Chapter 3

Engineering study

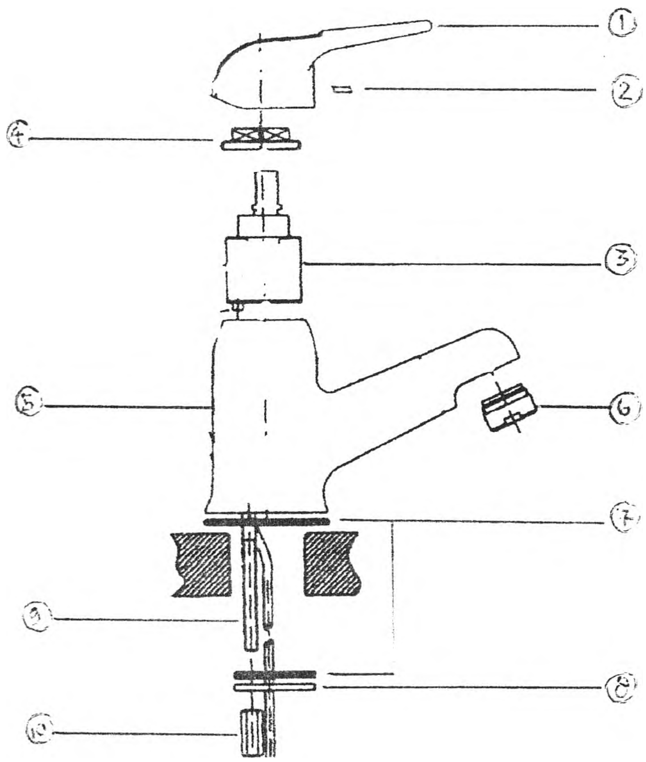
3.1 General specifications

3.1.1 Major components

Single lever mixer generally consists of the following components.

1. Lever	5. Body	9. Stud
2. Screw	6. Aerator	10. Bolt
3. Cartridge	7. Rubber ring	
4. Cap	8. Brass base	

Figure 7 Major components of single lever mixer.

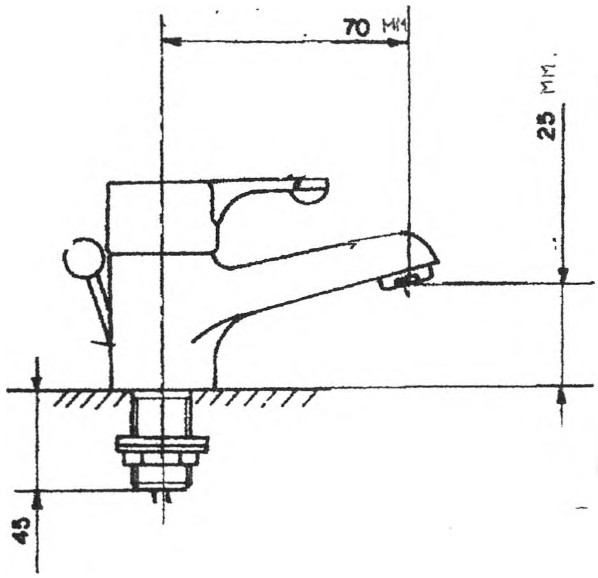


3.1.2 Thai Industrial Standard for single lever mixer

According to Thai Industrial Standard for wash basin faucets (No.1278-2538), the faucets for wash basin should meet the following specifications.

Dimension

Figure 8 Dimensional allowance of single lever mixer



Materials

- Non-oxidation metal e.g. bronze, brass, copper, etc.
- Rubber, polymer, ceramics

Test methods

- Leak test with water pressure under 1.75 ± 0.01 M.Pa. for 30 seconds.
- Flow test with water pressure 0.1± 0.01 M.Pa., the flow rate must more than 9 cubic decimeter per minute.
- Distribution of water must more than 95% complying with the test.
- Water impact test, pressure from the impact of water must less than 1.5 M.Pa.

- Plating test

Metal: heat at 250 ±10 C for 1 hour and cool down in water at room temperature for 1 minute.

Metal or polymer with color-plated, test under ISO 2409.

3.2 Production process of general faucets

Major processes of producing single lever mixers are:

1. Design

This stage is about designing the shape and size of parts and cores. After having a prototype, the molds and cores have to be made. Mold is used for forming the molten brass in desired shape, where core is used for making a hole in the work piece. Mold is normally made of metal, while core is made of sand.

2. Casting

This stage is about forming the raw material in rough shape. Normally, manufacturers use brass ingot as a raw material for making the body and the lever. Brass ingots will be heated and then poured into the mold. Some manufacturers use Low-pressure die casting technique (LPDC) to form the parts of faucet. With LPDC technique, molten metal is forced in to die under the pressure about 2 bar. Main advantages of LPDC are good surface quality, low porosity, and high production rate. However, the cost of machines and dies for LPDC are very high comparing with the other casting methods, therefore, in some factories, traditional methods such as sand casting are widely used. After removing work pieces from mold or die, cores and runners will be removed. Next, parts will be cleaned and then primarily inspected for defects such as cracking, etc.

3. Machining

This stage is mainly about making threads and retouching internal surface. Furthermore, some parts such as brass caps, screws, studs, etc. are also made in this area. CNC machines are normally used in large factories, whereas, lathes and punching machines are used in small factories.

