Project Planning for Small and
Medium Scale Industries No. 27

Match Manufacturing Plant

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JAPAN CONSULTING INSTITUTE

This technical brochure was compiled to help in the drafting of a suitable plan for the construction of a Match Manufacturing Plant.

The production scale and manufacturing process have been described in this brochure on the basis of a typical instance.

The profitability was estimated by fixing certain required conditions, which may differ from country to country.

We hope that the data contained in the brochure will help you to draw up the most suitable plan for the industrialization of your project.

In case a government or public organization requests the Japan Consulting Institute to conduct a feasibility study of the above industry for the purpose of establishing the most suitable plan, it is possible for us to carry this out free of charge.

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1. Introduction

Match is a short, slender, elongated piece of wood or cardboard, suitably impregnated and tipped to permit, through pyrochemical action between dry solids with a binder, the creation of a small transient flame. Until matches were developed as at present, creation of fire had been very troublesome task during long history of mankind.

The following shows an outline of the history of the development of modern matches. (Note 1)

White phosphorus (also called yellow phosphorus) was discovered by Henning Brand in 1669, and it is recorded that white phosphorus can easily ignite on sunlight warming or rubbing. Robert Boyle used, for the first time, white phosphorus for setting fire to wooden splints tipped with sulphur.

Between 1780 and 1830, numerous match like contrivances used this ignition principle. Since Berthollet discovered potassium chlorate in 1786, its combination with white phosphorus and modifying ingredient led to the manufacturing of friction matches which could create a fire at any place. However, because of its toxic property, manufacturing of white phosphorus matches was prohibited worldwide in the early 1900's.

Modern safety matches were made by using red, nonpoisonous, but easily ignitable allotrope of phosphorus called red phosphorus, which was discovered by V. Schrötter in 1844. In 1845 Pasch in Sweden and Böttger in Germany prepared striking surface containing the new material, thus separating the two major fire-producing components, potassium chlorate in the matchhead as the oxidizer and the most sensitive fuel-type material in the striker. This type of match was much improved, and was commercialized by J. E. Lundstrom in Sweden in 1855. And in 1898 French men Henri Sévene and Emile David Cahen patented the manufacturing method of phosphorus sulfide matches, using nonpoisonous P_4S_3 in place of phosphorus.

The final stage of the development of modern matches was a safety-type cardboard match which was invented by Joshua Pusey in 1892. This match is now called the book match.

Book matches are being more used for advertising compared with stick matches. Although it was much later that book matches became popular, they are now being manufactured dominantly in the match industry in America. Book matches have also come to be used increasingly in other countries.

As the global trends, it is becoming more and more difficult to obtain the wood that is suitable for manufacturing match sticks due to a shortage of wood and the protection of natural resources. Under such circumstances, the wax stick match, the demand for which is expected to expand in the future, will be taken up in this brochure.

Note 1: Kirk-Othmer: Encyclopedia of Chemical Technology, 3rd. Ed., Vol. 15, pp.1.

2. Outline of the Product

The matches, that are now being manufactured in the world, can be classified by use as follows.

(1) Matches for domestic use

They are sold on the market with a maker's trademark. Consumers buy the matches at the market.

(2) Matches for advertising

The matches have a label designed by an advertiser. The advertiser usually places an order with a match maker, and gives the matches to consumers free of charge.

Also in developing countries the ratio of advertising matches is recently on the increase; and with the development of printing and other related businesses, the demand for advertising matches is anticipated to expand in the future.

When the matches are classified by type of splint, there are three kinds as below.

(1) Stick match

This is made of wood. The section of this stick is commonly square. The sticks are separated each. This is what is generally called the match.

(2) Book match

This match is made of wood and/or paper board. Both the splints made of wood or paper board are connected at the bottom, and only the upper parts are separated and the tops are coated with head chemicals. The sticks are split when used.

(3) Wax stick match

This match is made using paper. Its cross section is usually round. There are also square or triangular splints. Like the stick match, splints of this wax stick match are separated each.

3. Raw Materials

The raw materials and their qualities, that are used for wax stick matches are shown in Table 1.

