separate parallel TXV H-block
  - ➢ Can cool below ambient air temp

- **Electric Water Pumps**
  - ➢ 3 electric water pumps, variable speeds

- **Mode and Bypass valves**
  - ➢ Able to control coolant flow to certain components
  - ➢ Can bypass radiator and chiller when needed
  - ➢ Eliminates need for thermostat

温控系统/HVAC 系统介绍

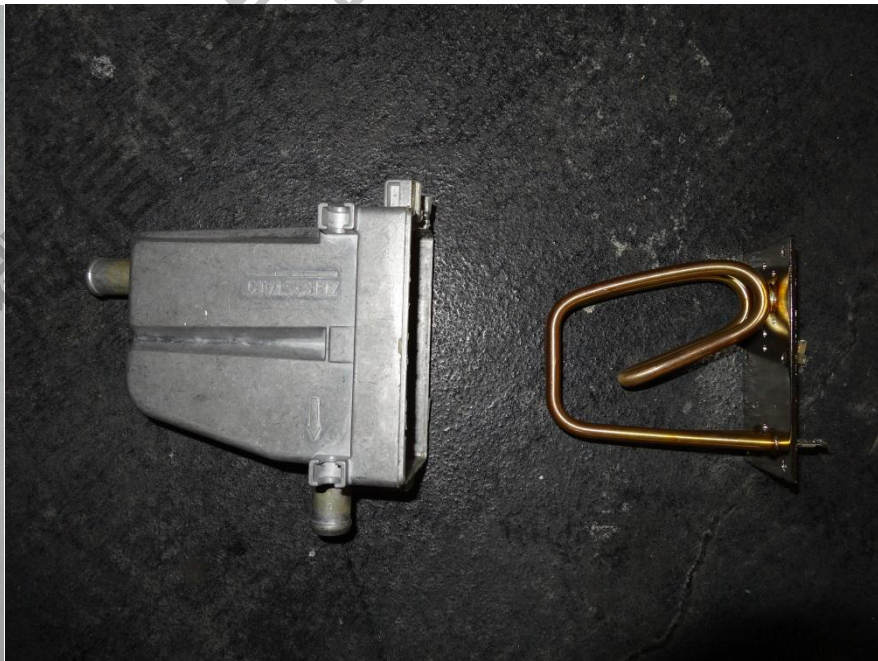**与内燃机最大差异是什么?**

- 电子暖风加热
    - 没有小水箱
    - 比小水箱加热快
- 电动AC压缩机
    - 不需要驱动皮带
    - 没有压缩机离合器
- 电子冷却液加热器
    - 不用内燃机来加热
    - 需要时可以仅仅迅速加热防冻液·
    - 取消节温器
    - 冷却液不是于车辆暖风系统
    - 冷却液温度由电子控制
- 制冷剂冷却液冷却
    - 冷却器应用R134a并且是单独并联的冷却系统
    - 能够冷却到环境温度以下
- 电动水泵
    - 3个可调速电子泵
- 工作模式和旁通阀
    - 可以控制冷却液流过特定部件
    - 需要时可以不通过水箱或冷却器
    - 取消节温器

温控系统/HVAC 系统介绍

- 电子冷却液加热器

- 电子冷却液加热器

Thermal / HVAC System Introduction

Purpose
- **Cooling the HV Battery**
  - Used in hot regions
  - Allows high amperage charging
  - Allows extended charging times
  - Increases battery life
- **Heating the HV Battery**
  - Allows more / higher draw on battery
  - Allows for faster charging
  - Allows high amperage charging when cold
- **Cooling the Drive Inverter and Motor**
  - Allows higher current draw without thermal limiting.
  - Used during heavy acceleration or regeneration
  - Reduces the need of thermal limiting
- **Cooling the Chargers,**
  - Allows high charge rates for extended time
- **Cooling the DCDC**
  - Prevents overheating
  - Remote location , no air flow needed
- **HVAC**
  - Heat and cool cabin occupants

温控系统/HVAC 系统介绍

目的

- 冷却高压电池
  - 用于比较热的地区
  - 允许大电流充电
  - 可以延长充电次数
  - 延长电池寿命
- 加热高压电池
  - 允许更多的放电
  - 可以更快的充电
  - 允许天冷时大电流充电
- 冷却逆变器和马达
  - 可以更高的电流消耗不用顾忌温度限制
  - 用于急加速和能量回收
  - 减少温度限制
- 冷却充电器
  - 可以长时间大功率充电
- 冷却DCDC
  - 防止过热
  - 灵活布置，无需空气冷却
- HVAC
  - 座舱加热和冷风

HEATING VENTILATION AIR CONDITIONING HVAC

HEATING VENTILATION AIR CONDITIONING
加热通风空调系统HVAC

HVAC System Interface

The dual zone Heating, Ventilation, Air Conditioning (HVAC) has three functions:
1. To control the flow volume, temperature and humidity of the air in the cabin.
2. To maintain the battery temperature.
3. To maintain the powertrain temperatures and the high voltage electronic system temperatures.

Cabin ventilation

The HVAC system, operated through the touch screen controls the temperature, humidity, flow volume, distribution and quality of air within the cabin. Temperature range that can be selected by the occupants is (LO_ 63 <) to (> 88°_ HI)

ECO mode
- Blower speed in manual can only go to speed 8 (rather than speed 11), auto blower runs on an ambient based limit to reduce power.
- PTC heater power output reduced to 1/2 full power (typically ~50%), thermal controller actively monitors feedback power and tries to tune
- A/C Compressor duty cycle limited to 40%.

HVAC 系统界面

双区空调，控制冷风与暖风， 3功能

1.控制车厢内部的风速，温度湿度
2.保持高压电池温度
3.保持动力系统温度和高压电系统温度

车内通风:
　　　HVAC通过触摸屏控制温度,湿度,风量,分配并改善车内空气质量. 温度调节范围（17℃-31 ℃）。

长途模式(经济模式)

- 手动调节最高风速减低到8(而不是风速11), 鼓风机自动调整为以经济转速运转

- 加热器输出降低到满功率的1/2，温控器主动监控反馈功率并调整

- 空调压缩机占空比限制到40%

HVAC Control

The RCCM (remote climate control module) controls all of the HVAC box related actuators. It takes A/C, Heat, Defrost mode requests and Temp requests from the Touchscreen to control the cabin HVAC.

The RCCM looks at inputs from the HVAC box and other temp sensors:
- Floor temp
- Panel temp
- Defrost temp
- Evaporator temp
- In-car temp
- Ambient temp

The RCCM and then controls the HVAC box actuators to achieve the mode request and temp request. The RCCM sends requests to the THC to activate the A/C compressor and PTC cabin heater.

HVAC 控制

RCCM (远程空调控制模块) 控制所有暖风相关执行器。它从MCU接收空调、加热、除霜模式和温度请求然后调节车厢温度。

RCCM 监测来自于暖风水箱和其他温度传感器输入信号：
- 地板温度
- 仪表板温度
- 除霜温度
- 蒸发器温度
- 车内温度
- 环境温度

然后，RCCM控制暖风执行器以满足模式请求和温度请求 。RCCM发送请求信号给THC，由其启动空调压缩机和PTC车厢加热器。

HVAC Control

The THC (thermal controller) controls all vehicle thermal system loop components, including the PTC cabin heater and A/C compressor. It takes requests from other modules such as the RCCM, BMS, DI, and Charger to determine if cooling or heating is required for each component on the thermal loop.

The THC looks at many inputs:
- Thermal loop temp sensors
- Ambient temp sensor
- Vehicle speed
- Solar sensor

The THC and then controls the thermal loop actuators (coolant pump, mode/bypass valves, A/C compressor / chiller, cooling fans, battery coolant heater, radiator/condenser shutters) to achieve the requested component temperature.''

HVAC 控制

THC (温度控制) 控制所有温度系统部件包括PTC车厢加热器、空调压缩机。它接收来自RCCM、BMS、DI和充电器的请求用来确定温度控制系统上的每个部件是否需要冷却或加热。

*THC*监测多个输入信号：
- 温度系统上的温度传感器
- 环境温度传感器
- 车速
- 日光传感器
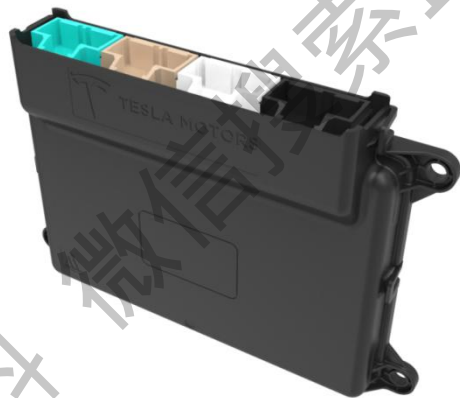
然后，THC 控制温度系统上的执行器（水泵，模式阀/旁通阀，压缩机/冷却器，风扇，电池冷却液加热器，水箱/冷凝器百叶窗）以满足温度请求。

HVAC SYSTEM COMPONENTS

HVAC SYSTEM COMPONENTS
HVAC系统部件

HVAC System Components

Front View
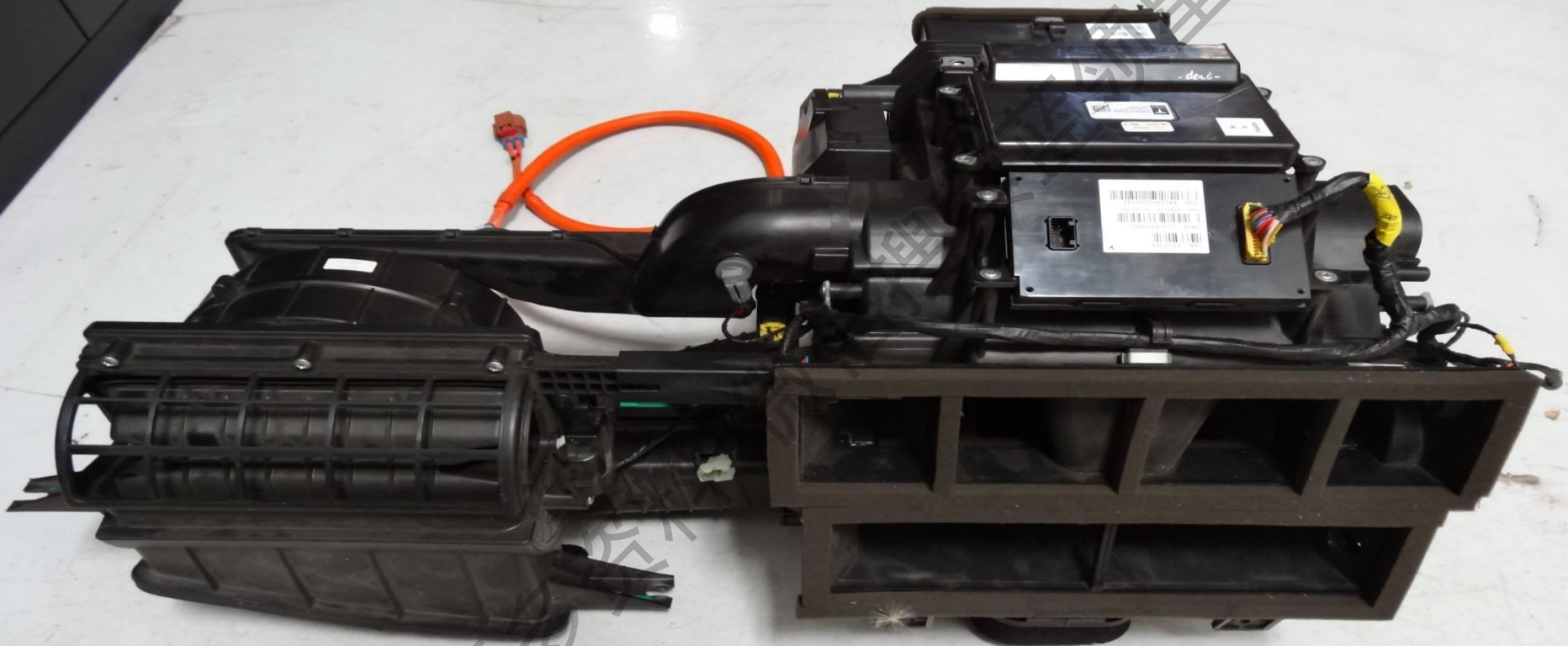

Driver Floor Air Temp Sensor

Defrost Air Actuator

Passenger Vent Air Temp Sensor

Intake Air Actuator

Blower Motor Resistor

Passenger Floor Air Temp Sensor

司机脚坑温度传感器

除霜翻板

室内通风温度传感器

前乘客脚坑温度传感器

进气翻板
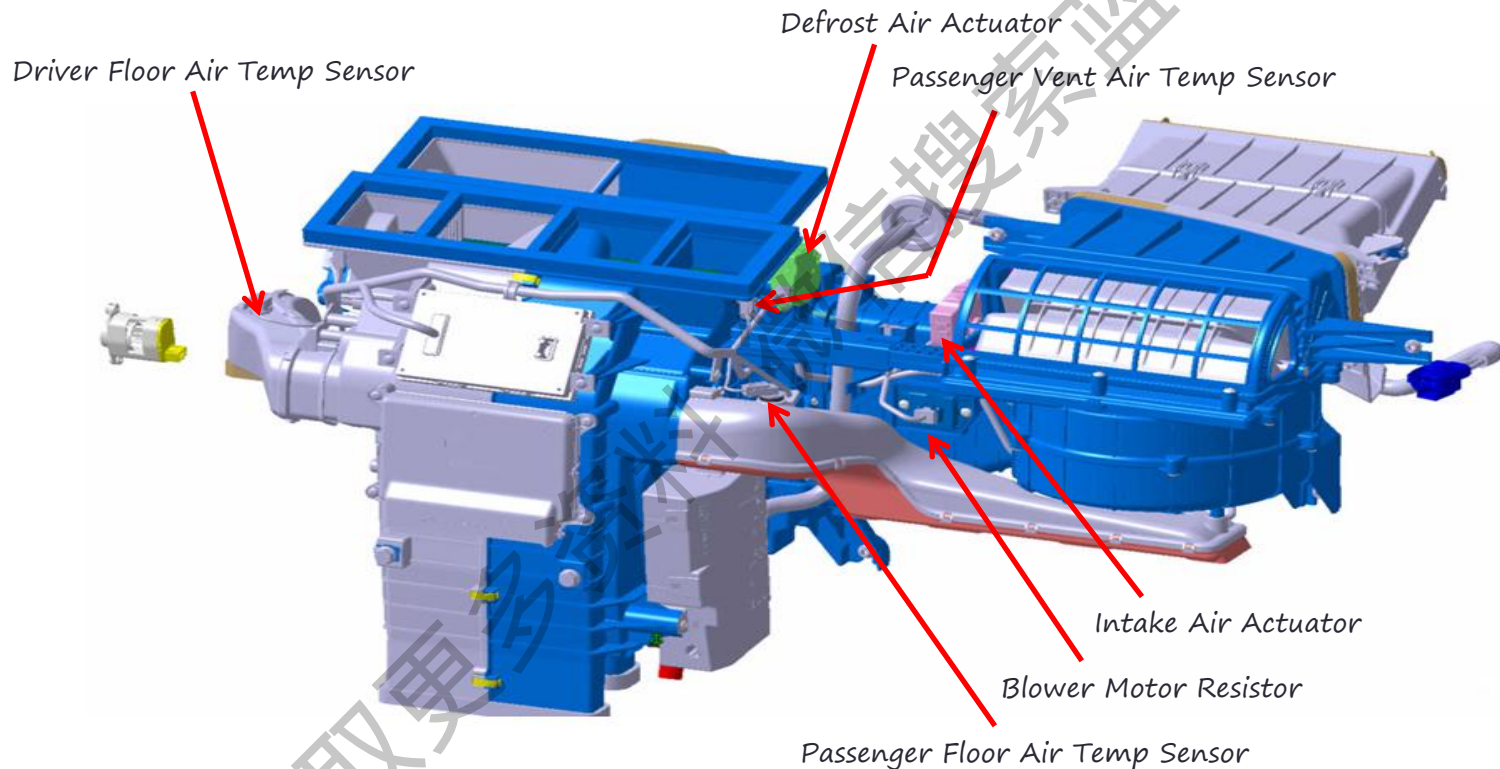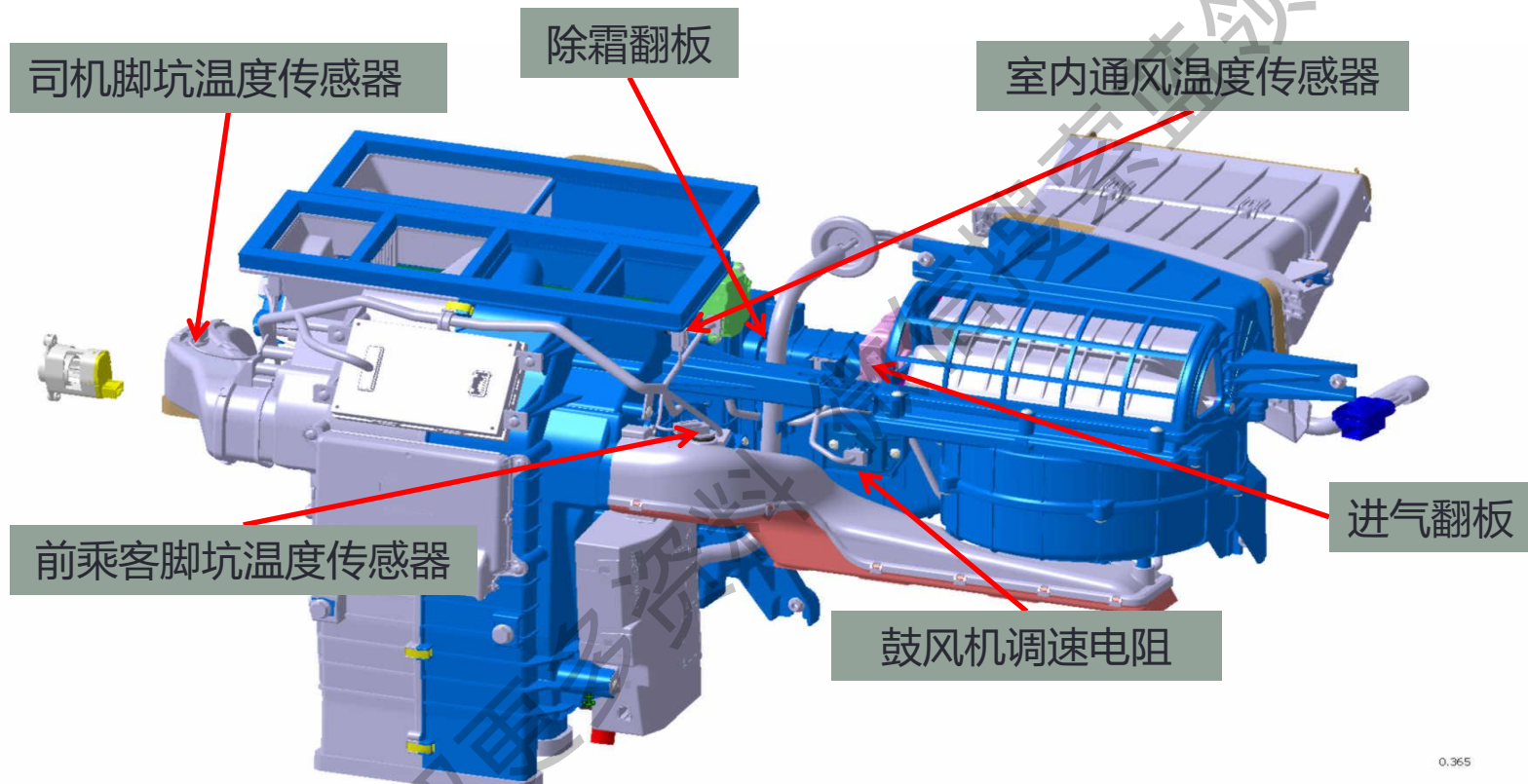
鼓风机调速电阻

