

## 4.12 Manufacture of Rubber Products

### 4.12.1 General Process Description<sup>1</sup>

Many of the rubber manufacturing facilities in the United States produce pneumatic tires for automobile, trucks, airplanes and farm machinery. However, many rubber manufacturing facilities produce other engineered rubber products. The processes involved in these industries are very similar. Differences basically consist of the raw rubber material (natural or synthetic) used, the chemical additives, and the type of curing employed. The following is a description of a generic rubber manufacturing facility applicable to both tire and other manufactured rubber products, except where noted.

The manufacturing of rubber products involves six principal processing steps (mixing, milling, extrusion, calendaring, curing, and grinding), with ancillary steps in between. Initially, the raw rubber (natural or synthetic) is mixed with several additives which are chosen based upon the desired properties of the final product. The mixed rubber is often milled and transferred to an extruder where it can be combined with other rubbers. Many rubber products contain synthetic fabric or fibers for strengthening purposes. These fibers are typically coated with mixed rubber using a calender. The extruded rubber and rubber coated materials are then assembled into a final shape and cured. Among the steps in the tire assembly process, described in more detail below, are bead building; cementing and marking; cutting and cooling; tire building; and green tire spraying. It is during the curing process that the rubber vulcanizes (crosslinks), producing the characteristic properties of finished rubber. Once the final product is cured, it is often ground to remove rough surfaces and/or to achieve symmetry.

Mixing consists of taking the raw rubber and mixing it with several chemical additives. These additives consist of accelerators (to initiate the vulcanization process), zinc oxides (to assist in accelerating vulcanization), retarders (to prevent premature vulcanization), antioxidants (to prevent aging), softeners (to facilitate processing of the rubber), carbon black or other fillers (to serve as reinforcing / strengthening agents), and inorganic or organic sulfur compounds (to serve as vulcanizing agents).

Mixing typically is performed in an internal batch mixer. The internal mixer contains two rotors which shear the rubber mix against the wall of the vessel. Internal mixing is performed at elevated temperatures up to approximately 330°F.

Once mixed, the rubber is discharged from the mixer and processed into slab rubber or pellets. Rubber mixing typically occurs in two or more stages wherein the rubber is returned to the mixer and re-mixed with additional chemicals. The initial stage results in non-productive compounds, and the final stage results in productive compounds. It should also be noted that various rubber compounds produced at a particular facility can be exported to other facilities for use there.

Non-productive compounds consist of the raw rubber, process oils, reinforcing materials such as carbon black and / or silica and the antioxidant / antiozonant protection system. These materials are mixed at temperatures around 330°F. The final, "productive," stage involves mixing the rubber from the last non-productive stage with the activators, accelerators and sulfur curing agents. This stage is mixed at a lower temperature (around 230°F) because the rubber compound will now scorch and cure at elevated temperatures.

The majority of rubber products produced in the United States are composed of one or more of 23 generic rubber compounds shown in Table 4.12-1<sup>4</sup>. Emissions factors were derived from the specific compound recipes shown in Table 4.12-2. Emissions from manufacturing aids such as solvents and adhesives ARE NOT included in these emission factors.

Table 4.12-1

Index of Rubber Compounds

Compound #1:	Tire Inner Liner (BrIIR/NR)
Compound #2:	Tire Ply Coat (Natural Rubber / Synthetic Rubber)
Compound #3:	Tire Belt Coat (Natural Rubber)
Compound #4:	Tire Base/Sidewall (Natural Rubber / Polybutadiene Rubber)
Compound #5:	Tire Apex (Natural Rubber)
Compound #6:	Tire Tread (Styrene Butadiene Rubber / Polybutadiene Rubber)
Compound #7:	Tire Bladder (Butyl Rubber)
Compound #8:	EPDM 1 (EPDM Sulfur Cure)
Compound #9:	EPDM 2 (Peroxide Cure)
Compound #10:	EPDM 3 (Non-Black EPDM Sulfur Cure)
Compound #11:	CRW (Polychloroprene W Type)
Compound #12:	CRG (Polychloroprene G Type)
Compound #13:	Paracryl OZO (NBR/PVC)
Compound #14:	Paracryl BLT (NBR)
Compound #15:	Hypalon (CSM)
Compound #16:	Fluoroelastomer (FKM)
Compound #17:	AEM (Vamac)
Compound #18:	Hydrogenated Nitrile (HNBR)
Compound #19:	Silicone (VMQ)
Compound #20:	Acrylate Rubber (ACM)
Compound #21:	Chlorinated Polyethylene (CPE)
Compound #22:	Emulsion SBR (SBR 1502)
Compound #23:	Epichlorohydrin (ECO)