4. Polishing

This stage concerns about retouching external surface into the desired shape, including burnishing the surface before plating. Normally, this stage is operated manually by workers because the body of faucets is normally designed in complex shape which difficult to operate with automatic machines. However, it is possible to use the automatic machine in this operation, such as operating in Siam Sanitary Fitting Company Limited in Thailand.

5. Plating

At this stage, work pieces are dipped in to chromium-anhydride tank in order to create attractiveness and durability. According to Thai Industrial Standard for faucet, the thickness of plating must obtain the below specifications.

Copper-Nickel-Chromium Plated.

Thickness of Copper and Nickel must not less than 5 Micrometers and thickness of chromium must not less than 0.1 Micrometers.

Nickel-Chromium Plated.

Thickness of Nickel must not less than 5 Micrometers and thickness of chromium must not less than 0.1 Micrometers.

Furthermore, the resistance for the moisture of salt water must obtain the rating number 9 of JIS H 8617.

6. Assembly

Main steps for assembling a single lever mixer are as following.

- Put the cartridge into the body.
- Place brass-cap over the cartridge and tighten it.
- Stick the lever with the spindle of the cartridge.
- Tighten the screw to fix the lever with the cartridge.
- Put aerator.
- Bring to final inspection.
- Pack the complete single lever mixer into a box.

The above steps refer to the assembling of a single lever mixer for wash basin. In case of assembling a shower mixer or a bath mixer, it may have some different steps e.g. a shower mixer does not require an aerator, etc.

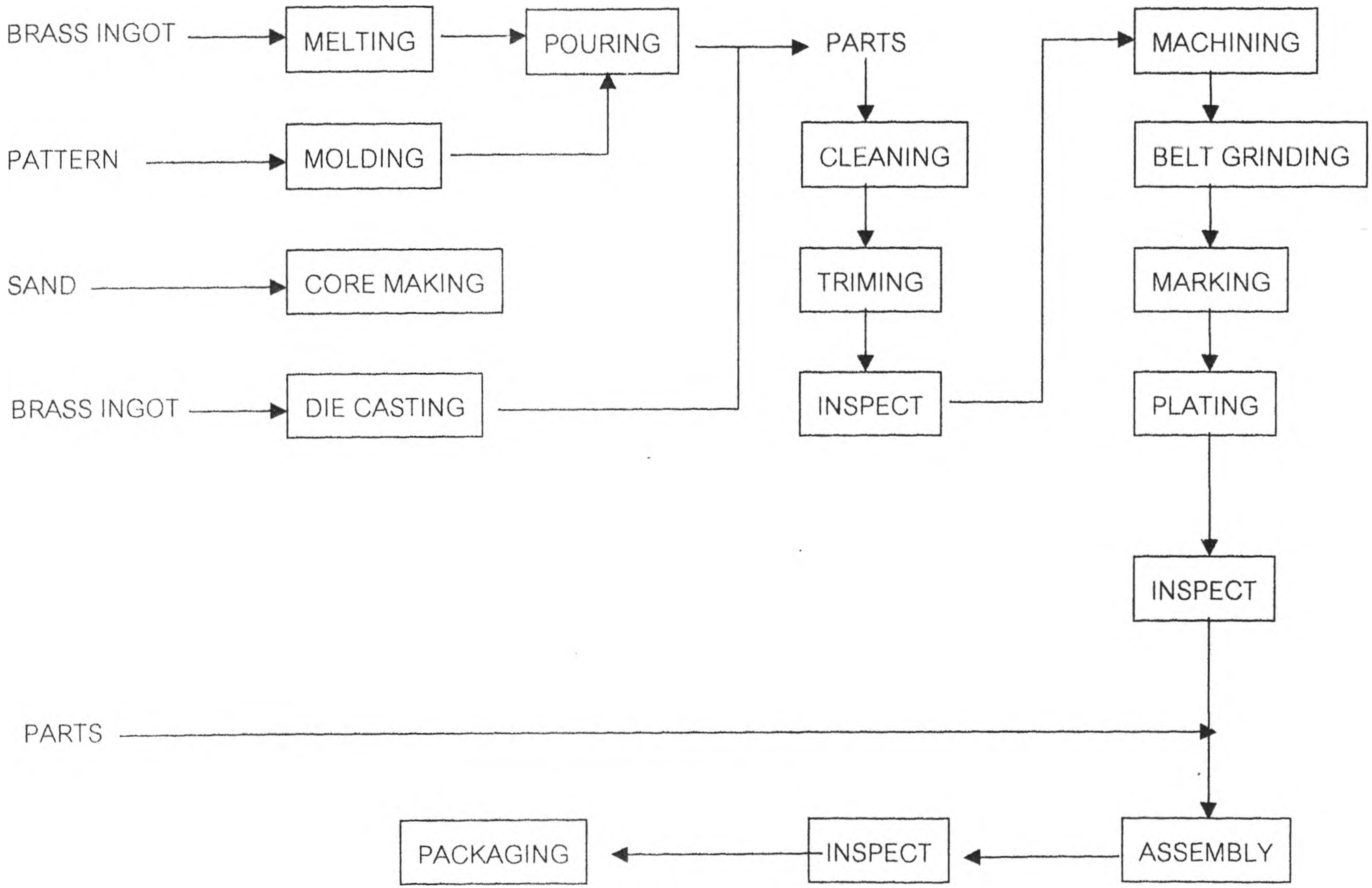


Figure-9 Production process of common single lever mixer

3.3 Selection of material and process

From the study, it was found that Brass has usually been the major raw material for general faucet production process. By shaping the brass into the desired shape and then further to the other processes. However, brass is relatively expensive and the machine using with brass also has high investment cost. Therefore, this study is conducted in attempt to search for cheaper raw material and alternative process that involved in lower cost. PP (Polypropylyne) is that desired material which can be used to replace brass, so this study suggests the production process that use PP instead of brass.

