

Radiation Effects on Polymeric Systems

Elastomers

Radiation Vulcanization of Elastomers Commercial Process

- **Most elastomers can be radiation vulcanized to give crosslinked products similar to those obtained by conventional thermal vulcanization**
- **Some radiation vulcanization on commercial scale is being done**
- **Conventional formulations can be radiation vulcanized**
- **Optimizing the formulations for radiation vulcanization gives better products**

Bradley (1984)

Radiation Vulcanization of Elastomers Free Radical Mediated

- **Radiation crosslinking of natural rubber (cis-1,4-polyisoprene) and gutta percha (trans-1,4-polyisoprene) is inhibited by oxygen**
 - **Gamma irradiation requires inert atmosphere**
 - **Electron irradiation can be done in air**
- **Radiation crosslinking of EPDM proceeds more efficiently than that of EPR**
 - **Crosslinking efficiency of EPDM depends on its ethylene content, and also varies with the crosslinking agent present e.g., ENB (5-ethylidene-2-norbornene) is very efficient**
- **Radiation crosslinking of polybutadiene is quite efficient**

Radiation Vulcanization of Elastomers

Wide Applicability

- **Radiation vulcanization of polychloroprene, polychloroprene/polyethylene blend, vinylidene fluoride based fluoroelastomers, silicone rubbers, and blends of conjugated diene butyl rubber with polyethylene and polybutylene, also proceeds well**
- **In contrast, polyisobutylene and butyl rubber degrade on irradiation**

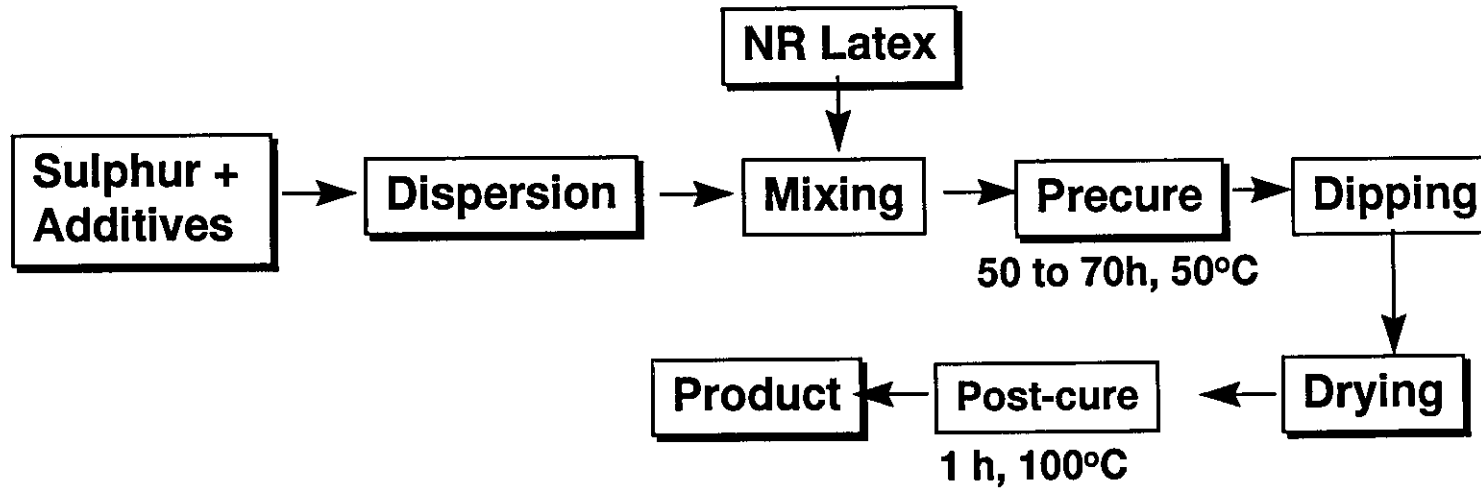
Natural Rubber Latex (NRL)

- **Studied since 1960**
- **Many Asian countries involved including Japan and Thailand, along with IAEA**
- **Technical feasibility demonstrated**
- **Pilot plants operating**
- **Cost comparable to thermal vulcanization**
- **Commercialization in progress**