0.365

HVAC System Components

Top View

Defrost Air Actuator

Passenger Air Temp Actuator

Passenger Floor Air Temp Sensor

HVAC 系统部件

顶视图

除霜空气翻板

前乘客空气翻板

前乘客脚坑温度传感器
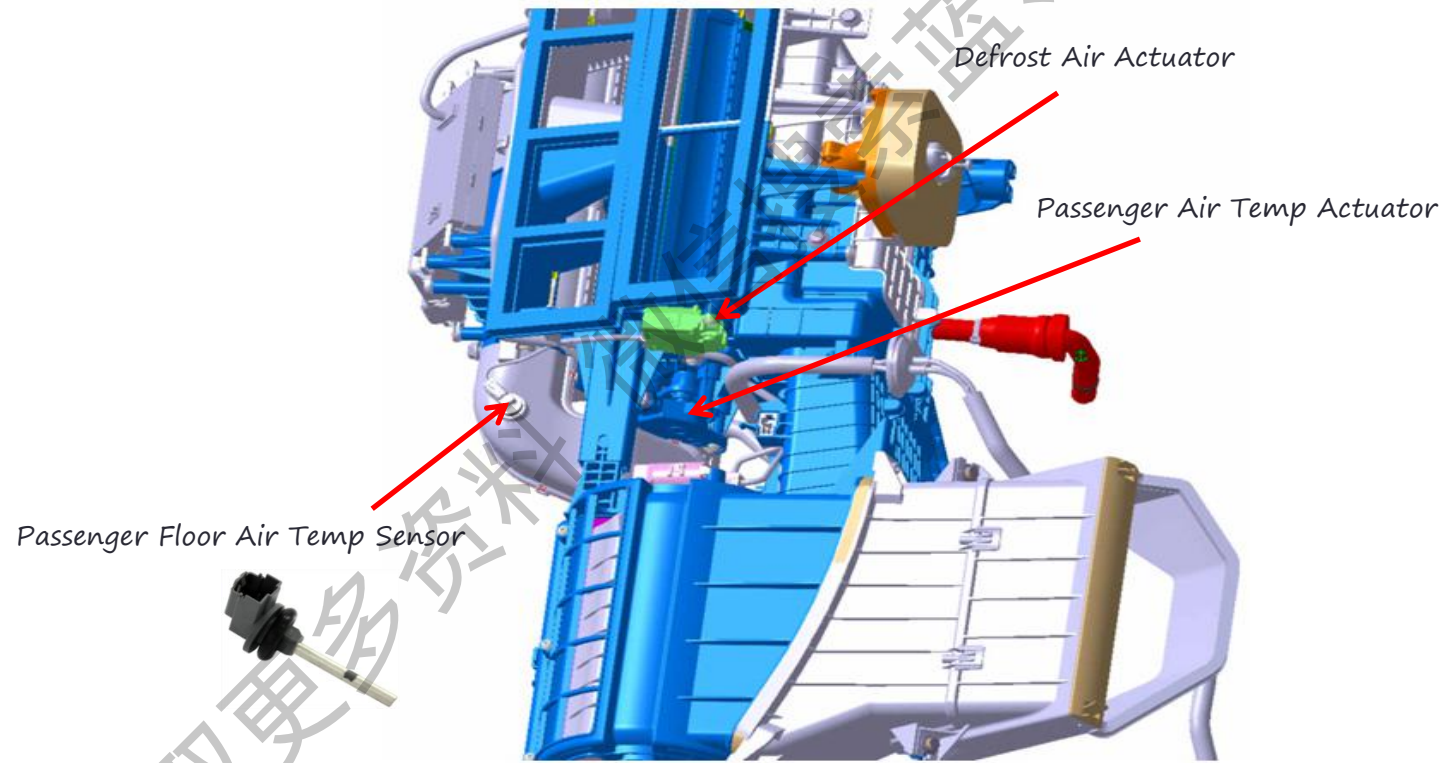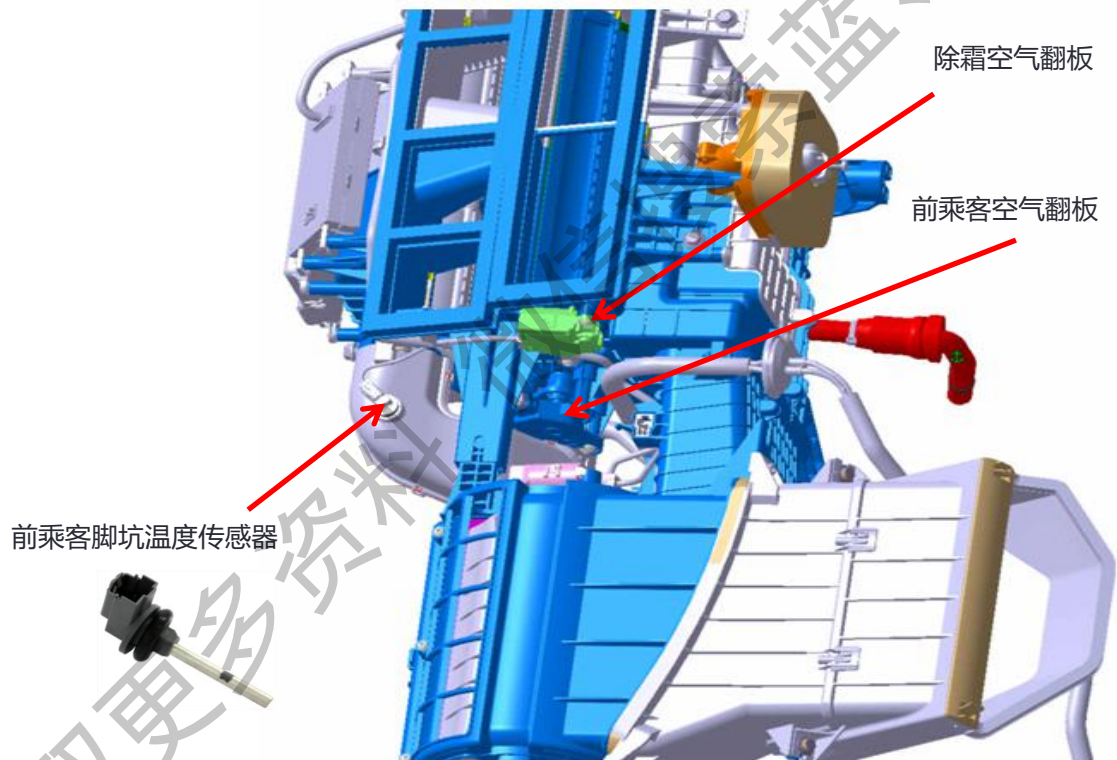
HVAC System Components

Bottom View

Blower Motor Resistor Power Connector

Blower Motor Power Connector

Blower Motor Resistor

Blower Motor

HVAC 系统部件

仰视图

鼓风机调速电阻插头

鼓风机供电接头

鼓风机调速电阻
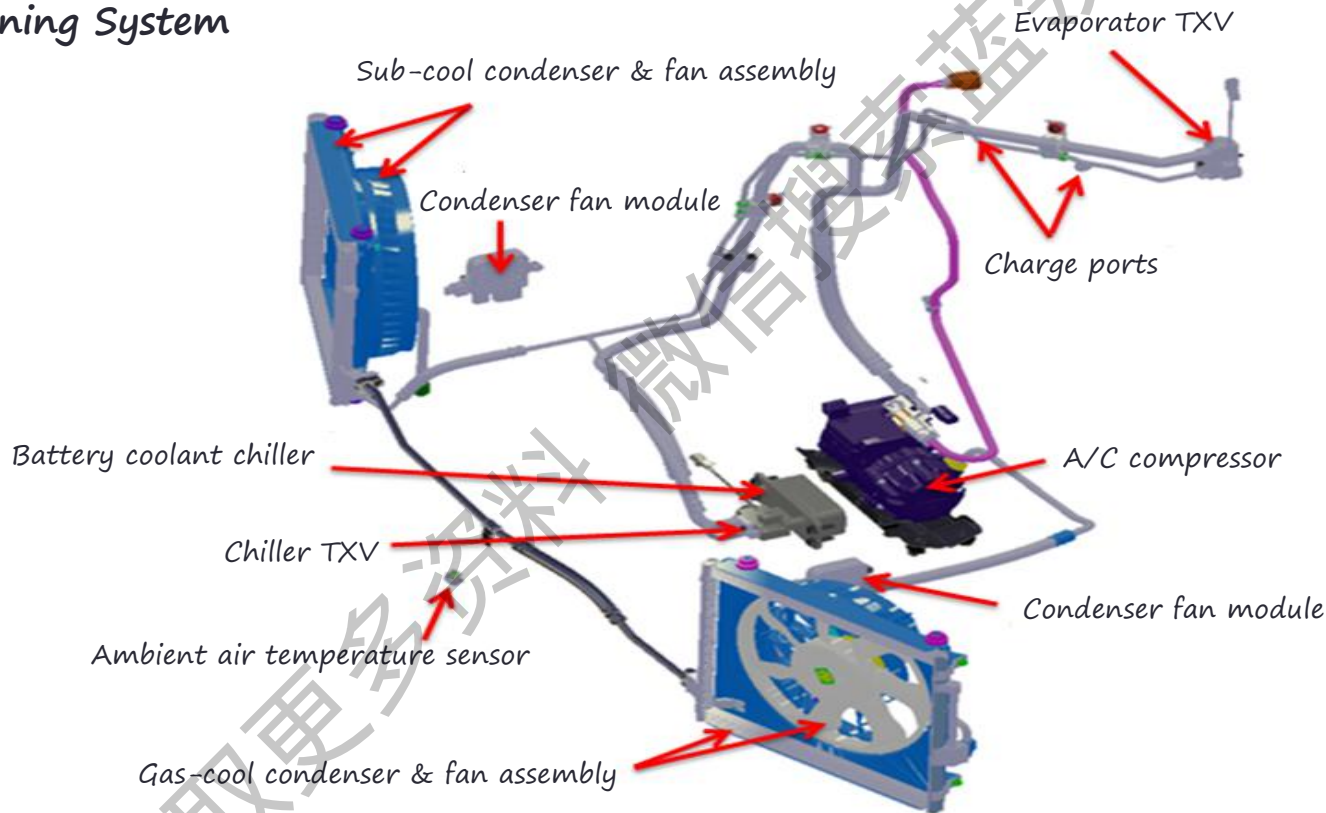
鼓风机马达
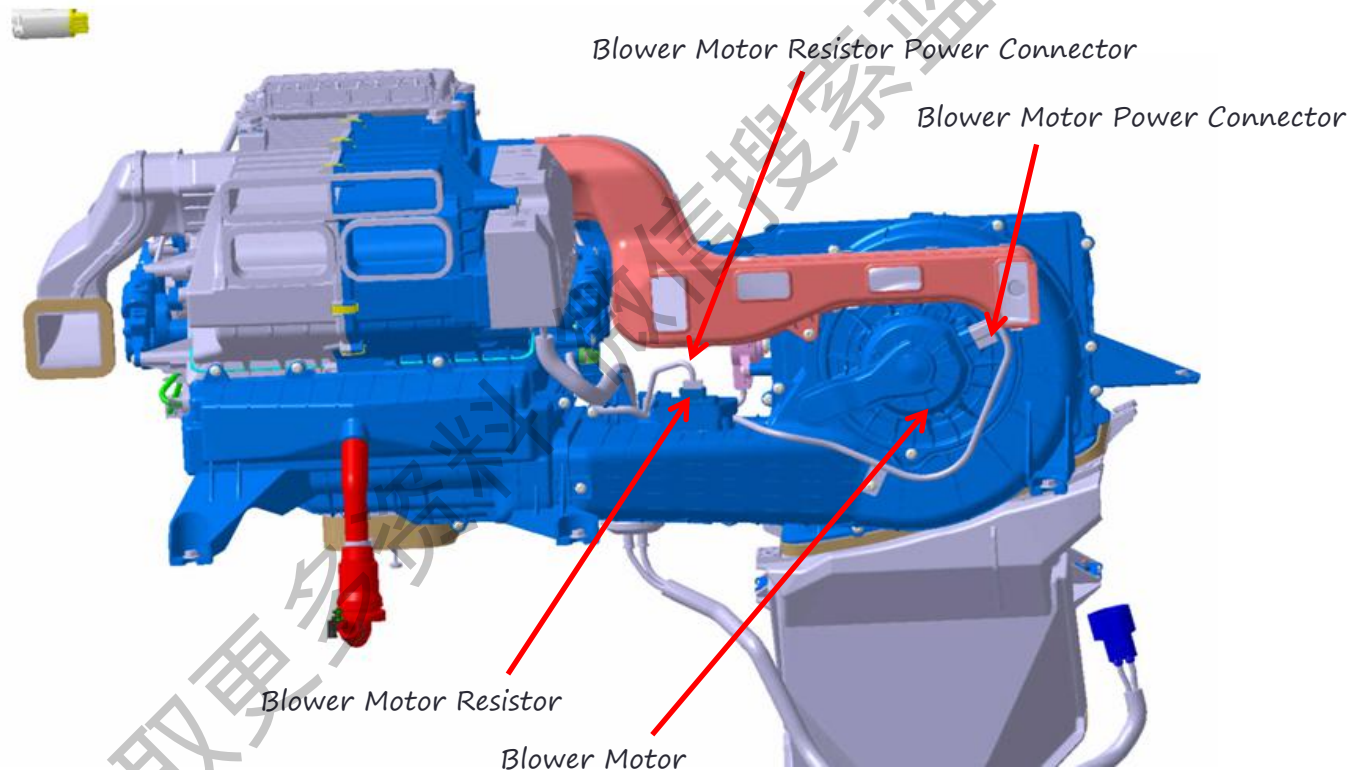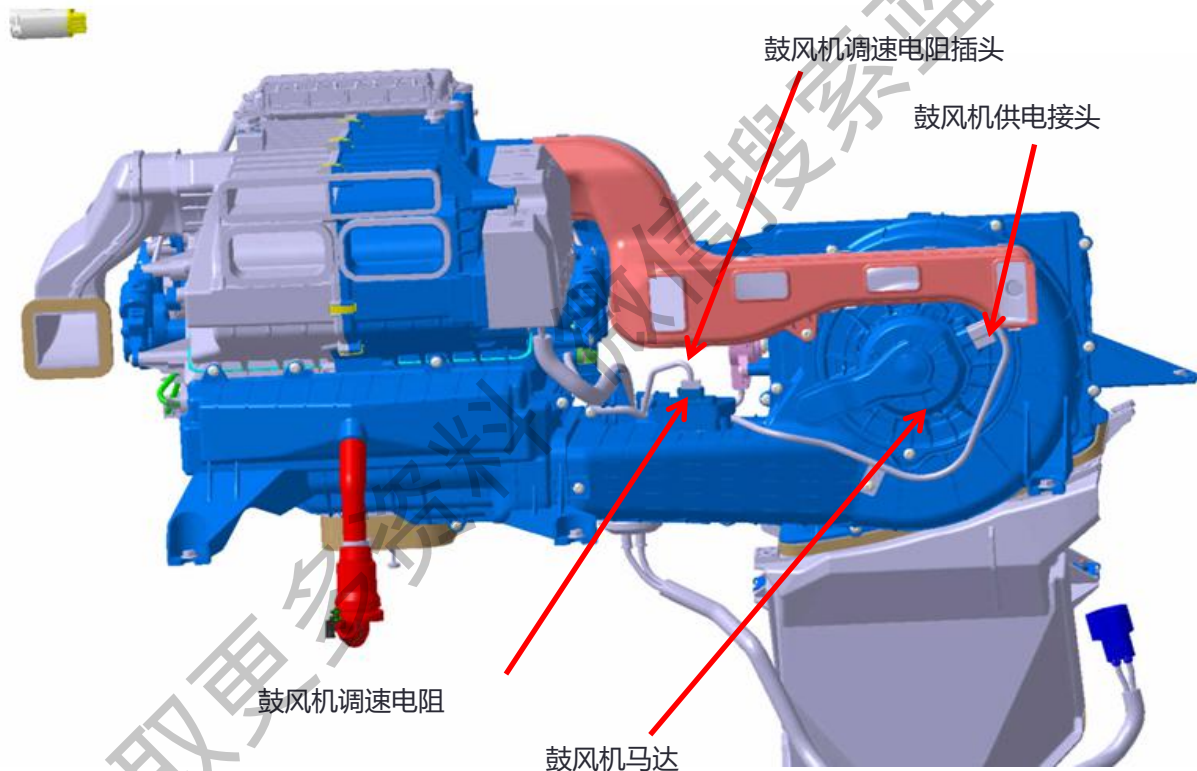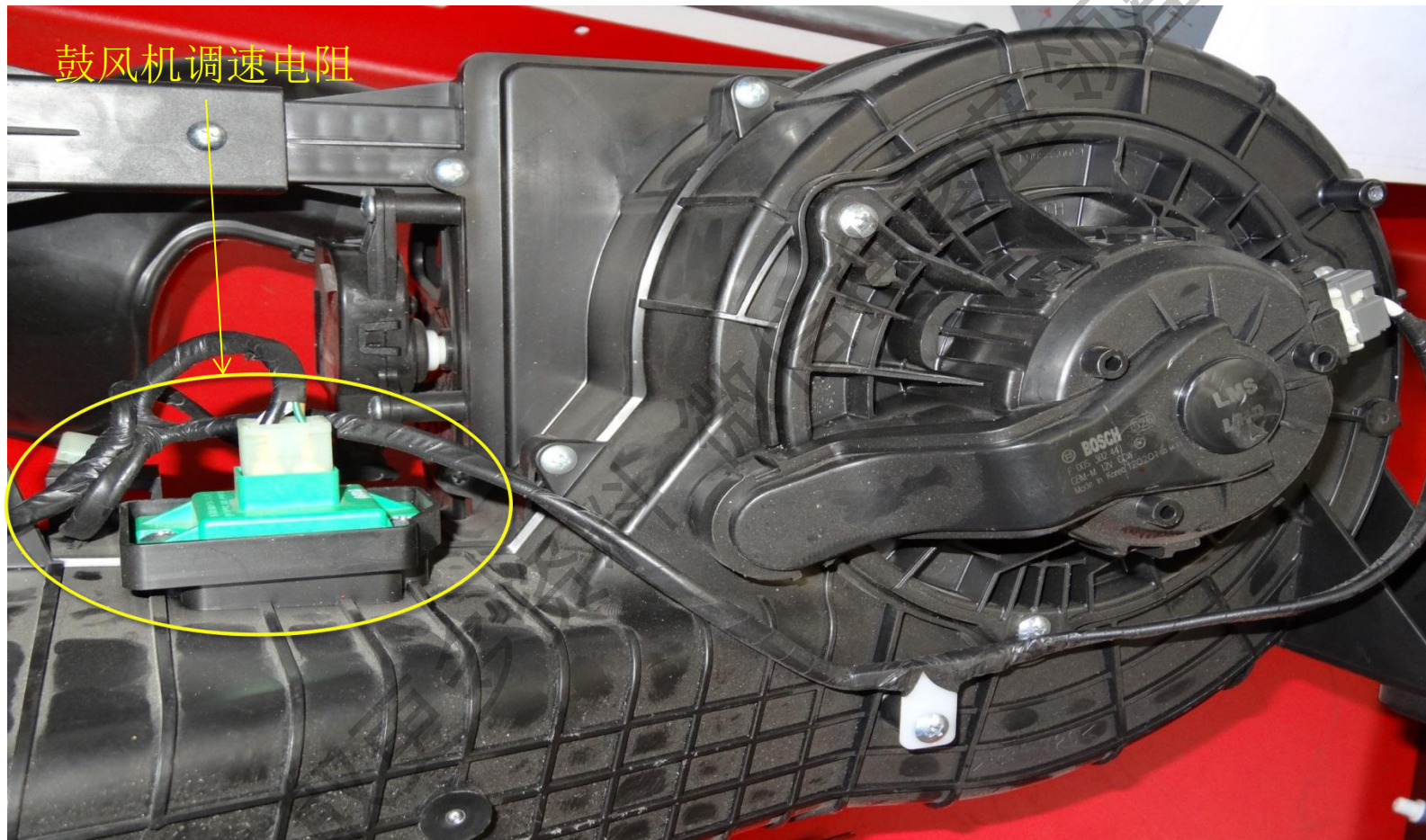
鼓风机调速电阻

鼓风机调速电阻

空调控制单元/温控控制单元

温控控制单元

空调控制单元/温控控制单元

温控控制单元

空调控制单元

温控控制单元

HVAC System Components

Air Conditioning System

- Evaporator TXV
- Sub-cool condenser & fan assembly
- Condenser fan module
- Charge ports
- Battery coolant chiller
- A/C compressor
- Chiller TXV
- Condenser fan module
- Ambient air temperature sensor
- Gas-cool condenser & fan assembly