Table 4.12-2

Rubber Compound Recipes<sup>a</sup>

**Compound #1: Tire Inner Liner (BrIIR/NR)**

*Recipe:*

Brominated IIR X-2	85.00
SMR 20 Natural Rubber	15.00
GPF Black	60.00
Stearic Acid	1.00
Paraffinic Medium Process Oil	15.00
Unreactive Phenol Formaldehyde Type Resin (Arofene 8318, SP1068)	5.00
Zinc Oxide	3.00
Sulfur	.50
MBTS	<u>1.50</u>
	186.00

Number of Passes/Temperature:

1 (NP Temperature: 320°F; Chlorobutyl or 290°F Bromobutyl)

2 (P) Temperature: 220°F

**Compound #2: Tire Ply Coat (Natural Rubber / Synthetic Rubber)**

*Recipe:*

50472 Natural Rubber	
SMR-GP Natural Rubber	70.00
Duradene 707	30.00
N330	36.50
Sundex 790	20.00
Flectol H	1.50
Santoflex IP	2.30
Sunproof Super Wax	1.20
Zinc Oxide	5.00
Stearic Acid	1.00
Sulfur	2.30
CBS	<u>.80</u>
	170.60

Number of Passes / Temperature:

1 (NP) Temperature: 330°F

2 (P) Temperature: 220°F

Table 4.12-2 (cont.)

Rubber Compound Recipes

**Compound #3: Tire Belt Coat (Natural Rubber)**

*Recipe:*

#1RSS Natural Rubber	100.00
HAF Black (N330)	55.00
Aromatic Oil	5.00
N-(1,3 dimethylbutyl)-N-phenyl-P-phenylene diamine (Santoflex 13)	1.00
Zinc Oxide	10.00
Stearic Acid	2.00
n-tertiary-butyl-2-benzothiazole disulfide (Vanax NS)	.80
Sulfur	4.00
Cobalt Neodecanate (20.5% cobalt)	<u>2.50</u>
	180.30

Number of Passes / Temperatures:

- 1 (NP) Temperature: 330°F; add 1/2 black, add 1/2 oil
- 2 (NP) Temperature: 330°F, add remainder of black and oil
- 3 (remill) Temperature: 300°F
- 4 (P) Temperature: 220°F

**Compound #4: Tire Base / Sidewall (Natural Rubber / Polybutadiene Rubber)**

*Non-Productive Recipe:*

NR-SMR-5 CV	50.00
Taktene 1220	50.00
N330 Carbon Black	50.00
Zinc Oxide	1.50
Stearic Acid	2.00
Agerite Resin D	2.00
Vulkanox 4020	3.00
Vanwax H Special	3.00
Flexon 580 Oil	<u>10.00</u>
	171.50

*Productive Recipe:*

Non Productive	171.50
Zinc Oxide	1.50
Rubber Maker Sulfur	1.75
DPG	0.10
CBS	<u>0.60</u>
	175.45

Number of Passes / Temperatures:

- 1 (NP) Temperature: 330°F
- 2 (P) Temperature: 220°F

Table 4.12-2 (cont.)

Rubber Compound Recipes

**Compound #5: Tire Apex (Natural Rubber)**

*Recipe:*

TSR 20 Natural Rubber	100.00
HAF Black (N330)	80.00
Aromatic Oil	8.00
Stearic Acid	1.00
Resorcinol	3.00
Hexamethylenetetramine	3.00
Zinc Oxide	3.00
N-tertiary-butyl-2-benzothiazole disulfide (Vanax NS)	1.50
n-cyclohexylthiophthalimide (Santogard PVI)	.30
Sulfur	<u>3.00</u>
	202.80

1 (NP) Temperature: 330°F; add 60 parts black, add 6 parts oil

2 (NP) Temperature: 330°F; add Resorcinol, add 20 parts black, add 2 parts oil

3 (P) Temperature: 200°F; add Hexam

**Compound #6: Tire Tread (Styrene Butadiene Rubber / Polybutadiene Rubber)**

*Non-Productive Recipe #1:*

SBR 1712C	110.00
N299 Carbon Black	60.00
Taktene 1220	20.00
Zinc Oxide	1.50
Stearic Acid	3.00
Vulkanox 4020	2.00
Wingstay 100	2.00
Vanox H Special	2.50
Sundex 8125 Oil	<u>20.00</u>
	221.00