Table 1. Raw Materials

Item	Name of raw material	Quality, etc.
1. Wax splint	Paper	Roll paper: 27mm x 2,000m Substance: 40.1 gr/m²
	Paraffin wax	Melting point: 92.5°C Solidification temp.: 80°C Needle penetration: 13 Viscosity: 8cps (at 100°C) Oil content: max. 0.5% PH: 7
2. Head chemicals	Potassium chlorate	($KClO_3$) 99.7% up Size: 250 mesh up
	Gelatine glue	Jelly strength: 220/250 gr PH: 7.4 Moisture: below 13% Ash, Grease & Chlorides: below 2%
	Glass powder	Colour: White Size: 200 mesh up Moisture: below 0.2%
	Sulphur powder	(S) 99.8% up Size: 250 mesh up Ash: below 0.2% Moisture: below 0.01%
	Ferric oxide	(Fe_2O_3) 90% up Size: 200 mesh up Moisture: below 0.5%
	Manganese dioxide	(MnO_2) 50% up Size: 200 mesh up Moisture: below 0.5%
	Potassium bichromate	($K_2Cr_2O_7$) 98% up
3. Side chemicals	Red phosphorus	(P) 98% up Size: 350 mesh up
	Antimony sulphide	(Sb_2S_3) 30–65% Size: 150 mesh up Moisture: below 0.3%
	Milky paste	Viscosity: 8,000 ± 500 CPS PH: 3–4 Ig. loss: 0.3%
4. Paste	Milky paste	Viscosity: 8,000 ± 500 CPS PH: 3–4 Ig. loss: 0.3%
5. Outer match box	Paper board	2 Colours print Sheet size: 450mm x 540mm Substance: 310 gr/m² Skillet size: 45mm x 104mm
6. Inner match box	Paper board	Sheet size: 460mm x 560mm Substance: 240 gr/m² Skillet size: 55mm x 90mm
7. Wrapping paper	Paper	Size: 140mm x 310mm Substance: 41.7 gr/m²
8. Label	Paper	Size: 58mm x 65mm Substance: 52.3 gr/m²
9. Carton box	Corrugated paper	2-ply

4. Manufacturing Process

Fig. 1 shows a general manufacturing process of wax stick matches. A brief explanation will be made on the process.