空调系统部件

附加冷却冷凝器与风扇总成

蒸发箱TXV

冷凝器风扇模块

空调加注口

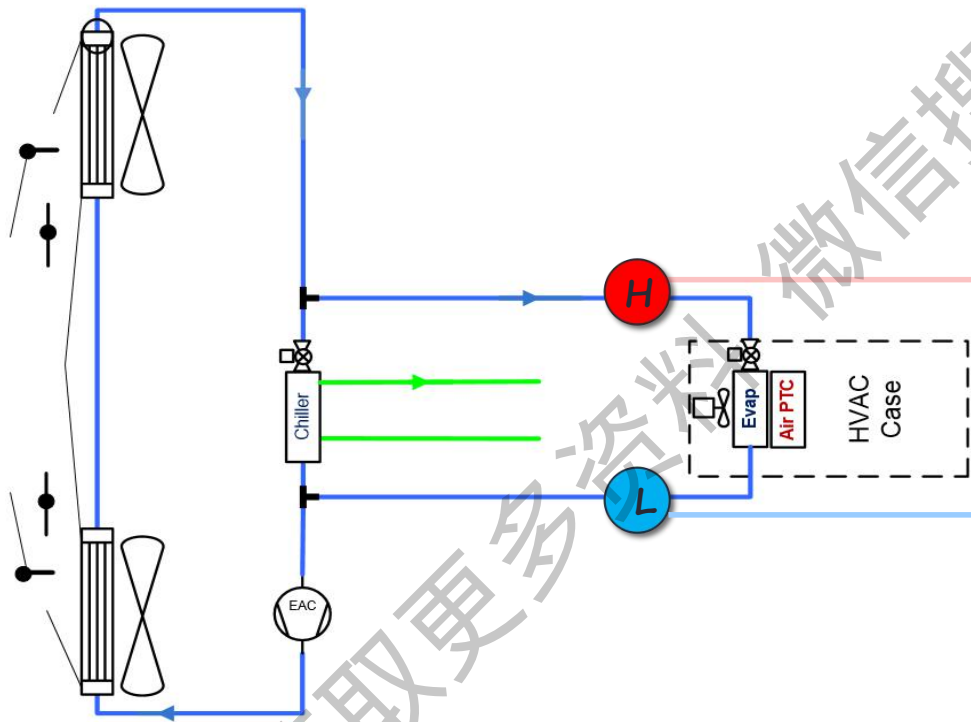高压电瓶冷却液冷却器

空调压缩机

冷却器TXV

冷凝器风扇模块

环境温度传感器

气态冷凝器与风扇总成
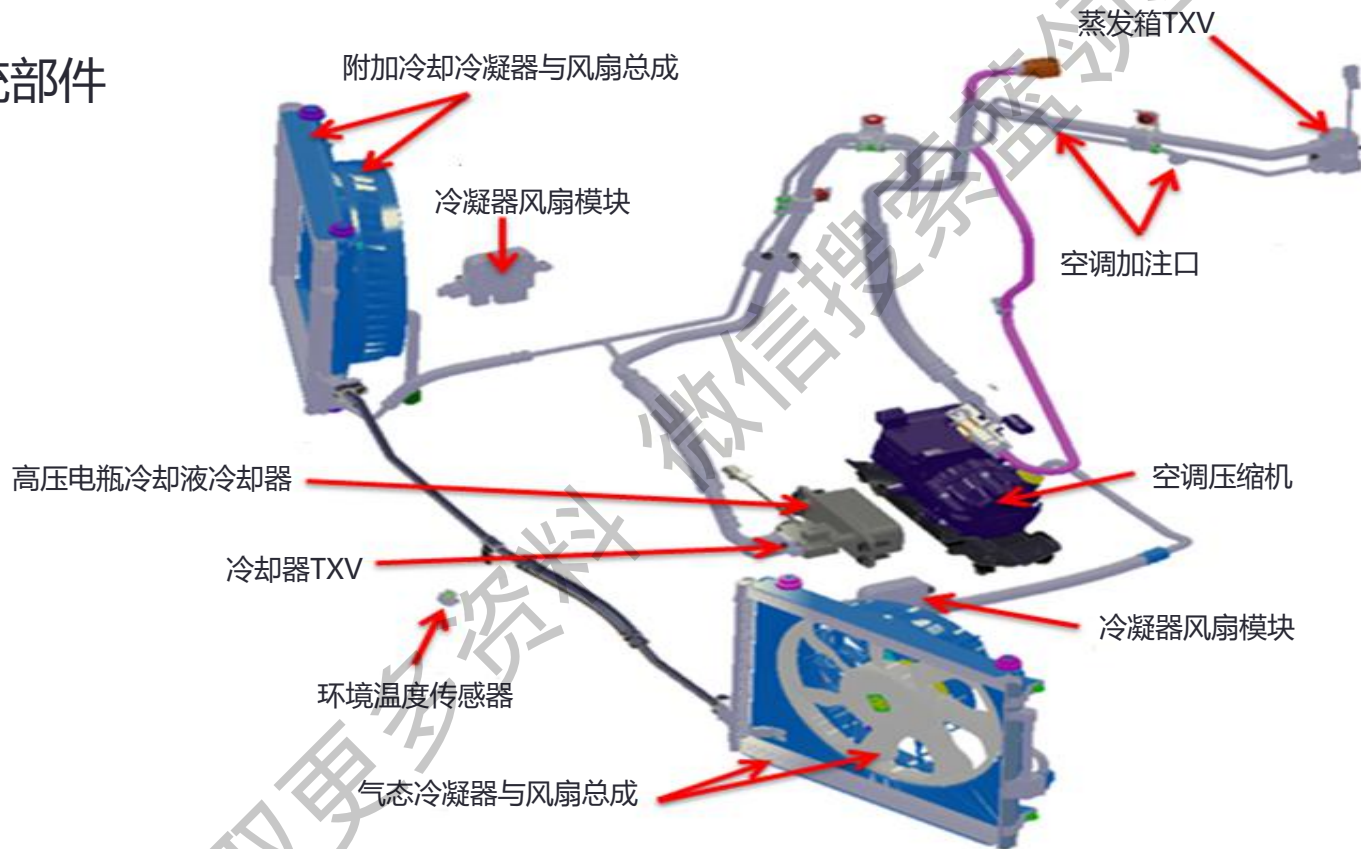
HVAC Refrigerant Loop

HVAC problems can be diagnosed using A/C manifold pressure gauge set or sensor data in carlogs
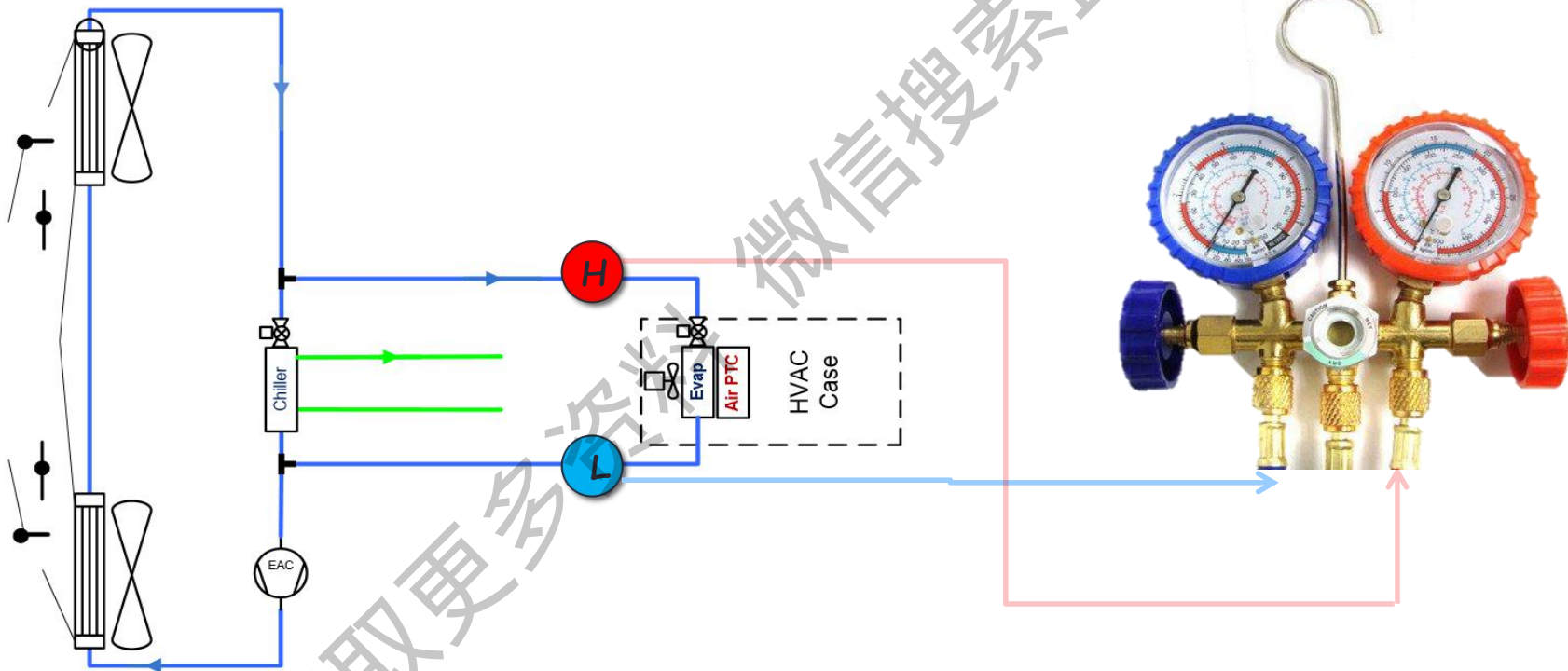
HVAC 制冷剂回路

HVAC 故障可以通过使用空调压力表或CARLOGS里面的传感器数据进行诊断

HVAC System Components

Denso AC Compressor

- AC compressor is powered by High Voltage (HV battery voltage)
- High Voltage is Fused through the DC/DC or Front HVJB (GEN2)
  - ➢ If fuse is blown may see under voltage UV faults, and must replace dc/dc (Gen 1)
- Does not use CAN data to communicate
- Compressor speed is a PWM signal
- Used for Thermal Management also used during chiller functions.

High voltage connector

Low voltage connector

Low pressure inlet

High pressure outlet

A/C compressor
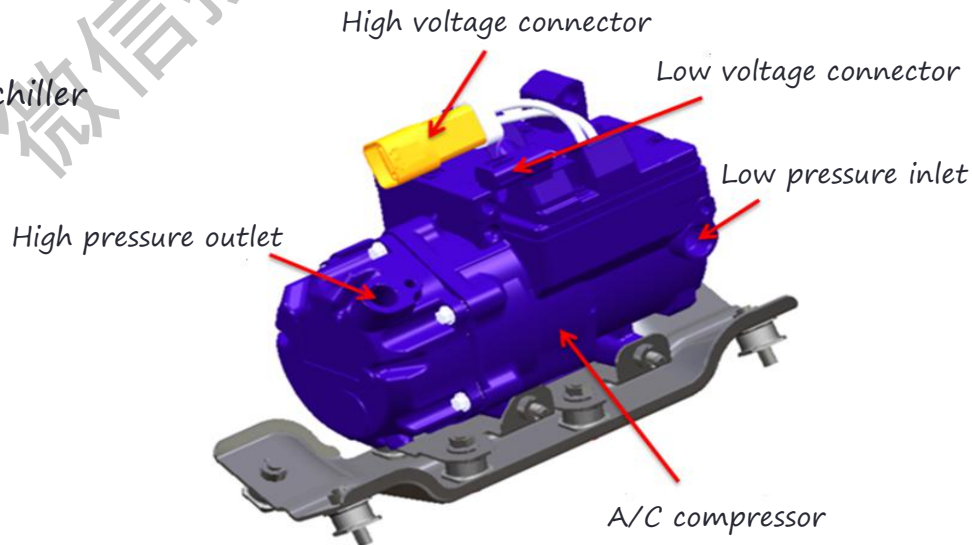
HVAC 系统部件

空调压缩机

- 空调压缩机高压供电（高压电池）
- 高压供电通过前HVJB（保险丝保护）(GEN2)
  - 不通过CAN传输数据
- 压缩机转速由PWM信号控制
- 同时应用在温控系统
  - 作用于冷却器

车厢加热器

- 车厢加热器高压供电（高压电池）
- 应用BFTCAN传输数据
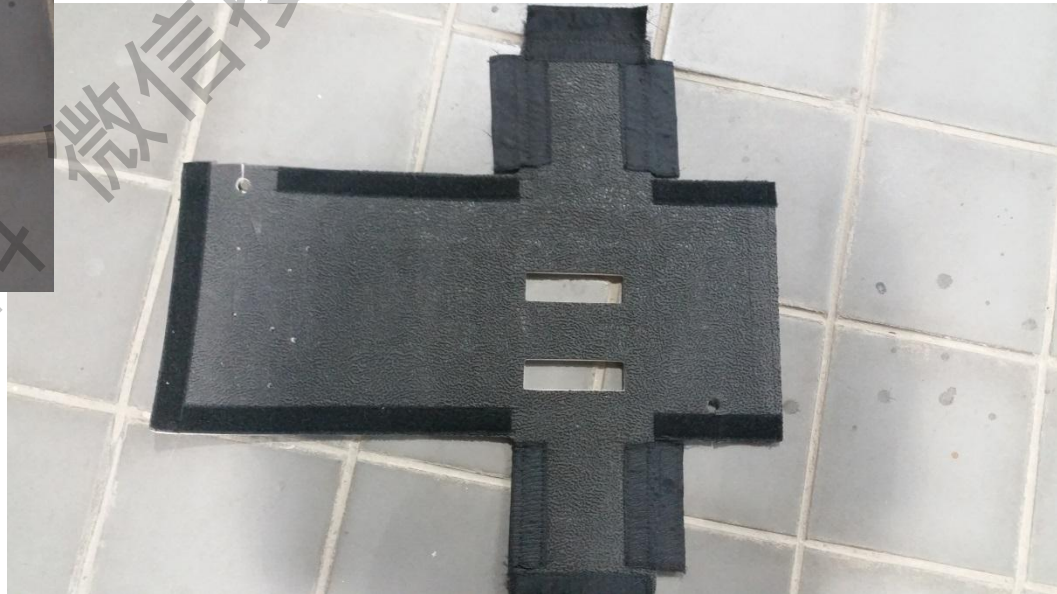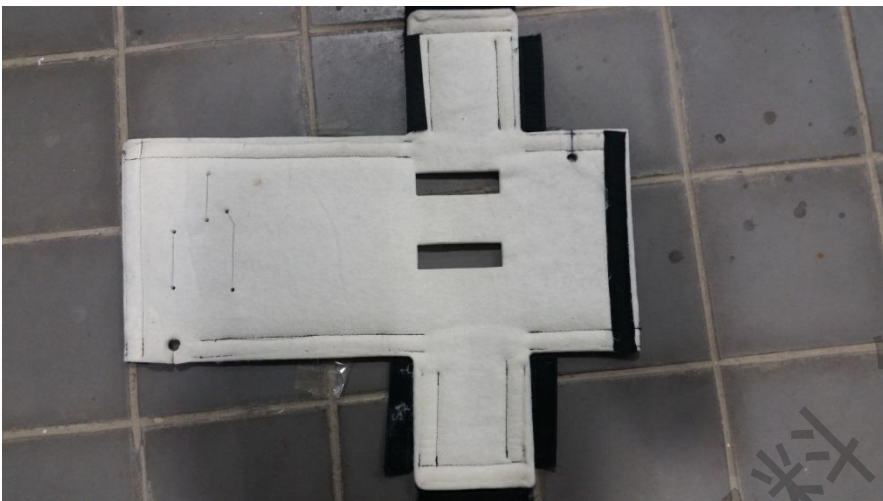- 高压供电通过前HVJB（保险丝保护）
  - 如果保险丝烧蚀可能看到 PTC_UV faults