PP has many advantages more than the other raw materials. The advantages of using PP are as following.

- Low cost

  Cost of PP is lower when comparing with the other polymers (Table-20). Selling price of PP is 28-35 baht per kilogram. Furthermore, density of PP is low (905 kg/m3), therefore the weight of work piece is light so transportation cost is low.
- Non-toxic grade is available.
- Availability

  It is not necessary to import PP from the other countries because the capacity of local manufacturers is currently more than market' requirement (Figure-10).
- Good abrasion resistance.
- Chemical resistance.
- Very low water absorption.
- Excellent dielectric properties.
- Painting is not necessary for colored faucet because color powder can be filled before injection.

- Low equipment cost

  Cost of injection machine (90-120 tons) varied from 1,000,000-3,000,000 baht. (1/20 of die casting machine for metal casting).

- Melting point is above working temperature of faucet.

  Melting point of PP (180-260'C depend on grade) is higher than hot water temperature supplied (normally maximum 80'C).

Figure 10 Capacity and requirement of PP in Thailand.

(Source: IFCT, Thailand)

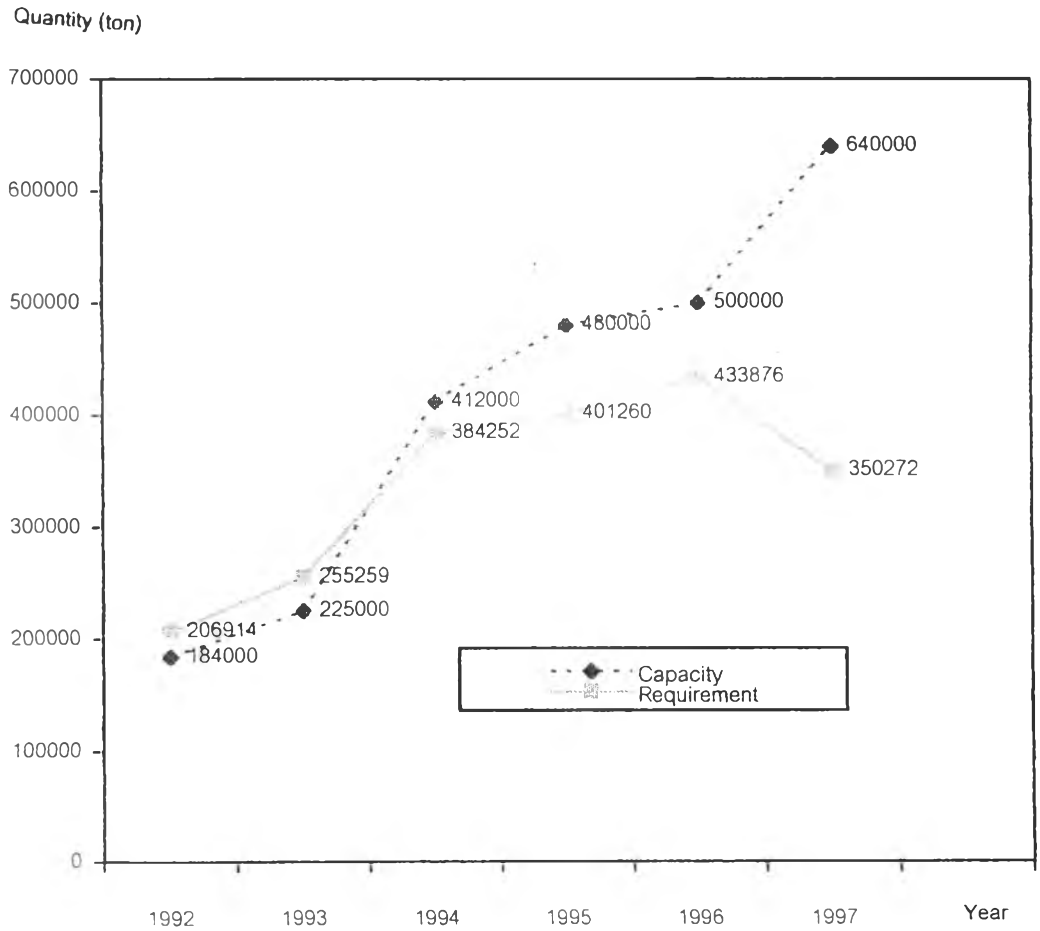


Table 19 Properties of some plastics.

