

Theoretical research and practical application of electric heating and steam heating technology for vulcanization machines

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Abstract: This paper addresses the problems of heat loss, uneven temperature distribution, and high investment and maintenance costs in the traditional steam heating of tire vulcanizing machines. It conducts a comparative analysis of the heat calculation, cost consumption and social benefits between electric heating and steam heating for vulcanizing machines, and elaborates on the power configuration and component structure design scheme of the electric heating technology developed by Qingdao Mesnac. This technology can achieve significant energy conservation and cost reduction, and shorten the plant construction cycle. Though there are still limitations in temperature control at the current stage, the technology has become mature and been applied in actual production. In line with the development direction of clean energy, it boasts broad application prospects in the future.

Key words: curing press; electric heating; hot plate; mold sleeve; external temperature steam; internal temperature steam

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1 R&D background

Tire curing is the final process in the tire production process and one of the processes that determine the quality of finished tires. Various tire machinery manufacturers are competing to develop tire vulcanizing presses with good performance and reliability. Especially in the past 30 years, the development and production of domestic tire vulcanizing presses have embarked on a rapid development path. Since the introduction of vulcanizing press technology in China in the 1980s, domestic vulcanizing press manufacturers have fully mastered technical aspects such as structure and process, driving the advancement of vulcanizing press technology. However, from a comprehensive perspective, mechanical or hydraulic vulcanizing presses are all improvements aimed at equipment power and vulcanization pressure. As for temperature, one of the three essential elements of vulcanization, it has been influencing and determining the development of tire vulcanizing presses, and steam heating has been used continuously until now. Currently, the medium used to provide temperature for vulcanizing presses at home and

abroad is mostly steam. The problems of heat loss, leakage, and uneven internal/external temperature during steam heating have been plaguing host machine manufacturers and end users, and the investment in equipment manufacturing and production use is also relatively large. Steam is produced by boiler heating, and tire factories need to calculate the construction investment of boilers, pipeline installation, and material investment at the initial stage of factory construction. At the same time, because steam is easily condensed into water, causing heat loss, a large amount of insulation measures need to be preset, which is a major investment in tire factory construction projects. During the vulcanization production process, high-temperature steam has a significant impact on pipelines, valves, seals, etc. Maintenance departments need to prepare a large number of spare parts, and the replacement process is extremely laborious

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in a high-temperature environment.

In summary, if there is a technology that can replace steam to provide qualified temperature transmission for the curing press, it can reduce the upfront investment in tire manufacturing projects, ease equipment maintenance, and improve the uniformity of internal and external temperatures, thereby effectively enhancing the quality of tire products. Alternative heating methods such as electric heating, oil heating, and electromagnetic heating have become viable options to replace steam heating. MESNAC Electromechanical Engineering Co., Ltd., in response to market demand and the development of clean energy, has long been paying attention to and participating in research and development teams. Currently, the company has achieved excellent results in the field of electric heating, ranging from theoretical research to practical applications, and has made a name for itself in the market.

2 Comparison of theoretical calculation values and practical values for electric heating and steam heating

Although the heating methods have changed from electric heating to steam heating, the structural components used for tire vulcanization heating remain unchanged. Therefore, the loss of thermal energy mainly includes external temperature loss, which involves the upper and lower hot plates and molds, and internal temperature loss, which involves the thermal energy loss of the central mechanism medium.

Electric heating technology involves the direct generation of heat energy from electric energy through certain forms of electric heating elements, replacing the traditional steam heating method for the hot plates of curing presses. This eliminates auxiliary structures such as steam generation devices, conveying pipelines, and power sources, thereby shortening the factory construction period, reducing equipment investment, and improving heat energy utilization efficiency. There are two parts of the curing press that require heat energy for tire curing: external temperature heating and internal temperature heating of the tire blank. External temperature heating is divided into two parts: ① external temperature heating of the mold, including the upper and lower hot plates; ② heating of the mold sleeve. Internal temperature heating

mainly involves the transfer of heat energy to the tire blank through the central mechanism of the curing press (see Figure 1).

