Tread Rubber and Tire Repair Materials Manufacturers' Group

Recommended Practice - RP-01-05

Updated 11/2019

RETREAD HEAT AND THERMOCOUPLE STUDIES FOR PROPER CURE TIMES

Contents **Page**

I. OBJECTIVE

The objective of this Recommended Practice (RP) is to provide basic instructions for conducting a thermocouple study in a retread curing system in order to determine an appropriate cure time for the system in question.

II. DEFINITIONS

A. Cure Rate Factor Chart

Chart of values used to calculate equivalent cure minutes of a compound during a thermocouple test.

B. Curing Temperature

Temperature which a given system will maintain once a warm up cycle has been completed.

C. Equivalent Cure Minutes

The amount of cure accumulated over a given time (in minutes) and temperature other than the reference temperature.

D. RMA Cure Class

A method of communicating a manufacturer's instructions for the curing of a rubber compound. Example: 15C, where 15 is the time in minutes to reach 100% cure at a given test condition which is identified by the letter C.

E. Reference Temperature

Temperature providing optimum cure for a compounded stated in terms of minutes at that temperature. This is established by a laboratory test used by the rubber manufacturer. Based upon the test performed, the appropriate cure rate calculation charts can be followed to determine when a tire has reached adequate cure.

F. Thermocouple

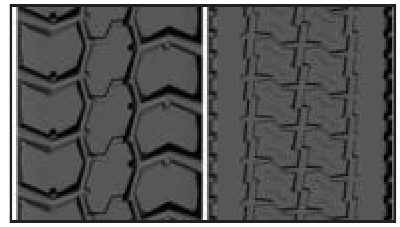
A cable made of two different metal wires joined together at the end (twisted tightly together). At the opposite end, the two wires are attached to an appropriate metering device. When the twisted end is subjected to a heat source (as when inside a curing tire), the metering device can accurately display the temperature in degrees F or degrees C.

G. Thermocouple Test

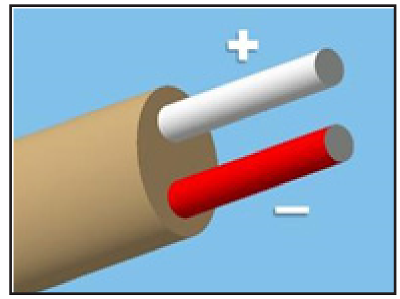
A test designed to measure how long it will take tread rubber or cushion gum (in a given piece of curing equipment) to reach a specific temperature and accumulate a sufficient amount of cure. This information is compared to a cure rate established for the rubber, typically by a laboratory rheometer test.

III. THERMOCOUPLE WIRE PREPARATION

A. Tread End Thermocouple Wire

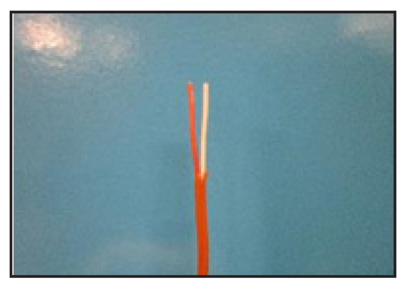


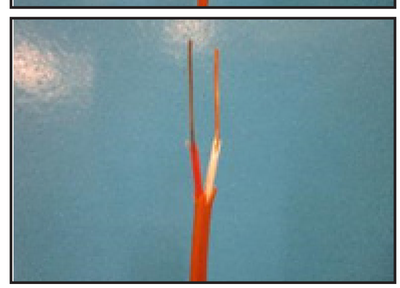
1. Select retread pattern to be thermocoupled to determine the number of tread wires required. For chamber cure, choose the heaviest gauge tread commonly used in the retread plant. An alternative is to choose a design which will be the heaviest of a group of treads cured together (such as trailer designs verses drive designs).



2. Select a thermocouple wire type to use. J or K-type thermocouple wires are common. Make sure to use compatible plugs for the wire selected. The wires will have a negative and positive designation. Make sure this polarity is followed throughout the thermocouple set-up.

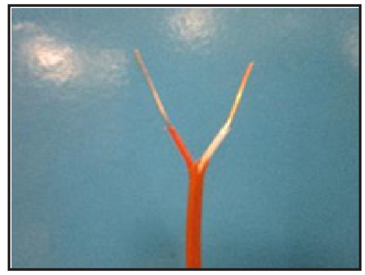
3. Next, the length of wire needed will be considered and then individual wires cut to that desired length. Length will depend on the curing equipment to be used. The wires must be long enough to exit out of the curing equipment allowing enough to safely hook up to the metering device. Alternatively, the wires can be about a foot long past the bead in order to be attached to an existing thermocouple wire harness.





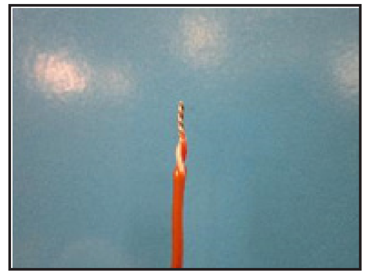
4. Strip the outer insulation back 1/2” (13mm), then strip the inner white and red wire insulation back 3/8” (10mm) exposing bright metal wire. Care should be taken not to break the thin wire.

5. With the wire ends stripped of insulation, separate the two metal wires (the length of the stripped wires) to a 45° angle.



6. Hold the wires at the separated junction with the forefinger and thumb. With pliers, wire strippers, or fingers, begin twisting the two wires tightly together. Keep the wires at a 45° angle as they are twisted together. This is important to achieve a tight thermocouple.

7. Trim the untwisted ends of the wire to a length of approximately 1/4” (6mm) long. This is to ensure the twisted wires will hold together tightly.

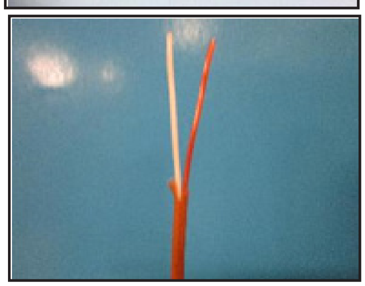


For better durability and a more reliable thermocouple, it is recommended to solder the thermocouple wires together. Apply a small amount of solder to the twisted wires to ensure they maintain good contact.

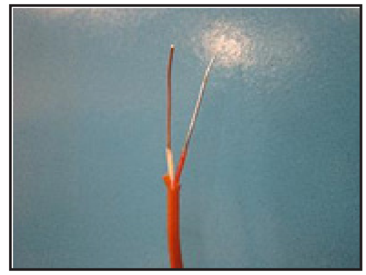
B. Plug End (Male or Female) Thermocouple Wire

1. Prepare the meter/plug end of the wire for insertion into a plug by sliding on the plug grommet. Plugs should be labeled for the appropriate thermocouple wire type. A male plug should be wired at the end plugging into the metering device

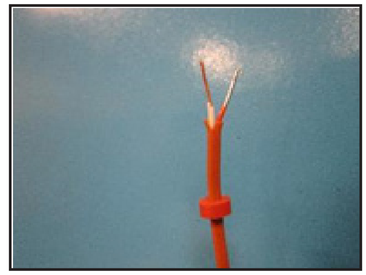
2. Strip back the outer insulation about 1” (25mm) and separate the two wires.