Material	Density (kg/m3)	Tensile strength (MN/m2)	Flexural modulus (GN/m2)	% elongation at break	Price *
ABS (high impact)	1040	38	2.2	8	2.1
Acetal (homopolymer)	1420	68	2.8	40	3.5
Acetal (copolymer)	1410	70	2.6	65	3.3
Acrylic	1180	70	2.9	2	2.5
Cellulose acetate	1280	30	1.7	30	3.2
CAB	1190	25	1.3	60	42
Epoxy	1200	70	3.0	3	8.3
Nylon 66	1140	70	2.8	60	3.9
PEEK	1300	62	3.8	4	42
PET	1360	75	3	70	3.0
Phenolic (mineral filled)	1690	55	8.0	0.8	1.25
Polymide-imide	1400	185	4.5	12	67
Polycarbonate	1150	65	2.8	100	4.2
Polyethersulphone	1370	84	2.6	60	13.3
Polyimide	1420	72	2.5	8	150
Polypropylene	905	33	1.5	150	1
Polysulphone	1240	70	2.6	80	11
Polystylene	1050	40	3.0	1.5	1.1
Polythene (LD)	920	10	0.2	400	0.8
PTFE	2100	25	0.5	200	13.3
PVC (rigid)	1400	50	3.0	80	0.88
SAN	1080	72	3.6	2	1.8
DMC (polyester)	1800	40	9.0	2	1.5
SMC (polyester)	1800	70	11.0	3	1.3

On a weight basis, relative to polypropylene (PP), Source: Introduction to Polymers, page22, Manufacturing process and technology, the University of Warwick.

There are many types of production process that are suitable for shaping thermoplastics. Each type is proper for different kinds of raw material, as illustrated in the below table.

Table 20 Common shaping process for thermoplastics

Material	Injection molding	Extrusion	Blow molding	Compression molding	Rotational molding	Thermo-forming
PEEK	/	/				/
PPS	/	/		/		
PPO	/	/				
PP	/	/	/	/	/	/
Polyacetal	/	/	/		/	
Polyamides	/	/	/		/	/
PES	/	/	/			/

Source: Case study (Polymers), page9, Somchai Puajindanetr, Chulalongkom University.

Furthermore, there are many factors involved in determining the appropriate production process, e.g. Equipment Capital Cost, Production Rate, Tooling Cost, Number of part, Tolerances and surface finish, etc.

Table 21 Comparative costs and production volumes for plastics processing

	Equipment Capital Cost	Production Rate	Tooling Cost	Typical production volume, number of parts
Machining	Medium	Medium	Low	10 – 10^2
Compression molding	High	Medium	High	10^3 – 10^6
Transfer molding	High	Medium	High	10^3 – 10^6
Injection molding	High	High	High	10^4 – 10^7
Extrusion	Medium	High	Low	*
Rotational molding	Low	Low	Low	10^2 – 10^3
Blow molding	Medium	Medium	Medium	10^3 – 10^7
Thermoforming	Low	Low	Low	10^2 – 10^3
Casting	Low	Very low	Low	10 – 10^2
Forging	High	Low	Medium	10 – 10^2
Foam molding	High	Medium	Medium	10^4 – 10^7

Source: After R. L. E. Brown, *Design and Manufacture of Plastic Parts.* Copyright © 1980 by John Wiley & Sons, Inc. Reprinted by permission of John Wiley & Sons, Inc.

* Continuous process.

Table 22 Typical tolerances and surface finish obtainable by processing methods

Methods	Tolerance (%)	Surface finish
Machining	0.1-0.3	Good to excellent
Injection molding	0.2-1.0	Good to excellent
Compression molding	0.2-1.0	Good to excellent
Extrusion	2.5	Fair
Extrusion blowing operation	2.5	Good
Thermo-forming	5.0-10.0	Good
Hand or spray lay-up	5.0-10.0	Varies
Rotational molding	2.5-10	Fair

Source: Case study (Polymers), page10, Somchai Puajindanetr, Chulalongkorn University.

According to the above information, the most suitable process should be the Injection molding process because:

- It is compatible with material such PP.
- High production rate.

- Provide low dimensional tolerance.
- Provide excellent surface which very important for faucet manufacturing.
- Even equipment cost and tooling cost is high when comparing with the other plastic processing, but it is low when comparing with the conventional process (Brass casting).

Regarding production process of injection molding, the major process is shown as follows.

1. Mold Making
2. Mixing raw material in case that colored work piece is required. Color powder is usually mixed with plastic grain in proportion 1:10. The mixed material will be heated in order to dehydrate around 2-3 hours before passing to the injection machine.
3. Injecting the mixed material into the mold, and cooling down by water.
4. Release the work piece from the mold. This step can be done automatically, but the work piece must not be stuck in the mold, otherwise, the mold can be damaged.
5. Trimming the work piece.
6. Passing the work piece to the next process, e.g. packing, coloring, etc.