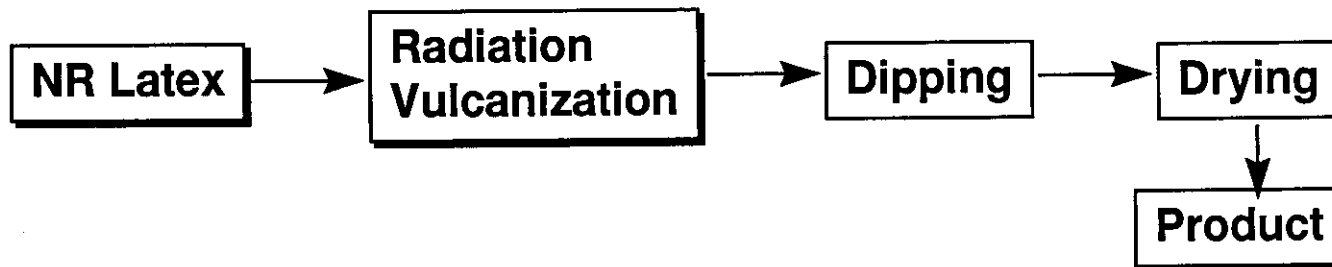
Radiation Vulcanization of NRL (RVNRL)

- **Much simpler than thermal vulcanization**
- **Requires flushing with nitrogen and stirring**
- **Crosslinking promoters (<5%) added, e.g., CCl₄, mono- or multi-functional acrylates**
- **Dose required, 10-30 kGy**
- **Product has very low cytotoxicity**
- **Nitrosamines, sulfur and zinc oxide eliminated (potential health risks)**
- **RVNRL safer than thermally vulcanized NRL**

Thermal Vulcanization



Radiation Vulcanization



Properties of Thermally Cured NRL and RVNRL

Property	RVNRL ¹	Thermally Cured NRL
Tensile Strength (T_b), MPa	38	41
Elongation at Break (E_b), %	900	870
Acid Resistance (10% HCl, 48h)		
T_b , MPa	23	33
E_b , %	900	850
Alkali Resistance (10% NaOH, 48h)		
T_b , MPa	32	35
E_b , %	920	920
Ageing Resistance (70°C, 48h)		
T_b , MPa	37	41
Combustion:		
Gas Production, mg/g	58.5	346.3
Ash, wt. %	0.5	2.2
Ignition Temperature, °C	348	333

¹ Crosslinking promoter, mixture of 2-ethylhexyl acrylate and ammonia; dose, 12 kGy

Tire Manufacture Synergy with Conventional Technology

- **Radiation crosslinking of innerliner has helped make tire manufacturing a more efficient and economical process**
- **It is an electron irradiation application (1-3 MeV)**
- **Irradiation of the green rubber innerliner allows a precise control of its strength and tack**
- **This enables precise assembly of the multi-layered tire, and the tack of the innerliner results in good adhesion between layers during conventional vulcanization**

Tire Manufacture Synergy with Conventional Technology (contd)

- **A good example of radiation technology and conventional technology working synergistically**
- **Most conventional formulations can be radiation crosslinked**
- **Optimization of the formulations for radiation crosslinking gives a better product**

Economics of Irradiation in Tire Manufacture (Bradley, 1984)

**Original liner 24" wide x .047" thick x 72" long x ρ 1.2
= 3.5 lbs = 1.59 kg**

**Reduced liner 24" wide x .040" thick x 72" long
x ρ 1.2 = 2.9 lbs = 1.32 kg**

Material savings of 0.6 lbs or 270 g/tire

**Cost savings are based on \$0.35/lb for the inner liner
Material cost saving is approx. \$0.20/tire
Irradiation cost is approx. \$0.03/tire
Actual savings \$0.17/tire**

Product Throughput

(Bradley, 1984)

- **800 kV electron accelerator, 31.25 kW**
- **40 kGy dose**
- **1077 Tires (innerliners)/h**

Conclusions

- **Crosslinking of elastomers is very important for the final mechanical properties of their products**
- **Radiation crosslinking has carved out a place in this industry**
- **With focussed R&D and involvement of visionary entrepreneurs, the use of radiation processing in the elastomer industry should increase**