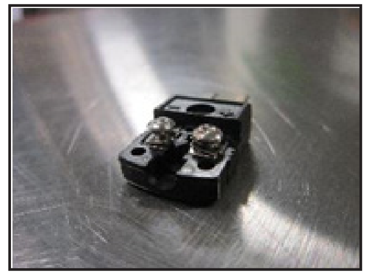
3. Strip each colored wire's insulation back 7/8" (22mm) to leave 1/8" (3mm) of insulation above outer insulation.



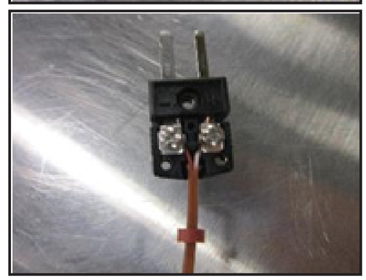
4. Slide on the rubber grommet from the thermocouple plug and cut the wires to leave 1/4" (6mm) exposed.



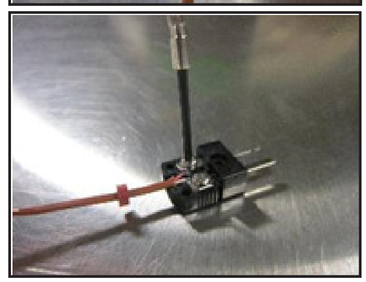
5. Loosen both the positive (+) and negative (-) terminal screws on the plug being careful not to remove them completely.



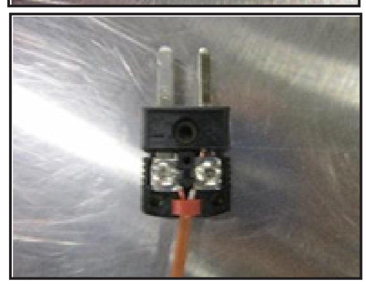
6. Slide thermocouple wire into plug so that the bare positive wire is underneath the positive (+) terminal plate and the bare negative wire is underneath the negative (-) terminal plate.



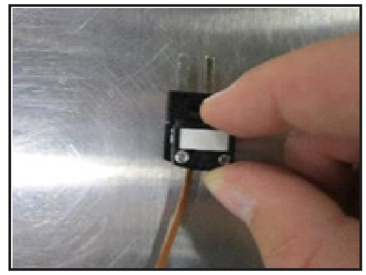
7. Tighten both the positive (+) and negative (-) terminal screws until snug.



8. Slide the plug grommet up the wire and insert it into the groove on the thermocouple plug.



9. Replace the plug cover and tighten screws.



It is recommended to put an identifying number on the end of the wire that will be connected to the metering device or wiring harness.

Finished thermocouple wires can be tested for functionality by plugging them into handheld metering device and verifying ambient temperature.

IV. CURING CHAMBER THERMOCOUPLE TEST

A. Overview

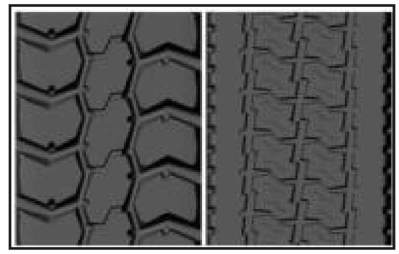
This system consists of a horizontal chamber (autoclave) in which assembled tires are placed for curing. Small chambers typically accommodate 10, 11, or 15 tires, while large chambers may hold 20-25 tires. Heat to the chamber air may be supplied by electric heating elements or encapsulated steam lines, and circulated with a fan at the back of the chamber. The chamber is controlled to a specified pressure and temperature, and tires are cured for a preset amount of time determined through a thermocouple test. Additionally, hoses run from the chamber to each loaded tire. Chambers usually are equipped with hoses for the purpose of:

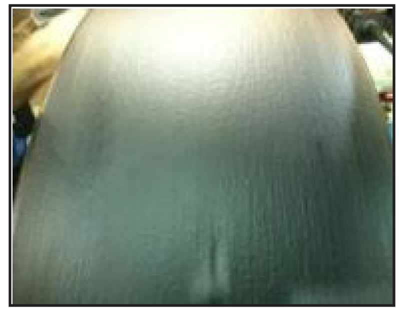
1. Inflating an inner curing tube in a rim and tube system
2. Envelope vacuum and/or pressurization

Whenever a new chamber is installed, a heat study and thermocouple test must be performed. Additionally, the following circumstances would call for a new thermocouple test to be conducted:

- Change in chamber location (either internally in the same building or in a new facility)
- Chamber piping (if steam, including trap size or model)
- Changes to the fan system (fan motor HP, fan blade width, fan blade pitch)
- Changes to the internal air ducts/heat shields
- Replacement of heating elements (if electric)
- New tread designs with non-skid deeper than a previous thermocouple tire design
- Change in curing temperature
- Boiler changes (if steam)

B. Curing Chamber Thermocouple Tire Preparation





1. Select the tire for the thermocouple test, buff to the proper specification, and apply tread cushion.

A casing size and tread pattern should be selected that is typically the largest casing size and tread thickness run in the chamber. Multiple sizes and designs can be tested if loads are segregated by this criteria

2. Verify cushion gauge in three spots (both shoulders and the center), to ensure the proper gauge was applied.

3. For ease of handling, cut a piece of precure tread in your selected pattern approximately 24" (610mm) in length on which to place the thermocouple wires. If desired, a full length tread may be used.

4. Carefully place the thermocouple wires on the base side of the cut piece of precure tread, exiting all wires to the same side. Stretched pieces of cushion can be used to keep the thermocouple wires in place once they are located. Make certain all wires are clearly identified.

Point of least cure (POLC) is generally in the centerline under the heaviest tread element. It is recommended that multiple wires be used to be certain the POLC will be covered. It is also recommended that at least one wire be placed accurately in each shoulder for cure comparison.

5. Place the piece of tread containing the wires onto the casing with the thermocouple wire plug ends toward the operator's side of the tire, and tape wires to the tire sidewall for building. The operator can then apply the rest of the tread rubber to the casing.

If the tire building machine is equipped with roller stitchers, the stitchers must be stopped before they go down the shoulder and pinch the thermocouple wires. Failing to do this can result in broken thermocouple wires.

6. Clean the side of the sidewall where the thermocouple wires come down using a wire brush on a low speed buffer.

7. Apply tread end cement, if desired, to the brushed area and allow to dry completely.

8. Gather all of the thermocouple wires midway down the sidewall. If desired, cover the wires with calendered cushion gum up to the point where they emerge from the tread and stitch down. Other means to hold the wires in place may also be used as long as the wires are not damaged in the process.

C. Optional Thermocouple Wires

C.1 Buzzout / Skive

A buzzout/skive thermocouple is recommended if using rim and tube curing.

1. Prepare a maximum allowable buzzout/skive at the centerline of the buffed tire.

2. Place a thermocouple wire in the bottom of the buzzout/skive and fill with extruded uncured gum.

3. Stitch down the gum thoroughly using a narrow hand stitcher.

4. Exit this buzzout/skive wire to the same side that the other thermocouple wires will be placed.

C.2 Repair Unit

1. Repair units can add extra time to curing a tire. To determine

this influence, a large reinforced section repair unit should be used for repair unit thermocouples.