加热器左右两侧有内部温度传感器

高电压接头

低电压接头

制冷剂低压口

制冷剂高压口
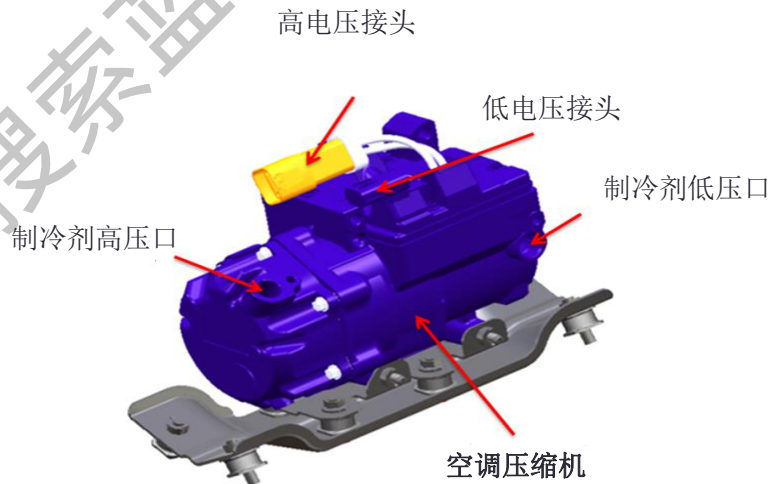
空调压缩机

空调压缩机隔音处理：

HVAC 系统部件

空调压缩机隔音处理：

隔音棉的PN:1028988-00-A
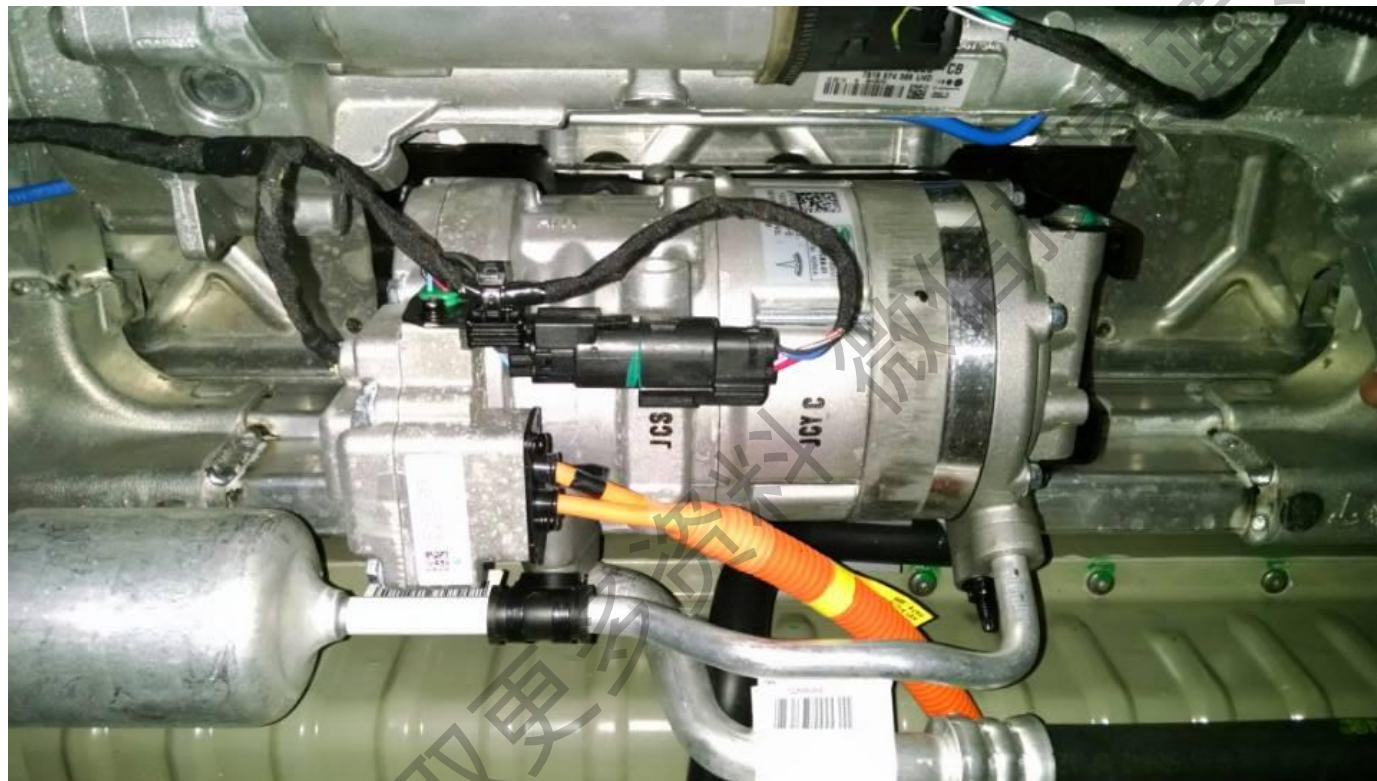

里　　面

外　　面

HVAC 系统部件

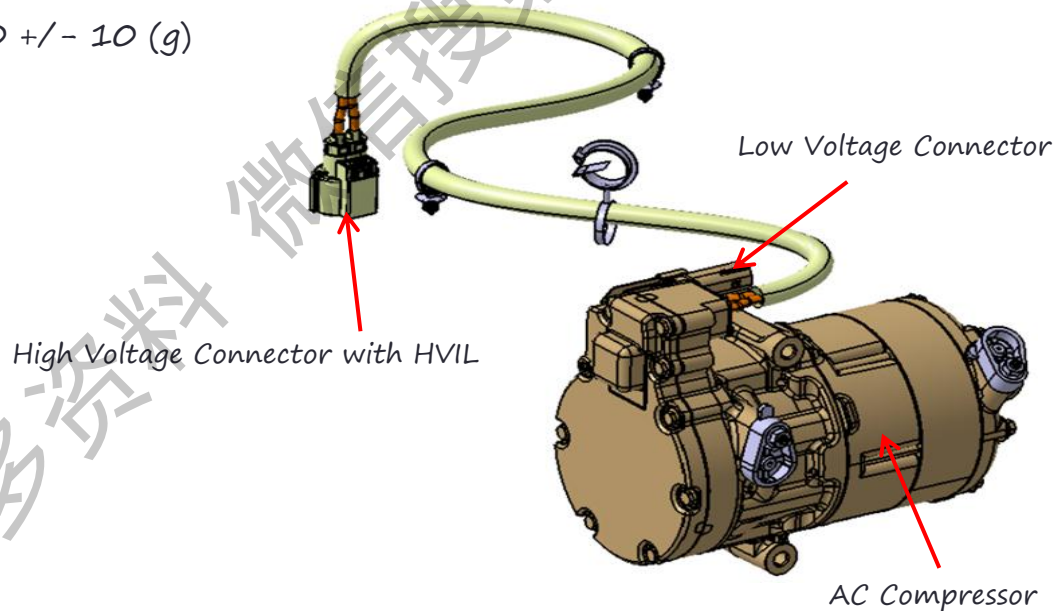**空调压缩机隔音处理：**

支架PN：1006079-00-D

HVAC 系统部件

空调压缩机新型：

HVAC System Components

Halla AC Compressor
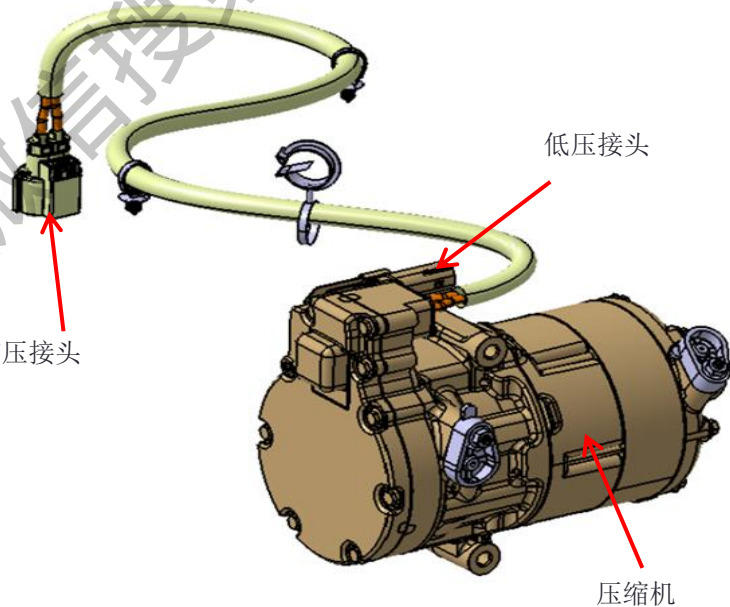
- AC compressor is powered by High Voltage (HV battery voltage)
- Compressor type: Electric Scroll
- Communication: High speed CAN
- Lubricant oil: POE (RB100EV) 150 +/- 10 (g)

Low Voltage Connector

High Voltage Connector with HVIL

AC Compressor

HVAC 系统部件

Halla 压缩机

- 压缩机由高压供电 (高压电池电压)
- 压缩机类型: 电子卷轴
- 通信方式: 高速CAN
- 冷冻机油: POE (RB100EV) 150 +/- 10 (g)

低压接头

带高压互锁的高压接头

压缩机

HVAC System Components

Cabin Heater

- The Cabin heater is powered by High Voltage (HV battery voltage)
- Uses BFT CAN to Communicate
- HV is Fused through the DC/DC or Front HVJB (GEN2)
  - ➢ If fuse is blown may see PTC_UV faults
- Has internal core temp sensors for left and right sides
 - ➢ Have been known to fail

乘客厢加热器

- 乘客厢加热器由高压供电 (高压电池电压)
- 使用 BFT CAN 通信
- 高压通过装有保险丝的DC/DC或HVJB(GEN2)
  - ➢ 如果保险丝熔断可能是PTC_UV faults
- 左侧和右侧有内部温度传感器
  - ➢ 可以确认系统故障

HVAC System Components

Thermal Expansion Valves TXV/H-Block

- Automatically adjust the orifice size depending on evaporator out gas temp.
- Helps prevent the evaporator from freezing up.
- The Model S uses a solenoid to open or close the flow through the Evaporator TXV
  - ➤ Solenoid valve is normally closed and powered open with compressor request.
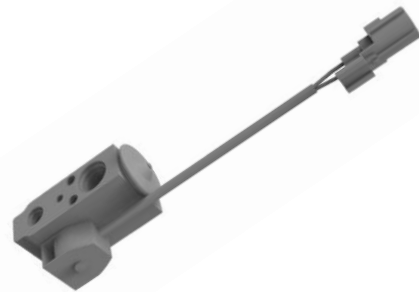
Refrigeration Pressure/Temperature Sensors

- Analog signals
- Low side Pressure/ Temp. sensor
  - ➤ On early production vehicles
  - ➤ Located on suction line in before compressor inlet
- High side Pressure / Temp. sensor
  - ➤ On all vehicle to date
  - ➤ Located before driver side condenser in fender well
  - ➤ Most accessible from top under driver side apron

HVAC 系统部件

膨胀阀 (H型)

- 根据流经蒸发箱气体温度, 自动调节节流面尺寸
- 防止蒸发箱结冰
- Model S使用电磁阀允许和阻止制冷剂流到膨胀阀
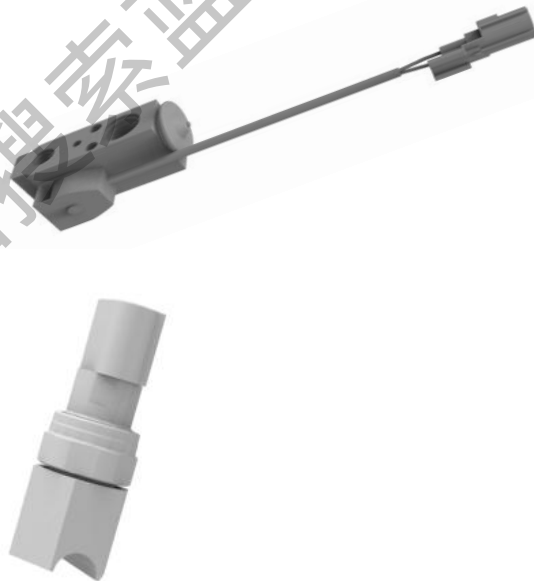- 电磁阀是一个常关阀，车辆空调开启后打开

制冷剂压力/温度传感器

模拟信号
低压端压力/温度传感器
- 仅在早期产品上使用
- 在压缩机前端吸入管侧

高压端压力/
- 至今所有车辆安装使用
- 位置处于司机侧冷凝器（翼子板内）
- 司机侧仪表台下最容易接触到
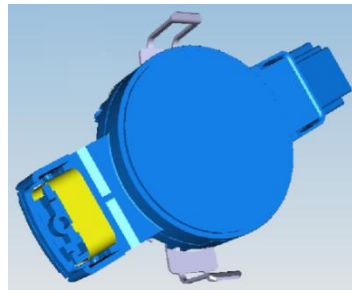
HVAC System Components

Interior Temperature Sensors

- Located in the center console
  - ➢ In the drivers knee panel on early production cars
- Used for interior temperature regulation
- Has a fan to constantly sample air
  - ➢ If fan fails auto setting may function erratic

Rain/Light/Solar/Humidity Sensor

- Located behind the rear view mirror
- Used in RCCM HVAC algorithms
- Connected to BCM through LIN Bus
- Must be replaced if removed from the windshield
- Provides info for auto wipers

HVAC 系统部件

车内部温度传感器

位于中扶手内
　　　司机侧膝部盖板内（车辆早期版本）
用于车内温度的控制
传感器内有风扇持续采样空气温度
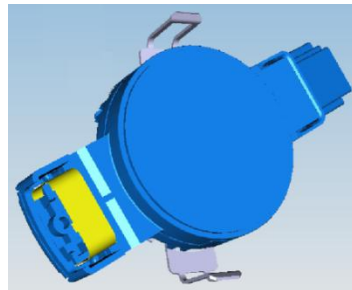　　　一旦该风扇出现问题可能造成系统功能紊乱

雨水/灯光/阳光/湿度传感器

在后视镜后面
用于空调系统运算
通过LIN线与BCM通讯
如果更换风挡必须更新
为自动雨刷提供信息

HVAC System Components

Description

The function of the cluster ion generator is to clean the in coming air by decomposing harmful particles such as mould and unpleasant smells.

Ionisers use electrostatically charged plates to produce positively or negatively charged gas ions that particulate matter sticks to in an effect similar to static electricity.

The air ionizer is a device that uses high voltage to ionise (electrically charge) air molecules.

- Negative ions, or anions, are particles with one or more extra electrons (negatively charged particles).

- Cations are positive ions missing one or more electrons (positively charged particles).

HVAC 系统部件

描述
离子发生器分解诸如霉臭味等有害颗粒物来清洁进入乘客厢的空气。
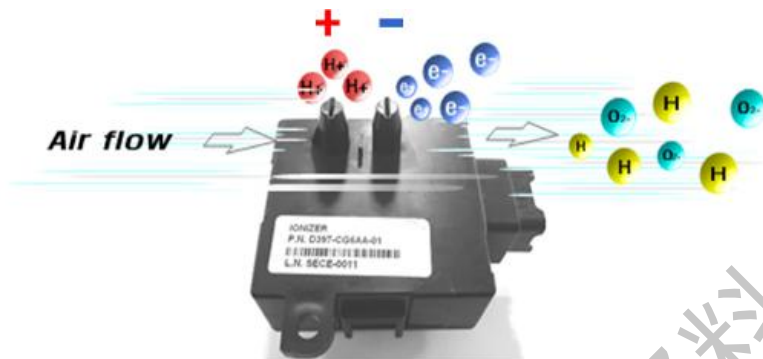
离子发生器使用静电荷板产生正离子或负离子，它可以利用静电效应吸附悬浮颗粒物。

气体离子发生器是利用高电压电离（电荷）颗粒物。
* 负离子（阴离子）是一个或多个电子（负电子颗粒）。
* 阳离子是正离子失去一个或多个电子（正电子颗粒）。

HVAC System Components

It is a device that enhances the environment in the vehicle by deodorizing effects.

With raising Hydroxyl Radical (OH), disinfecting evaporator and eliminating offensive odor

Air flow

Fungi, Bacteria

OH   OH

Removal of Odor material
(fungi., Bacteria)

- Hydroxyl radical(OH-) surround and attach to the harmful airborne substances and eliminate them by breaking the hydrogen bond in their protein structure.
- This forms water molecules which evaporate into the air, leaving the interior fresh and free of bacteria.

HVAC 系统部件

它可以通过除臭改善车内环境。

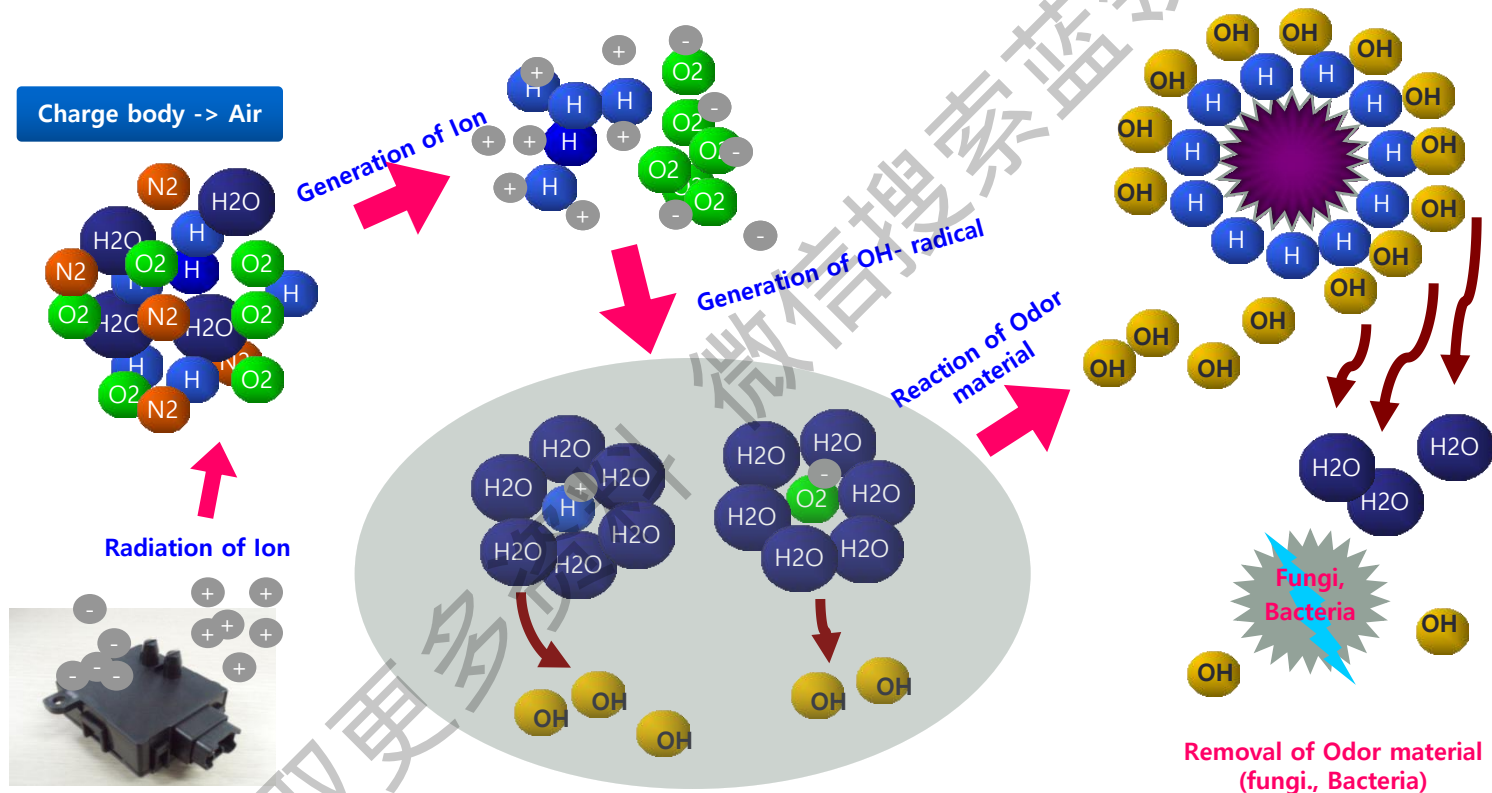随着氢氧自由基上升，可以消毒除臭。
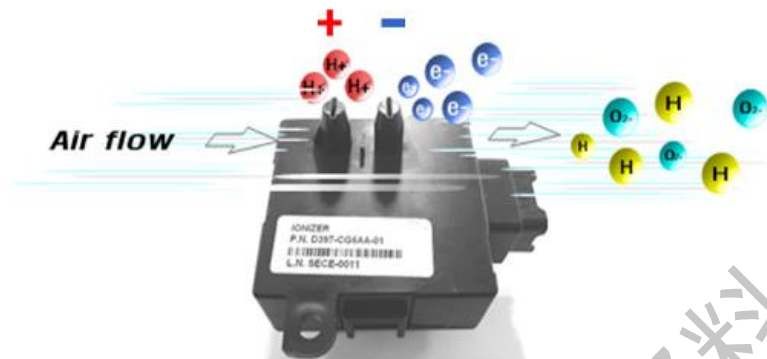
去除有气味的物质(真菌，细菌）

- **氢氧自由基**(*OH*–) 四处漂浮，并依附在有害物质上，通过破坏蛋白质结构上的氢键消灭它们。
- 这样就可以形成水分子蒸发到空气中，使车内环境清新无菌。

HVAC System Components

Charge body -> Air

Generation of Ion

Generation of OH- radical

Reaction of Odor material

Radiation of Ion

Removal of Odor material
(fungi., Bacteria)

Fungi, Bacteria

电荷体-> 空气

产生离子

产生氢氧自由基

与臭味物质反应

辐射离子

去除臭味物质(真菌，细菌)

Fungi, Bacteria
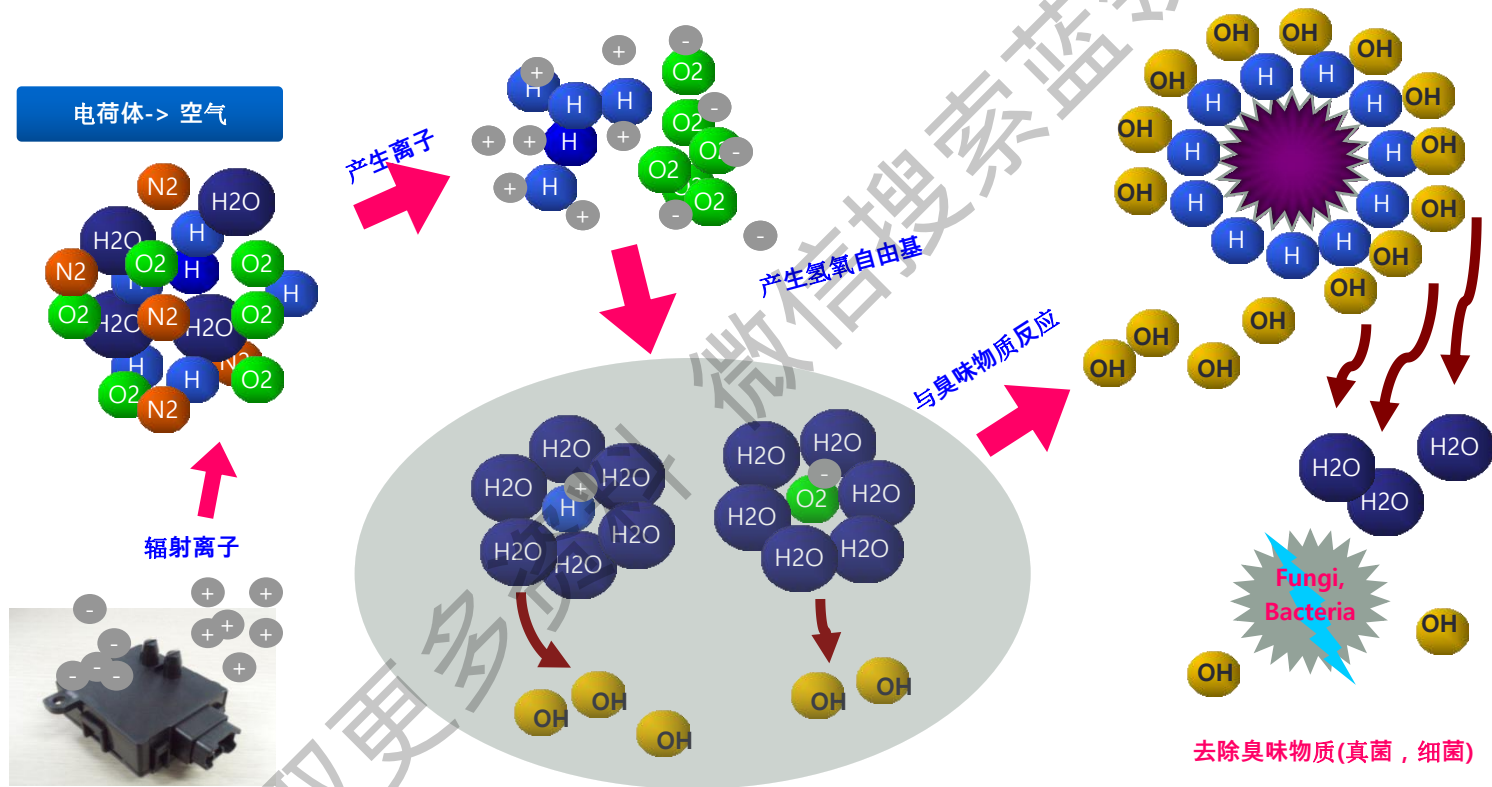
HVAC System Components

* Clean mode : Hi ion mode
* Ion mode : Low ion mode
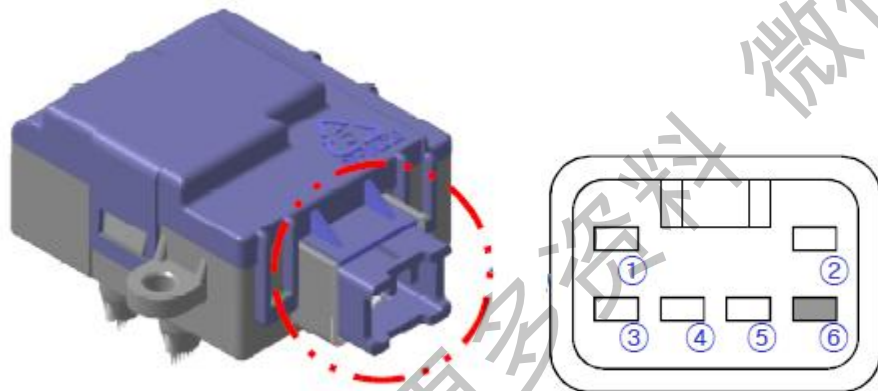
PIN No.	USAGE	CLEAN MODE	ION MODE
PIN 1	EARTH	-12V	-12V
PIN 2	IGNITION	+12V	+12V
PIN 3	ION MODE SIGNAL	---	+12V
PIN 4	CLEAN MODE SIGNAL	+12V	+12V
PIN 5	DIAGNOSIS	---	---
PIN 6	NOT ALLOCATED	---	---