*Non-Productive Recipe #2:*

Non-Productive #1:	221.00
N299 Carbon Black	20.00
Sundex 8125 Oil	<u>5.00</u>
	246.00

*Productive Recipe:*

Non-Productive #2	246.00
Zinc Oxide	1.50
Rubber Makers Sulfur	1.60
TMTD	0.20
CBS	<u>3.00</u>
	252.30

Table 4.12-2 (cont.)

Rubber Compound Recipes

Number of Passes / Temperatures:

1(NP) Temperature: 330°F; add 60 parts black, add 20 parts oil

2(NP) Temperature: 330°F; add 20 parts black, add 5 parts oil

3 (P) Temperature: 220°F

**Compound #7: Tire Bladder**

*Recipe:*

BUTYL268	100.00
N330	55.00
Castor Oil	5.00
SP 1045 Resin	10.00
Zinc Oxide	5.00
Neoprene W	<u>5.00</u>
	180.00

Number of Passes / Temperatures:

NP 1 All Butyl, Castor Oil, Zinc Oxide, 45 phr N330, discharge approx 330°F / 340°F  
+Resin, 10 phr N330, discharge approx 270 / 280°F DO NOT EXCEED 290°F

PROD NP2 = neoprene, discharge approx 250F / 260°F

**Compound #8: EPDM 1 (EPDM Sulfur Cure)**

*Non-Productive Recipe:*

Vistalon 7000	50.00
Vistalon 3777	87.50
N650 GPF-HS Black	115.00
N762 SRF-LM Black	115.00
Process Oil Type 104B (Sunpar 2280)	100.00
Zinc Oxide	5.00
Stearic Acid	<u>1.00</u>
	473.50

*Productive Recipe:*

Non-Productive	473.50
Sulfur	0.50
TMTDS	3.00
ZDBDC	3.00
ZDMDC	3.00
DTDM	<u>2.00</u>
	485.00

Number of Passes / Temperatures

1 (NP) Temperature: 340°F; upside down mix, rubber then black and oil

2 (P) Temperature: 220°F

Table 4.12-2 (cont.)

Rubber Compound Recipes

**Compound #9: EPDM 2 (Peroxide Cure)**

*Non-Productive Recipe:*

Royalene 502	100.00
N 762 Carbon Black	200.00
Sunpar 2280 Oil	85.00
Zinc Oxide	5.00
Stearic Acid	<u>1.00</u>
	391.00

*Productive:*

Non-Productive	391.00
DICUP 40C	6.00
SARET 500 (on carrier / 2 parts active)	<u>2.56</u>
	399.56

NP Temperature: 330°F

P Temperature: 240°F

**Compound #10: EPDM 3 (Non-black EPDM Sulfur Cure)**

*Recipe:*

Vistalon 5600	50.00
Vistalon 3777	87.50
Hard Clay (Suprex)	180.00
Mistron Vapor Talc	100.00
Atomite Whiting	40.00
Process Oil Type 104B (Sunpar 2280)	60.00
Silane (A-1100)	1.50
Paraffin Wax	5.00
Zinc Oxide	5.00
Stearic Acid	1.00
Sulfur	1.50
Cupsac	0.50
TMTD	<u>3.00</u>
	535.00

Number of Passes / Temperatures:

1 (NP) Temperature: 330°F

2 (P) Temperature: 220°F, add Sulfur, Cupsac, and TMTDS

Table 4.12-2 (cont.)