2. Prepare and cement the liner according to repair standards. This should be in the area considered to be the point of least cure (POLC) to check the worst case scenario.

3. Place the thermocouple wire between the repair unit and liner before stitching down the repair unit thoroughly in both directions with a hand stitcher.

4. Exit this repair unit wire to the same side that the other thermocouple wires will be placed.

D. Thermocouple Tire Preparation - Sealing Ring System and Inside – Outside Envelopes

1. Cement the bead area where the thermocouple wires emerge from under the tread and allow to dry completely.

2. Bring all wires down the sidewall and over the cemented bead area. Spread the wires carefully over the bead area and then cover wires from the tread down to, and over, the bead with cushion gum. Be careful to feather the edges of the cushion gum covering the wires crossing the bead. Other means to hold the wires in place may also be used as long as the wires are not damaged in the process.

3. Carefully place the outer envelope over the wires keeping the loose ends inside the tire.

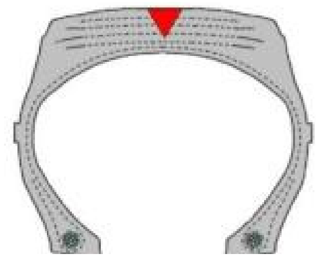
4. Carefully install the sealing rings so that the thermocouple wires are not pinched or damaged. In most cases the tire should be oriented so that the thermocouples under the tread rubber are located at the 6 o’clock position when hanging in the chamber.

5. Check the envelope system to ensure there are no leaks.

6. For an inside envelope system, the wires will extend along the outside of the tire to the edge of the outer envelope. Cover the wires with calendered gum as they travel over the sealing ribs of the outer envelope so that a seal can be created between the inner and outer envelope. Check the system for any vacuum leaks.

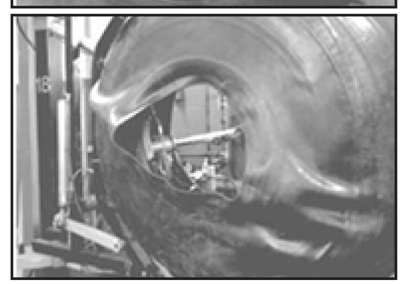
7. Alternately, a hole may be placed in the side of the outer envelope to allow the wires to exit the envelope. However, this hole needs to be prepared so that the envelope can still hold a vacuum.

E. Thermocouple Tire Preparation – Rim and Tube



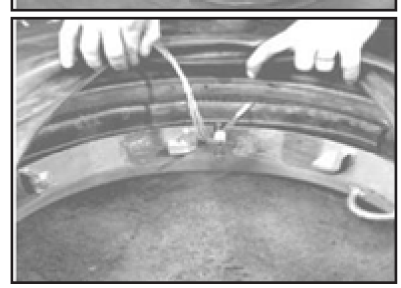
1. For rim and tube systems, a maximum allowable buzzout/skive is recommended and should be placed near the centerline of the tire under the heaviest tread element.

2. Hold the wires clear while the curing tube is inserted into the tire and enveloped.

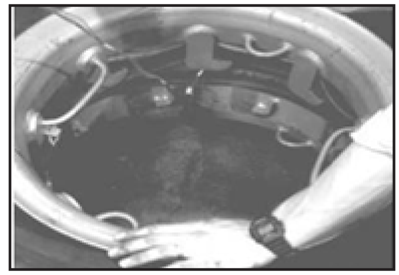


3. Position the tire bead area (where the wires cross the bead) so the cable is lined up with the curing tube stem and stem slot in the rim.

4. With the tire now on the bottom rim half, bring the thermocouple wires to the tube stem (stem now protruding through the slot in the rim) and tape them to the stem.



5. When ready to position the top rim half, pass the wires through the middle of the top rim half. Hold the wires clear while the two rim halves are joined and locked in place.



Do not allow the wires to be pinched between the rim halves.

F. Curing Chamber Heat Study

Before beginning a thermocouple test to establish curing time in a chamber, it is recommended to conduct a chamber heat study. A heat study will determine the heating characteristics of the chamber and establish the coolest area. It should begin with an inspection of the chamber.

F.1 Chamber Inspection Checklist

1. Check the steam, condensate return, and air lines to ensure they are in good condition.

2. Check that the air circulation system is working properly.

   - Check to see if the radiator fins or air ducts are not bent in such a way that inhibits the free circulation of air and transfer of heat.
   - Check for leaking seams in air ducts. Leaking seams may cause localized cooling of some of the tires being cured and/or disturb the flow (distribution) patterns of air required to obtain a good cure.
   - Check that an air diffuser is in place to deflect the compressed air as it enters the chamber (rim and tube only).
   - If equipped with a weep hole, use an anemometer to check velocity. If excessive air loss is discovered, fan packing should be tightened or replaced.

3. Inspect the chamber insulation for any damaged or missing sections.

4. Ensure that the first tire loaded does not touch the back wall of the chamber (check chamber monorail to see if it extends too far into chamber).

5. Pressure check the chamber to see if the pressure can be maintained.

6. Calibrate any pertinent controls or sensors.

7. Check chamber fan air velocity.

F.2 Heat Study Thermocouple Placement

1. If the chamber has never been studied before, thermocouple all of the tires in the chamber. If previous work has been done, the tires in the general area of the cold spot should be thermocoupled.

2. Place one thermocouple per tire located in free flowing air at least 1” (25mm) away from the envelope surface at the 6 o’clock position.

3. Additional thermocouples should be placed 1/2” (13mm) from the heat controller and chart recorder probes (some chambers may have the controller and recorder on the same probe).

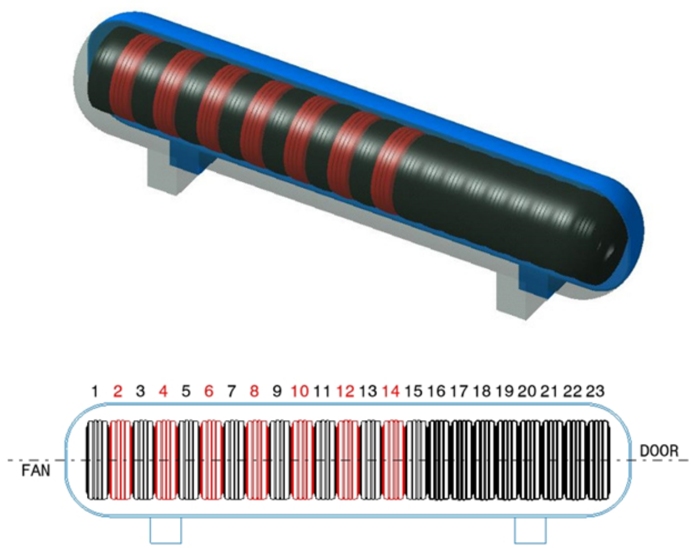
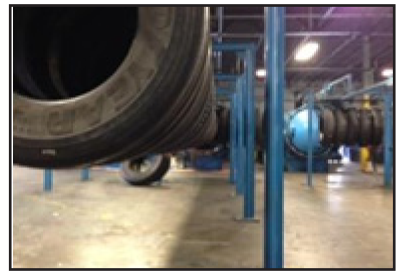
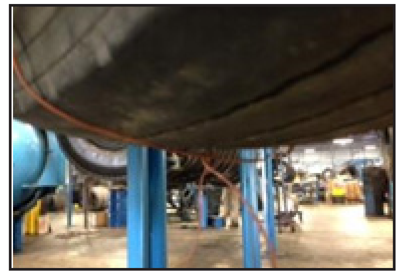