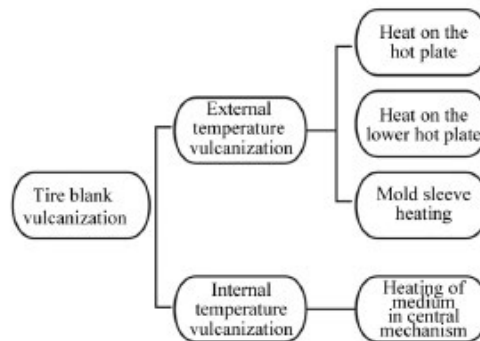


Figure 1 Tire blank vulcanization heating components

2.1 Relevant calculations regarding steam heat

During the tire vulcanization process, the external heat conduction process involves: steam → hot plate cavity (mold cavity) → upper and lower molds, tread blocks → raw tire blank; the internal heat conduction process involves: steam → capsule cavity → raw tire blank.

2.1.1 Relevant calculations regarding external temperature consumption

The external temperature consumption of the curing press mainly includes the hot plate and the mold sleeve, with a simplified expression of the cross-sectional area of the hot plate and the mold sleeve (See Figure 2 and Figure 3).



Figure 2 Sectional view of the hot plate

The dimensions of the hot plate mold sleeve of the curing press vary with different specifications and models of the curing press. Taking the 51" curing press as an example (see table 1).

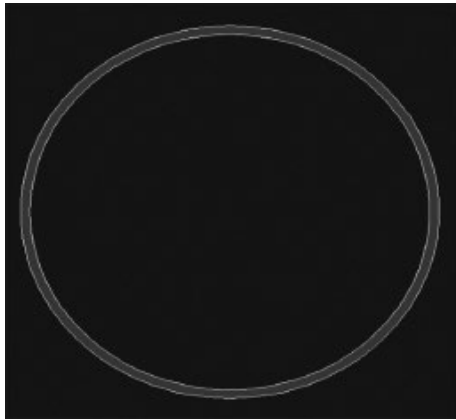


Figure 3 Sectional view of the mold sleeve

Table 1 Parameters of 51-inch curing press hot plate mold capsule

name	geometric tolerance	numerical value	unit	Remarks
hot plate	Diameter d	1.3	m	
	Height h	0.04	m	
	Area s	0.58	m ²	
	volume v ₁	0.023	m ³	
Mold sleeve	diameter d _{max}	1.2	m	
	height h _{max}	0.047	m	
	area S _{max}	0.12	m ²	
	volume	0.054	m ³	
capsule	diameter	0.9	m ²	
	height	0.36	m	
	volume v ₃	0.23	m ³	

Steam is continuously introduced into the interior of the hot plate and the interior of the mold sleeve → the mass flow rate is equal to the mass of steam in the hot plate or mold sleeve during any given time period.

Steam heat calculation formula $\Phi = qh_s$

q —Steam mass in the cavity, Kg

Table 3 Comparison table of internal temperature steam pressure/temperature/density/specific enthalpy

Absolute pressure / MPa	Temperature t/°C	Density ρ	Specific volume v ⁺ /(m ³ ·kg ⁻¹)	Specific enthalpy h ⁻ /(kj·kg ⁻¹)
1.90	209.797	9.556	0.104 650	2 796.10
2.00	212.375	10.047	0.099 536	2 797.20
2.10	214.855	10.539	0.094 890	2 798.20

Based on the internal vulcanization temperature of 210°C (if there is a temperature drop after the process temperature inside the capsule, condensate will be discharged + steam will be supplied for temperature rise, meaning that there is always 210°C steam inside the capsule), the table shows:

Density: 9.556 kg/m³

Mass of warm steam inside the capsule: $m_{\text{capsule}} = \rho v = 9.556 \times 0.23 = 2.2$ kg;

Specific enthalpy: 2 796.1 kJ/kg

h_s —Specific enthalpy of steam at a certain temperature and pressure, KJ/Kg (see table 2).

