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A Sample Plant Design for System 6

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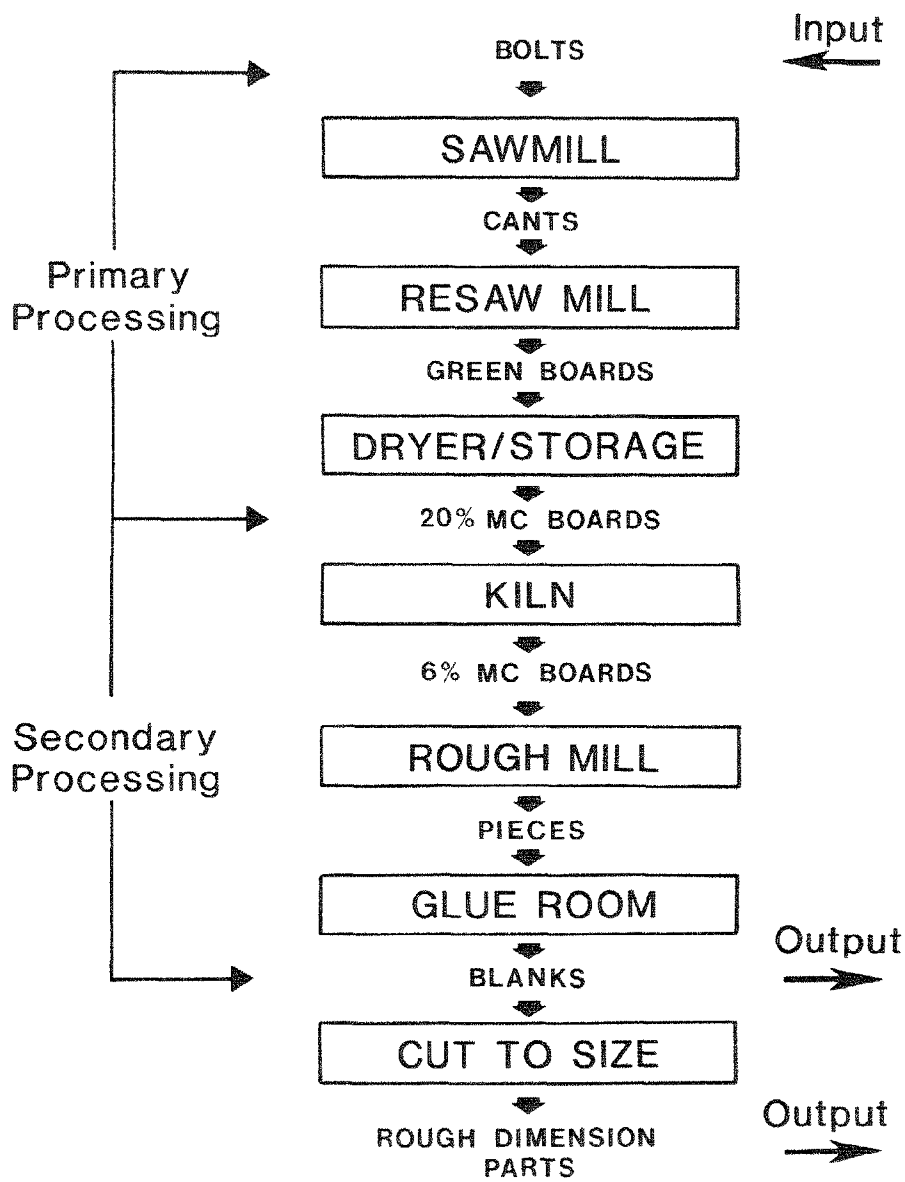

The Authors

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Abstract

A plant to make standard blanks from cants by System 6 can be assembled from off-the-shelf equipment with few modifications. From the production rates and manpower requirements of each piece of equipment, we designed a typical plant and determined by economic analysis that it could return 21 percent on an investment of $2 million by making blanks for sale from purchased cants.

Introduction

System 6 is a new technique for converting small, low-grade hardwood timber into high-valued blanks (the process flow is shown in Figures 1 and 2). This timber is available in large quantities from small-diameter Factory Grade 3 or local-use logs and from small timber not normally harvested. Blanks are edge-glued panels manufactured to standard qualities, thicknesses, lengths, and widths. These blanks are used by furniture and kitchen cabinet manufacturers instead of No. 1 Common and Better hardwood lumber. Lumber must be kiln dried and sent through a rough mill; blanks are ready for ripping to part sizes.