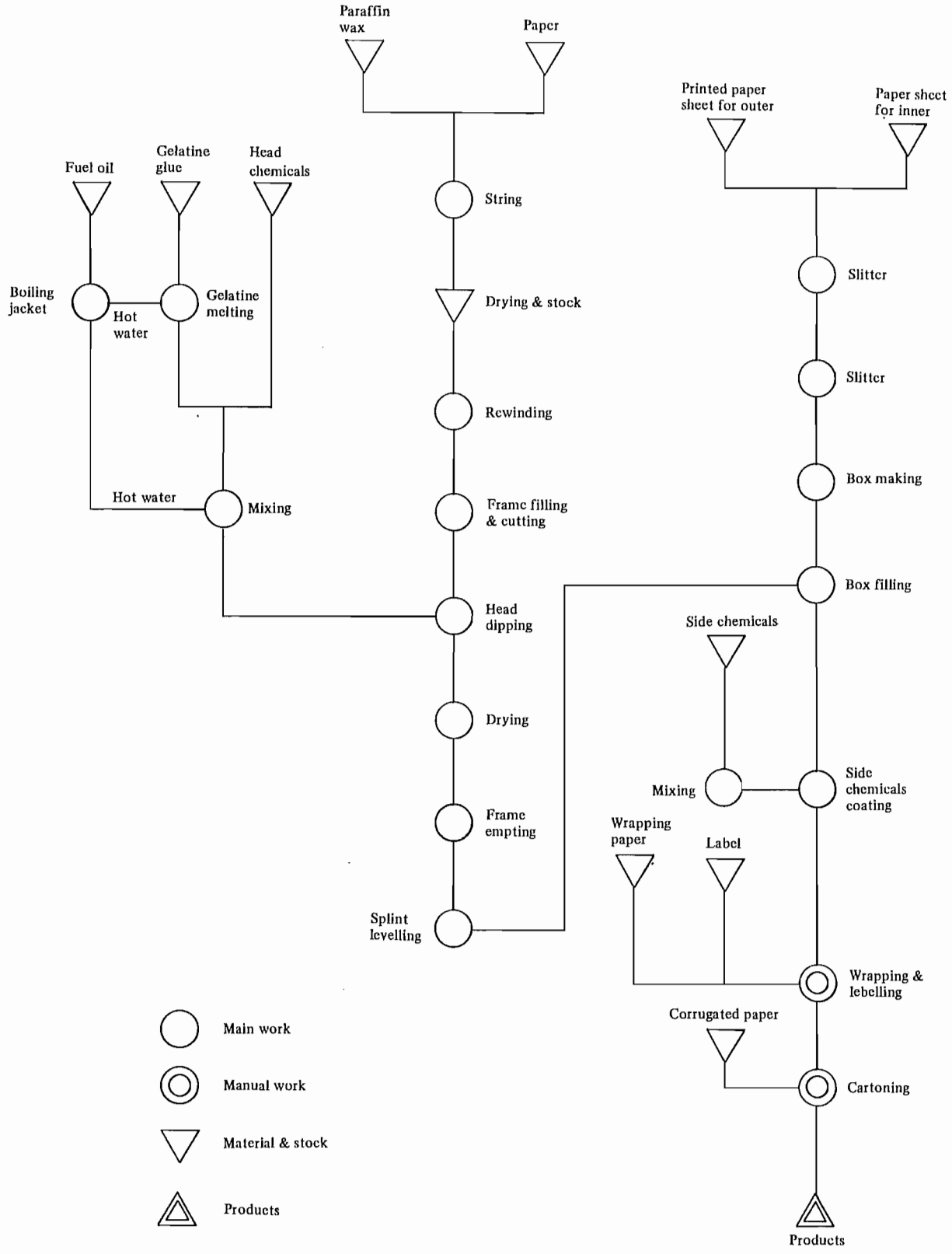


Fig. 1 Manufacturing Process of Wax Stick Match

(1) Head chemicals preparation

The fixed quantity of head chemicals and gelatine glue are put into a mixer having a hot water jacket, and are mixed until they become a uniform composition.

(2) Splint making

① Paper is dipped into a paraffin wax, and a stringy splints are made with a splint making machine.

② The splints are passed through nozzles and into a cooling tank to solidify the paraffin wax of splints.

③ The splints are wound around aluminium bobbins and are air-dried completely.

(3) Head dipping

Stringy splints are cut into a uniform length and are placed in the same direction (arranged on the stick frame), and the other end of splints are dipped into the head chemicals so that the splint ends are coated with head chemicals, and then, the splints are dried in a drying chamber.

(4) Box making

Paper sheet to be used for outer and inner boxes is cut into the fixed size and is pasted around the box, making the match boxes.

(5) Box filling

① The dried splints, which are coated with head chemicals, are removed from the stick frame.

② The splints are placed in the same direction and set into a match filling machine and a definite quantity of matches is filled into each box.

(6) Side chemicals coating and wrapping

① Side chemicals are applied to the side of match boxes and are dried sufficiently.

② Label is attached on the match boxes by hand, and 10 boxes are wrapped together.

5. Outline of a Model Plant

This brochure will take up a wax stick match manufacturing plant as a model, and explanation will be made on its outline.

5.1 Kind of Product and Production Scale

(1) Kind of wax stick match

Box size: 45mm x 33mm x 14mm
Stick size: 36mm x 1.7mm ϕ
Number of sticks contained:
Average 50 pieces
Wrapping: 10 boxes/package, 100 packages/carton

(2) Plant operation

Operating hours per day: 8 hours
Annual operating days: 300 days

(3) Production scale

72,000 boxes/day, and 21,600,000 boxes/year

5.2 Required Quantity of Raw Materials

The required quantity of raw materials are shown in Table 2.