Table 2 Comparison table of external temperature steam pressure/temperature/density/specific enthalpy

Pressure absolute bar	Saturation temperature/°C	Steam density (in kg/m ³)	Steam specific enthalpy (Hg)(kj·kg ⁻¹)
9.6	178.15	4.948	2 776.18
9.7	178.60	4.997	2 776.58
9.8	179.04	5.046	2 776.98
9.9	179.48	5.095	2 777.36
10	179.92	5.144	2 777.75
10.1	180.35	5.194	2 778.12

According to the table, at a vulcanization external temperature of 180 °C, we find that:

Steam density: 5.194 Kg/m³;

Steam mass on the hot plate: $m_{\text{hot}} = \rho v = 5.194 \times 0.023 = 0.12$ kg;

Steam conditioning of the mold sleeve: $m_{\text{mold}} = \rho v = 5.194 \times 0.054 = 0.28$ kg;

Steam specific enthalpy: 2,778.12 kJ/kg;

The heat quantity of the hot plate $\Phi_{\text{heat}} = qhs = 0.12 \times 2778.12 = 334.51$ kJ;

The heat quantity of the mold sleeve $\Phi_{\text{mold}} = qhs = 0.28 \times 2778.12 = 778.60$ kJ.

Each unit of curing press has 2 hot plates,

The external temperature of vulcanization Φ_1 is equal to Φ_{heat} multiplied by 2 plus Φ_{mold} , which equals $334.51 \times 2 + 778.60 = 1 447.62$ kJ.

2.1.2 Related calculations on internal temperature consumption

Calculation of internal temperature of sulfurized steam:

$\Phi_2 = qh_s = \rho v h_s = 2.2 \times 27 96.1 = 6151.42$ kJ;

The total heat provided by the external and internal temperatures during vulcanization is $\Phi = \Phi_1 + \Phi_2 = 1,447.62 + 6,151.42 = 7,599$ kJ.

Theoretical calculation of heat demand for tire vulcanization:

$$Q_x = c \cdot M \cdot \delta_t$$

Q_x —Heat, J;

c —specific heat capacity of rubber, J/kg°C;

M —Mass (kg), 15 kg for 51-inch semi-steel tires

δ_t —For the increased (decreased) temperature (°C), the specific heat capacity of rubber is: instantaneous value 1,700 J/kg·°C, average value 1,275 J/kg·°C, (calculated based on the highest value), temperature range: from 0°C to 210°C, then $\delta_t=210^\circ\text{C}$.

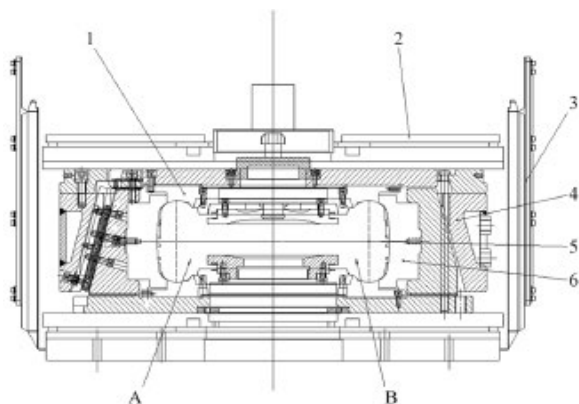
$$Q_x = c \cdot m \cdot \delta_t = 1\,700 \times 15 \times 210 = 5\,355\,000 \text{ J} = 5\,355 \text{ kJ}$$

Steam heat loss (excluding pipeline loss):

$$\eta = \frac{\Phi - \Phi_x}{\Phi} \times 100\% = \frac{7\,599 - 5\,355}{7\,599} = 29.53\%$$

2.2 Calculation of heat quantity for electric heating in tire vulcanization

Electric heating is used to simulate the calculated heat for vulcanized tires, and the required heat distribution of the electric heating components is shown in figure 4.



1-Upper airbag; 2-Heat shield; 3-Outer insulation layer; 4-Tire mold;
5-Capsule; 6-Tire
A: Steam inlet; B: Steam and water outlet

Figure 4 Cross-sectional view of the structure of the electric heating component

In electromechanics, $1\text{J}=1\text{W}\cdot\text{s}$ represents the energy released when a current of 1A flows through a resistor of 1Ω for 1 second;

Semi-steel tire curing time:

$$15 \text{ min} = 0.25 \text{ h} = 900 \text{ s}$$

Based on the high-value heat calculation of 7,599 kJ from steam heating,

Formula: Power required for the green tire to reach the optimal vulcanization time:

$$P = \frac{7\,599 \text{ kJ}}{900 \text{ s}} = 8.4 \text{ kW}$$

Preliminary estimation shows that it takes 8.4 kW to vulcanize one tire.