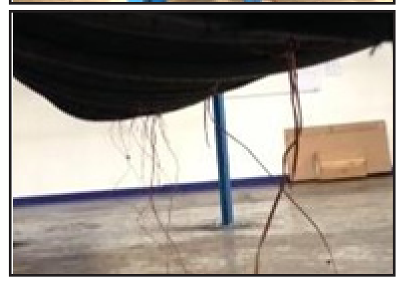
Figure A. Thermocouples on tires indicated in red - 23 tire previously tested chamber

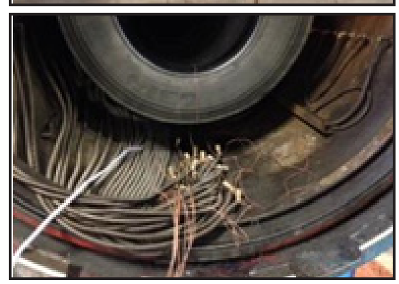
F.3 Heat Study Procedure





1. Place properly identified thermocouple wires in specified positions on selected tires.

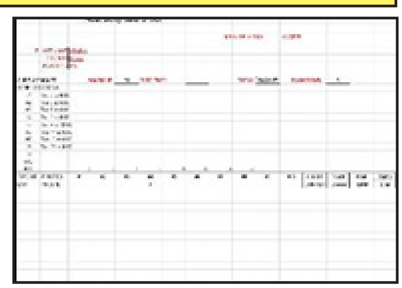




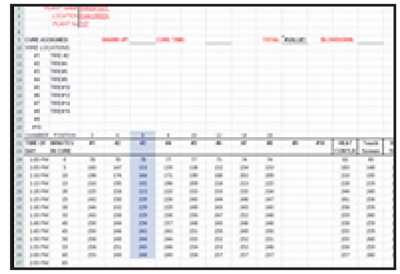
2. Load the chamber running the thermocouples to the metering device or wiring harness.

3. Close the chamber door and start the cure cycle.

Cure time should be set to a time where the temperature will stabilize



4. Take readings every five minutes. Readings should continue for the balance of the cure cycle time. By monitoring the temperature readings in each column, the heating characteristics of the chamber should show a pattern.



5. The column with the lowest temperature readings will determine the coolest spot in the chamber.

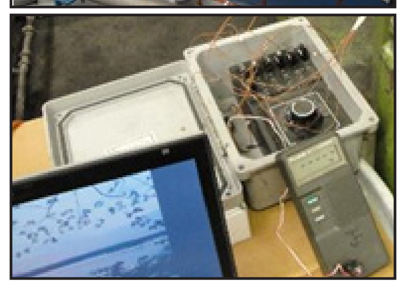
G. Chamber Thermocouple Test Procedure

1. Begin with all enveloped tires at ambient temperature. If possible, the thermocouple test should be the first chamber of the day during the coolest part of the year.

2. The thermocouple tire must be placed in the coolest spot in the chamber determined by the heat study and connected to either the metering device or wiring harness.

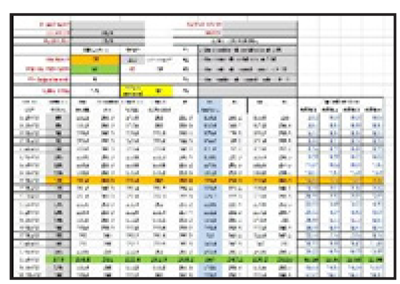
3. Load the chamber with a full load of tires.

4. Thermocouple wires should exit the chamber through a manufacturer's tapped and plugged access port along the chamber wall.



5. Connect the thermocouple wiring harness to the metering device.

6. Close the chamber door and start the cure cycle.



7. Use a data collection sheet to take readings on a regular time interval. Readings should continue until the correct number of cure equivalents has been reached. Continue to take a few more readings beyond the point where the cure equivalents has been obtained.

8. Blow down the chamber and remove the tires. Disconnect the metering device or wiring harness from the thermocouple tire before removal.

9. Allow the thermocouple tire to cool. A thermocouple tire can

be used multiple times for checking chambers as long as the wires are not damaged or the need for a different tread pattern occurs. The tire should be at ambient temperature before it is reused.

10. See appendix A, Tables 1 and 2, for example data collection sheet and calculations.

V. MOLD CURE THERMOCOUPLE TEST

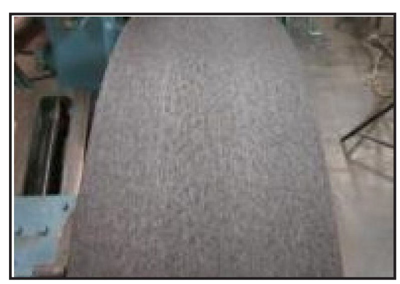
A. Overview

Mold curing is the process of curing unvulcanized rubber prepared on a casing in a retread mold or segment set in a curing press.

Whenever a newly manufactured mold is installed, a thermocouple test must be performed. As mold materials and manufacturers will have differences, all new molds should have a thermocouple test performed regardless if it is an existing design and non-skid. Additionally, the following circumstances would call for a new mold cure thermocouple test to be conducted:

- New mold cure press installed
- Steam piping changes (including trap size or model)
- Boiler changes

B. Mold Cure Thermocouple Tire Preparation



1. Select the tire for the thermocouple test and buff to the proper mold cure specification

Some retread plants may cement and/or apply cushion to the casing prior to building the mold cure tire. Follow each individual plant's procedure for casing preparation.

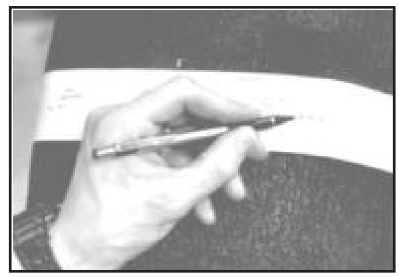
A rejected/scrapped tire can be used as long as it can hold air.

2. Determine the number of thermocouple wires required for that mold's tread pattern and prepare/label them according to section ***III. Thermocouple Wire Preparation.***

B.1 Tire Preparation

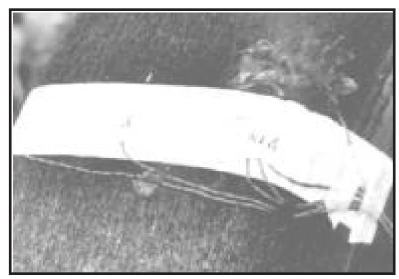
1. Place at least a 2" (50mm) wide piece of masking tape across the crown of the tire, from shoulder to shoulder. Start the tape at least 2" (50mm) from the shoulder on the upper sidewall and stop the tape a similar distance down the sidewall on the opposite side.

Masking tape should be used over other tapes such as duct tape because it will not melt under the elevated mold temperatures.



