



6.2 Cost Evaluation of Radiation Vulcanization of Natural Rubber Latex

K. MAKUUCHI

EB System Corporation, Takasaki, Japan

Cost of radiation vulcanized NR latex was evaluated. The plant would be built in an existing dipping factory in an industrial area in a Southeast Asian country. One thousands dry tons of NR latex are vulcanized with a low energy electron accelerator. The electron accelerator is a self-shielding low energy type. The maximum accelerating voltage is 300 kV and the output power is 10 kW. The total construction cost of the plant is \$ 400,000 including electron accelerator and other equipments. Costs of raw materials and utilities are \$1.165 and \$ 0.023 per one kg of product, respectively. The fixed costs of the plant consist of labor costs, labor overhead, maintenance, plant overhead, depreciation, and bank interest. It is \$ 0.190/ kg of product. The company overhead for operation including company management, R&D and insurance is \$0.044/kg of product. Thus, the total production cost is estimated to be \$ 1.422/ kg of product.

1. Outline of a RVNRL Plant with a Low Energy Electron Accelerator

A RVNRL plant is comprised of production and supporting equipment. Production equipment is divided into direct and indirect equipment. Direct production equipment in a RVNRL plant refers to equipment within the bio-shielded area, e.g., the electron accelerator and irradiation vessel. Indirect production equipment describes necessary facilities not located within the bio-shielded area, e.g., storage tanks. Support equipment referred to as offsite include facilities such as office buildings, storehouses, maintenance shops, roads, land, waste disposal systems, water systems, electrical power distribution networks, cafeterias, and employee recreational facilities.

Figure 1 shows the direct production equipment of the RVNRL plant. The annual production capacity of the plant is 1,000 dry tons of RV NR latex. The RVNRL plant is built in an existing dipping factory. All the necessary equipment, electricity, water and wastewater treatment are fully installed. The electron accelerator is a self-shielding low energy type. The maximum accelerating voltage is 300 kV and the output power is 10 kW. Newly-needed equipment and supplies are an irradiation vessel, tanks for NR latex, 10 % KOH solution, 1 % ammonia solution, pure water, RV NR latex and BA, and tanks with a mixer for emulsification of a vulcanization accelerator and formulation.