This paper is one of a series describing System 6 concepts. The marketing differences between System 6 and conventional hardwood processing have been explained by Reynolds and Gatchell (1979). The System 6 technology was explained in a second paper by Reynolds and Gatchell (1982). Blank sizes and their derivation have been explained in a paper by Araman et al. (1982).

In this paper, production rates and manpower requirements are calculated separately for each major piece of processing equipment. The individual rates are then used to design a typical System 6 processing plant using requirements from a previous study (Reynolds and Araman 1983). The economic feasibilities of the plant are then tested by cash flow analysis (CFA). A complete discussion of CFA, together with other System 6 design examples, is given in a companion paper.[1]

[1]Hansen, Bruce G.; Reynolds, Hugh W. System 6 alternatives and economic analysis. (In preparation for publication, Northeast. For. Exp. Stn., U.S.D.A. Forest Service, Princeton, WV.)

Plant Specifications

Companies that make living room furniture need both frame parts and clear parts. We will consider building a new plant near a supply of low-grade, small-diameter white oak timber. This plant will make blanks and ship them to furniture plants. Annual production will be 1.55 million square feet of frame blanks and 0.45 million square feet of clear blanks, for a total of 2.0 million square feet. The blanks will be sold to the furniture plants at market prices of $1 per square foot for frame blanks and $1.70 per square foot for clear blanks.

Capital investment will be limited to $2 million. A 20-percent after-tax return on investment (ROI) will be required over the proposed plant's 10-year life.

Plant Design

A single-shift plant to operate 240 days per year will be designed. CFA will then be used to determine whether this design meets the $2 million maximum investment and the 20-percent minimum ROI requirements. If the requirements are met, the plant design will be acceptable. If not, alternative designs will have to be evaluated. Also, additional designs can be tested to determine whether there are better designs that require less capital investment and give a higher profit (ROI).

The annual input board requirements are as follows:

	Output				Input	
Blanks	*(ft²)*		*Yield*		*bd ft*	*(%)*
Frame	1,550,000	÷	0.56	=	2,770,000	73
Clear	450,000	÷	0.45	=	1,000,000	27
Total	2,000,000				3,770,000	100

A research study (Reynolds and Araman 1983) showed that poor-quality white oak boards gave a 56-percent yield of frame blanks. The better quality boards yielded 45 percent in clear blanks. In that study, 68 percent of the board footage was in poor boards. As 73 percent of the boards used here will be made into frame blanks, the white oak board quality is well suited for this use.

With single-shift production 240 days per year, the daily input will be 15.7 Mbf (thousand board feet). The production rates for the principal machines and operations are shown in Table 1.

Raw material will be in the form of cants 6 and 8 feet long. One forklift will unload trucks and put cants into storage or into the resaw mill. The cant receiving and storage area, as well as the rest of the plant layout, is shown in Figure 3.

The resaw will make cants into boards. With the shift input rate at 15.7 Mbf, only one resaw is needed. But two stackers will be required, as one stacker can only handle 10.9 Mbf per shift. A crew of nine is required: one for cant input to work with the cant storage workers; one to feed the cants and operate the cutoff saw; two to operate the cant gang ripsaw; two per stacker (two stackers); and one to band the stickered board stacks.