Rubber Compound Recipes

**Compound #11: CRW (Polychloroprene W Type)**

*Recipe:*

Non Productive:

Neoprene WRT	100.00
N 550	13.20
N 762	15.70
Agerite Staylite S	2.00
Sunproof Super Wax	2.00
Santoflex IP	1.00
Magnesium Oxide	4.00
Stearic Acid	0.50
PlastHall Doz	15.00
	<u>153.40</u>

*Productive Recipe:*

Non-Productive	153.40
Zinc Oxide	5.00
TMTD	0.50
Dispersed Ethylene Thiourea	1.00
	<u>159.90</u>

Number of Passes / Temperatures:

1 pass at 240°F; add accelerator package at 200°F

**Compound #12: CRG (Polychloroprene G Type)**

*Non-Productive Recipe:*

Neoprene GN	100.00
SRF	50.00
Sundex 790	10.00
Octamine	2.00
Stearic Acid	1.00
Maglite D	4.00
	<u>167.00</u>

*Productive Recipe:*

Non-Productive	167.00
TMTM	0.50
Sulfur	1.00
DOTG	0.50
Zinc Oxide	5.00
	<u>174.00</u>

Number of Passes / Temperatures:

1 (NP) Temperatures: 240°F; add zinc oxide and curatives late at 200°F

2 (P) Temperature: 200°F



Table 4.12-2 (cont.)

Rubber Compound Recipes

**Compound #13: Paracryl OZO (NBR / PVC)**

*Recipe:*

PARACRIL OZO	100.00
Zinc Oxide	5.00
OCTAMINE	2.00
Hard Clay	80.00
FEF (N-550) Black	20.00
Stearic Acid	1.00
MBTS	2.50
TUEX	1.50
ETHYLTUEX	1.50
DOP	15.00
KP-140	15.00
Spider Sulfur	0.20
	<u>243.70</u>

Number of Passes:

(NP) Temperature: 330°F

(P) Temperature: 220°F; add MBTS, TUEX, ETHYLTUEX, Spider Sulfur

**Compound #14: Paracryl BLT (NBR)**

*Recipe:*

PARACRIL BLT	100.00
Zinc Oxide	5.00
SRF (N-774) Black	100.00
TP-95	15.00
Paraplex G-25	5.00
AMINOX	1.50
Stearic Acid	1.00
ESEN	0.50
MONEX	1.50
Sulfur	0.75
	<u>230.25</u>

Number of Passes / Temperatures:

(NP) Temperature: 280°F

(P) Temperature: 220°F; add sulfur, MONEX, and possibly ESEN

Table 4.12-2 (cont.)

Rubber Compound Recipes

**Compound #15: Hypalon (CSM)**

*Recipe:*

Hypalon 40	100.00
CLS 4 PBD	3.00
Carbo wax 4000	3.00
PE 617A	3.00
Mag Lite D	5.00
PE 200	3.00
Whiting (Atomite)	100.00
N650	100.00
TOTM Oil	70.00
MBTS	1.00
Tetrone A	1.50
NBC	0.50
HVA-2	<u>0.50</u>
	390.50

Uses of Formulas / Temperatures:

Number of Passes:

1 (P) Temperature: 280°F

**Compound #16: Fluoroelastomer (FKM)**

*Recipe:*

Viton E60C	100.00
N990 Black	20.00
Calcium Hydroxide	6.00
Maglite D	<u>3.00</u>
	129.00

**Compound #17: AEM (Vamac)**

*Recipe:*

VAMAC*B-124 Masterbatch	124.00
ARMEEN 18D	.50
Stearic Acid	.20
SRF Carbon Black (N-774)	10.00
DIAC #1	4.00
DPG	<u>4.00</u>
	142.70

Table 4.12-2 (cont.)

Rubber Compound Recipes

**Compound #18: Hydrogenated Nitrile (HNBR)**

*Non-Productive Recipe:*

HNBR Zetpol 2020	100.00
N650 Black	45.00
Flexone 7P	1.00
Agerite Resin D	1.00
ZMTI	1.00
Kadox 911 C	5.00
Stearic Acid	1.00
Trioctyl trimellitate (TOTM)	<u>7.00</u>
	161.00

*Productive Recipe:*

Sulfur	0.50
MBTS	1.50
TMTD	1.50
MTD Monex	<u>.50</u>
	165.00

Number of Passes / Temperatures:

1 (NP) Temperature: 275°F

2 (P) Temperature: 210°F

**Compound #19: Silicone (VMQ)**

*Recipe:*

Silicone Rubber	70.00
Silastic NPC-80 silicone rubber	30.00
5 Micron Min - U - Sil	68.00
Silastic HT - 1 modifier	0.80
Vulcanizing agent: Varox DBPH 50	<u>1.00</u>
	169.80

**Compound #20: Acrylate Rubber (ACM)**

*Non-Productive Recipe:*

Hytemp AR71	100.00
Stearic Acid	1.00
N 550	<u>65.00</u>
	166.00

*Productive Recipe:*

Non-Productive	166.00
Sodium Stearate	2.25
Potassium Stearate	0.75
Sulfur	<u>0.30</u>
	169.30

Number of Passes / Temperatures:

1 (NP) Temperature: 260°F

2 (P) Temperature: 220°F

Table 4.12-2 (cont.)