The above calculation is under ideal conditions, and the actual problem to be solved is:

Preheat to process temperature externally: upper and lower molds at 180°C (heated by hot plate), pattern blocks at 180°C (heated by mold sleeve), maintaining a temperature difference of $\pm 2^\circ\text{C}$;

When the internally heated nitrogen enters the capsule, it needs to quickly reach the process temperature of 210°C within 20 s;

After the secondary vulcanization, the temperature should be maintained at a process temperature of 210°C for the first 5 minutes;

Hot plate, mold sleeve, internal temperature nitrogen, power required to reach temperature, and temperature control module;

2.2.1 Regarding the calculation of internal temperature of tire electric heating

According to the maximum tire size for 51-inch vulcanization: (see table 1 above)

Sulfurization internal pressure is 2.5MPa, and internal temperature is 210°C (converted to $210+273=483\text{K}$), both provided by nitrogen gas;

$$\text{Equation of state for ideal gas: } pV = nRT$$

p —pressure (Pa),

V —gas volume (m^3),

T —Temperature (K),

The amount of substance (mol) of n-gas,

R —Molar gas constant ($\text{J}/(\text{mol}\cdot\text{K})$)

If the gas is an ideal gas with a mass of m and a molar

mass of M , and $n = \frac{m}{M}$, its state equation can be expressed as:

$PV = nRT = \frac{m}{M} \cdot RT$ calculation. The value of R in the formula is related to the units of the state parameters. In the International System of Units (SI), $R = 8.314\text{J}/(\text{mol}\cdot\text{K})$.

According to the table, the molar mass of nitrogen is $M = 28 \text{ g/mol}$.

(1) Mass of nitrogen gas inside the capsule

From: Ideal gas equation:

$$PV = nRT = \frac{m}{M} \cdot RT, \text{ we can derive: gas mass}$$

$$m = \frac{PV\mu}{RT} \left(\frac{\text{Pa}\cdot\text{m}^3\cdot\text{gmol}}{\text{J}\cdot\text{K}} \right) = \frac{2.5 \times 10^6 \times 0.23 \times 28}{8.314 \times 483} =$$

$$4\,009.3 \text{ g} \approx 4 \text{ kg}$$

(Note: $J=N \cdot M$, $Pa=N/m^2$ Substitute the above unit formula)

(2) The heat required to heat nitrogen to the process temperature (210 °C):

Conditions: Specific heat capacity of nitrogen is 1,038 J/Kg·K, nitrogen mass is 4 kg, and nitrogen temperature ranges from 20 to 210°C (converted to unit interval: $180+273=453K$)

Calculation: $Q_{\text{nit}} = c \cdot M \cdot \delta_t = 1.038 \times 4 \times 180 = 747.4 \text{ kJ}$

Option 1: If nitrogen is directly heated inside the capsule, it is required to reach the process temperature within 40 s (including the primary/secondary setting time). The power consumption is calculated as follows:

$$P = \frac{747.4 \text{ kJ}}{40 \text{ s}} \approx 18.69 \text{ kW}$$

Option 2: Preheat nitrogen outside the capsule, which can reach the process temperature within 10 minutes. The power demand is calculated as follows:

$$\text{Time } T = 10 \text{ min} = 600 \text{ s}$$

$$\text{The power } P = \frac{747.4 \text{ kJ}}{600 \text{ s}} \approx 1.25 \text{ kW}$$

2.2.2 Regarding the calculation of external temperature for tire electric heating

2.2.2.1 Regarding the calculation of external temperature of the hot plate

Hot plate structure plan: Currently, the thickness of the steam channel of the hot plate is 60 mm, while the thickness can be reduced to 40 mm for the electrically heated hot plate, with the material being Q235A;

The temperature of the hot plate needs to be maintained at 180°C, and the mass of the hot plate is 460 kg;

Calculation basis: First Law of Thermodynamics, $Q = c \cdot M \cdot \delta_t$ (the amount of heat absorbed or released by a substance due to temperature change)

Q —heat (J),

c —specific heat capacity of the substance ($\frac{J}{kg \cdot ^\circ C}$);

M —Mass (kg), δ_t - Temperature Change ($^\circ C$)