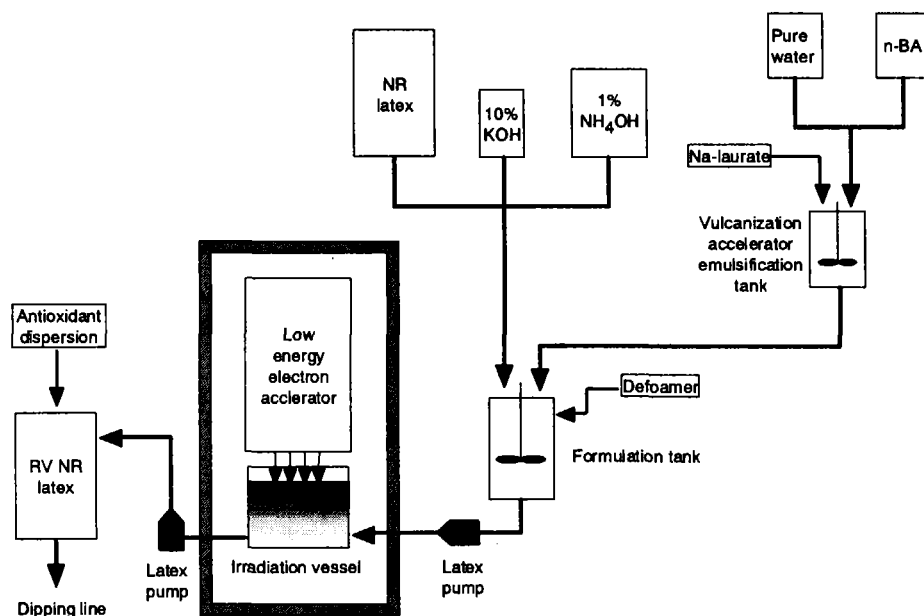


Fig. 1 Outline of RVNRL plant

2. Operation of RVNRL plant

High ammonia NR latex concentrate is recommended for RVNRL. The latex is first diluted to 50% total solids with 1% ammonia solution followed by 0.2 phr of 10% KOH solution in the formulation tank. The emulsion of BA is prepared by mixing potassium laurate with BA and water in the ratio of emulsifier : water : BA = 1 : 99 : 100 in the emulsification tank. The BA emulsion is added to the latex slowly and mixed by stirring in the formulation tank. Weighed defoamer is added to the formulation tank. The formulated NR latex is transferred to the irradiation vessel by means of latex pump and irradiated for a definite period of time with definite operation conditions of the accelerator. The irradiated NR latex is transferred to the RV NR latex tank by means of a pump. Weighed antioxidant dispersion supplied from the dipping facility is added to the radiation vulcanized NR latex in the RV NR latex.

3. Construction Cost of RVNRL Plant

Construction cost of facility depends largely on where it is located. In this calculation, the plant is assumed to be built in an industrial area in a Southeast Asian country.

Table 1 shows the construction cost of a RVNRL plant. Usually, the plant comprises production and supporting equipment. However, a RVNRL plant utilizes the existing supporting equipment as much as possible. The direct cost includes purchase of an

electron accelerator and other equipment, installation fee for the accelerator and latex handling piping. Indirect costs include engineering and supervision fees and construction overhead. Contingency is estimated to be 15 % of the sum of direct and indirect costs. The total construction cost of the plant is \$ 400,000 (399,377).

Table 1 Construction cost calculation for production of RV NR latex of 1,000 dry t/y

Item		Capital, \$		
1	Process construction cost	D + T	363,070	90.91
1.1	Direct cost	D	345,780	86.56
	Construction	P	339,000	84.88
	Machinery and equipment	E	300,000	75.12
	EB machine installation	10 % E	30,000	7.51
	Latex process piping	3 % E	9,000	2.25
	Utilities and offsites	2 % P	6,780	1.70
1.2	Indirect cost	T	17,290	4//33
	Engineering and supervision	5 % D	17,290	4.33
2	Contingency	10 % (D+T)	36,307	9.09
	Total	1 + 2	399,377	100

4. Production Cost of RVNRL

Production costs are continuing operating expenditures after a manufacturing facility has been built. Production costs are the sum of plant production cost and company overhead. The plant production cost consists of variable costs and fixed costs. The variable costs include the costs of raw materials and utilities. The fixed costs consist of labor costs, labor overhead, maintenance, plant overhead, depreciation, and bank interest. These are presumed as follows; labor overhead, 35% of direct labor; maintenance, 3% of fixed capital; plant overhead, 4.5% of fixed capital; depreciation, 10% of fixed capital; bank interest, 20% of fixed capital. The labor costs includes wages, salaries, and overtime paid to operating personnel, labor overhead, taxes, social security payments, pension plans paid for by the company, employee recreational subsidies, and health insurance premiums paid by the company. The company overhead includes headquarters and company management, R&D, sales, and insurance (1% of fixed capital).

The annual production of the RV NR latex is 1,000 dry tons. The followings are the irradiation conditions:

TSC of NR latex: 55 %
 Vulcanization accelerator: 5 ph of BA
 Dose: 80 kGy
 Radiation utilization efficiency: 60 %
 Total volume: 1,817 ton/y
 Total actual operation time: 6,730 hours

5. Variable Cost

Costs of raw materials and utilities are the component of variable cost and shown in Table 2.