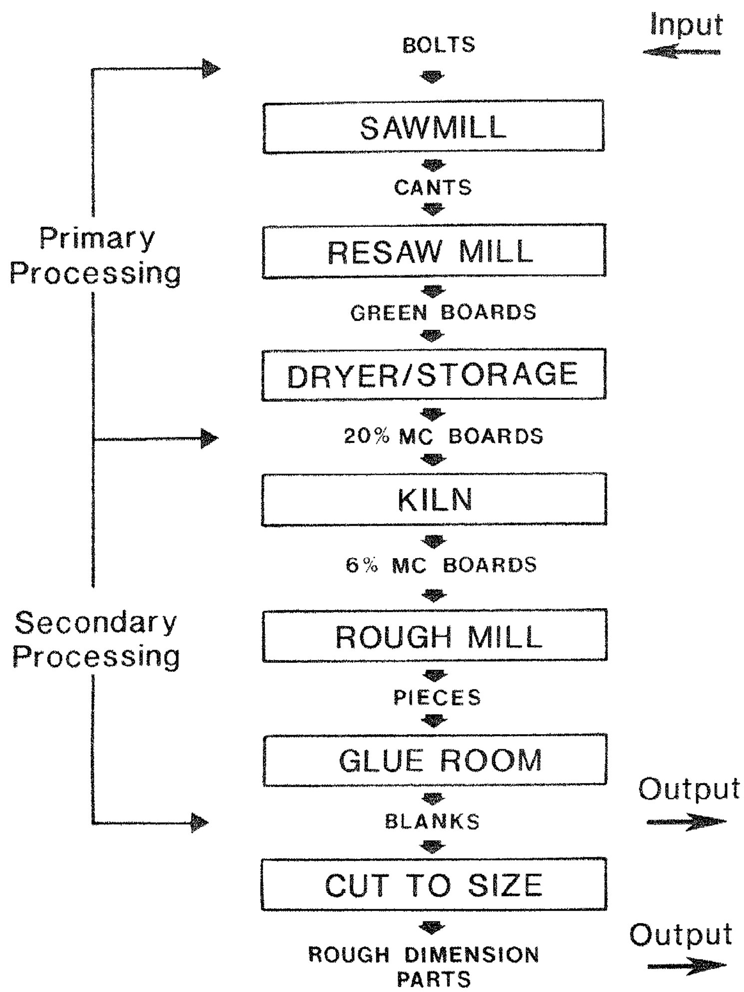

Figure 1. S/6 PROCESS FLOWCHART

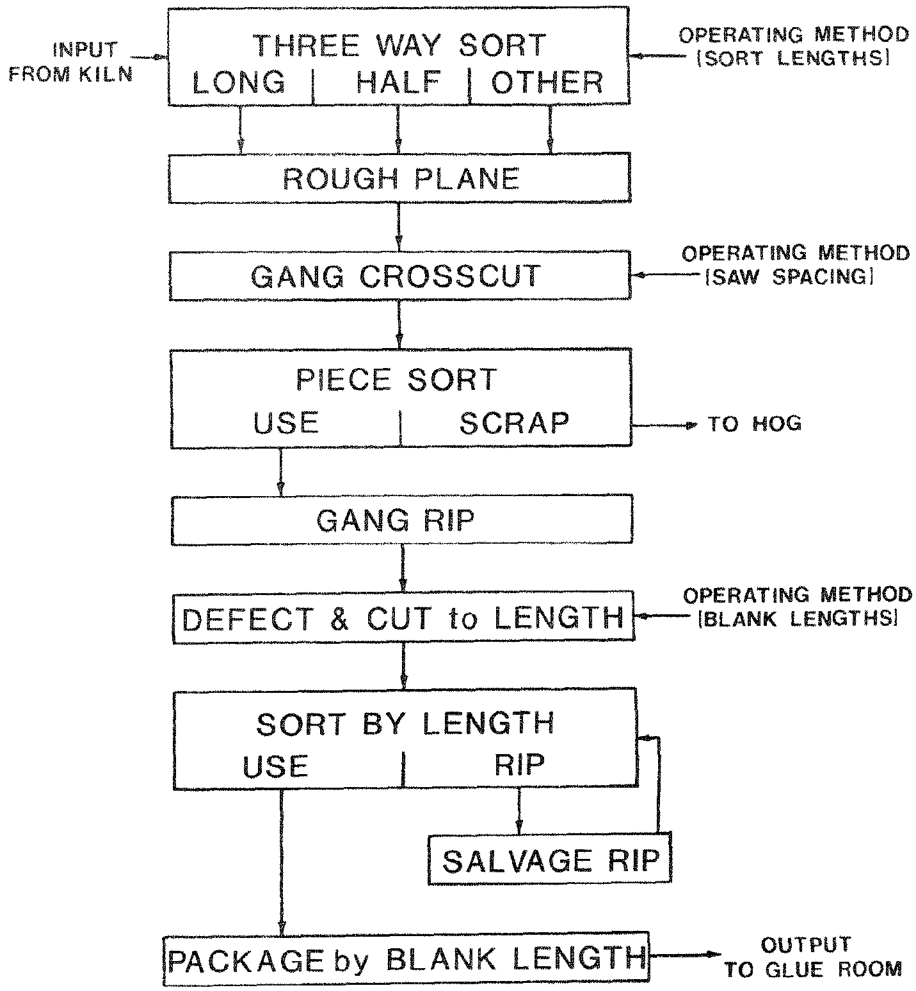

Figure 2. S/6 ROUGH MILL FLOWCHART

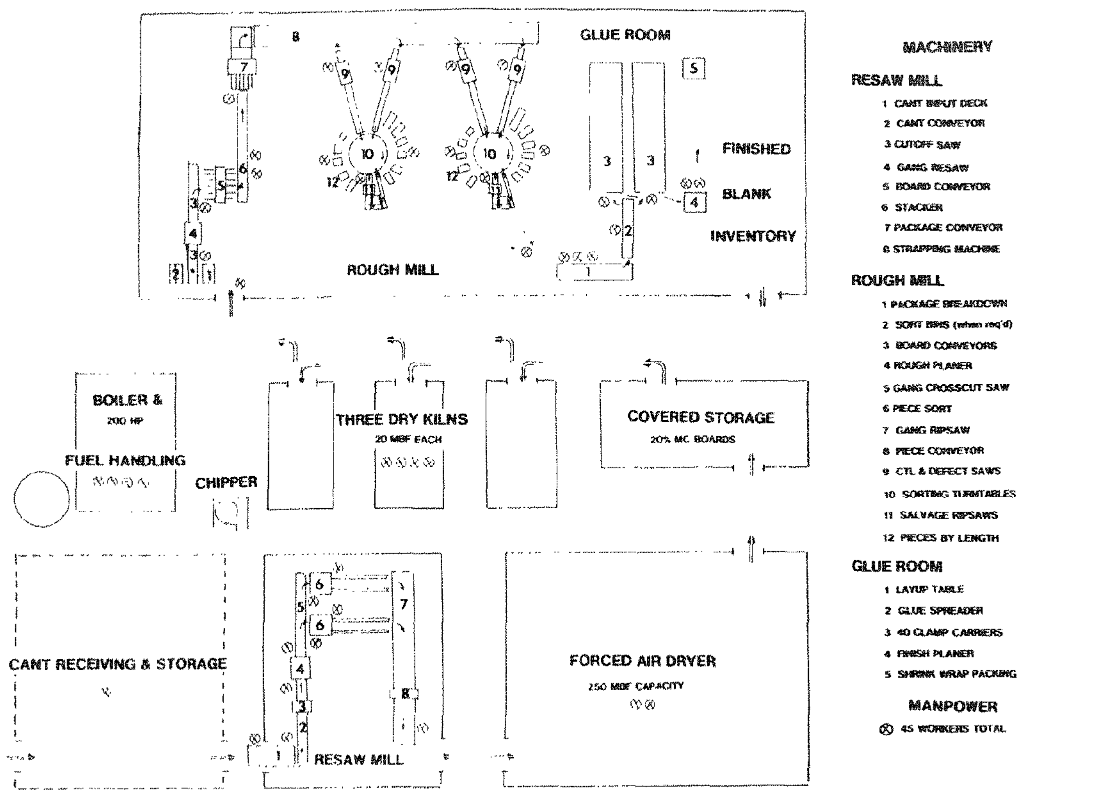

Figure 3. – **TYPICAL S/6 PLANT - 16 MBF/SHIFT INPUT CAPACITY** NO SCALE

Table 1. Machinery production rates

Processing step	Production rate[a] bd ft input/shift
Cant gang resaw	28.6 Mbf/shift
Board stacker	10.9 Mbf/shift
Dryer	50 Mbf each
Dry kilns	20 Mbf each
Rough mill	
3-way sort	13.9 Mbf/shift/operator
Rough plane	30.0 Mbf/shift
Gang crosscut	21.0 Mbf/shift
Piece sort	7.6 Mbf/shift/operator
Gang rip	62.5 Mbf/shift
Defect/cut-to-length	4.2 Mbf/shift/operator
Sort by length	5.7 Mbf/shift/operator
Salvage rip	16.0 Mbf/shift

[a]Production rate formulas and their derivation are available from the authors.

Low-temperature dryers are used to reduce the moisture content (MC) of the green boards to 20 percent. With a 21-day average drying time, 215 Mbf of dryer capacity will be needed. Since the dryers are built in 50 Mbf units, 5 units or 250 Mbf total capacity will be bought. Two workers on one shift will load, unload, and run the dryer. The dryer will work continuously and unattended at other times.

The stacks of boards at 20 percent MC are held in the covered storage until required for blank production, when they are brought to the kilns for drying. On the average, 120 hours of kiln time, or 5 days, will be needed to dry them to 6 percent MC. Therefore, kiln capacity of 52 Mbf is needed. Since the kilns are built in 20 Mbf units, three units or 60 Mbf total capacity will be bought. The kilns will be operated by four workers who will each work a 42-hour week.

The rough mill operation (Fig. 2) starts when the kiln-dried stacks of boards are brought to the rough mill from the kilns. One forklift is given this task.

One operator feeds the two-sided rough planer and does the three-way sorting. This requires 3 seconds per board, which translates to 13.9 Mbf per shift. But not all operating methods require sorting, so one worker can handle the job. The two-sided planer can process 30.0 Mbf per shift, so only one is used. The three-way sorting, planing, and gang crosscutting are coordinated, so all "other" boards are planed and crosscut, then the "half" boards, and finally the "long" boards.