The specific heat capacity of Q235A material is related to its carbon content. According to Tables 4 and 5, it is found to be $C_{Q235A} = 0.47 \frac{kJ}{kg \cdot ^\circ C}$

Carbon steel material composition table (Appendix 4)

and steel carbon content under different temperature conditions (Appendix 5)

Table 4 Material composition table

material	C content	Mn content	Si content	S content	P content
Q235A	≤ 0.22%	≤ 1.4%	≤ 0.35%	≤ 0.050%	≤ 0.045%
Q235B	≤ 0.20%	≤ 1.4%	≤ 0.35%	≤ 0.045%	≤ 0.045%
Q235C	≤ 0.17%	≤ 1.4%	≤ 0.35%	≤ 0.040%	≤ 0.040%
Q235D	≤ 0.17%	≤ 1.4%	≤ 0.35%	≤ 0.035%	≤ 0.035%

Table 5 Carbon content of steel under different temperature conditions

Temperature $^\circ C$	Carbon content of steel (%)				
	0.09	0.224	0.3	0.54	0.61
100	0.465	0.465	0.469	0.473	0.477
200	0.477	0.477	0.482	0.482	0.486
300	0.494	0.498	0.502	0.507	0.511
400	0.515	0.515	0.515	0.523	0.523
500	0.532	0.532	0.536	0.536	0.54

The calculation process for the heat required to maintain the hot plate at 180°C is as follows:

$$Q = c \cdot M \cdot \delta_t = 0.47 \times 460 \times 180 \left(\frac{kJ}{kg \cdot ^\circ C} \cdot kg \cdot ^\circ C \right) = 38916 \text{ kJ}$$

The preheating time is set to $t = 1.5$ hours and 5400 s,

The electric heating power required to meet the heat demand of the hot plate is calculated as follows:

$$P = \frac{38916 \text{ kJ}}{5400 \text{ s}} \approx 7.2 \text{ kW}$$

If the temperature drops by $2^\circ C$ (δ_t) during normal production, the rapid temperature rise calculation is as follows:

$$\delta_Q = c \cdot M \cdot \delta_t = 0.47 \times 460 \times 2 \left(\frac{kJ}{kg \cdot ^\circ C} \cdot kg \cdot ^\circ C \right) = 433 \text{ kJ}$$

Heating time for 7.2Kw power: $T_{\text{升}} = \delta_Q / 7.2 = 433 / 7.2 = 60 \text{ s}$

2.2.2.2 Regarding the calculation of external temperature of the mold sleeve

According to the first law of thermodynamics, $Q = c \cdot M \cdot \delta_t$

Q — heat (J),

c —specific heat capacity of the substance ($\frac{J}{kg \cdot ^\circ C}$),

M —Mass (kg);

δ_t —Temperature change, $^\circ C$

Mold sleeve material: Q235A,

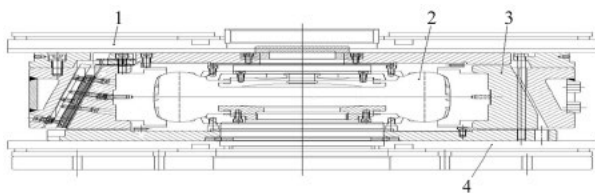
$$C_{Q235A} = 0.47 \frac{kJ}{kg \cdot ^\circ C}$$

Upon checking the mold specification sheet, the mold sleeve of the largest mold has a mass of approximately 400 kg;

If the material of the mold sleeve is the same as that of the hot plate and its quality is comparable to that of the hot plate, then:

The power distribution for electric heating of the mold sleeve can be referenced from that of the hot plate. Since the heating area of the pattern block corresponding to the mold sleeve is the tread rubber, the power should be amplified by 1.5 times, that is, $7.2 \times 1.5 = 10.2$ kW. At the same time, due to uneven temperature distribution during vulcanization of the tire sidewall, under-vulcanization often occurs, so power distribution should be emphasized on the upper and lower parts of the mold sleeve.

In summary, the power distribution of the electric heating vulcanization chamber is as follows, as shown in figure 5.