Table 2. Required Quantity of Raw Materials

Item	Name of raw material	Annual required quantity
1. Wax splint	Paper	50 splints x 300 days x 72,000 boxes ÷ 0.9 = 1,200,000,000 splints 1,200,000,000 splints x 0.036m/splints ÷ 2,000m/roll = 21,600 rolls
	Paraffin wax	2.14 kgs/roll x 21,600 rolls = 46,220 kgs
2. Head chemicals	Pottasium chlorate	38.6 kgs/72,000 boxes x 300 days = 11,580 kgs
	Gelatine glue	9.2 kgs/72,000 boxes x 300 days = 2,760 kgs
	Glass powder	11.06 kgs/72,000 boxes x 300 days = 3,320 kgs
	Sulphur powder	5.03 kgs/72,000 boxes x 300 days = 1,510 kgs
	Ferric oxide	2.53 kgs/72,000 boxes x 300 days = 760 kgs
	Manganese dioxide	3.6 kgs/72,000 boxes x 300 days = 1,080 kgs
	Potassium bichromate	1.8 kgs/72,000 boxes x 300 days = 540 kgs
3. Side chemicals	Red phosphorus	3.03 kgs/72,000 boxes x 300 days = 910 kgs
4. Paste	Antimony sulphide	3.16 kgs/72,000 boxes x 300 days = 950 kgs
	Milky paste	3.97 kgs/72,000 boxes x 300 days = 1,190 kgs
5. Outer match box	Paper board	72,000 boxes x 300 days ÷ 50 skillets/sheet ÷ 0.95 = 454,740 sheets
6. Inner match box	Paper board	72,000 boxes x 300 days ÷ 48 skillets/sheet ÷ 0.95 = 473,680 sheets
7. Wrapping paper	Paper	72,000 boxes x 300 days ÷ 10 boxes/wrapper ÷ 0.95 = 2,273,680 sheets
8. Label	Paper	72,000 boxes x 300 days ÷ 10 boxes/wrapper ÷ 0.95 = 2,273,680 labels
9. Carton box	Corrugated paper	72,000 boxes x 300 days ÷ 10 boxes/wrapper ÷ 100 wrappers/carton box = 21,600 cartons

5.3 Utilities

(1) Electricity:

150 kWh/d x 300d = 45,000 kWh/y

(2) Industrial water:

0.5 ton/d x 300d = 150 ton/y

(3) Fuel oil (kerosene):

28 ℓ/d x 300d = 8,400 ℓ/y

5.4 Machinery and Equipment Required

The following table shows the necessary machinery and equipment.

Name of machinery and equipment	Specification	Quantity
1. Waxed Splint Making Dept.		
–1. Wax-splint making machine	Capacity: 37,800 m/hr Motor: 1.9 kW Heater: 14 kW	1
–2. Waxed paper-string assembly machine	Capacity: 1 million pcs./hr Motor: 0.75 kW	1
–3. Waxed paper-string filling & cutting machine	Capacity: 0.54 million pcs./hr Motor: 0.6 kW	1
–4. Continuous wax-splint heating & dipping machine	Capacity: 2 million pcs./hr Motor: 2.2 kW Heater: 12 kW	1
–5. Frame emptying machine	Capacity: 1 million pcs./hr Motor: 1.75 kW	1
–6. Aluminium bobbin		28
–7. Waxed paper-string reel		10
2. Paper-Box Making Dept.		
–1. Slitter	Capacity: 72,000 skillets/hr Motor: 0.2 kW	1
–2. Slitter	Capacity: 36,000 skillets/hr Motor: 0.2 kW	1
–3. Outer/inner paper-box making & combining machine (Feed skillet type)	Capacity: 8,100 boxes/hr Motor: 0.4 kW Heater: 0.8 kW	2
3. Final Dept.		
–1. Automatic match levelling machine	Capacity: 0.2 million pcs./hr Motor: 0.45 kW	3
–2. Automatic match filling machine	Capacity: 9,000 boxes/hr Motor: 0.6 kW	2
–3. Side phosphorus coating machine	Capacity: 7,200 boxes/hr Motor: 0.6 kW Heater: 12 kW	1
4. Chemical Mixing Dept.		
–1. Ignition composition mixing machine	Motor: 1.5 kW	1
–2. Gelatine melting machine	Motor: 0.4 kW Heater: 2 kW	1
–3. Side chemicals grinding machine	Motor: 0.2 kW	1
–4. Boiling jacket	Motor: 0.3 kW	1

5.5 Machinery and Equipment Cost

The cost of machinery and equipment is estimated as below.