* 清洁模式：高离子模式
* 离子模式：低离子模式
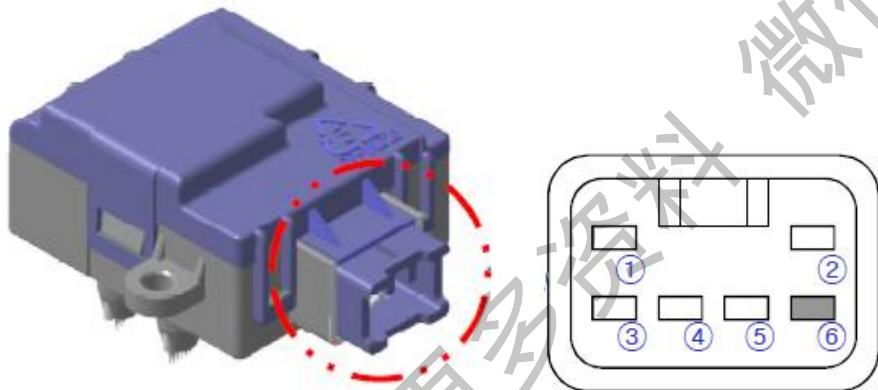
PIN No.	USAGE	CLEAN MODE	ION MODE
PIN 1	EARTH	-12V	-12V
PIN 2	IGNITION	+12V	+12V
PIN 3	ION MODE SIGNAL	---	+12V
PIN 4	CLEAN MODE SIGNAL	+12V	+12V
PIN 5	DIAGNOSIS	---	---
PIN 6	NOT ALLOCATED	---	---

HVAC Service Functions

Refrigerant Oil
- 3 types of oil used by Tesla
  - PVE – Roadster 1.5
  - POE – Roadster 2.0+ 2.5
  - ND11 POE – Model S US and EU

AC Evacuation and Fill
  - Use Toolbox function
  - Opens TXV solenoids, checks status (will fault if not ok)
  - Will exit if DI or Charge is enabled
  - If Toolbox is not available, Refrigerant evacuation an fill may be performed but you must pull a vacuum and fill from both High and Low sides.

Cabin HVAC signals
  - Can be used to view HVAC signals to help diagnose issues

Thermal System Test
  - Used to test the entire thermal system
  - Will test AC system and cabin heater after repairs.

HVAC 服务功能

制冷剂油
- Tesla 使用3种制冷剂油
  - PVE – Roadster 1.5
  - POE – Roadster 2.0+
  - ND11 POE – Model S US and EU

车辆空调信号
- 可查看HVAC信号帮助诊断

温控系统检查测试
- 用于检查测试整个系统
- 可以检测空调，加热器（类似小水箱功能）和蒸发箱

空调抽空与加注
- 用Toolbox相关功能
- 打开TXV电磁阀，检查状态（一旦not ok带有故障）
- 如果DI或charger工作，系统将退出
- 如果Toolbox不能用，制冷剂抽空与加注还是可以进行的但需要从高低压管路同时进行抽真空与加注。

HVAC Performance Test

Overview

Whenever a customer complains that the air conditioner is ineffective, it will be necessary first of all to perform an air conditioner system inspection in order that the corresponding fault may be identified.

If a problem cannot be found at this stage, it is most likely the customer simply feels that the air container is not effective, where in actual fact it is operating quite normally.

An air conditioner performance test can be performed in such a situation to determined that the air conditioner is operating within normal parameters.

HVAC 性能测试

综述

无论何时客户抱怨空调工作不良，首先必须进行空调系统检查确认是否是空调问题。

如果在此阶段没有发现问题，很有可能是客户个人感觉空调的问题，实际空调工作正常。

对于此类情况，我们可以进行空调系统性能测试，检查空调的工作是否在正常范围内。

HVAC Performance Test

Preparation
Set up the vehicle to for the test to be performed:
1. Park the vehicle inside, and out of direct sunlight;
2. Open the front doors and windows down;
3. Allow the vehicle's body and interior to cool down to ambient temperature;
4. Connect the manifold-gauges to the high and low pressure ports;
5. Allow the AC to run for about 10 minutes;
6. Record the ambient temperature
7. Record the relative humidity
   ➢ Turn ON AC
   ➢ Set to max 'Lo'
   ➢ Maximum blower fan speed
   ➢ Select fresh air
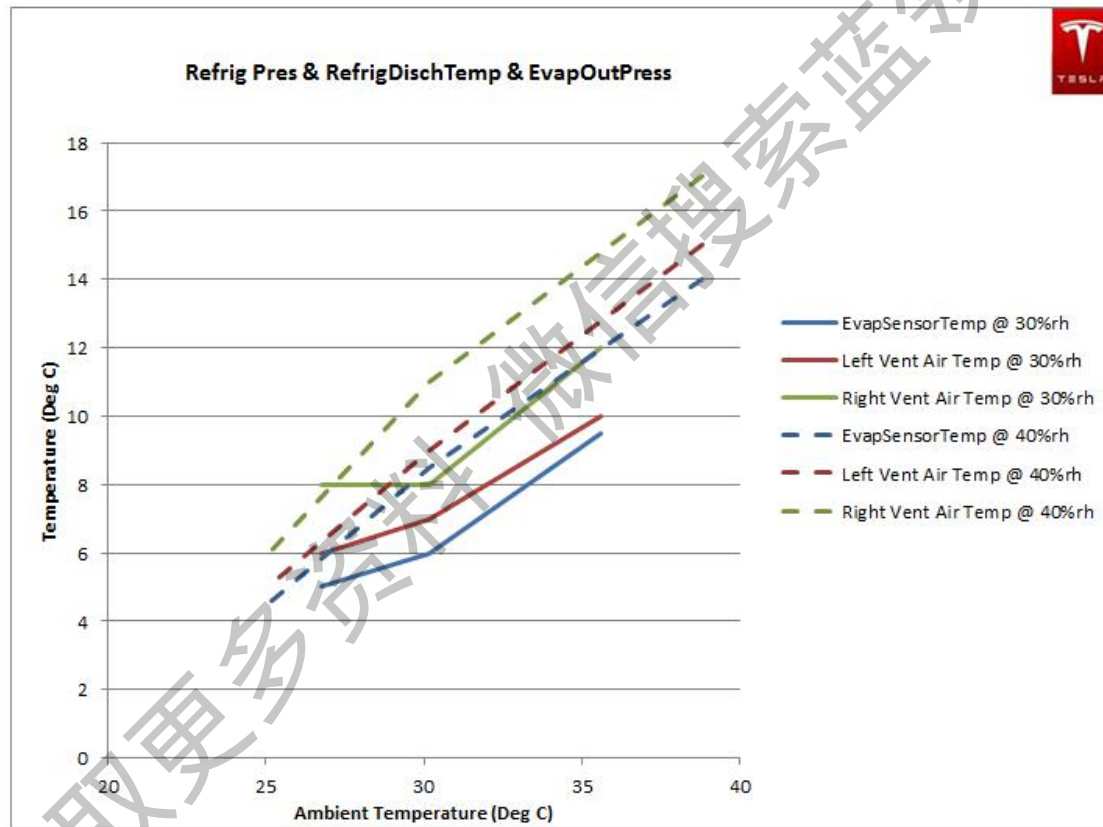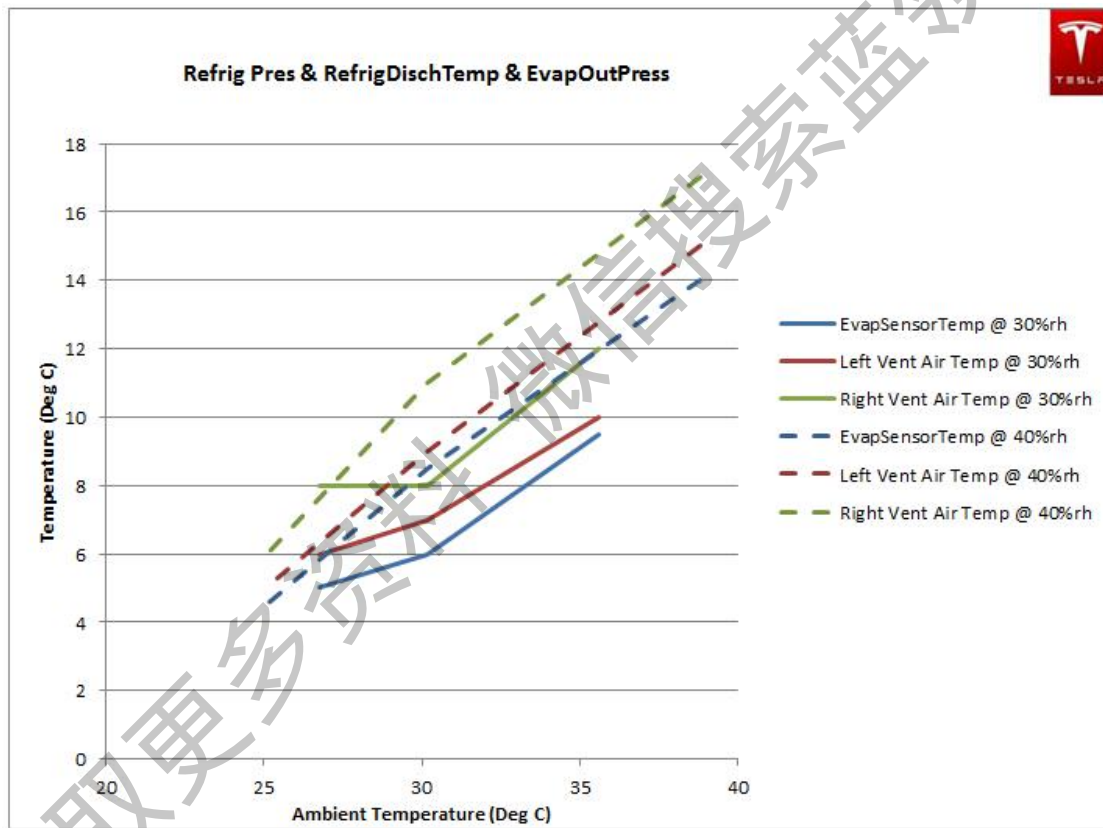8. Record the temperature at the center vents.

HVAC 性能测试

准备

设置好将要要进行测试的车辆:

1. 停在车间内，没有阳光直射的地方;
2. 打开前车门，降下车窗;
3. 让车身及车内与室温相同;
4. 在高低压侧连接歧管式加氟表;
5. 空调运行10分钟;
6. 记录环境温度
7. 记录相应湿度
   ➢ 打开空调
   ➢ 设置max 'Lo'
   ➢ 最大风速
   ➢ 选择 fresh air
8. 记录中央出风口温度。

Performance Chart

性能表

Performance Chart

Refrig Pres & RefrigDischTemp & EvapOutPress
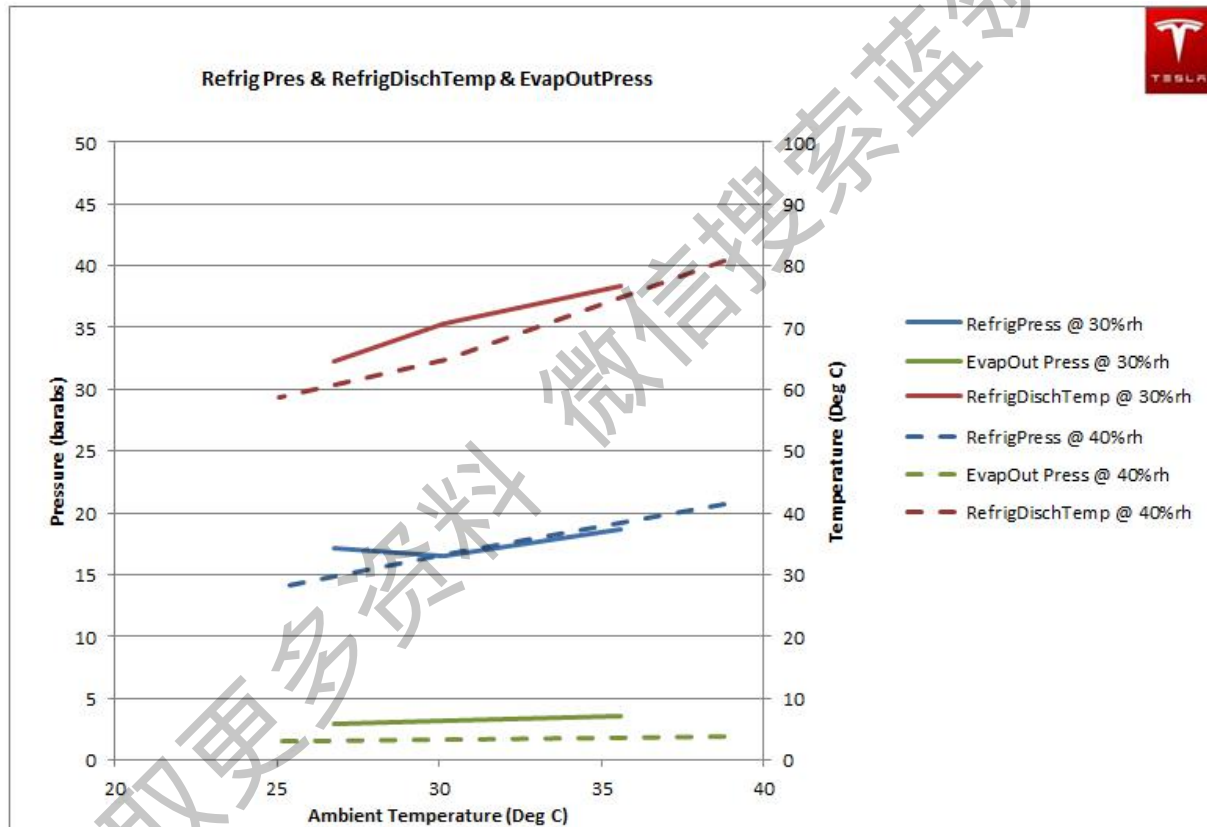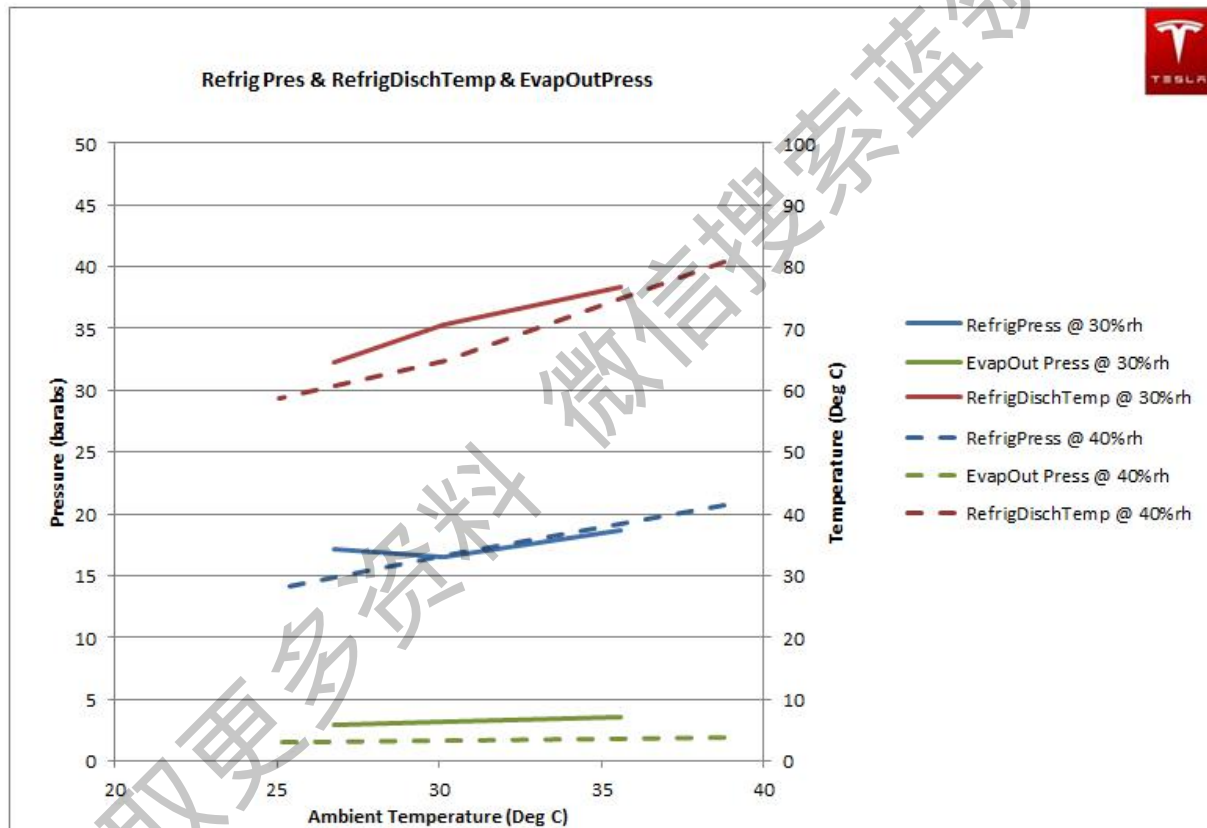
THERMAL MANAGEMENT SYSTEM
HV THERMAL

温度管理系统
高压温度系统

Thermal Management System

Coolant Circuit

- 3-way radiator by-pass valve
- Battery coolant pump 1
- PTC coolant heater
- Coolant radiator
- Battery coolant chiller
- Coolant reservoir
- Battery coolant pump 2
- 3-way chiller by-pass valve
- 4-way diverter valve
- Powertrain coolant pump
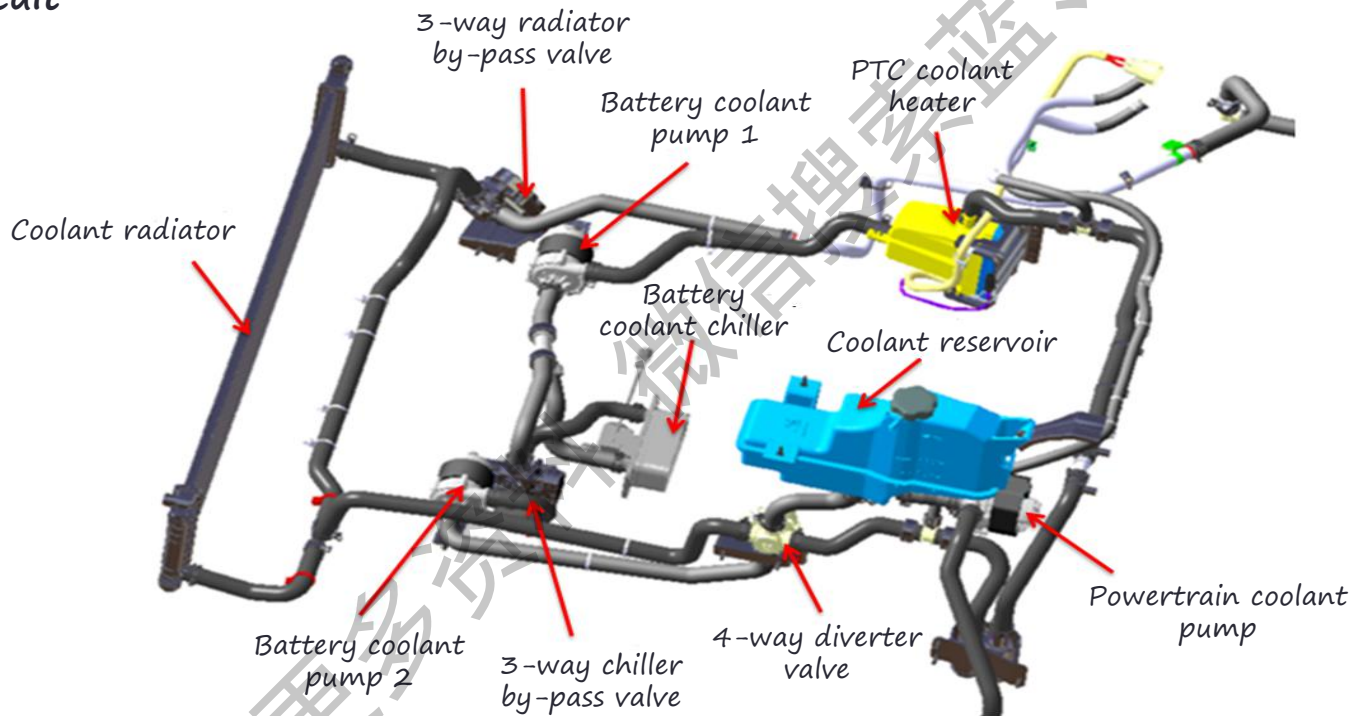
Coolant

The cooling system uses Ethylene Glycol G-48, a long life coolant designed for high aluminum content powertrain systems.