Rubber Compound Recipes

**Compound #21: Chlorinated Polyethylene (CPE)**

*Recipe:*

CM 0136	100.00
Maglite D	10.00
N 774 Black	30.00
Sterling VH	35.00
DER 331 DLC	7.00
Agerite Resin D	0.20
TOTM Oil	35.00
Triallyl Isocyanurate Cure 5223 (provided by Gates)	2.90
Triganox 17/40	10.00
	<u>230.10</u>

Number of Passes / Temperatures:

Single pass mixed to 240°F; add Triallylisocyanurate,  
Triganox 17/40 at 200°F

**Compound #22: Emulsion SBR (SBR 1502)**

*Non-Productive Recipe:*

SBR 1502	100.00
N330 Carbon Black	58.50
Zinc Oxide	10.00
Stearic Acid	2.00
Agerite Resin D (Naugard Q)	2.00
Flexone 7P	1.00
Sunproof Super Wax	1.50
Sundex 790 Oil	7.00
	<u>182.00</u>

*Productive Recipe:*

Non-Productive	182.00
Rubber Makers Sulfur	2.00
TBBS	1.80
	<u>185.80</u>

Number of Passes / Temperatures:

Non-productive pass mixed to 330°F,  
Second pass mixed to 220°F.

Table 4.12-2 (cont.)

Rubber Compound Recipes

**Compound #23: Epichlorohydrin (ECO)**

*Recipe:*

Hydrin 2000	100.00
N330 Carbon Black	50.00
Stearic Acid	1.00
Vulkanox MB-2 / MG / C	1.00
Calcium Carbonate	5.00
Zisnet F-PT	1.00
Diphenylguanadine	0.50
Santogard PVI	<u>0.50</u>
	159.00

Number of Passes / Temperatures:

1 Pass at 240°F

<sup>a</sup>Reference 4

Emissions of volatile organic compounds (VOCs) due to use of cements, solvent tackifiers, and release agents in rubber manufacturing are generally determined by either material balance, assuming a 100% loss to the atmosphere or, in some cases, by direct measurement. In cases where solvent emissions are determined by a mass balance calculation which assumes 100% loss at the time of application to the rubber substrate, there is a potential for double-counting a small percentage of the solvent emissions when using the emission factors to determine process volatile organic emissions. This situation is due to the partial absorption of some solvents into the rubber surface during manufacturing, and subsequent volatilization during downstream processing or curing.

It is not possible to determine to what extent typical hydrocarbon solvent constituents reported in the emission factors may have resulted from use of solvents or adhesives upstream in the manufacturing process. Anecdotal evidence suggests that as much as 5% of the solvent applied to the surface of the rubber may migrate into the rubber and appear later in the process as a volatile emission. Caution should therefore be exercised when compiling a facility-wide VOC emission inventory which combines the use of process emission factors and mass balance calculations of solvent usage. Otherwise, this methodology will generally result in an overstatement of the actual facility-wide VOC emissions.

Milling operations are conducted to form the rubber compounds into sheets or strips for introduction into calenders or extruders, for warming up rubber for ease of handling and processing and to homogenize recycled rubber compounds for reuse in the process.

In the mixing area rubber compound is discharged from the Banbury mixer into a drop mill, extruder or pelletizer which forms it into a long sheet of rubber compound. Additional mills may be located directly downstream from the Banbury drop mill to provide additional mixing or handling capability. From the mill(s) the hot, tacky rubber sheet is then passed through a water-based "anti-tack" solution which prevents the rubber sheets from sticking together as they cool to ambient temperature. The rubber sheets are placed directly onto a long conveyor belt (festoon) which, through the application of cool air or water, lowers their temperature. After cooling the rubber sheets are piled onto a storage pallet for transfer to the component preparation area.

Mills are also used to prepare rubber for introduction to calendaring and extruding processes. In these cases the mills are used to heat the rubber compound in order to make the rubber stock more flexible for further handling and processing.

Mills are also used to homogenize recycled rubber compounds for reintroduction into the process.