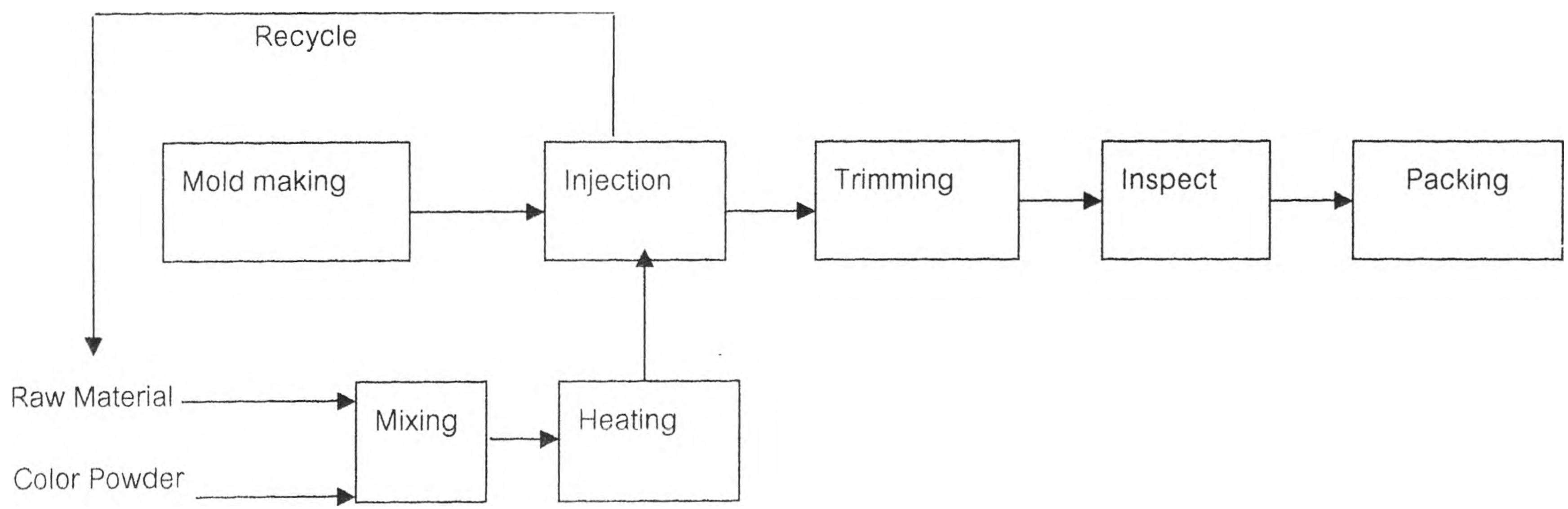


Figure-11 Injection molding process

3.4 Comparison between Brass faucet and PP faucet

This section studies on the differences and similarities between common single lever mixer in the market and PP faucet.

Table 23 Comparison between common single lever mixer and PP single lever mixer.

	Brass faucets	PP faucets	Remark
Difficulty in design for production	Normal, but easier than plastic faucet because core (sand) can be crumbled.	Normal, but some designs may require more consideration because mold and core are rigid.	
Appearance	No limit	No limit	Depend on designer
Quality			
- Mechanism	Ceramic valve	Ceramic valve	Depend on quality of cartridge.
- Surface	Good	Good	
- Chrome plated	Possible with additional cost	Possible with additional cost	Quality and cost depend on plating method
- Colored plated	Possible with additional cost	Possible with lower cost	Quality and cost depend on plating method
- Strength	Good	Good but plastic lever is normally more frail than metal lever	

Conclusion, there is no major differences between common faucet and PP faucet but PP faucet requires more consideration on mold design, method of chrome plated, and strength of lever.

3.5 The selected production for the project

3.5.1 Production process

Production process consists of the following steps:

1. Mold design
2. Injection
3. Trimming
4. Machining
5. Assembly
6. Inspection and testing
7. Packaging

Production process of plastic single lever mixer processing is shown in figure-12.