温控管理系统

防冻液回路

防冻液回路示意图：3路旁通阀、高压电池防冻液泵1、PTC 防冻液加热器、水箱、高压电池防冻液冷却器、防冻液储存罐、高压电池防冻液泵2、3路冷却器旁通阀、4路防冻液控制阀、驱动单元防冻液泵
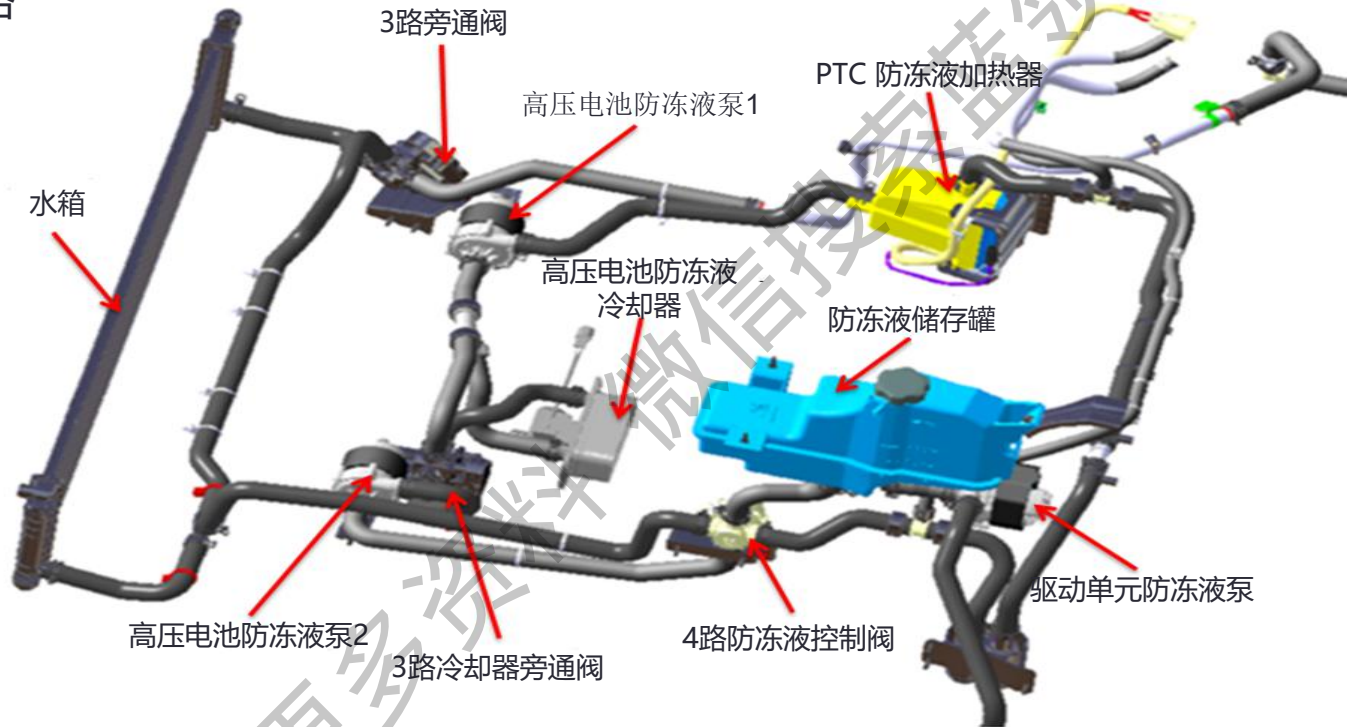
防冻液
冷却系统使用乙烯甘油 G-48, 这种长效防冻液是为铝制发动机设计的.

Thermal Management System

Schematic RWD

Model S
Thermal Management System

Fluid Circuits:
1) Battery Coolant Loop
2) HVAC Cabin and Battery Refrigerant Loop
3) PEM, Charger, & Motor/Transmission Cooling Loop
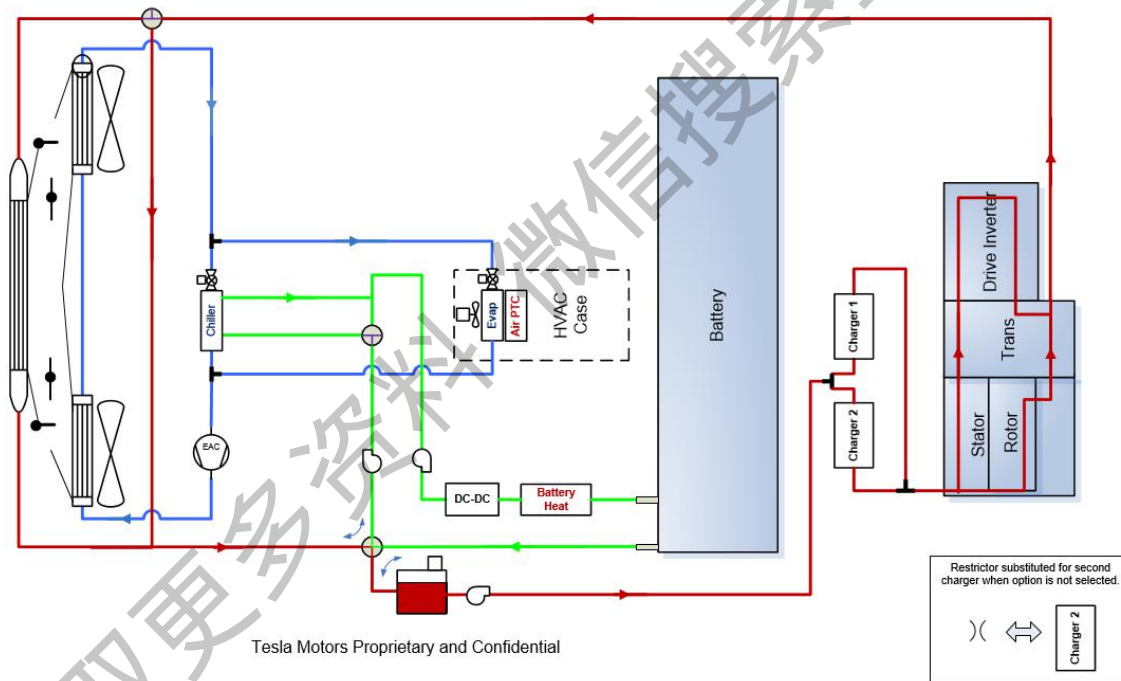
Tesla Motors Proprietary and Confidential

后轮驱动图

Model S
Thermal Management System

Fluid Circuits:
1) Battery Coolant Loop
2) HVAC Cabin and Battery Refrigerant Loop
3) PEM, Charger, & Motor/Transmission Cooling Loop

Tesla Motors Proprietary and Confidential
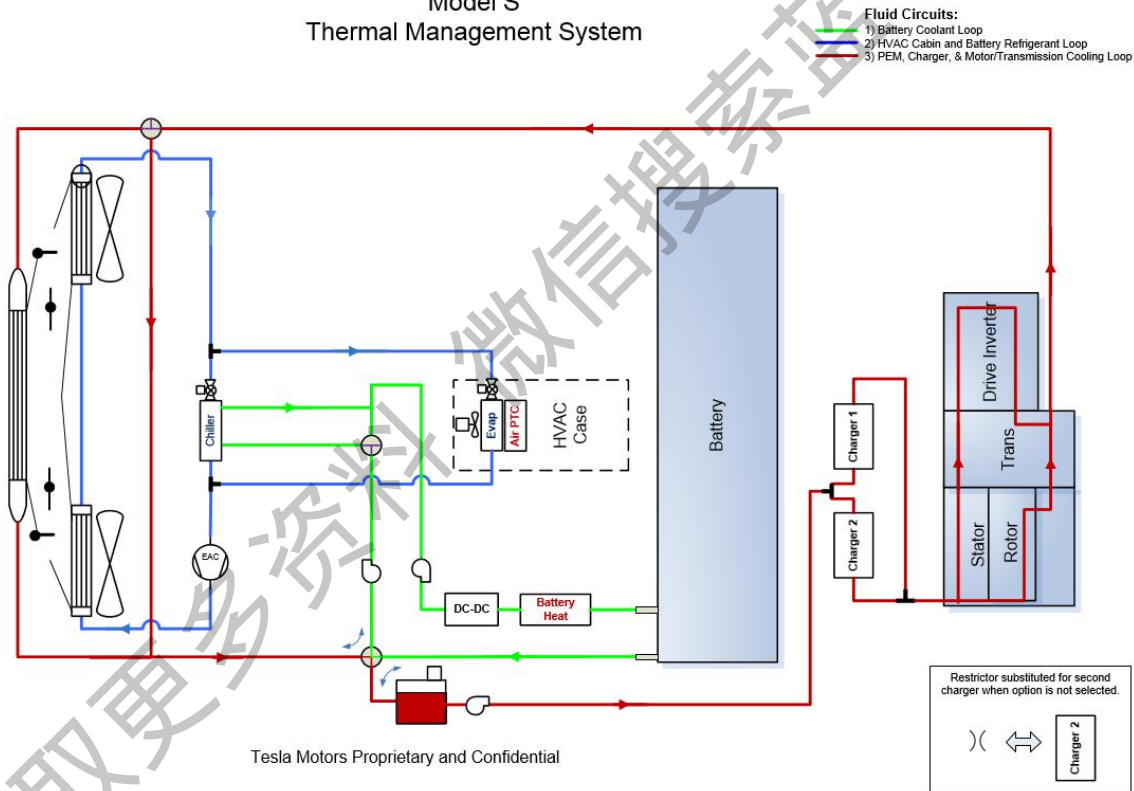
Thermal Management
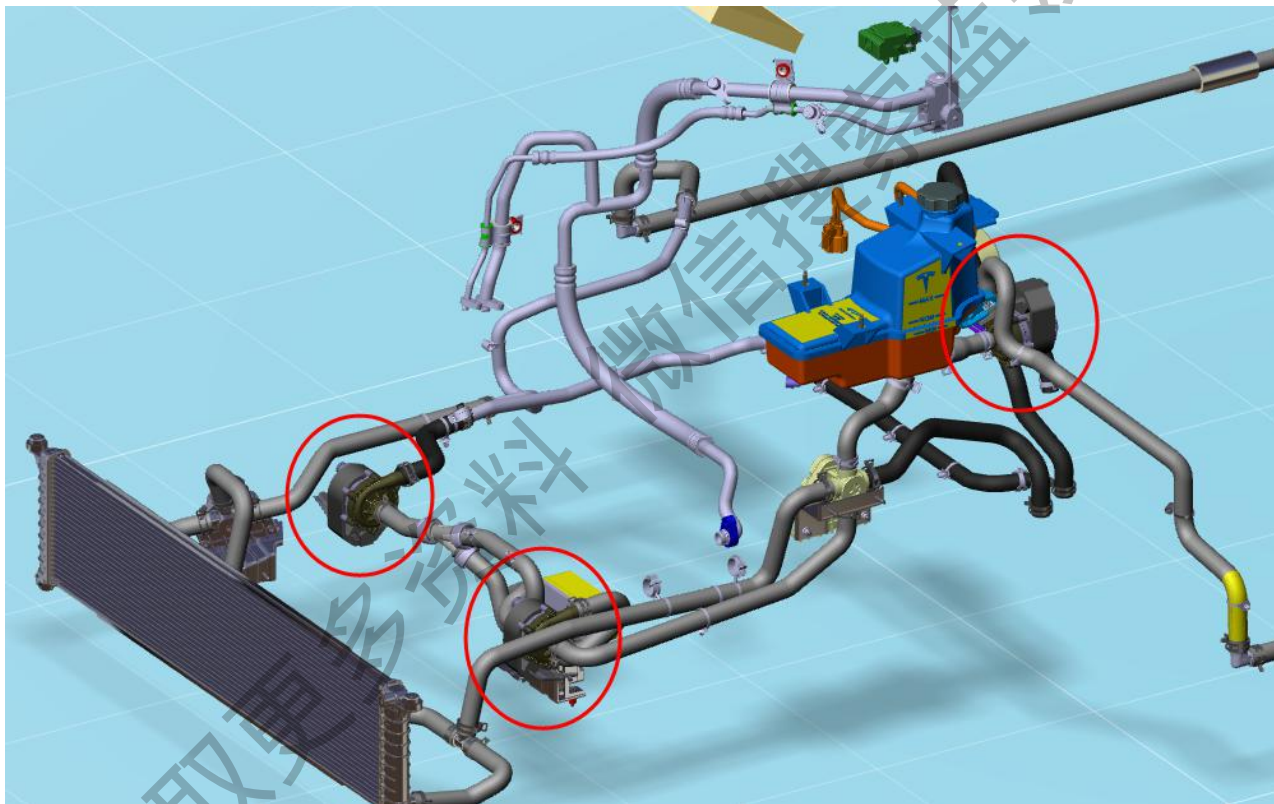
Thermal Management System

Schematic DM (small/small)

- New cooling layout for both motors

- Pump located upstream of front motor, located in the front of the car

Model S Dual Motor
Thermal Management System

Fluid Circuits:
1) Battery Coolant Loop
2) HVAC Cabin and Battery Refrigerant Loop
3) PEM, Charger, & Motor/Transmission Cooling Loop
4) Motor Oil Cooling Loop

Restrictor substituted for second charger when option is not selected.
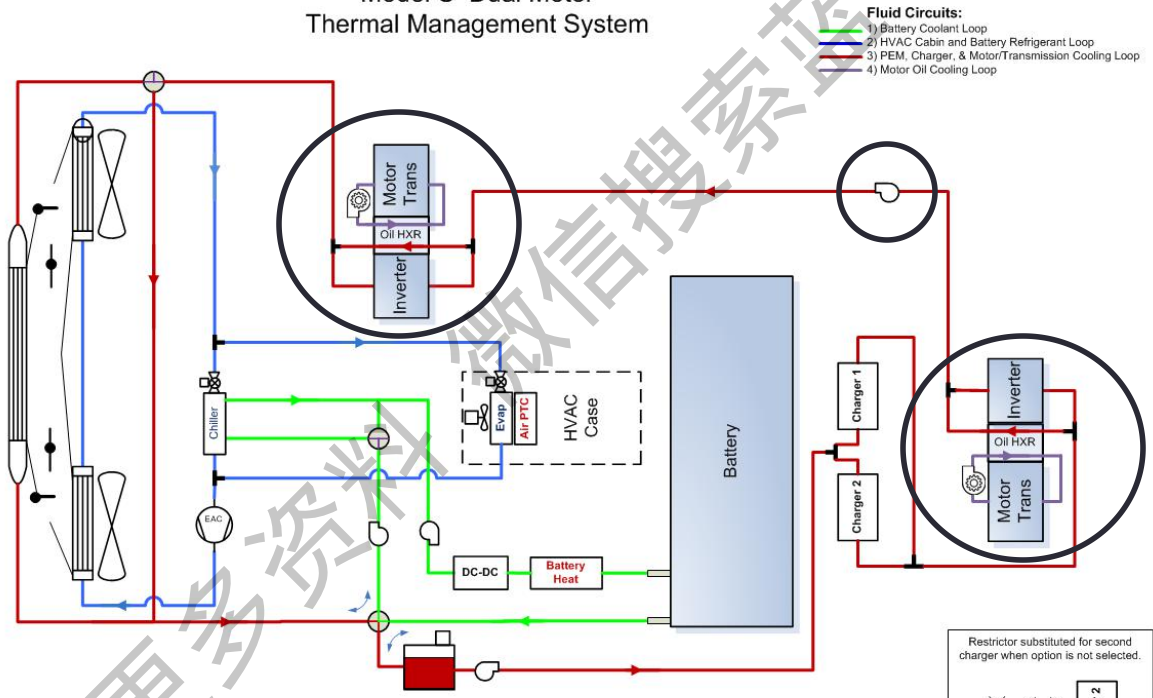
Tesla Motors Proprietary and Confidential

双电机图 (前后皆为小电机)

- 双电机新的冷却系统布置

- 车辆前部电机前方水泵

Model S Dual Motor
Thermal Management System

Fluid Circuits:
1) Battery Coolant Loop
2) HVAC Cabin and Battery Refrigerant Loop
3) PEM, Charger, & Motor/Transmission Cooling Loop
4) Motor Oil Cooling Loop