US$700,000 FOB Japan, 1989

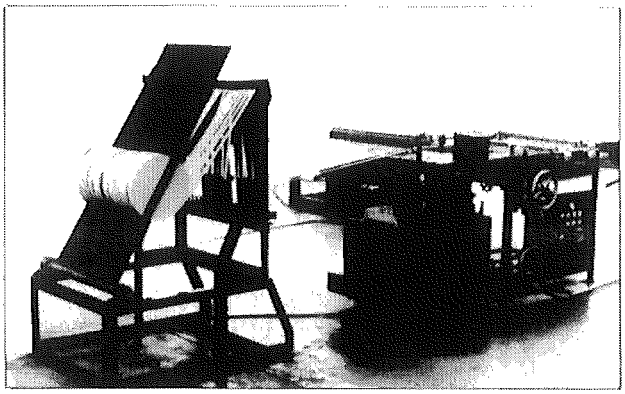


Photo 1. Bobbin Holding Apparatus and Paraffin Tank and Tray

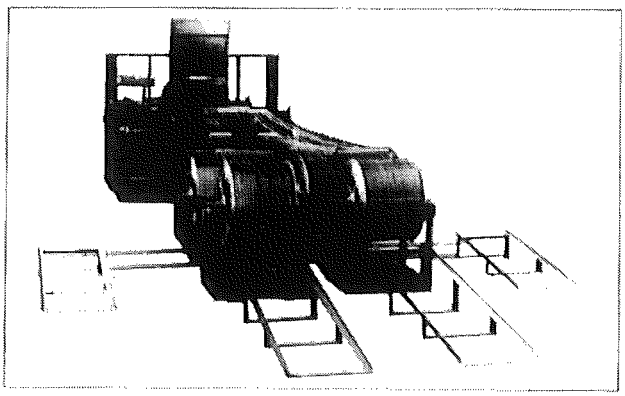


Photo 2. Waxed Paper String Frame Filling & Cutting Machine

5.6 Area of Plant and Building

The area of plant and factory building are as below.

(1) Plant area: 5,000m²

(2) Factory building: 1,972m²

5.7 Plant Layout

Plant layout is shown in Fig. 2.

5.8 Required Number of Personnel and Placement

The required number of personnel is 42 as below.

	(Male)	(Female)
Factory manager	1	
Engineer	2	
Clerical staff	1	3
Skilled worker	3	
Unskilled worker	10	22
Total	17	25

Note: Of the above two engineers, one is in charge of machinery, and the other is in charge of chemicals.

6. Production Cost and Profitability

In calculating the production cost, it needs to take into consideration the real condition of each country concerned. In this brochure, calculation will be made on the following basic conditions.

6.1 Basic Conditions for Calculation

(1) Fixed capital

(a) Land cost is not included.