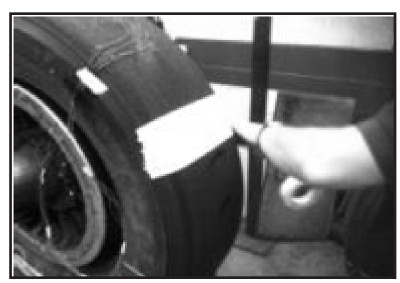
2. Measuring from the centerline, mark the exact spots the thermocouple wires are to be placed. All marks are to be placed on one edge of the masking tape.

Point of least cure (POLC) is generally in the shoulder for mold cure.



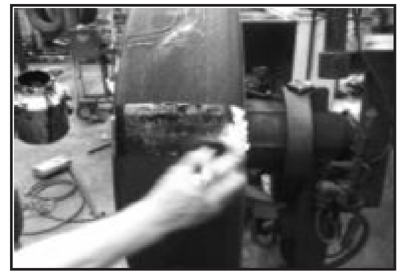
3. Place the prepared and identified thermocouple wires on the previously marked spots (place on top of the masking tape and secure with more tape or cushion if on the buffed surface). Multiple wires on the shoulder may not all be on the masking tape.

A cable can be made of the various wires holding them together with tape to make the thermocouple wires more manageable (use small pieces of masking tape spacing them approximately every 12" (30cm)).



4. Approximately 20"-24" (51-61cm) away from the thermocouple wire location, place masking tape on the buffed casing to cover an area 6" (15cm) wide (about 7 or 8 pieces of tape if using 1" (25mm) wide tape).

5. Apply retread cement to the masking tape with a stipple brush and allow to dry. The extruded tread rubber will not adhere to the tape when building if it is not cemented.



6. If the thermocouple tire tread is to be applied using a strip winding method, all wires need to be attached to the sidewall with tape securely so they will not be caught and broken by the revolving hub assembly.

7. Apply the tread rubber to the buffed casing using the specific program for the mold to be used. Monitor the tread rubber application to ensure the thermocouple wires do not become loose during the process.

8. After the tread rubber has been applied, cut the tread 12” (30cm) away from the wires on the buff. Peel back the tread rubber being careful not to deform the rubber profile since it will be reused.

9. Bring all of the wires to the point of the cut on the centerline and tape the wires to the tire using cushion.

10. Replace the cut tread with the exiting wires securely in place.

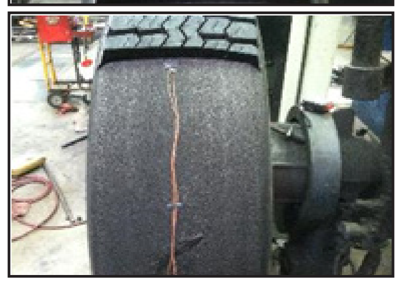
11. Place a final thermocouple wire on top of the built tire rubber at the other thermocouple wire location to record the temperature of the mold matrix. Run the wire down the tire and out with the other thermocouple wires.

B.2 Tire Preparation – Previous Mold Cure Tread Cut-Out Available

If a thermocouple for the exact same mold has been done in the past, a tread cut from that thermocouple test may be available in order to assist in placing new thermocouple wires. Follow this procedure if such a mold cure tread cut-out exists.

1. Place the previously cured cut-out on the buffed surface.

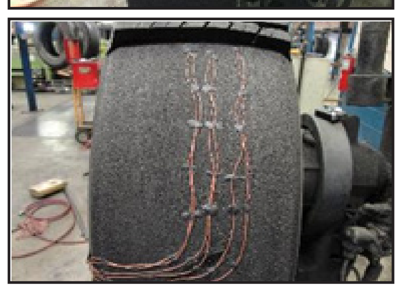
2. Align each thermocouple wire to the specified tread pattern feature and adhere to the buffed casing using a small piece of calendered cushion or extruded rope rubber.



Point of least cure (POLC) is generally in the shoulder for mold cure.

3. Run each thermocouple wire down the buffed surface approximately 12” (30cm) securing it to the casing with more cushion as it travels along the buff and exit out the tire sidewall.

4. Continue this process until all thermocouple wires are placed and properly secured. Remove the mold cure tread cut-out from the buffed casing.



5. Approximately 20”-24” (51-61cm) away from the thermocouple wire location, place masking tape on the buffed casing to cover an area 6” (15cm) wide (about 7 or 8 pieces of tape if using 1” (25mm) wide tape).

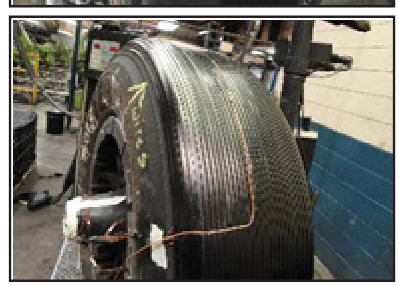
6. Apply black cement to the masking tape with a stipple brush and allow to dry. The extruded tread rubber will not adhere to the tape when building if it is not cemented.

A cable can be made of the various wires. Holding them together with tape will make the thermocouple wires more manageable (use small pieces of masking tape spacing them approximately 12” (30cm)).

7. If the thermocouple tire tread is to be applied using a strip winding method, all wires need to be attached to the sidewall securely with tape so they will not be caught and broken by the revolving hub assembly.

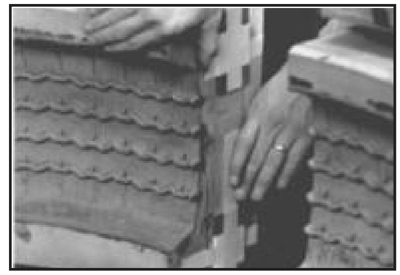
8. Apply the tread rubber to the buffed casing using the specific program for the mold to be used. Monitor the tread rubber application to ensure the thermocouple wires do not become loose during the process.

9. After the tread rubber has been applied, place a final thermocouple wire on top of the rubber at the location of the other thermocouple wires to record the temperature of the mold matrix. Run the wire down the tire and out with the other thermocouple wires.

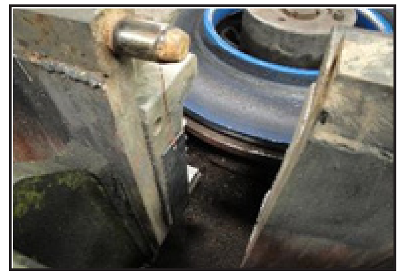


Press and mold type will dictate how the thermocouple wires can be handled in order to properly exit the mold.

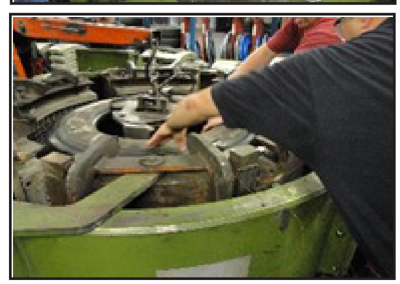
C. Mold Cure Thermocouple Test

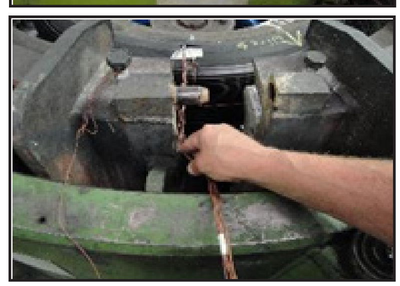


1. Use masking tape to secure shims approximately 3/16” (5mm) thick to the top and bottom of a segment edge. Alternatively, a steel shim can be hung from a press bolt. This will allow the thermocouples to pass through the segment split without pinching the wires. Either method is acceptable.