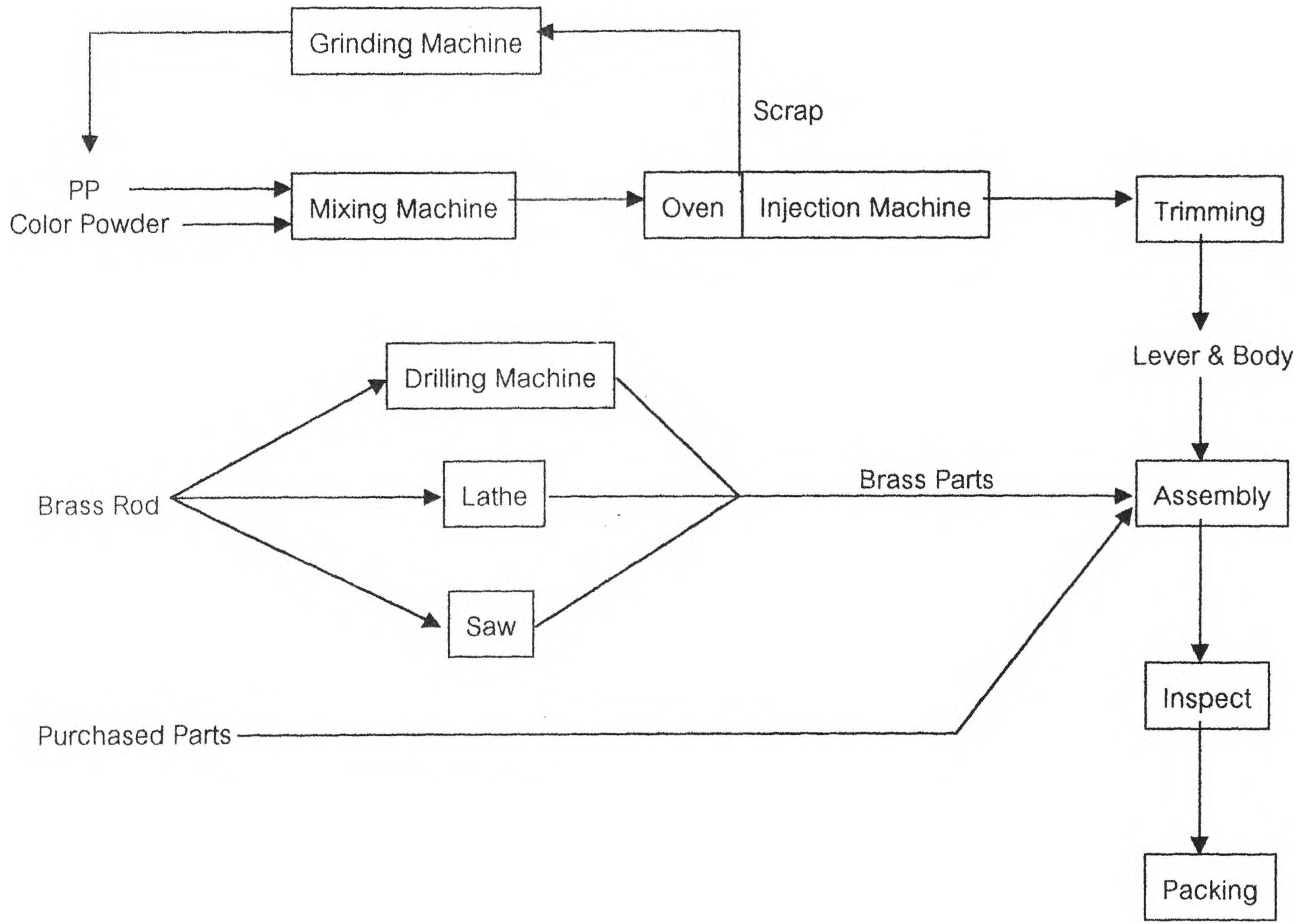


Figure-12 Production process of PP faucet

3.5.2 List and capacity of machines

List of machine and equipment are as follows.

Item	Description	Qty.
1	Injection machine (50 tons)	1
2	Cooling tower (10 tons)	1
3	Mixing machine (single head 50 kg)	1
4	Hopper dryer	1
5	Lathe (4 feet)	1
6	Drilling machine	1
7	Sawing machine	1
8	Grinding machine	1
9	Pliers	2
10	Hand tools	2
11	Test equipment	1
12	Trolley	4

Capacity of machines

The study will consider only the capacity of injection machine because injection machine is the major machine in production process. The other machines are used for minor processes e.g. drilling, sawing, and eviscerating, etc. These processes take few times and do not be operated all the time, therefore we can neglect them and consider only the capacity of injection machine.

Capacity of injection machine

$$\text{Capacity} = \frac{\text{Working time}}{\text{Cycle time}} \times \text{Efficiency of machine}$$

Where,

Working time = 300 days/year = 2,400 hours/year = 144,000 minutes/year

Cycle time = cycle time of body + cycle time of lever + cycle time of cap

Efficiency of machine = 90% (due to set up and maintenance)

Since one set of single lever mixer consists of 3 plastic parts; body, lever, and cap-covering cartridge. Cycle time of each part can be found from cachine specification, experience of specialists, and survey on cycle time of similar products. An example of machine specification (Appendix-4) shows that plasticticizing capacity of an injection machine is 3.7-6.5 g/sec depend on screw diameter, therefore cycle time for 3 parts (total 340 g) is 52-92 sec. However, according to experience of specialists and production time of similar products, body requires around 30 seconds for an injection cycle, while the lever and cap requires around 15 seconds for an injection cycle. Thus, in order to make on set of single lever mixer, we require time around 60 seconds i.e. capacity of an injection machine is one set per minute or 144,000 sets per year (based on working time: 8 hrs per day and 300 days per year). However, the actual capacity should be lower than 144,000 set per year due to set up time and maintenance. If the efficiency of machine is 90%, the actual capacity of injection machine should be 129,600 sets per year.

In conclusion, capacity of an injection machine is around 130,000 sets per year.

3.5.3 List of raw materials and material requirement

We can classify the parts of single lever mixer into 3 groups as follows.

- Plastic parts

Plastic parts are body, lever, and cap for covering the cartridge. Process starts at dehydrating plastic grains by heating them in an oven around 1-2 hours. Next, PP will be injected into mold. Work piece requires trimming after released from mold.

- Brass parts

Brass parts are brass base, stud, and bolt. These parts are made from brass rod. At first, brass rod will be sawed and then machined into desired shapes.

- Purchased parts

Purchased parts are cartridge, aerator, rubber ring, and box, etc. Cartridge and aerator can be imported from Italy, Japan, Germany, and Spain, while, the other parts can be ordered from local suppliers.

With reference to the above parts, direct and indirect materials that needed for production of single lever mixer are:

Direct materials

- Polypropylene
- Colored powder
- Brass rod
- Cartridge
- Aerator
- Rubber ring
- Packaging

Indirect materials

- Lubricants
- Hydraulic oil
- Mold
- Cooling water
- Cutting tools e.g. saw blade, drill, etc.
- Glove
- Electricity
- Spare parts

Material requirement

This section shows only requirement of direct material because they do not vary by the production volume.

Material	Requirement for a single lever mixer
PP	0.34 kg
Cartridge	1 set
Brass rod	0.3 kg
Aerator	1 set
Box	1 set