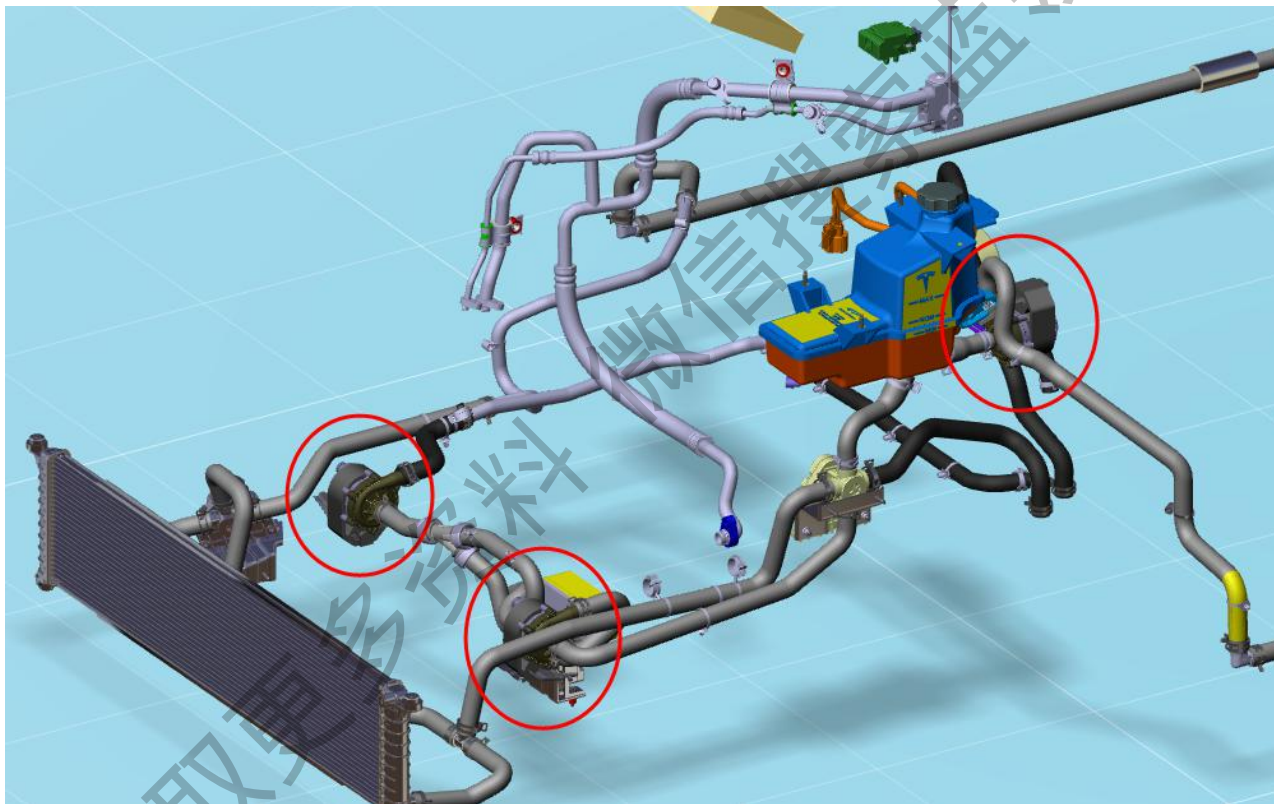Tesla Motors Proprietary and Confidential

Restrictor substituted for second charger when option is not selected.
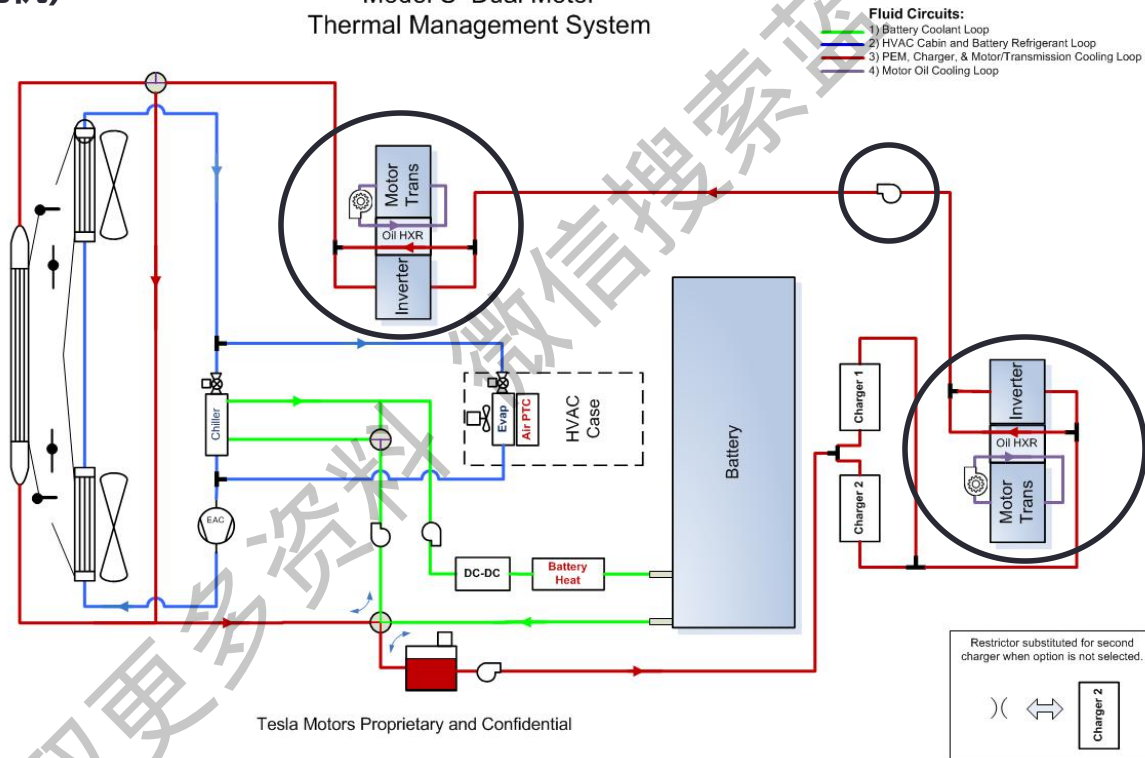
Thermal Management
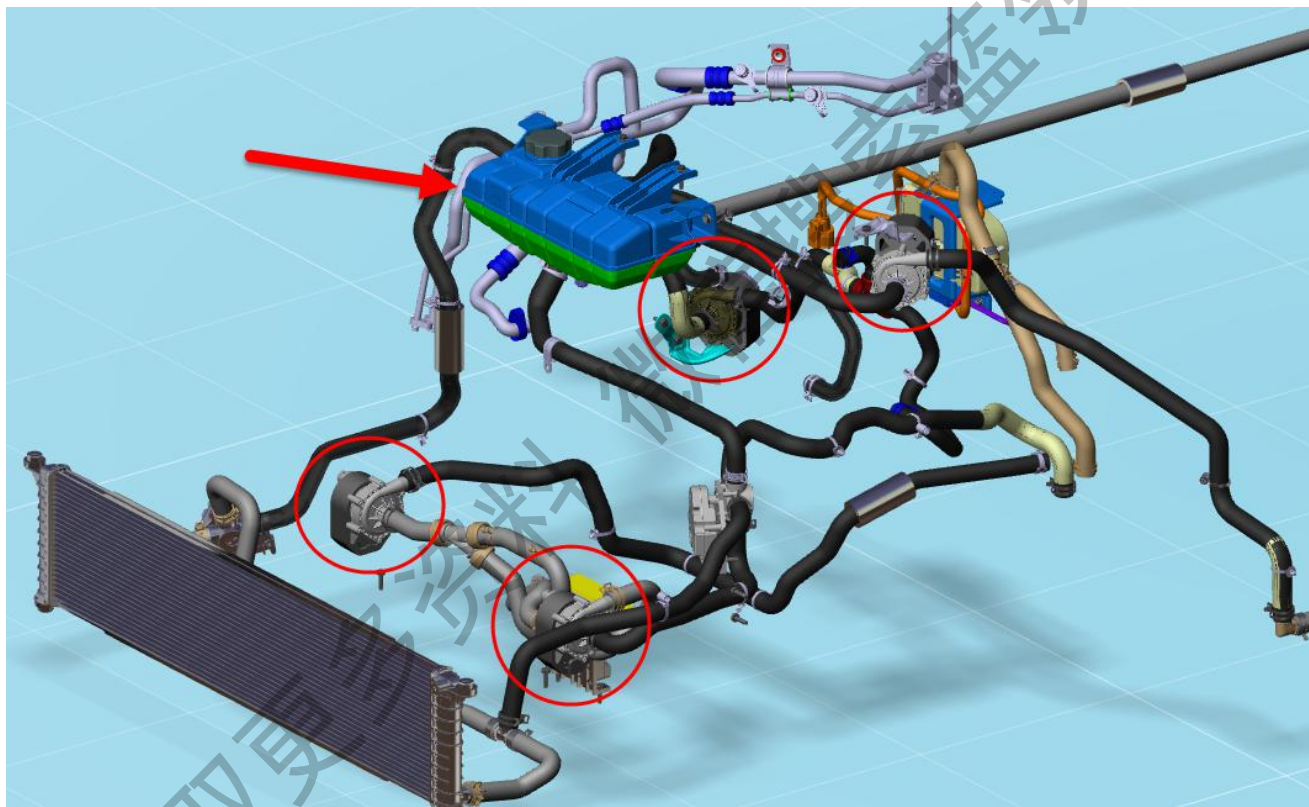
温控管理
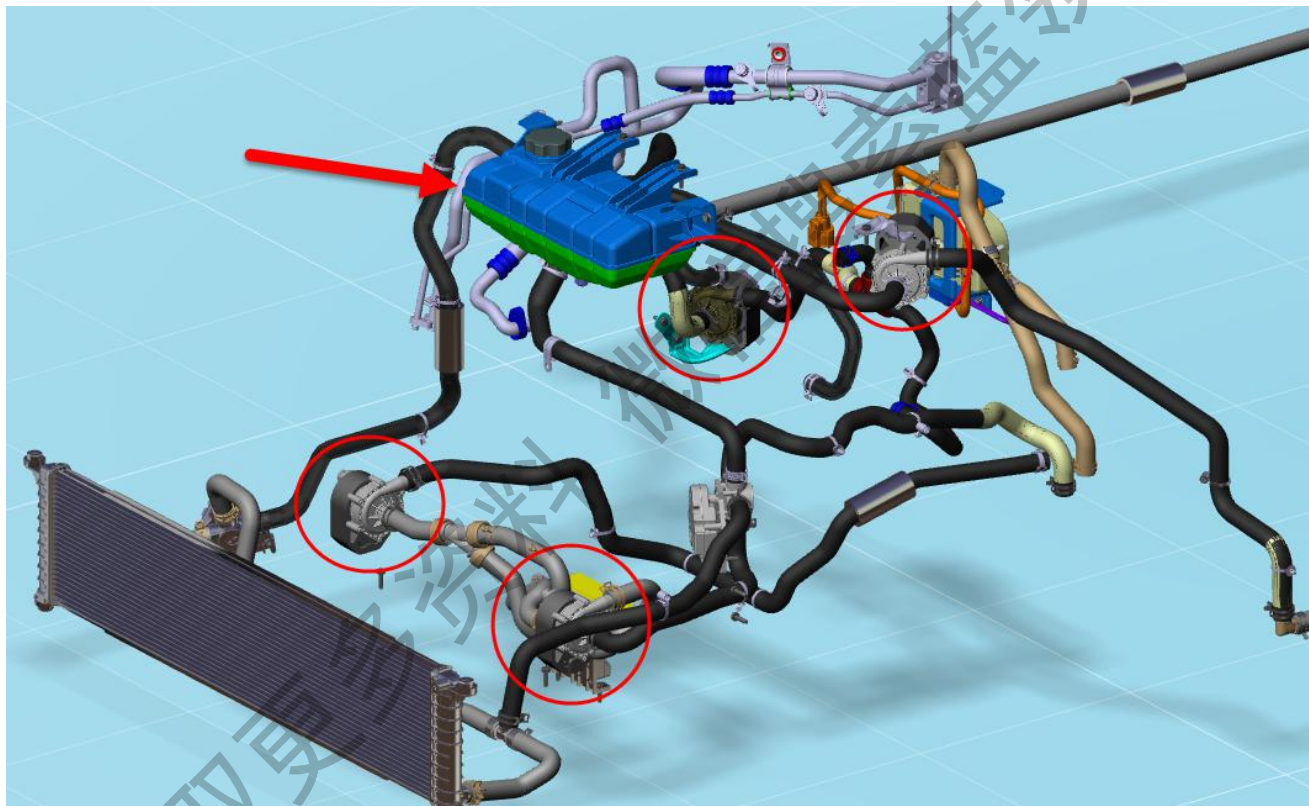
HV Component Temps

Battery operating temperatures
- 40 to 50°C for optimal performance
- >50°C regeneration is limited
- >55°C performance is limited
- HV Battery minimum temperature – 20°C
- HV Battery maximum temperature 60°C
- HV battery coolant capacity 7.7lts
- Coolant: Ethylene Glycol G-48

Drive Unit limiting temperatures
- >180°C (Performance)
- >185°C (Standard)
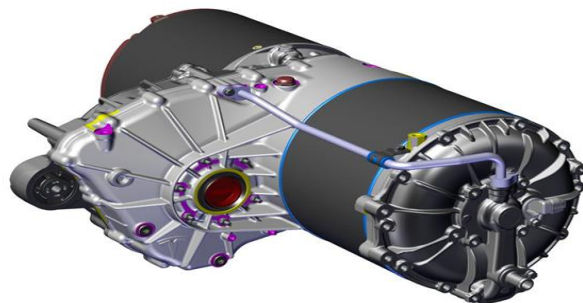
HV 部件温度

蓄电池工作温度
- 40 到 50ºC 是电机最佳性能温度
- >50ºC 能量回收受限
- >55ºC 电池性能受限
- 高压电池最低工作温度是 -20ºC
- 高压电池最高工作温度是 60ºC
- 高压电池冷却液量7.7lts
- 冷却液: 乙二醇G-48

驱动单元性能受限温度
- >180ºC (Performance)
- >185ºC (Standard)
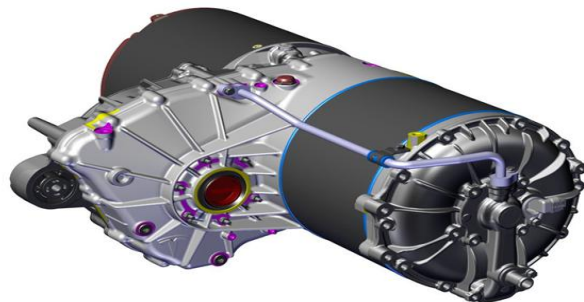
Thermal Management Components

Coolant Circuit

Bypass and Mode Valves
- Bypass valves controls coolant flow through components
- Mode Valves controls the coolant flow strategy
  - Changes from series to parallel cooling circuit

- 4 way Valve
  - Parallel vs. series cooling
  - Mode valve

- 3 Way valve
  - Radiator by pass
  - Chiller by pass

- Uses PWM inputs with inverted analog outputs (feedback)
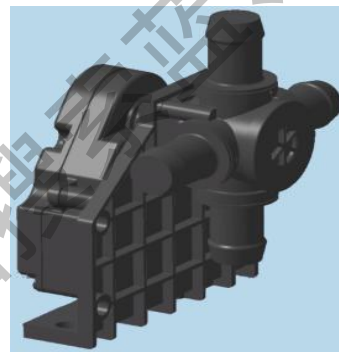
4 Way Valve
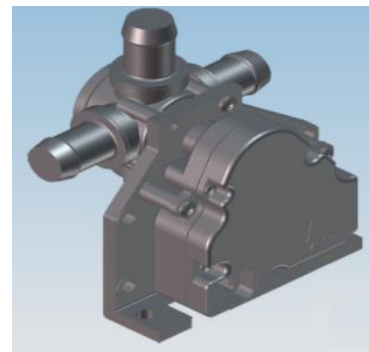
3 Way Valve

温控管理部件

冷却回路

旁通与模式阀

旁通阀控制冷却液流过部件

模式阀控制冷却液的流动策略

　　　改变串联和并联

四通模式阀
　　　并联或串联 冷却（电池和动力环路）
　　　模式阀

三通旁通阀
　　　水箱旁通
　　　冷却器旁通
使用PWM输入与反向模拟输出（反馈）
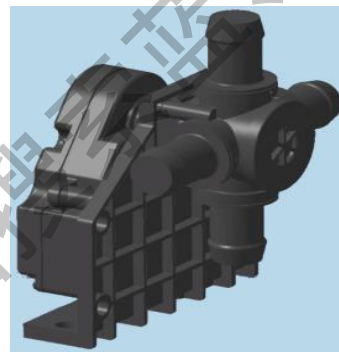
四通阀
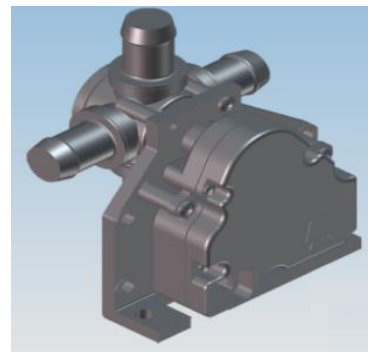
三通阀

Thermal Management Components

Coolant Chiller

- New version of chiller TXV does not have solenoid valve
  - TXV solenoid was deleted
  - THC determines type of system when rebooted or brought up
  - TXV closed do to the lack of energy transfer, reducing the refrigerant flow to a negligible amount.

- If solenoid is disconnected the THC must rebooted to clear DTC. Pull fuse or through the center display.

- Be sure not to disconnect chiller solenoid and reboot THC. This will code the THC to ignore the chiller solenoid once plugged in.
  - This will cause the chiller to fault during thermal tests and during operation.
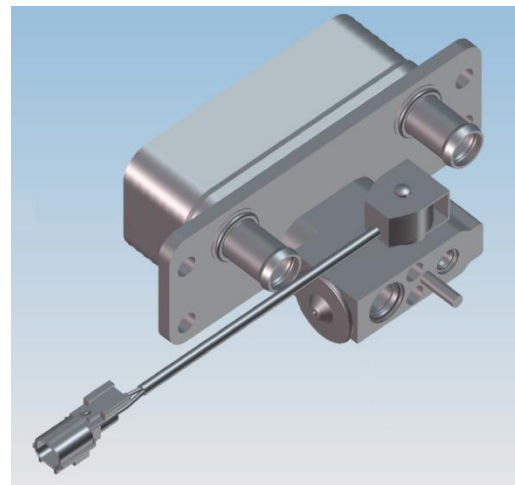
温控管理系统部件
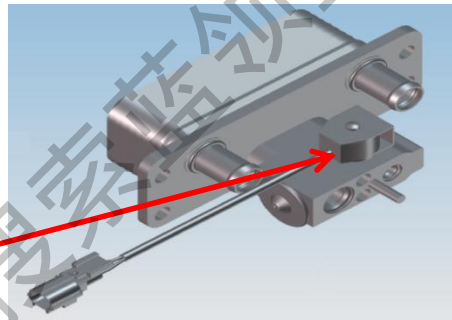
膨胀阀电磁阀

防冻液冷却器

- 新型冷却器膨胀阀没有电磁阀
  - 取消电磁阀
  - 控制模块在启动时决定系统方式
  - TXV在缺乏能量交换时将关闭，制冷剂流量在此时可以忽略不计

- 如果电磁阀断开，THC要重启清故障码，拔保险或从中央显示屏清除。

- 保证冷却器电磁阀不断电并重启THC. 那么在电磁阀重新插入时可能会忽略这个故障码
  ➤ 这样会造成冷却器测试中故障

Thermal Management Components

Battery/Coolant Heater
- Powered and controlled by the DC/DC or Front HVJB (GEN2)
- Fused in DCDC or Front HVJB (GEN2)
- THC commanded
- ON or OFF, not modulated
- Has internal temp sensor
- Coil resistance 37Ω measured at HV+ to HV–
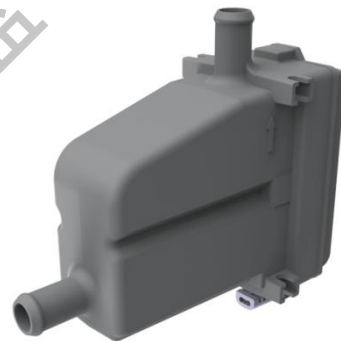
Coolant In-Line Temperature Sensor
- Used to determine coolant temp
- Locations
  - ➢ Battery Inlet Temp Sensor
  - ➢ PT output temp sensor
- NTC style temp sensor
- Known issues
  - ➢ Temp sensor is slow or has delayed signal
    - ○ Replace sensor
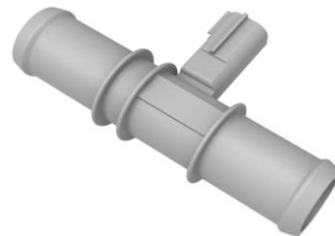
温控管理系统部件

电池/冷却液加热器

- 由DC-DC或前接线盒（二代）高压供电并加以控制
- 前接线盒有保险丝保护
- THC控制
- 使用开关信号，不用PWM信号
- 有内部温度传感器
- 在HV+ 到 HV-测量的线圈电阻是37Ω
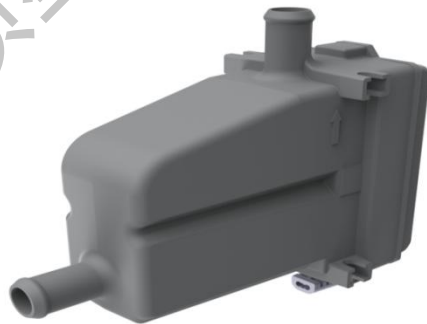
冷却液管路温度传感器