(b) Unit construction cost of factory and office buildings: US$200/m²

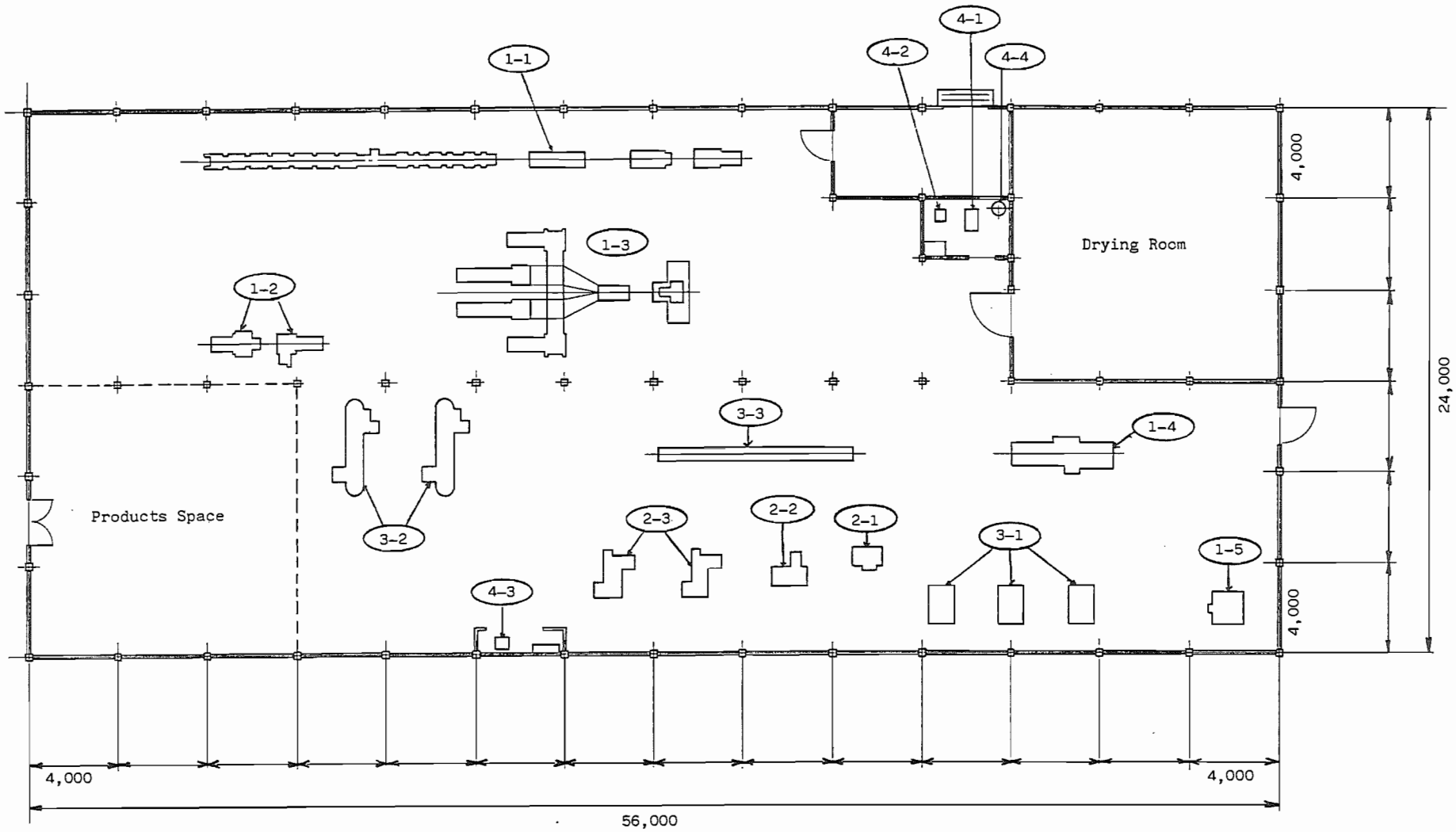
(c) Price of machinery and equipment: FOB Japanese port as of 1989

(d) Spare parts cost is assumed to be 5% of the FOB price of machinery and equipment.

(e) Freight and insurance is assumed to be 10% of the FOB price of machinery and equipment.

(f) Erection cost is assumed to be 3% of the FOB price of machinery and equipment.

(g) Supervision cost is assumed to be 5% of



1-1	Wax-splint making machine	2-1	Slitter	3-3	Side phosphorus coating machine
1-2	Waxed paper-string assembly machine	2-2	Slitter	4-1	Ignition composition mixing machine
1-3	Waxed paper-string filling & cutting machine	2-3	Outer/inner paper-box making & combining machine (Feed skillet type)	4-2	Gelatine melting machine
1-4	Continuous wax-splint heating & dipping machine	3-1	Automatic match levelling machine	4-3	Side chemicals grinding machine
1-5	Frame emptying machine	3-2	Automatic match filling machine	4-4	Boiling jacket

Fig. 2 Plant Layout

the FOB price of machinery and equipment.

(h) Commissioning cost is assumed to be 3% of the FOB price of machinery and equipment.

(i) Training cost is assumed to be 3% of the FOB price of machinery and equipment.