1—Upper hot plate electric heating power: 7.2 kW;

2—Capsule internal temperature: 18.69 kW (according to Plan A); 1.25 kW (according to Plan B);

3—Mold sleeve electric heating: 10.2 kW;

4—Lower hot plate electric heating power: 7.2 kW

Figure 5 Power distribution diagram of electric heating vulcanization chamber

External temperature power: $P_1 = 7.2 + 7.2 + 10.2 = 24.6$ kW;

Internal heating power: $P_2 = 1.25$ kW (in power-saving mode, execute as per Plan B, 1.25 kW);

Theoretical total power: $P_{\text{theory}} = P_1 = 7.2 + 7.2 + 10.2 = 24.6$ kW ;

The power loss is calculated based on 30%, assuming a range of 10%-30%;

Actual total power $P_{\text{actual}} = (1 + 30\%)P_{\text{theory}} = 33.6$ kW

Temperature control scheme:

External temperature: Preheat for 1.5~2 hours. After reaching the process temperature, the temperature drops by 2°C, and automatic heating compensation is performed;

Internal temperature: Preheat externally with nitrogen, reach process temperature within 10 minutes, recycle nitrogen, and reduce normal operating power by 50%.

2.2.2.3 Implementation plan for electric heating vulcanization power and energy consumption

The implementation plan for the power and energy consumption of electric heating vulcanization is detailed in Table 6.

3 Comparison of cost consumption between steam heating and electric heating

The cost advantages of electric heating curing presses and steam heating curing presses (energy saving and consumption reduction), calculated based on an annual production of 1 million sets, are shown in Table 7.

Calculated on a per-tire basis

Taking the semi-steel 51" tire as an example:

With an average vulcanization time of 15 minutes, each tire consumes 18 kg of steam, and each ton of steam is priced at 220 yuan:

The steam consumption cost for one unit of curing press in one year is: $(60/15) \times 2 \times 24 \times 300 \times 18 \times 0.22 = 228,096$ yuan;

If estimated based on a 40% energy saving: 1 unit of curing press saves: $228,096 \times 0.4 = 91,238.4$ yuan per year

4 Focus points of electric heating technology and steam heating technology

Whether it's electric heating technology, steam heating technology, or other heating technologies, as long as the components required for tire vulcanization remain unchanged, the key points to focus on during vulcanization are common.

a. The temperature difference between the upper and lower heating plates should be $\pm 2^\circ\text{C}$; b. The temperature difference of a single heating plate should be $\pm 2^\circ\text{C}$; c. The time for heating from 10°C to 200°C should be quickly controllable; d. The internal temperature drop from 200°C to 20°C should be completed in a short period of time, as shown in figure 6.

After all, steam heating technology has undergone more than 50 years of development. Both domestic and foreign curing press manufacturers have been continuously absorbing and improving upon advanced technologies from others. The technology has become highly refined and mature, with extensive experience in temperature control, fully capable of meeting the requirements of tire manufacturing processes. In contrast, electric heating technology has only just begun to take off in recent years, both domestically and internationally, and is still in the exploratory stage. Most have not achieved mass production, and there are still shortcomings in temperature control. Qingdao MESNAC Electromechanical Engineering Co., Ltd. is at the forefront of domestic curing press

Table 6 Process route and energy consumption of electric heating vulcanization for 51-inch semi-steel vulcanizing machine

Serial Number	Operation Step	Duration			Energy Consumption			Factory Configuration
	Definition	Description	Value	Unit	Heat conversion	Input power value / kW	Energy consumption value/(kw-h)	
0	Prepare	Hot mold	90	min	Upper and lower hot plates - upper and lower templates, mold sleeves - pattern blocks	34	51	1.In the preparation stage, it is not included in the vulcanization cycle 2.During the vulcanization stage using an external heating plate, the workshop can proceed in batches 3.External heating with nitrogen, initiated after the hot molding process is completed or 20 minutes before the vulcanization process begins 4.The working step time is adjusted according to the actual process
		External heating with nitrogen	10	min	Electric energy - Internal energy of nitrogen	5	0.83	
	Vulcanization cycle		15.33	min	\	\	2.72	
1	Stereotype	Primary/ Secondary setting	20	s	Electric heating inside the capsule - internal heating of the capsule	3	0.02	
					External temperature compensation activation	34	0.19	
					Nitrogen external heating for insulation, not activated	0	0	
2	3 minutes before proper vulcanization	High-pressure and high-temperature nitrogen gas enters the capsule	3	min	External temperature compensation starts for 1 minute	34	0.57	
					Electric heat within the capsule - Heat within the capsule	3	0.15	
3	Positive sulfurization	Sulfidation is proceeding	5	min	External temperature compensation starts for 1 minute	34	0.57	
					Electric heat within the capsule - Heat within the capsule	3	0.25	
					The external heating system using nitrogen has been initiated, but it is not considered for the time being	0	0	
4	vulcanization	Thermal insulation vulcanization	7	min	Heat with nitrogen for 5 minutes, and maintain the temperature once it reaches the desired level	5	0.42	
					External temperature compensation starts for 1 minute	34	0.57	
					Electric heat within the capsule - Heat within the capsule	3	0	