2. Place the built mold cure thermocouple tire in the curing press with the thermocouple wires between the shimmed segments. Rotate the tire so that the thermocouple wires will be properly aligned with the tread pattern.

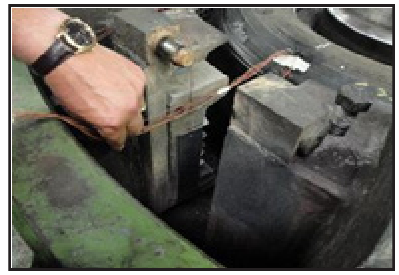


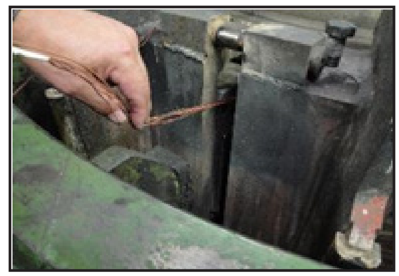


3. The thermocouple wires should be in the center of a segment after placing the exiting wires between segments.

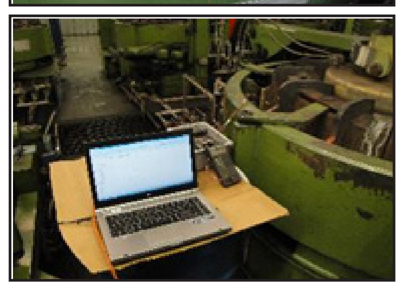
4. Connect the thermocouple wires to the metering device.

5. Set the timer for an amount of time that is beyond the typical cure time of the tire being tested and press the button to begin the curing cycle.



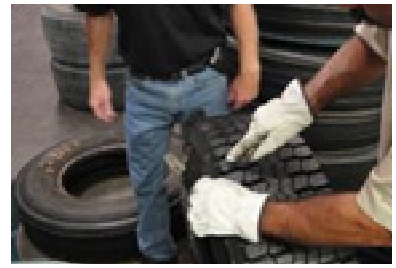


6. Carefully guide the thermocouple wires or cable between the segments while the press is closing to ensure the wires are in between the shims and not pinched at the segment split.



7. Use a data collection sheet to take readings on a regular interval of time. Readings should continue until the correct number of cure equivalents has been reached. Continue to take a few more readings beyond the point where the cure equivalents has been obtained.

8. Stop the cure and remove the tire from the press.



9. While the tire is still hot, cut a cross section of tread 2” (50mm) to 3” (76mm) wide out of the tire where the masking tape was placed on the buffed surface.

10. Check the tread cross section for proper undertread gauge (4/32-5/32” (3-4mm)) and for any porosity. If porosity did occur, the cure was not complete and the thermocouple study will need to be rerun once the mold has cooled.

D. Data Recording and Calculations

The following are standardized Heat Study and Thermocouple Chart worksheets which can be used for all thermocouple tests to record data. Filled in sheets for examples can be found in Appendix A, Table 3.

The Thermocouple Chart worksheet only shows entry for one thermocouple wire placed at the cold spot in a chamber at the coldest location on the tire. A spreadsheet can also be constructed to add multiple wires. This is convenient if the cold spot on the tire is uncertain.

VI. CURE RATE FACTOR TABLES

The following are examples of cure rate factor tables to be used for the thermocouple data collection sheet. Find the average cure temperature lowest 10's value across the top row and then find the nearest 1's number along the left side of the table. The intersection in the table of these two values is the number to enter into the CRF column. For example, in the 280°F table below, a temperature of 237°F would have a cure equivalent of 0.191 (column 230, row 7).

CURE RATE FACTOR
EQUIVALENT MINUTES @ 280°F OF MINUTES @ OBTAINED TEMPERATURE

FAHRENHEIT

	140°	150°	160°	170°	180°	**190°**	200°	210°	220°	230°	240°	250°	260°	270°	280°	**290°**	300°	310°	320°	330°	340°	350°
0°	.005	.007	.010	.014	.021	.031	.046	.067	**.099**	.146	.214	.315	.463	.681	1.00	1.47	2.16	3.18	4.67	6.86	10.08	14.82
1°	.005	.007	.010	.015	.022	.032	.048	.070	.103	.152	.223	.328	.481	.707	1.04	1.53	2.25	3.30	4.85	7.13	10.48	**15.39**
2°	.005	.007	.011	.016	.023	.034	.050	.073	.107	.158	.232	.340	.500	.735	1.08	**1.59**	2.33	3.43	5.04	7.41	10.88	16.00
3°	.005	.008	.011	.016	.024	.035	.052	.076	.111	.164	.241	.354	.520	.764	1.12	1.65	2.42	3.56	5.24	7.70	11.31	16.62
4°	.005	.008	.011	.017	.025	.036	.054	**.079**	.116	.170	.250	.368	.540	**.794**	1.17	1.72	2.52	3.70	5.44	8.00	11.76	17.28
5°	.006	.008	.012	.018	.026	.038	.056	.082	.120	.177	.260	.382	.562	.825	1.21	1.78	2.62	3.85	5.66	8.31	12.22	**17.97**
6°	.006	.008	.012	.018	.027	**.039**	.058	.085	.125	.184	.270	**.397**	.584	.858	1.26	1.85	2.72	4.00	5.88	8.64	12.70	18.67
7°	.006	**.009**	.013	**.019**	.028	.041	.060	.088	.130	**.191**	.281	.413	.606	**.891**	1.31	**1.92**	2.82	4.16	6.11	**8.98**	13.20	**19.39**
8°	.006	**.009**	.013	.020	**.029**	.043	.062	**.092**	.135	**.199**	**.292**	**.429**	.630	**.926**	1.36	2.00	**2.94**	4.32	6.35	**9.34**	13.72	20.16
9°	.006	**.009**	.014	.020	.030	.044	.064	**.095**	.140	.206	.303	.445	.655	**.962**	1.41	2.08	3.05	**4.49**	6.60	**9.70**	14.25	**20.96**

CURE RATE FACTOR
EQUIVALENT MINUTES @138°C OF MINUTES @ OBTAINED TEMPERATURE

CELSIUS

	60°	70°	80°	**90°**	100°	110°	120°	130°	140°	150°	160°	170°	180°
0°	.005	**.009**	.018	.036	.073	.146	**.292**	.584	1.17	2.33	4.67	**9.34**	18.67
1°	.005	.010	.020	**.039**	**.079**	.158	.315	.630	1.26	2.52	5.04	10.08	20.16
2°	.005	.011	.021	.043	.085	.170	.340	.681	1.36	2.72	5.44	10.88	21.76
3°	.005	.011	.022	.044	.088	.177	.354	.707	1.41	2.82	5.66	11.31	22.62
4°	.006	.012	.024	.048	**.095**	**.191**	.382	.764	1.53	3.05	6.11	12.22	24.44
5°	.006	.013	.026	.052	.103	.206	.413	.825	1.65	3.30	6.60	13.20	26.40
6°	.007	.014	.028	.056	.111	.223	.445	**.891**	1.78	3.56	7.13	14.25	28.50
7°	.008	.015	.030	.060	.120	.241	.481	**.962**	**1.92**	3.85	7.70	**15.39**	30.78
8°	.008	.016	.031	.062	.125	.250	.500	1.00	2.00	4.00	8.00	16.00	32.00
9°	.006	.017	.034	.067	.135	.270	.540	1.08	2.16	4.32	8.64	17.28	34.56