- 测量冷却液温度
- 位置
  - ➢ 电池入口温度传感器
  - ➢ 动力单元出口温度
- NTC 温度传感器
- 已知问题
  - ➢ 信号慢或延时
  - ○ 更换传感器
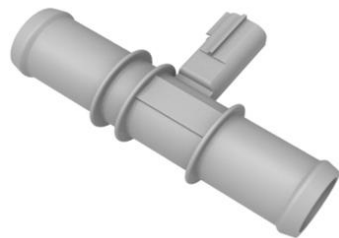
温控管理系统部件
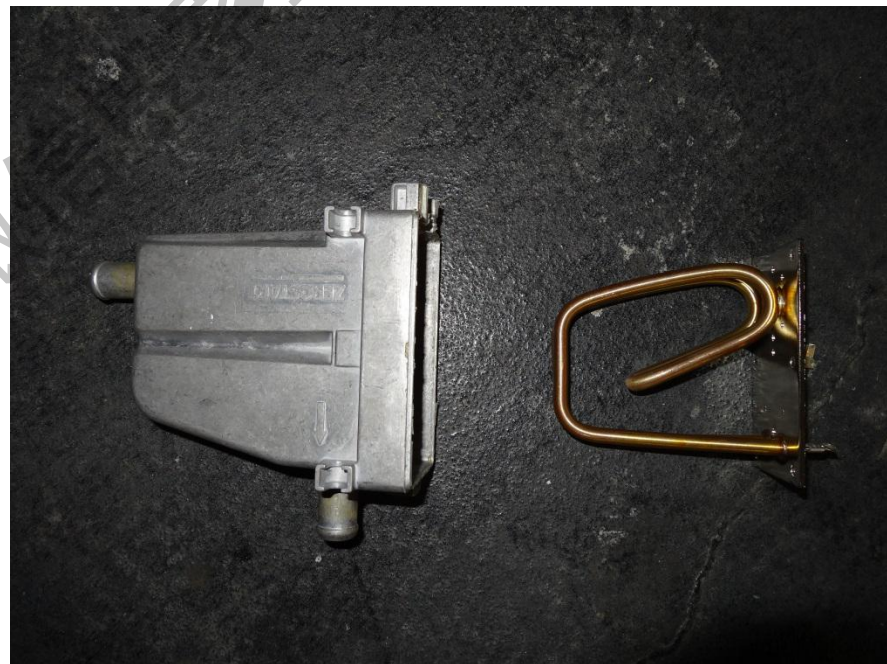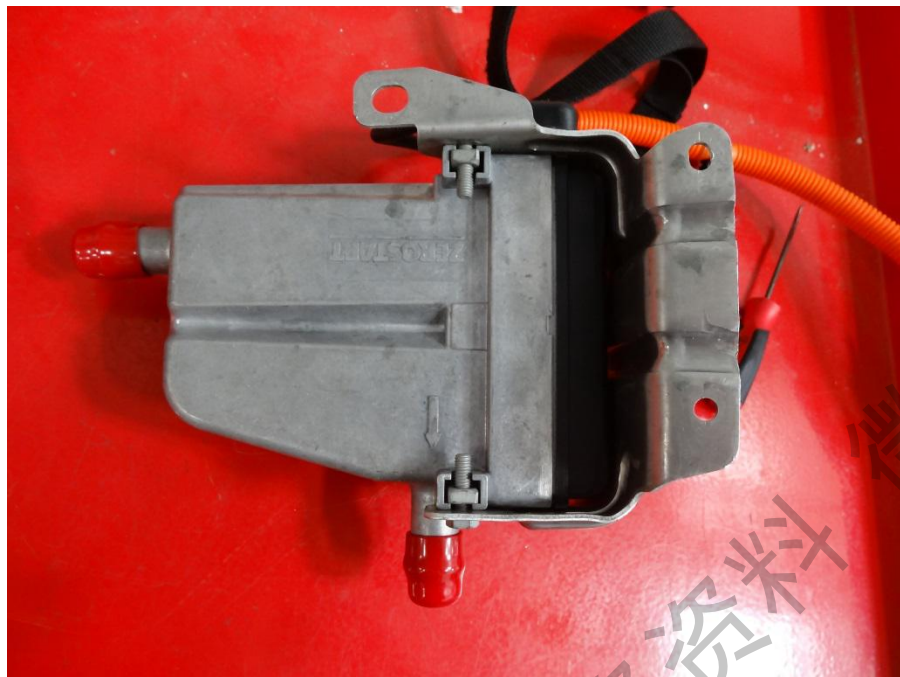
Thermal Management Components

Louvers and Throat Valves
- Louvers are used to control the air flow through the condensers and aero dynamics.
- Throat valves are used to control the air flow through the radiator.
- Drive Motors are addressed and must be in correct position (Lin-Bus signal)
    - Can not swap between different locations
- Must reboot after repairs to clear DTCs
    - Preform louver test after repair.
- After 6th failed attempt the louvers will stop attempting to actuate
- Known issues
    - Broken end stops, feedback fault
        - Replace parts, visually different
    - All louver issues will result in a feedback fault
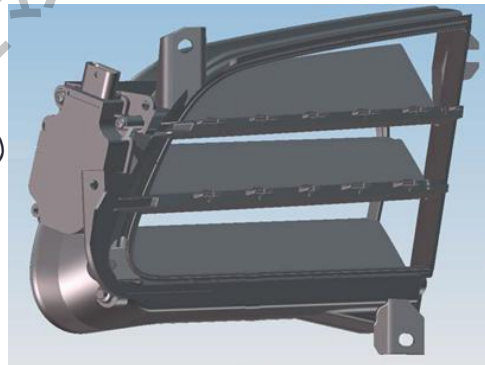
Coolant Pumps
- 3 coolant pumps total
    - Powertrain Pump
    - Battery Pump1 (Passenger side)
    - Battery Pump 2 (Drivers side)
- Pumps have constant fused power
- Feedback signal to THC
- Default is 100% if signal is lost
- All 3 pumps are the same with different mount orientations.

温控管理系统部件

风门与节流阀
- 控制流过冷凝器与水箱的气流
- 改善空气动力特性
- 驱动马达必须初始化，（确认准确位置）(LIN Bus 信号)
  - 不能调换位置
- 维修后重启部件清除DTC
  - 维修后做百风门测试
- 在6次尝试调整风门失败后，风门停止操作
- 已知问题
  - 限位器/花键破损损坏，报故障
    - 更换，外观不同
  - 所有问题有反馈故障
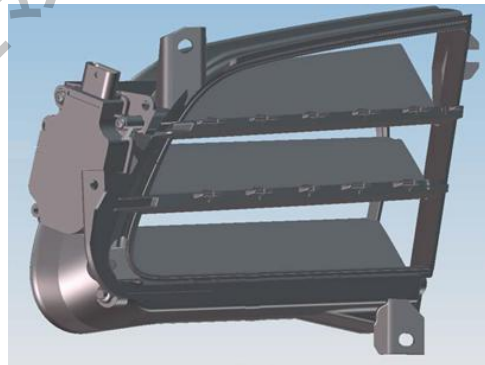
冷却液泵
- 总共3个泵
  - 动力单元泵
  - 电池泵1
  - 电池泵2
- 有保险丝保护持续供电
- 信号反馈到THC
- 一旦信号或THC供电故障，默认 100%运转
- 3个泵一样但安装方向不同

Thermal Management Logic

- Operation of thermal system
- Different modes
  - Battery heat
  - Motor cool
  - Battery cool
- Parameters for modes

Battery & Powertrain Cooling
The heating and cooling system provides heating and cooling to the Powertrain components and the High Voltage battery.

The system uses a 4 way coolant diverter valve that switches the routing of the coolant between series and parallel mode.

Series Mode
Series mode configures the cooling system such that the battery and powertrain are heated or cooled in series, with heat transfer occurring between the two subsystems.

Parallel Mode
In parallel mode the battery and powertrain loops run decoupled from each other and there is no appreciable heat transfer between the two subsystems.

温控管理逻辑

- 温控系统操作
- 不同模式
  - ➢ 电池加热
  - ➢ 电机冷却
  - ➢ 电池冷却
- 模式参数

电池和动力单元冷却

加热与冷却系统保证动力系统与高压电瓶的温度

系统用一个4通模式阀来转换冷却液以串并的路径

串联模式

串联模式把电池和动力部分连在一起。在此模式下热量在两个系统中转换。

并联模式

并联模式把电池和动力系统分开，在此模式下热量在两个系统中不转换。

Thermal Management Logic

Series Mode

温控管理逻辑

串联模式

Thermal Management Logic

Parallel Mode – Battery Loop

Fluid Circuits:
1) Battery Coolant Loop
2) HVAC Cabin and Battery Refrigerant Loop

并联模式–电池回路

Fluid Circuits:
1) Battery Coolant Loop
2) HVAC Cabin and Battery Refrigerant Loop

Thermal Management Logic

Parallel Mode – PT Loop

温控管理逻辑

并联模式–驱动单元回路

Thermal Management Logic

TESLA

HV Inputs to THC

Tesla Motors Model S
Thermal Controls Diagram
Revision: 0.6   Date: 5-Oct-11

Tesla Thermal Controller

BMS
- Battery loop flow rate (LPM)
- Battery loop fluid T$_{IN}$

Inlet fluid T targets: Passive, Active cooling, Active heating
% of maximum flow request
No-flow request
Active heating worthwhile
Discharge power available
SOC
Thermal system active request

Charger
- Powertrain loop flow rate (LPM)
- Powertrain loop T$_{IN}$

Charger magnetic T (single/slave)
Charger heatsink T (single/slave)
Active cooling maximum magnetic T (single/slave)
Active cooling maximum heatsink T (single/slave)
Passive inlet fluid T target (single/slave)
No-flow needed (single/slave)
Charger power available
Thermal system active request (single/slave)

Drive Inverter
- Powertrain loop flow rate (LPM)
- Powertrain loop T$_{IN}$
- Waste Heat Request (0-100%)

Drive inverter T
Stator winding T
PCB T
Mode-dependent active cooling maximum T:
    Drive inverter, Stator winding, PCB
Passive inlet fluid T target
No-flow needed
Flow request (LPM)
Drive inverter dissipation
Waste Heat Mode On/Off

DC/DC
DC/DC Coolant request
DC/DC over-temperature
DC/DC thermally limited
Alerts/Faults

Battery heater duty cycle

电池输入到*THC*

Tesla Motors Model S
Thermal Controls Diagram
Revision: 0.6   Date: 5-Oct-11

BMS

Battery loop flow rate (LPM)
Battery loop fluid T$_{IN}$

Inlet fluid T targets: Passive, Active cooling, Active heating
% of maximum flow request
No-flow request
Active heating worthwhile
Discharge power available
SOC
Thermal system active request

Charger

Powertrain loop flow rate (LPM)
Powertrain loop T$_{IN}$

Charger magnetic T (single/slave)
Charger heatsink T (single/slave)
Active cooling maximum magnetic T (single/slave)
Active cooling maximum heatsink T (single/slave)
Passive inlet fluid T target (single/slave)
No-flow needed (single/slave)
Charger power available
Thermal system active request (single/slave)

Tesla Thermal Controller

Drive Inverter

Powertrain loop flow rate (LPM)
Powertrain loop T$_{IN}$
Waste Heat Request (0-100%)

Drive inverter T
Stator winding T
PCB T
Mode-dependent active cooling maximum T:
    Drive inverter, Stator winding, PCB
Passive inlet fluid T target
No-flow needed
Flow request (LPM)
Drive inverter dissipation
Waste Heat Mode On/Off

DC/DC Coolant request
DC/DC over-temperature
DC/DC thermally limited
Alerts/Faults

DC/DC

Battery heater duty cycle

Thermal Management Logic

Series Mode – Battery Heat-Up:

- During cold driving conditions, Coolant flowing through the powertrain is heated, it bypasses the radiator and is transferred into the battery warming the battery cells.

- In the event that additional heating is required, the high voltage coolant heater can be activated to provide additional heat to the coolant just prior to entering the battery.

Series Mode – Reduced Cooling Energy:

- Series-mode is also an effective configuration when used in low ambient temperatures.

- This allows cooling of battery and Powertrain, using only the radiator, without the need for operating the A/C compressor and chiller system for battery cooling.

Series Mode – High Ambient Powertrain Cooling:

- In extremely hot conditions when the radiator cooling of the powertrain is limited, the battery can act as a thermal capacitor to absorb powertrain heat and allow the motor to run cooler, therefore more efficiently.

- This is only effective until the battery temperature exceeds its thermal limits. To extend the high temperature operation, the chiller and A/C compressor can be engaged to chill coolant going to the battery and the powertrain components.

温控管理逻辑

串联模式—电池加热

在寒冷天气下驾驶，冷却液流过动力单元被加热，在并通过水箱流进电池给电池加热
在某些条件下，加热器工作加热冷却液，再流进电池。

串联模式—减少冷却能耗

串联模式在环境温度不高时高效地冷却。可以用水箱冷却，而不需空调额外冷却。

串联模式—高温下动力单元冷却

在极热情况下，电池可以吸收动力单元的热量使得电动机保持适合的温度，这样比较高效。

直到电池温度到达限值，其余热量通过Chiller冷却来保持电池与动力单元的温度。

Thermal Management Logic

Parallel Mode:

- Parallel-mode allows the most efficient use of the radiator for powertrain cooling because the powertrain coolant can run at much higher temperatures than the battery coolant.

- For example, if the battery requires cooling but the powertrain does not, the battery coolant chiller system can be activated solely to cool the battery. Also, in cold ambient conditions the battery coolant heater can be activated to heat the battery without heating the powertrain components.

- Parallel mode is also used for cooling the chargers during charge mode without affecting the battery temperature.

并联模式

并联模式允许动力单元冷却液用水箱高效冷却，因为动力单元可以比电池温度高。

例如，电池需冷却，但动力单元不需，电池冷却单独流过Chiller，或冷却液流过加热器加热来加热电池而动力单元不用。

并联模式也用于冷却charger，在充电时不影响电池温度。

Thermal Management Service

Coolant drain and fill
- Toolbox function
- Used when draining or filling the coolant circuit
- Opens all valves to 50% so that all the coolant can be drained / filled
- Do not drive car while in this function
  - ➢ Pumps will not run
- Drain / Fill will be exited when put in drive or charge
- Will report fault if valves do not operate correctly

Coolant purge
- Removes air from the system
  - Three 5 min steps
    - ➢ (5 min) Series, radiator 100%, chiller 100%, pumps 100% **most coolant flow**
    - ➢ (5 min) Series, Radiator 0 %, chiller 0%, pumps 100%
    - ➢ (5 min) Parallel, radiator 100%, chiller 100%, pumps 100%
  - Don't dive car while in purge mode.
  - May over heat do to improper coolant flow
- May have to run purge several time if HV battery is empty.
- Run any time the coolant system is opened or drained
- Be care not to burn up pumps if pumps are cavitating or have air pocket.

Note: *HV battery must be pre-filled with coolant prior to installation.*

温控系统管理维修模式

冷却液排放和加注

- 相应的Toolbox功能
- 当防冻液排放或加注时使用
- 把所有阀打开50%，这样防冻液排放和加注更加彻底
- 该功能运作时时不要驾驶车辆
  - 冷却液泵不转（D档）
- 当车进入驾驶状态或充电模式此功能退出
- 当阀操作异常时将报故障码

冷却液排气

- 系统排气
  - 排气过程3个步骤每个步骤持续5分钟
    - （5 分钟）串联,水箱100%， 冷却器100%， 泵100% 最大流量
    - （5分钟）串联，水箱0%， 冷却器0%， 泵100%
    - （5分钟） 并联， 水箱100% 冷却器100%，泵100%
  - 不要在排气时驾驶汽车
  - 可能造成过热因为不合适的冷却液流
- 如果电池没电的话可能要多做几次排气
- 使用真空加注的话更好。
- 只要冷却系统开放或排空需要运行该操作
- 不要烧泵（水泵中有气室）

注意：安装前电池一定要加注冷却液。

Thermal Management Service

Thermal Test

- Can be used to test entire thermal system operation
  - **Coolant Temp Sensor Test**
    - ➢ Checked 10 seconds after the thermal test is started
    - ➢ must be 15-30°C to start test
  - **Refrigerant Suction Pressure Test**
    - ➢ Checked 10 seconds after the thermal test is started
    - ➢ Must be 2-10 Bar
  - **Coolant Valve Test**
    - ➢ Checked 20 seconds after the thermal test is started
    - ➢ Test moves the radiator bypass valve to the 100% bypass position and monitors the valve feedback.
  - **Cooling Fan Test**
    - ➢ Checked 20 seconds after the thermal test is started
    - ➢ The thermal controller sends a request of 100%
  - **Cooling Pump Test**
    - ➢ checked 30 seconds after the thermal test is started
    - ➢ Test runs battery coolant pump 1, battery coolant pump 2 and the powertrain coolant pump at 1%, 50% and 100% speed and monitors the pump feedback.

温控测试

- 能够用来测试整个温控系统
  - 冷却温度测试
    - 测试启动后检查10秒
    - 温度要求15-30*C
  - 制冷剂吸入压力测试
    - 温控测试后启动后检查10秒
    - 系统压力必须2-10bar
  - 冷却液阀测试
    - 启动后检查20秒
    - 测试水箱旁通阀100%打开后检测阀门位置。
  - 冷却风扇测试
    - 测试开始后检查20秒
    - 控制模块发送100%信号
  - 冷却水泵测试
    - 检查开始后测试30秒
    - 测试电池水泵1，2，动力单元水泵用1%， 50%和 100%速度运转然后检查泵的反馈。

Thermal Management Service

Thermal Test Continued

- **Evaporator Test**
  - ➤ Checked 180 seconds after the thermal test is started
  - ➤ Test looks for the duct temperatures to be below certain thresholds
    - ○ RCCM_LeftVentDuctSnsRaw_DegC – must be less than 16°C
    - ○ RCCM_RightVentDuctSnsRaw_DegC – must be less than 16°C
    - ○ RCCM_LeftFloorDuctSnsRaw_DegC – must be less than 16°C
    - ○ RCCM_RightFloorDuctSnsRaw_DegC – must be less than 16°C
    - ○ RCCM_DefDuctSnsRaw_DegC – must be less than 21°C
    - ○ RCCM_EvapSnsRawHighRes – must be less than 8°C
- **Battery Heater Test**
  - ➤ Checked 180 seconds after the thermal test is started
  - ➤ Test runs the battery heater for 60 seconds and looks for the battery inlet coolant temperature increase by at least 2°C and the battery heater surface temperature to increase by at least 4°C during that period.
- **Chiller Test**
  - ➤ Checked 270 seconds after the thermal test is started
  - ➤ The test sends a chiller request to the Thermal controller and looks for the battery inlet temperature to decrease by at least 7°C.
- **Recommended after all thermal / HVAC repairs**
- **Clears DTC when done**

温控系统管理维修模式

- 蒸发箱测试
    - 测试开始后测试180秒
    - 测试查看以下通风管的温度限值
        - 空调左侧通风管低于16°C
        - 空调右侧通风管低于16°C
        - 空调地板左侧通风管低于16°C
        - 空调地板右侧通风管低于16°C
        - 空调除雾风口低于21°C
        - 空调蒸发箱传感器低于8°C

    - 电池加热测试
        - 测试开始后检查180秒
        - 测试时电池加热器工作60秒，然后测试冷却液电池人口至少提升2°C，电池加热器表面至少提升4 °C
    - 冷却器测试
        - 温控系统测试开始后持续270秒
        - 测试时向Daimler CPC发一个冷却器请求給 然后检查电池进口的温度应至少下降7 °C 。
- 最好在 空调系统和温控系统维修之后做这个测试
- 完成测试后后清除DTC

Thermal Management Service

Louver and throat test

- Will operate and test all the louvers and throat valves
- Will fault out if not operating properly
- Can be used in diagnosis and testing of louvers / throat valves
- Great way to activate louvers when they would not normally function

温控系统管理维修模式

- **风门测试（现在测试风门不动）**
    - 会操作所有的百叶窗与节流阀
    - 如果操作不正确会报故障
    - 可用于测试百叶窗和节流阀
    - 当风门不能正常工作时，可以用这个操作是个不错的选择。