Table 7 Cost comparison between electric heating and steam heating (annual production of 1 million sets)

Project	Unit	Comparison (① - ②) / ①	Steam heating curing press ①	Electric heating curing press ②	Remarks
Energy consumption cost	10,000 yuan	51.80%	1400	674.96	Nitrogen recycling
Steam cost	10,000 yuan	\	360	\	
Single tire consumption	kg	\	18	\	
Unit price of steam	Yuan/kg	\	0.2	\	
Nitrogen cost	10,000 yuan	44.40%	720	400	
Single tire consumption	kg	\	18	10	
Unit price of nitrogen	Yuan/kg	\	0.4	0.4	
Electricity cost	10,000 yuan	\	\	184.96	
Power consumption per tire	Kw-h	\	\	2.72	
Electricity unit price	Yuan/Kw-h	\	\	0.68	
Spare parts consumption	10,000 yuan	71.90%	320	90	Valve/pipeline maintenance

manufacturers, leading both domestically and internationally in steam heating. It has also made significant progress in electric heating technology, with the technology becoming increasingly refined and mature. Especially in terms of electric heating

structure and temperature control, it has continuously explored and grown, and has been applied in factory practice. A brief introduction is provided below.

4.1 Steam thermal valve group structure

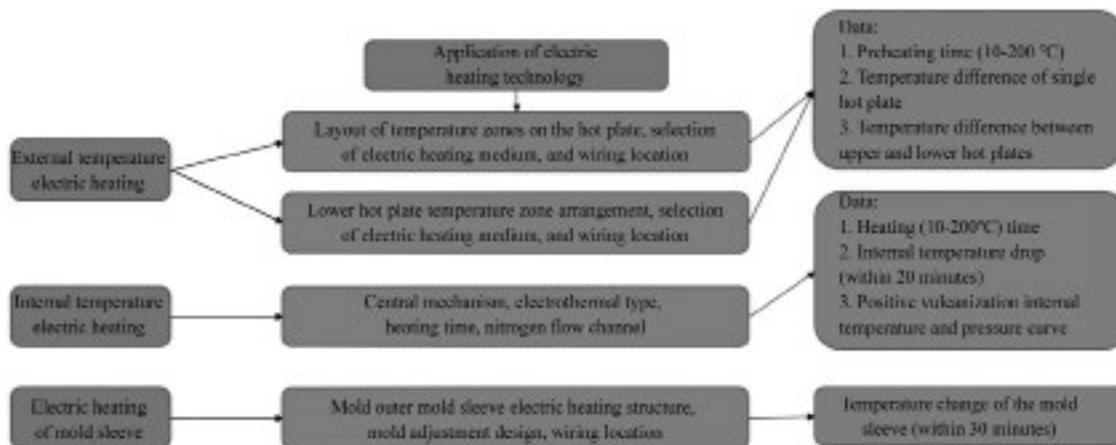


Figure 6 Distribution and application of electric heating technology in curing press components