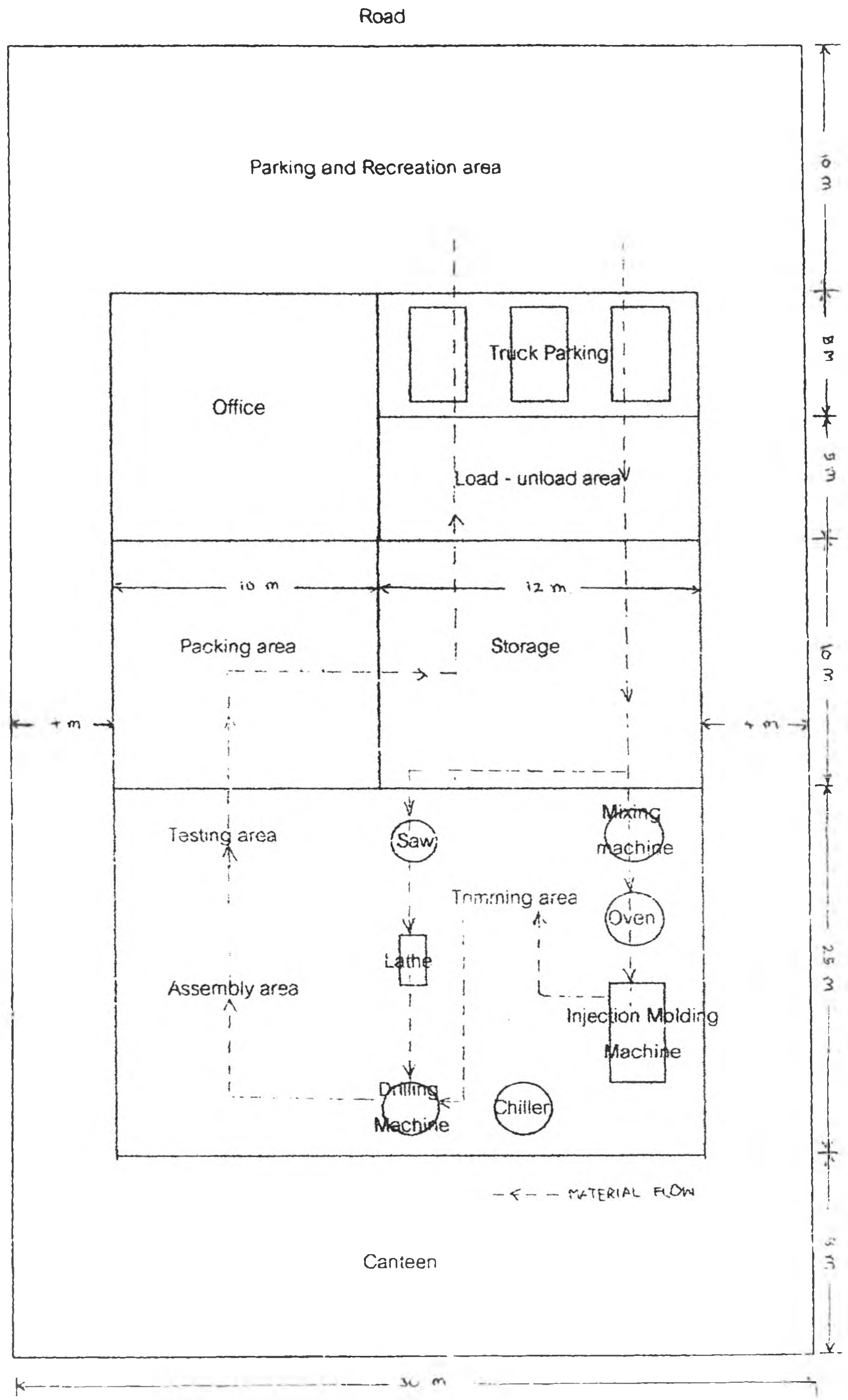
3.5.4 Plant layout and material flow

According to production process and machine, factory area should be around 1 Rai (0.4 acre), which consists of the following areas.

Production area	550 sqm.
Office	100 sqm.
Storage area & loading area	240 sqm.
Packing area	100 sqm.
Canteen, parking, and recreation area	600 sqm.
Total	1590 sqm.

Layout of plant is illustrated in figure-13.

Figure 13 Plant Layout and material flow



3.6 Optimum capacity

There are many factors that should be considered before determining the optimum capacity. These factors are:

- The expected sale or demand of the market
- Opportunity of new market
- Capacity of machine
- Production cost per unit
- Rate of return on investment
- Availability and source of funds
- Availability of raw materials
- Existing of machine or transferring of machine
- Costs of expansion in future

After studying on researches, we found out that the optimum capacity is determined by comparing unit cost at different capacities. The capacity that provided the minimum unit cost will be chosen to be the optimum capacity of the project. However, after studying on the expected demand and the selected production process, we found out that the optimum capacity can not be determined because demand of single lever mixer is not sufficient to consider the differences if the factory operate in different capacities.

With reference to 2.4 and 3.5.2, the expected sale is 93,000-133,000 sets per year and the capacity of the selected production process depends on capacity of injection machine. After surveying injection machines in the market, we found out that the minimum capacity of injection machine for production of our single lever mixer is 130,000 sets per year. When we compare demand with capacity of machine, we can see that the expected demand is less than the minimum capacity of an injection machine, so we can not find the optimum capacity of the project. However, if we consider at the capacity of injection machine, the suitable capacity for setting up a single lever factory according to the expected demand is 130,000 sets per year.

3.7 Production cost and unit cost for capacity 130,000 sets per year

Production costs consist of the following items.

- Material cost
- Labor cost
- Overhead cost
- Depreciation

Below is the production costs for capacity 130,000 sets per year.