Extrusion is often performed to combine several types of previously mixed rubber compounds. The extruder consists of a power-driven screw within a stationary cylinder. A die is attached to the head of the screw to produce the desired shape or cross section of the extruded rubber.

Extruders may have multiple heads providing laminations of extruded shapes. Extruding heats the rubber and the rubber remains hot until it is cooled via air cooling or use of a water bath or spray conveyor where cooling takes place.

Extrusion can be performed with both warm or cold rubber feed. The extruder is jacketed to maintain the desired operating temperature.

Extruders may be utilized in the mixing area, along with mills to shape mixed rubber compound for further processing.

Calendering is often used in the rubber manufacturing industry to apply a rubber coat onto a continuous textile or metal mesh web. The calender is a heavy-duty machine equipped with multiple rolls revolving in opposite directions. Calenders receive hot strips of rubber from mills and squeeze the rubber into reinforcing fibers of cloth or steel or cloth-like fiber matrices, thus forming thin sheets of rubber coated materials. Calenders are also used to produce non-reinforced, thickness controlled sheets of rubber called innerliner or gum strip. After calendering, the calendered stock is wound into a liner to prevent sticking on itself. The calendered material is next cut to desired width and / or length for use in tire building.

The function of the bead is to provide a proper seal between the tire and the wheel rim when a tire is mounted on the rim. Bead compounds produced in mixing are used to coat bead wires. Brass-plated bead wire is received on large spools. Bundles of wires are passed through an extrusion die and given a coating of rubber. The rubber coated wire is then wound into a hoop of specific diameter and thickness and sent to the tire-building machine. In some cases, cement may be applied to the finished bead.

Cementing operations are used at various stages in the tire building process. For example, cements (adhesives) may be used to improve the adhesion of different components to each other during the tire building process. Traditionally cements have been used in the bead building process, applied to extruded tread stock (end cementing for cut treads and undertread cementing for retreads and certain other tread stocks) and at tire building machines. It is important to note that cement usage can vary significantly from facility to facility depending on the type of tire being manufactured and the process being utilized.

Marking inks are used at various stages of the process to aid in the identification of the components being managed. Typically marking inks are applied to extruded tread stocks to aid in the identification and handling of cured tires. Again, it is important to note that marking practices can vary significantly from facility to facility.

The various components manufactured in component preparation must be cut and cooled prior to introduction into tire building. Typically, the processing of the rubber compounds generates heat which causes an increase in rubber temperature. If this temperature is not controlled properly the compound may begin to cure prematurely, thus rendering it unusable.

Tire components from bead making, extrusion, and calendering are moved to the component assembly area. The assembly of various tire components is referred to as tire building. The main mechanical component of the tire-building operation is the drum, which is a collapsible cylinder that can be turned and controlled by the tire builder.

The typical tire building process begins with the application of a thin layer of special calendered rubber compound, called the inner liner, to the drum. Next, plies are placed on the drum, one at a time. The cords (calendered stock - rayon, nylon, polyester and related fabrics coated with rubber) are laid in alternate direction in each successive ply. This step is followed by a process of setting the beads in place. The plies are turned up around the beads and incorporate the beads into the tire. Chafer (extruder) stock from extruding or calendering is added if needed. Belts (metal or fabric calendered stock), if any are then applied. Finally, the tread and sidewalls are added to complete the tire. The tire may be "stitched" under pressure to remove air from between the components and bind them together. Radial tire production involves limited use of cements and solvents. Cement usage during tire building will vary significantly from facility to facility.

The drum is then collapsed and the uncured (green) tire is transferred to the green tire spraying operation. In preparation for curing, the uncured green tire may be coated with a lubricant (green tire

spray). The lubricating spray is either a solvent-based or a water-based silicone. The function of the green tire spray is to ensure the cured tire does not stick to the curing mold when being removed.

The final step in manufacturing of rubber products is vulcanizing (curing). There are three predominant vulcanizing processes: press mold curing, autoclave curing, and hot air curing. Press mold curing uses high temperature and pressure to cure the final product. The high pressure (600-10,000 psi) forces the rubber to conform to the shape of the mold. Press mold curing is used in tire and engineered products manufacturing.

Autoclave curing utilizes saturated steam at an elevated pressure to cure the rubber mix. Unlike press mold curing, the product is formed into its final shape prior to the curing process. Autoclave curing is the common method in non-tire rubber manufacturing facilities.