The steam thermal valve groups designed, developed, and manufactured by MESNAC can be broadly divided into two forms in terms of structural style. One form is the single valve connected through welded flange pipelines to achieve control of the curing medium. That is, the valve + flange + pipeline form, simply referred to as the traditional valve group mode. In the traditional mode, the thermal valve group of the curing press is divided into four parts: the external temperature inlet valve group, the external temperature return valve group, the internal temperature inlet valve group, and the internal temperature return valve group. The other form is the integrated thermal valve group, which designs the valve's switching function for the medium inside the valve block. The valve block serves both as a process flow channel and as a valve body. The valve is an external pneumatic actuator that controls the valve's switching. Overall, the integrated thermal valve group of the curing press integrates the four separately designed pipelines of the external temperature inlet valve group, external temperature return valve group, internal temperature inlet valve group, and internal temperature return valve group into one valve group according to actual conditions, or integrates the internal temperature inlet and return valve groups into one valve group, and integrates the external temperature inlet and return valve groups into one valve group. This form of pipeline integration and valve group integration is simply referred to as the integrated thermal valve group mode. Steam-type thermal valve groups generally include shut-off valves, check valves, filters, pneumatic diaphragm regulating valves, self-operated pressure regulating valves, solenoid valves, mechanical valves,

hand-pull valves, etc., as shown in figure 7.

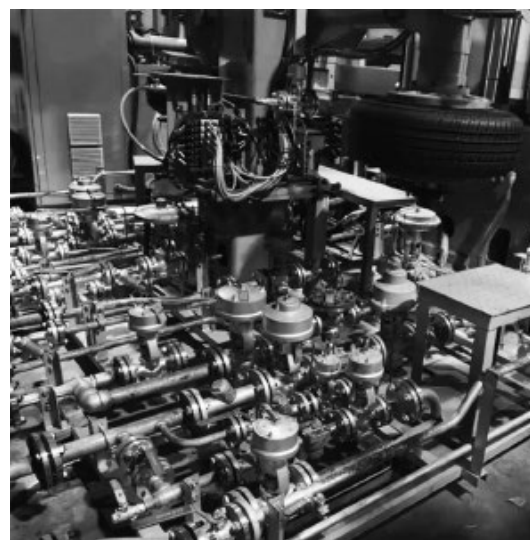


Figure 7 Steam-heated thermal pipeline

4.2 Structure of electric heating component

The electric heating system designed, developed, and manufactured by MESNAC eliminates the boiler, auxiliary equipment, and thermal valve group system as shown in figure 8. The direct effect is the reduction of at least 6 circuits of 18 various valves, simplifying the pipeline arrangement at the rear of the equipment. The nitrogen circulation heating system for electric heating mainly includes: regulating valve, pressure sensor, Roots blower, pressure sensor, nitrogen heating device, temperature sensor, etc.

5 Comparison of social benefits between electric heating and steam heating.

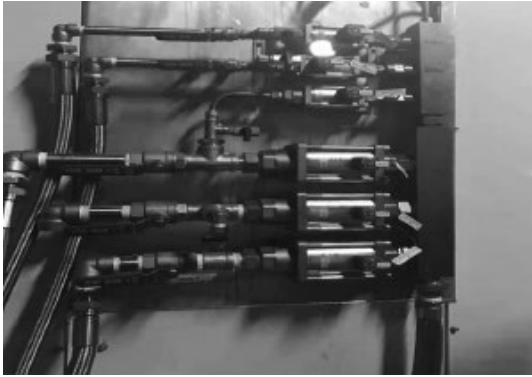


Figure 8 Structure of electric heating component

Compared with steam heating, electric heating curing presses are limited by current technology. Firstly, the temperature control of curing is not stable. Secondly, compared to steam heating, electric energy consumption is huge, which is not yet accepted by the majority of tire manufacturers. However, the development prospects are still great. MESNAC has been continuously investing in research and development in recent years, and technology has made continuous progress. Electric heating technology has made significant breakthroughs both in theory and practice, which has also driven other related rubber and plastic industry enterprises to progress and

develop together. It is believed that with the development of technology, electric heating replacing steam heating is a future development trend, and it is also possible for the two to coexist.

Overall, electric heating has the following advantages over steam heating.

(1) Investment in factory construction: The investment in boiler and main pipeline construction can be saved by no less than 2 million yuan.

(2) Since electric energy is directly used to generate heat, there is no need for steam pipelines, boilers, or other steam auxiliary equipment, which can shorten the construction period by 30%.

(3) Without transmission structure, there is ample space for equipment maintenance, resulting in low maintenance costs;

(4) Upgrading of nitrogen recycling, direct energy conversion, and high utilization efficiency; compared to steam, nitrogen consumption is reduced by 40~60%.

(5) Overall energy savings of over 30%.

(6) Less heat loss, resulting in a comfortable workshop environment.