CURE RATE FACTOR
EQUIVALENT MINUTES @ 260°F OF MINUTES @ OBTAINED TEMPERATURE

	120°	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°	250°	260°	270°	280°	290°	300°	310°
0°	.005	.007	.010	.014	.021	.031	.046	.067	.099	.146	.214	.315	.463	.681	1.00	1.47	2.16	3.18	4.67	6.86
1°	.005	.007	.010	.015	.022	.032	.048	.070	.103	.152	.223	.328	.481	.707	1.04	1.53	2.25	3.30	4.85	7.13
2°	.005	.007	.011	.016	.023	.034	.050	.073	.107	.158	.232	.340	.500	.735	1.08	1.59	2.33	3.43	5.04	7.41
3°	.005	.008	.011	.016	.024	.035	.052	.076	.111	.164	.241	.354	.520	.764	1.12	1.65	2.42	3.56	5.24	7.70
4°	.005	.008	.011	.017	.025	.036	.054	.079	.116	.170	.250	.368	.540	.794	1.17	1.72	2.52	3.70	5.44	8.00
5°	.006	.008	.012	.018	.026	.038	.056	.082	.120	.177	.260	.382	.562	.825	1.21	1.78	2.62	3.85	5.66	8.31
6°	.006	.008	.012	.018	.027	.039	.058	.085	.125	.184	.270	.397	.584	.858	1.26	1.85	2.72	4.00	5.88	8.64
7°	.006	.009	.013	.019	.028	.041	.060	.088	.130	.191	.281	.413	.606	.891	1.31	1.92	2.82	4.16	6.11	8.98
8°	.006	.009	.013	.020	.029	.043	.062	.092	.135	.199	.292	.429	.630	.926	1.36	2.00	2.94	4.32	6.35	9.34
9°	.006	.009	.014	.020	.030	.044	.064	.095	.140	.206	.303	.445	.655	.962	1.41	2.08	3.05	4.49	6.60	9.70

CURE RATE FACTOR
EQUIVALENT MINUTES @ 127°C OF MINUTES @ OBTAINED TEMPERATURE

CELSIUS

	50°	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°	160°	170°
0°	.005	.010	.020	.039	.079	.158	.315	.630	1.26	2.52	5.04	10.08	20.16
1°	.005	.011	.021	.043	.085	.170	.340	.681	1.36	2.72	5.44	10.88	21.76
2°	.006	.011	.023	.046	.092	.184	.368	.735	1.47	2.94	5.88	11.76	23.52
3°	.006	.012	.024	.048	.095	.191	.382	.764	1.53	3.05	6.11	12.22	24.44
4°	.006	.013	.026	.052	.103	.206	.413	.825	1.65	3.30	6.60	13.20	26.40
5°	.007	.014	.028	.056	.111	.223	.445	.891	1.78	3.56	7.13	14.25	28.50
6°	.008	.015	.030	.060	.120	.241	.481	.962	1.92	3.85	7.70	15.39	30.78
7°	.008	.016	.031	.062	.125	.250	.500	1.00	2.00	4.00	8.00	16.00	32.00
8°	.008	.017	.034	.067	.135	.270	.540	1.08	2.16	4.32	8.64	17.28	34.56
9°	.009	.018	.036	.073	.146	.292	.584	1.17	2.33	4.67	9.34	18.67	37.34

CURE FACTOR
EQUIVALENT MINUTES @200°F OF MINUTES @ OBTAINED TEMPERATURE

FAHRENHEIT

	110°	120°	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°	250°	260°	270°
0°	.031	.046	.067	.099	.146	.214	.315	.463	.681	1.00	1.47	2.16	3.18	4.67	6.86	10.08	14.82
1°	.032	.048	.070	.103	.152	.223	.328	.481	.707	1.04	1.53	2.25	3.30	4.85	7.13	10.48	15.39
2°	.034	.050	.073	.107	.158	.232	.340	.500	.735	1.08	1.59	2.33	3.43	5.04	7.41	10.88	16.00
3°	.035	.052	.076	.111	.164	.241	.354	.520	.764	1.12	1.65	2.42	3.56	5.24	7.70	11.31	16.62
4°	.036	.054	.079	.116	.170	.250	368	.540	.794	1.17	1.72	2.52	3.70	5.44	8.00	11.76	17.28
5°	.038	.056	.082	.120	.177	.260	.382	.562	.825	1.21	1.78	2.62	3.85	5.66	8.31	12.22	17.97
6°	.039	.058	.085	.125	.184	.270	.397	.584	.858	1.26	1.85	2.72	4.00	5.88	8.64	12.70	18.67
7°	.041	.060	.088	.130	.191	.281	.413	.606	.891	1.31	1.92	2.82	4.16	6.11	8.98	13.20	19.39
8°	.043	.062	.092	.135	.199	.292	.429	.630	.926	1.36	2.00	2.94	4.32	6.35	9.34	13.72	20.16
9°	.044	.064	.095	.140	.206	.303	.445	.655	.962	1.41	2.08	3.05	4.49	6.60	9.70	14.25	20.96

CURE FACTOR
EQUIVALENT MINUTES @93°C OF MINUTES @ OBTAINED TEMPERATURE

	50°	60°	70°	80°	90°	100°	110°	120°	130°
0°	.050	.099	.199	.397	.794	1.59	3.18	6.35	12.70
1°	.054	.107	.214	.429	.858	1.72	3.43	6.86	13.72
2°	.058	.116	.232	.463	.926	1.85	3.70	7.41	14.82
3°	.062	.125	.250	.500	1.00	2.00	4.00	8.00	16.00
4°	.064	.130	.260	.520	1.04	2.08	4.16	8.31	16.62
5°	.070	.140	.281	.562	1.12	2.25	4.49	8.98	17.97
6°	.076	.152	.303	.606	1.21	2.42	4.85	9.70	19.39
7°	.082	.164	.328	.655	1.31	2.62	5.24	10.48	20.96
8°	.085	.170	.340	.681	1.36	2.72	5.44	10.88	21.76
9°	.092	.184	.368	.735	1.47	2.94	5.88	11.76	23.52

NOTE: OBTAIN CORRECT CURE FACTOR TABLE AND REFERENCE TEMPERATURE FROM YOUR RUBBER SUPPLIER.

VII. CALCULATING TARGET CURE EQUIVALENTS MINUTES

The RMA CURE CLASS value is used to determine the target value for the cure equivalents minutes. The number shown in the cure class is the number of minutes to reach 100% cure at the reference temperature for the given test method (referenced by the letter suffix). For example, a rubber with a cure class 25A obtains 100% cure in 25 minutes in the test method A at the given reference temperature.