(j) Contingency is assumed to be 5% of the FOB price of machinery and equipment.

(2) Working capital

Raw material cost: For one month
Products inventory: For one month

(3) Production cost

(a) Raw material cost

The unit price of raw materials will be fixed as 6.3 (a) according to international market prices respectively.

(b) Unit price of utilities

Electricity	US$0.06/kWh
Industrial water	US$0.20/ton
Fuel oil	US$200/kℓ

(c) Labor cost

The annual labor cost is assumed to be as follows.

Factory manager	US$6,000
Engineer	US$3,000
Clerical staff	US$2,400
Skilled worker	US$2,400
Unskilled worker	US$1,200

(d) Maintenance cost

Maintenance cost is assumed to be 3% of the FOB price of machinery and equipment.

(e) Depreciation

Straight-line method will be used for depreciation.

Machinery and equipment:
(Fixed capital – building construction cost) x 7%
Building:
Building construction cost x 3%

(f) Insurance cost

Insurance cost is assumed to be 0.5% of the fixed capital.

(g) Selling and administration expense

Selling and administration expense is assumed to be 5% of the annual sales revenue.

(h) Interest

Fifty percent of the fixed capital is to be covered by a long-term loan and its annual rate of interest is 10%.

(i) Exchange rate

The exchange rate of the US dollar to the Japanese Yen is assumed to be US$1 = ¥140.

6.2 Capital Required

(1) Fixed capital

	US$
Land cost	not included
Building construction cost	394,400
Machinery and equipment cost	700,000
Spare parts cost	35,000
Freight and insurance cost	70,000
Erection cost	21,000
Supervision cost	35,000
Commissioning cost	21,000
Training cost	21,000
Contingency	35,000
Subtotal	US$ 1,332,400

(2) Working capital

		US$
Raw material cost for one month:		20,872
Storage of product for one month:		34,696
Subtotal	US$	55,568

(3) Capital required

(1) + (2) US$1,387,968

6.3 Production cost

(a) Raw material cost

The following table shows the annual raw material cost.

Item	Name of raw material	Annual raw material cost
1. Wax splint	Paper	US$2.60/roll x 21,600 rolls = US$56,160
	Paraffin wax	US$1.15/kg x 46,220 kgs = US$53,153
2. Head chemicals	Potassium chlorate	US$1.15/kg x 11,580 kgs = US$13,317
	Gelatine glue	US$3.20/kg x 2,760 kgs = US$ 8,832
	Glass powder	US$0.40/kg x 3,320 kgs = US$ 1,328
	Sulphur powder	US$0.55/kg x 1,510 kgs = US$ 831
	Ferric oxide	US$0.70/kg x 760 kgs = US$ 532
	Manganese dioxide	US$0.70/kg x 1,080 kgs = US$ 756
	Potassium bichromate	US$3.00/kg x 540 kgs = US$ 1,620
3. Side chemicals	Red phosphorus	US$5.80/kg x 910 kgs = US$ 5,278
4. Paste	Antimony sulphide	US$3.70/kg x 950 kgs = US$ 3,515
	Milky paste	US$1.50/kg x 1,190 kgs = US$ 1,785
5. Outer match box	Paper board	US$9.20/100 sheets x 454,740 sheets = US$41,836
6. Inner match box	Paper board	US$5.50/100 sheets x 473,680 sheets = US$26,052
7. Wrapping paper	Paper	US$0.46/100 sheets x 2,273,680 sheets = US$10,459
8. Label	Paper	US$0.15/100 sheets x 2,273,680 labels = US$ 3,411
9. Carton box	Corrugated paper	US$1.00 x 21,600 cartons = US$21,600
Subtotal		US$250,465

(b) Utilities cost

Electricity:	
US$0.06/kWh x 45,000kWh	= US$ 2,700
Industrial water:	
US$0.20/ton x 150 tons	= US$ 30
Fuel oil:	
US$0.20/ℓ x 8,400ℓ	= US$ 1,680
Subtotal	US$ 4,410