Raw material cost

Due to our plan is to sell our products in two finishes; colored faucet and chrome-plated faucet, therefore, material cost for each style is different as be shown below:

Material cost for colored faucet

Item	Materials	Unit	Unit cost	Qty./unit	Total (baht)
1	PP	Kg	38	0.35	13
2	Color powder	Kg	100	0.04	4
3	Cartridge	Set	402	1	402
4	Brass rod	kg	100	0.3	30
5	Aerator	Set	91	1	91
6	Rubber ring	Piece	1	2	2
7	Packaging	Set	10	1	10
				Total	552

Material cost for chrome-plated faucet

Item	Materials	Unit	Unit cost	Qty./unit	Total (baht)
1	PP	Kg	38	0.35	13
2	Cartridge	Set	402	1	402
3	Brass rod	kg	100	0.3	30
4	Aerator	Set	91	1	91
5	Rubber ring	Piece	1	2	2
6	Plating	Piece	50	2	100
7	Packaging	Set	10	1	10
				Total	648

If we produce both types equally, an average of raw material cost per unit will be (552 + 648) / 2 = 600 baht per set. Hence, material cost for capacity 130,000 sets is 78,00,000 baht.

Direct Labor cost

Item	Job description	Number	Salary		Total (baht)
			Per month	Per year	
1	Engineer	1	17,000	204,000	204,000
2	Technician	1	10,000	120,000	120,000
3	Worker	9	3,500	42,000	378,000
				Total direct labor	702,000

Source: Costs of doing business in Thailand, Office of the Board of Investment, Thailand.

Overhead costs

Overhead costs are electricity charge, water charge, lubricant, injection molds, saw, blade, drill, glove, maintenance and spare parts, etc.

Electricity charge

Item	Description	Qty.	Power(KW)	Total (KW)
1	Injection machine (50 tons)	1	13.20	13.20
2	Cooling tower (10 tons)	1	5.00	5.00
3	Mixing machine (single head 50 kg)	1	3.70	3.70
4	Hopper dryer	1	3.00	3.00
5	Lathe (4 feet)	1	5.50	5.50
6	Drilling machine	1	1.50	1.50
7	Sawing machine	1	1.50	1.50
8	Grinding machine	1	3.70	3.70
	Total	=		37.10

Average efficiency of machines	=	90%
Therefore, actual power	=	41.22
Average working hours per day	=	8
Thus, power requirement per day	=	329.78
If working days per month	=	20
Therefore, power requirement per month	=	6,595.56
Energy charge (baht/KW)*		
- First 35 KW	=	89.89
- 35-150 KW	=	1.12
- 150-400 KW	=	2.13
- above 400 KW	=	2.42
Therefore, electricity charge per month	=	18,800.69
Electricity charge per year	=	225,608.33

Source: Costs of doing business in Thailand, Office of the Board of Investment, Thailand.

Water fee =	600 baht/month =	7,200.00
Hydraulic oil =	30,000 per 6 months	60,000.00
Injection molds (design changed every year)		150,000.00
Cutting tools e.g. saw, drill, etc.	2,000 baht/month	24,000.00
Glove	500 baht/month	6,000.00
Spare parts & maintenance	5% of machine & equipment cost	72,055.00
Insurance premium	0.5% of factory & machine cost	47,205.50
		366,460.50

Total overhead costs 225,608.33 + 366,460.50 = 592,068.83

Depreciation

Machine and equipment

Item	Description	Qty.	Unit price	Total (baht)
1	Injection machine (50 tons)	1	1,100,000	1,100,000
2	Cooling tower (10 tons)	1	22,000	22,000
3	Mixing machine (single head 50 kg)	1	44,000	44,000
4	Hopper dryer	1	44,000	44,000
5	Lathe (4 feet)	1	71,500	71,500
6	Drilling machine	1	22,000	22,000
7	Sawing machine	1	11,000	11,000
8	Grinding machine	1	50,000	50,000
9	Pliers	2	300	600
10	Hand tools	2	5,000	10,000
11	Test equipment	1	50,000	50,000
12	Trolley	4	4,000	16,000
	Total machine and equipment cost			1,441,100

Economic life for machine and equipment = 5 years

Therefore,

Depreciation of machine and equipment = 288,220

Factory

Item	Description		Amount (baht)
1	Building (7,000 baht/m^2)		7,000,000
2	Parking		1,000,000
		Total	8,000,000

Economic life of constructions = 20 years

Therefore,

Depreciation of factory = 400,000 baht / year

Therefore, total depreciation = 288,220 + 400,000 = 688,220 baht.

In conclusion, production cost and unit costs for capacity of 130,000 sets per year are as follows.

Item	Description	Amount (baht)
1	Material cost	78,000,000
2	Direct labor cost	702,000
3	Depreciation	
	3.1 Machines and equipment	288,220
	3.2 Factory	400,000
4	Overhead costs	592,069
	Total production cost =	79,982,269
	Production cost per unit =	615.25

3.8 Production Capacity Planning

With reference to the forecast sales in 2.4 and the capacity of the machine in 3.5.2, the production volume for the factory should be as follows:

Table 24 Production Capacity Planning

Year	1999	2000	2001	2002	2003
Production volume (unit)	96,317	102,078	109,447	120,744	130,000

3.9 Summary of engineering study

After studying about major components, industrial standard, and production process of general single lever mixer, we can conclude that it is possible to set up a single lever mixer factory in Thailand.

However, if the factory is set up under the conventional process (casting) and raw material (brass), the cost of production will be rather high. Therefore, this study proposes to use Polypropylene (PP) instead of Brass. Many of plastic processing had been considered and finally an injection molding process was selected for shaping parts of faucets. Capacity of a 50-ton injection machine is around 130,000 sets per year. The project requires area around 0.4 acre for setting up a factory.

Finally, the suitable capacity of the project is 130,000 sets per year. However, during the year 1999-2002, production volume of the project will be changed in order to in line with the expected sale in section 2.4.