Table 2 Raw materials for production of 1,000 ton of RV NR latex

Cost item	kg/product	Units/y	\$/unit	\$/y
NR Latex	1.62 kg	1,620,000 kg	0.62	1,004,400
Liquid ammonia	0.002 kg	2,000 kg	0.65	1,300
KOH	0.002 kg	5,000 kg	1.8	9,000
Emulsifier	0.005 kg	5,000 kg	1.5	7,500
BA	0.05 kg	50,000 kg	1.5	75,000
Antioxidant	0.002 kg	2,000 kg	15	30,000
Defoamer	0.002 kg	2,000 kg	15	30,000
Process water	0.165 kg	165,000 kg	0.05	8,250
Total raw materials				1,165,450
Electricity, kWh	30 kWh	180,000 kWh	0.08	14,400
Water	10 kg	10,000,000 kg	0.0008	8,000
Total utilities				22,400
Total variable cost				1,187,850

6. Operation Cost

One operator per shift will operate the plant 24 hours a day in three shifts. The plant is managed supervisors and the overall supervisor of the dipping factory. The costs of the supervisory and management personnel in overall control are allocated as percentages of sales or capital assets. In addition to these costs related to a specific production operation, there are laboratory costs include analytical, testing, problem solving, and quality control functions. Maintenance costs include both labor and material. Taxes, considered as part of the production cost are related to the value of

plant assets, annual sales, or other standards. Income taxes are not included.

Table 3 shows the production cost for the production of RVNRL of 1,000 t/y. This calculation is based on US dollars and dry rubber.

Table 3 Production cost for production of RVNRL of 1,000 t/y (dry rubber base)

Cost item	\$/y	\$/kg Product	%
Variable costs	1,187,850	1.188	83.544
Raw materials	1,165,450	1.165	81.927
Utilities	22,400	0.0224	1.575
Fixed costs	190,000	0.190	13.361
Labor			
3 Operators	15,000		
1/2 Supervisor	10,000		
1/3 Overall supervisor	5,000		
Direct labor	30,000		
Labor overhead	10,000		
Total labor	40,000	0.040	2.813
Maintenance	12,000		0.844
Plant overhead	18,000		1.266
Depreciation	40,000		2.813
Bank interest	80,000		5.626
Plant production cost	1,377,850	1.378	96.91
Company overhead	44,000	0.044	3.094
Administration, R&D, sales	40,000		
Insurance	4,000		
Total production cost	1,421,850	1.422	100

7. Working Capitals

Working capital is the short term operating cost. It is given by the current assets minus the accounts payable. The current assets include (1) cash reserves, (2) inventories and (3) accounts receivable. Though the RV NR latex is consumed in the same factory, the sale price of the RV NR latex is assumed to be \$ 1.5 - 2.0 /dry kg for calculation of accounts receivable. Cash reserves are estimated at one-month plant production cost (\$115,070), similarly raw material inventory, one month of raw material cost (\$97,370), product inventory, one-month production cost (\$115,070) and accounts payable, one month of raw material cost (\$97,370). Table 4 shows the changes of working capital

with sales price.

Table 4 Working capital

Sales price \$/kg	Accounts receivable/y	Accounts receivable/m	Working capital
1.5	1,500,000	125,000	355,140
1.6	1,600,000	133,333	363,473
1.7	1,700,000	141,667	371,807
1.8	1,800,000	150,000	380,140
1.9	1,900,000	158,333	388,473
2.0	2,000,000	166,667	396,807
2.1	2,100,000	175,000	405,140

8. Return on Investment

The return on investment is the ratio of profit after taxes (assumed to be 45%) and total fixed capital and working capital. The total fixed capital is \$400,000. Total production cost is \$1,425,000. The cash recovery time is roughly estimated by dividing fixed capital by profit after taxes. Table 5 shows the return and cash recovery time of this plant.

Table 5 Return and cash recovery time of the plant

Sales price (\$/kg)	Profit before tax	Profit after taxes 45%	Total fixed capital and working capital	Return (%)	Cash recovery (year)
1.5	75,000	33,750	755,140	4.5	11.9
1.6	175,000	78,750	763,473	10.3	5.1
1.7	275,000	123,750	771,807	16.0	3.3
1.8	375,000	168,750	780,140	21.6	2.4
1.9	475,000	213,750	788,473	27.1	1.9
2.0	575,000	258,750	796,807	32.5	1.6
2.1	675,000	303,750	805,140	37.7	1.4