For calculating cure equivalent minutes, the target number is 85% of the value of the cure class. In this case, the ECM's would be 85% x 25 = 21.2 minutes. Therefore, in the accumulated cure minutes column in the thermocouple data sheet, the time at which 21.2 or greater is reached is the cure time for the chamber or press.

The cure equivalent minutes are determined from the proper cure factor table as stated above. These are summed together until the accumulated value reaches the target equivalent cure number or greater. It should be noted that a tire will continue to accumulate cure once the temperature and pressure are discontinued. However, this rate will vary depending on how quickly the cools. Because of this variability, it is recommended to set the cure time based on the accumulated cure while the tire is under full pressure and steady state temperature.

See Tables 3 and 4 in Appendix A for examples of completed data sheets for a heat study and a thermocouple study.

TABLE 1

RECORDING FORM
THERMOCOUPLE CURE CHECKS

Technician			Date		
Retreader			Non-Skid	Die Size	Tire OD
Address			Matrix Mfg.		
Press	Chamber X	Mfg.	Tread Design		
Chamber Size (No. Tires) 1			Rubber Mfg.		
No. of Tires in Chamber			Rubber Stock Name/No.		
Curing Temperature		127°C	Mfg./RMA Cure Class		
Ambient Temp.		26°C	Air	Steam	Pressure psi
Position of Tire in Chamber			Tire Pressure		psi
Equip. Start Temp. °F		°C	Stock is Tread		Cushion
	Preheated	Unheated		Repair	Stock

Time of Day	Time Minutes		TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14	TC 15	TC 16	TC 17	TC 18	TC 19	TC 20	TC 21	TC 22
am pm	Start 0	Location																						

_________ Heat Study _________ Cure Study

TABLE 2

Thermocouple Tire Data Collection Worksheet		
RETREADERS NAME	DATE OF STUDY	TIRE OD
ADDRESS	NON-SKID	DIE SIZE
PLANT DOT	MATRIX MFG.	
CHAMBER MFG	TREAD DESIGN	
PRESS MFG.	RUBBER MFG	
CHAMBER SIZE (NO. OF TIRES)	RUBBER STOCK NAME / NO.	
CURING TEMPERATURE	RMA CURE CLASS	
AMBIENT TEMP.	REFERENCE TEMP	
POSITION OF TIRE IN CHAMBER	AIR (psi)	STEAM (psi)
	TREAD DESIGN	CUSHION
	REPAIR	
EQUIP. START TEMPERATURE		

TIME OF DAY	TIME INTERVAL	TEMPERATURE	AVG TEMP	CURE RATE FACTOR (CRF) (1)	CRF * TIME INTERVAL (2)	CULATIVE CURE (MINUTES) (3)

(1) This value is from the appropriate cure rate factor table for the average temperature
(2) This is the CRF times the time interval between readings
(3) This is the running total of the CRF times the time interval

TABLE 3

RECORDING FORM
THERMOCOUPLE CURE CHECKS

Technician			Date		
Retreader			Non-Skid	Die Size	Tire OD L-5 LUG
Address			Matrix Mfg.		
Press	Chamber X	Mfg.	Tread Design		
Chamber Size (No. Tires) 1			Rubber Mfg.		
No. of Tires in Chamber			Rubber Stock Name/No.		
Curing Temperature 260°F		127°C	Mfg./RMA Cure Class 30A/30 min. @ 280°F		
Ambient Temp. 78°F		26°C	Air	Steam	Pressure psi
Position of Tire in Chamber			Tire Pressure psi		
Equip. Start Temp. °F		°C	Stock is Tread X		Cushion
	Preheated	Unheated X		Repair	Stock

Time of Day	Time Minutes		TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14	TC 15	TC 16	TC 17	TC 18	TC 19
7:00 am pm	Start 0	Location																			
	0		225	132	159	155	141	143	148	151	142	169									
	5		173	170	177	184	181	180	172	177	181	184									
	10		188	186	188	196	197	196	188	194	200	193									
	15		204	201	205	210	210	214	210	216	214	209									
	20		216	215	217	220	221	223	225	224	225	227									
	25		228	226	228	231	232	229	234	237	237	237									
	30		238	235	238	241	241	241	243	246	245	246									
	35		246	245	247	249	250	251	253	252	253	255									
	40		253	252	254	256	257	259	259	261	261	262									
	45		260	260	262	263	263	262	264	263	264	264									
	50		262	260	261	262	262	262	264	264	263	263									
	55																				

_________ Heat Study ____X____ Cure Study

TABLE 4

Thermocouple Tire Data Collection Worksheet

RETREADERS NAME	DATE OF STUDY	TIRE OD
ADDRESS	NON-SKID	DIE SIZE
PLANT DOT	MATRIX MFG.	
CHAMBER MFG	TREAD DESIGN	
PRESS MFG.	RUBBER MFG	
CHAMBER SIZE (NO. OF TIRES)	RUBBER STOCK NAME / NO.	
CURING TEMPERATURE	RMA CURE CLASS **20C / 20 min@ 260F**	
AMBIENT TEMP.	REFERENCE TEMP	
POSITION OF TIRE IN CHAMBER	AIR (psi)	STEAM (psi)
	TREAD DESIGN	CUSHION
	REPAIR	
EQUIP. START TEMPERATURE		

TIME OF DAY	TIME INTERVAL	TEMPERATURE (F)	AVG TEMP	CURE RATE FACTOR (CRF) (1)	CRF * TIME INTERVAL (2)	CULATIVE CURE (MINUTES) (3)
4:22 PM	**0**	75.0				
4:27 PM	**5**	90.0				
4:32 PM	**10**	103.0				
4:37 PM	**15**	127.0				
4:42 PM	**20**	148.0				
4:47 PM	**25**	167.0	157.0	0.0	0.09	0.09
4:52 PM	**30**	185.0	176.0	0.0	0.19	0.28
4:57 PM	**35**	197.0	191.0	0.1	0.35	0.63
5:02 PM	**40**	208.0	202.0	0.1	0.53	1.16
5:07 PM	**45**	220.0	214.0	0.2	0.85	2.01
5:12 PM	**50**	230.0	225.0	0.3	1.3	3.31
5:17 PM	**55**	237.0	233.0	0.4	1.77	5.08
5:22 PM	**60**	244.0	240.0	0.5	2.31	7.39
5:27 PM	**65**	255.0	249.0	0.7	3.27	10.66
5:32 PM	**70**	258.0	256.0	0.9	4.29	14.95
5:37 PM	**75**	248.0	253.0	0.8	3.82	18.77
5:42 PM	**80**	243.0	245.0	0.6	2.81	21.58
5:47 PM	**85**	235.0	239.0	0.4	2.22	23.8
5:52 PM	**90**	226.0	230.0	0.3	1.57	25.37
5:57 PM	**95**	210.0	218.0	0.2	0.99	26.36
6:02 PM	**100**	180.0	195.0	0.1	0.41	26.77
6:07 PM	**105**	155.0	167.0	0.0	0.14	26.91
6:12 PM	**110**					
6:17 PM	**115**					
6:22 PM	**120**					

(1) This value is from the appropriate cure rate factor table for the average temperature
(2) This is the CRF times the time interval between readings
(3) This is the running total of the CRF times the time interval

NOTE: Accumulated Cure Equivalents for 20C RMA class is 0.85*20 = 17 minutes.