Hot air curing entails passing uncured, engineered products through a chamber with a heated atmosphere. Temperature and residence times may vary, depending on the product type and formulation. As with the autoclave curing, these products have already been formed into their final shape prior to undergoing the curing process.

Grinding is often performed to remove rough edges and other blemishes from the final product or in some cases to actually form and shape the product. The ground rubber is occasionally recycled and utilized as filler in some rubber manufacturing processes. In the tire manufacturing industry, grinding is performed to balance the tire and also to expose the white sidewall or lettering. Relative to the engineered products industry, grinding may actually be used to obtain the correct shape of the final product such as the final shaping of drive belts.

#### 4.12.2 Equipment Scale Considerations

Emissions testing was performed on several sizes of similar process equipment. These size differences are the most profound on the sizes of internal mixers tested. Emissions tests were performed on internal mixers ranging from a two-pound laboratory mixer, to a 200-pound pilot scale system up to a 500-pound production mixer. On a pound of pollutant emitted per pound of rubber mixed basis, test data indicated that emissions were not dependent on mixer size. This is especially true for the volatiles and semivolatile emissions. There was some variability of metals emissions which is most likely the result of greater particulate losses into the ventilation system on the larger mixers during charging than on smaller scale equipment.

Since there was no direct correlation to process equipment size and emissions, no scaling factors were developed for equipment size.

#### 4.12.3 Emissions And Controls

The mechanically-created or externally-added heat present during the six principal processes (mixing, milling, extrusion, calendering, curing, and grinding) cause volatile organic compounds (VOC) and hazardous air pollutants (HAP) to be emitted. Particulate matter is primarily emitted from the dry chemicals utilized in mixing and as a result of grinding.

Dust collectors (baghouses, fabric filters) are commonly used to control particulate matter emissions from mixing. Cyclone separators in combination with dust collectors or electrostatic precipitators are typically used in grinding applications.



#### 4.12.4 Emission Factors<sup>3</sup>

The following is common to each of the emission factors tables:

- (1) Total VOCs were analyzed by EPA Reference Method 25A / FID.
- (2) Total speciated organics were analyzed by EPA Reference Methods TO-14 / GC-MS (speciated volatiles), TO-14 / GC-FID (volatile ozone precursors) and M8270 (semi-volatiles).  
Note: Results from Method 25A and results from the total speciated organics reference methods are not directly comparable due to the inherent differences in the method of analysis.
- (3) Total Organic HAP are hazardous air pollutants as defined by the Clean Air Act Amendments of 1990, Section 301 and were analyzed by EPA Reference Method TO-14 / GC-MS and M8240 (volatiles), M8270 (semi-volatiles), and TO-14 / GC / FPD (sulfur compounds).
- (4) Total Metal HAP are hazardous air pollutants as defined by the Clean Air Act Amendments of 1990, Section 301 and were analyzed by EPA Reference Methods M6010 and M7000 (metals).
- (5) Total HAP are the sum of total organic HAP and total metal HAP.
- (6) Total Particulate Matter (PM) was analyzed by EPA Reference Method 5.
- (7) Target analytes which were not detected in any runs for a particular process and compound were not included in the tables. The assumption is that if a target analyte went undetected in any runs, there is a high probability that even if it was present, the low detection limits indicate that its overall contribution is insignificant.
- (8) Target analytes detected in one or more runs were averaged together. Target analytes that were not detected in a test run were assumed to have been present at a concentration of one-half the test detection limit for averaging purposes.
- (9) Metals were expected to be detected in the particulate matter emitted during rubber mixing but were not expected to be a significant emission in any other process. To confirm this assumption, the extruder emissions were analyzed for metals. Metals emitted proved to be so insignificant that they could be within the margin of error of the analytical procedure. Metal emissions were therefore considered to be insignificant in other processes.

Nine separate tables of emission factors comprise the remainder of this section. The tables are available in spreadsheets on the CHIEF web site at <http://www.epa.gov/ttn/chief/ap42/ch04/>. The tables are too large to include in the section and are more useful as spreadsheets. The contents of the MS Excel spreadsheet are shown in Table 4.12-3.

#### 4.12.5 Updates since the Fifth Edition

This section was released as a draft in 1997 for review and comment. It was not finalized.