(c) Labor cost

Factory manager:	
US$6,000 x 1	= US$ 6,000
Engineer:	
US$3,000 x 2	= US$ 6,000
Clerical staff:	
US$2,400 x 4	= US$ 9,600
Skilled worker:	
US$2,400 x 3	= US$ 7,200
Unskilled worker:	
US$1,200 x 32	= US$38,400
Subtotal	US$67,200

(d) Maintenance

US$700,000 x 3%	= US$21,000

(e) Depreciation

Machinery and equipment	
US$938,000 x 7%	= US$65,660
Buildings	
US$394,400 x 3%	= US$11,832
Subtotal	US$77,492

(f) Insurance cost

US$1,332,400 x 0.5%	= US$ 6,662

(g) Selling and administration expense

US$648,000 x 3%	= US$19,440

(h) Interest

US$1,332,400 x 1/2 x 10%	= US$66,620
Total	US$513,289

6.4 Annual Sales Revenue

Unit selling price of product:
US$0.30/10 boxes

Annual sales of products:
US$0.30/10 boxes x 21,600,000 boxes
= US$648,000

6.5 Profitability

On the basis of the above conditions, the profitability of the model plant will be estimated as below.

Annual sales revenue	US$648,000
Annual production cost	US$513,289
Profit	US$134,711

Profit ratio to sales revenue and profit ratio to capital required are estimated as follows.

Profit ratio to sales revenue:
US$134,711 ÷ US$ 648,000 = 20.8%

Profit ratio to capital required
US$134,711 ÷ US$ 648,000 = 20.8%

Profit ratio to capital required
US$134,711 ÷ US$1,387,968 = 9.7%

7. Matters to be taken into Consideration in Connection with Safety

In the manufacture of matches, materials having a danger of combustion and explosion such as oxidizable solid (potassium chlorate) and combustible solid (red phosphorus and sulphur) are handled. Therefore, in many countries the technical standards concerning manufacturing facilities and warehouses of raw materials and products have been established by the law. Arrangement, structure, and quality of materials on the above facilities have been provided minutely in the technical standards.

Also in many occasions concrete standard have been established on the production process and the handling, preservation and transportation of raw materials and products. In these cases, it is necessary to strictly observe the matters as provided by the law.

The matters mentioned below are obtained from our long experience, and in the case of planning a manufacturing plant, selection of equipment, and preparation of the operation manual, special consideration should be paid.

(1) Nonflammable materials are used for all buildings.

(2) The manufacturing equipment and workers in the head chemicals production department should be separated completely from those of the production department.

(3) Foreign matters such as metals should be prevented from entering into the head chemicals and side chemicals, while being produced.

Project Planning for Small and Medium Scale Industries

No. 1 Rice Milling Plant and Rice Bran Oil Manufacturing Plant
No. 2 Plastic Woven Bag Manufacturing Plant
No. 3 Container Board Manufacturing Plant
No. 4 Plastic Blow Bottle Manufacturing Plant
No. 5 Concrete Block Manufacturing Plant
No. 6 Glassware Manufacturing Plant
No. 7 Galvanized Iron Sheet Manufacturing Plant
No. 8 Fishing Net Manufacturing Plant
No. 9 Ice Making, Refrigeration and Cold Storage Plant
No.10 Starch and Syrup Manufacturing Plant
No.11 Instant Noodle Manufacturing Plant
No.12 Surimi and Surimi-Based Food Manufacturing Plant
No.13 Polyethylene Shopping Bag Manufacturing Plant
No.14 Retreading Tire Manufacturing Plant
No.15 Husk Fired Thermal Power Plant
No.16 Fishmeal Manufacturing Plant
No.17 Assorted Animal Feed Manufacturing Plant
No.18 Sanitary Napkin Manufacturing Plant
No.19 Sanitary Ware Manufacturing Plant
No.20 Toilet Tissue Manufacturing Plant
No.21 Powder Milk Manufacturing Plant
No.22 Mosquito Coils Manufacturing Plant
No.23 Solar Pond Power Generation Plant
No.24 Manufacturing Plant of Textile Products for Medical Use
No.25 Ceramic Tableware Manufacturing Plant
No.26 Manufacturing Plant of Ethanol for Medical Use
No.27 Match Manufacturing Plant

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