Update 2008 -

The draft section was originally released for review and comment in 1998. The following changes were made to the emissions factors following the review in 1999:

- The interpolated compound 3 emission factor for hexachlorobenzene (HCB) in tables for calendaring, extruding, and mixing, has been updated from the original based on mixing emission testing performed by the Rubber Manufacturers Association (RMA) in July 1999. RMA conducted testing to confirm that HCB is not present in tire manufacturing. This result was formalized in the Federal Register on August 3, by removing tire manufacturing from the list of sources of HCB in the CAA 112(c)(6) inventory (65 FR 47725). The updated factor was submitted to EPA as an update to the AP-42. The factors for Total Speciated Organics, Total Organic HAPs and Total HAPs have also been updated to reflect this update.
- Toluene and methylene chloride factors in the table for carcass grinding were updated from the original by testing performed by Michelin North America in January 1999. The updated factors were submitted to EPA for inclusion in the AP-42. The revisions for toluene and methylene chloride are also reflected in the factors for Total HAPs, Total Organic HAPs and Total Speciated Organics.
- Since 1999, the tables were revised to remove compounds not observed during emissions testing (including HCB), to remove interpolated emissions factors, and to group similar types of tires for tire cure emissions factors. The section was edited to reflect final EPA approval in 2008.

Table 4.12-3  
Key to Emission Factor Tables and Files

Table Name	Rubber Compounds Included	File Name
Autoclave SCC 3-08-001-41	Compounds 1-23 (see Table 4.12-2 Rubber Compound Recipes)	MS Excel Spreadsheet c04s12_tables.xls
Calender SCC 3-08-001-15		
Extrude SCC 3-08-001-12		
Hot Air SCC 3-08-001-42		
Milling SCC 3-08-001-28		
Mixing SCC 3-08-001-11		
Platen Press SCC 3-08-001-43		
Grinding - Belt SCC 3-08-001-51 - Carcass SCC 3-08-001-52 - Retread SCC 3-08-001-53 - Sidewall/ Whitewall SCC 3-08-001-54	N/A	
Tire Cure SCC 3-08-001-07	N/A	

## References For Section 4.12

1. *Development of Emission Factors for the Rubber Manufacturing Industry, Volume 1: Emission Factor Program Results. Final Report*, prepared for the Rubber Manufacturers Association (RMA) by TRC Environmental Corporation, Lowell, MA, May 1995.
2. *Development of Emission Factors for the Rubber Manufacturing Industry, Volume 2: Project Data. Final Report*, prepared for the Rubber Manufacturers Association (RMA) by TRC Environmental Corporation, Lowell, MA, May 1995.
3. *Development of Emission Factors for the Rubber Manufacturing Industry, Volume 3: Test program Protocol. Final Report*, prepared for the Rubber Manufacturers Association (RMA) by TRC Environmental Corporation, Lowell, MA, May 1995.
4. *Development of Emission Factors for the Rubber Manufacturing Industry, Volume 4: Emission Factor Application Manual. Final Report*, prepared for the Rubber Manufacturers Association (RMA) by TRC Environmental Corporation, Lowell, MA, May 1995.
5. *Stationary Source Sampling Report for Michelin North America, Inc., Duncan, South Carolina* by Trigon Engineering Consultants, Inc., Charlotte, NC, January 1999.
6. *Stationary Source Sampling Report for Farrel Process Laboratory*, prepared for the Rubber Manufacturers Association (RMA) by Trigon Engineering Consultants, Inc., Charlotte, NC, July 1999.
7. *Section 112(c)(6) Source Category List: Tire Production*, Federal Register. 40 CFR Part 63. Vol. 65, No. 150. August 3, 2000. pp. 47725.
8. *National Emission Standards for Hazardous Air Pollutants: Rubber Tire Manufacturing*, Federal Register. 40 CFR Part 63. Vol. 65, No. 202. October 18, 2000. pp. 62414.
9. *National Emission Standards for Hazardous Air Pollutants: Rubber Tire Manufacturing - Final Rule*, Federal Register. 40 CFR Part 63. Vol. 67, No. 161. July 9, 2002. pp. 45588.
10. *National Emission Standards for Hazardous Air Pollutants: Rubber Tire Manufacturing - Final Rule, technical correction*, Federal Register. Vol. 68, No. 48. March 11, 2003. pp. 11745.
11. Letter from T.J. Norberg, Rubber Manufacturing Association to R. Ryan, US Environmental Protection Agency, September 7, 1999. Data Review and Tire Carcass Grinding Update.