With the feed chain at 40 feet per minute, each gang crosscut saw can process 21.0 Mbf per shift. Only one operator is needed to feed this machine. Two seconds per piece, on the average, will be allowed for each operator behind the gang crosscut saw to inspect the pieces. Pieces with a 1½- by 15-inch defect-free area will be accepted and all others will be scrapped. Each operator can process 7.6 Mbf per shift, so two piece sort operators are used.

The gang ripsaw has five pockets and feeds at 100 feet per minute. Such a machine, fully loaded at all times, could handle a rough mill input rate of 62.5 Mbf per shift, so obviously only one is used. One operator is required to put the pieces into the proper input bin pocket. The ripped pieces automatically fall onto a cross conveyor to be picked up by the defecting and cut-to-length crosscut operators.

At the defecting crosscut saws, the operators inspect each piece and, if necessary, crosscut out the end defects. Pieces are made to the longest possible blank length. We have found that an average of 4.5 seconds will be required for each piece leaving the gang ripsaw. Each operator can handle 4.2 Mbf per shift, so four defecting crosscut saw stations are used for the 15.7 Mbf per shift.

Pieces will be sorted by length manually at an average of 2 seconds per piece. Thus each worker can sort all the pieces generated at an input rate of 5.7 Mbf per shift and three workers can handle the 15.7 Mbf per shift input rate. Salvage ripsawing of 25 percent of the pieces leaving the defecting crosscut saws will require one ripsaw.

But we have designed the plant layout so that two defecting crosscut saws will drop their pieces onto one revolving sorting table. Each table will have half the pieces, so sorting on each table has to be done at a rough mill input rate of 7.85 Mbf. Therefore, there will be two workers per sorting table, and one salvage ripsaw at each table with a single operator.

In the glue room three workers lay up the pieces to blank width. With a closed clamp time of 60 minutes, 120 sections of clamp carrier will be needed. Two 60-section clamp carriers will be used with one worker per carrier plus a glue spreader operator. Two additional workers plane the dried blanks, package them, and load them for shipment.

A 500K memory minicomputer, with linear programing and inventory software, is used to determine the best way to operate the System 6 mill. The design requirements for this mill are taken from a specific study (Reynolds and Araman 1983); but when other blank requirements are considered, different gang crosscutting and blank length options will have to be considered (Reynolds 1984). The minicomputer is used to determine the least costly processing methods to obtain the blanks required. The minicomputer will be operated by the System 6 mill manager.

A steam boiler using waste wood (from the System 6 process) for fuel is required to heat the dryers, kilns, and buildings. The boiler specifications, fuel-handling equipment, and costs are taken from manufacturers' recommendations. A crew of four is used for full-time attendance.

Table 2. Equipment costs—installed (Prices current: October 1982)

Item	Cost
Primary processing machinery	
Cant gang resaw: Hazelthorne K140, 11 saws, 10 boards (100 hp)	$ 22,000
Cant cutoff saw: Hazelthorne R180, 6 × 25 (15 hp)	9,000
Receiving deck, unscrambler and conveyors (25 hp total)	36,000
Two manual board stackers $7,500 each (10 hp total)	15,000
Board conveyors and strapping machine (25 hp total)	30,000
Hog/screen chip-pac and infloor sawdust/refuse conveyor (75 hp total)	48,500
Forklift 4,000 pounds propane	12,500
	$ 173,000
Secondary processing machinery	
Package breakdown hoist and 3-way sort conveyors (25 hp total)	$ 24,000
Rough planer: 2-side 4 × 12 spiral knives (50 hp total)	30,000
Gang crosscut saw: 5-saw variable spacing Stetson-Ross (30 hp total)	54,000
Gang ripsaw Stetson-Ross MR-24 modified (100 hp)	60,000
Piece conveyors and piece sort station (25 hp total)	24,000
Four defecting saws $8,500 each (20 hp total)	34,000
Two rotary sorting tables $4,500 each (10 hp total)	9,000
Two salvage ripsaws w/return conveyors $8,500 each (50 hp total)	17,000
Forklift 4,000 pounds propane	12,500
Glue spreader, conveyors, and panel layup tables (15 hp total)	15,000
Clamp carrier: Air motors 80 section @ $65,000; 40 section @ $35,000	100,000
Panel trimsaw: 3 saws variable spaced (30 hp total)	35,000
Blank planer: 2-side, 2 × 30 spiral knives (75 hp total)	40,000
Dust collection system and bins (50 hp total)	65,500
Minicomputer w/500K memory and software	10,000
	$ 530,000
Dryers, Kilns, and Boilers	
Boiler 200 hp and fuel handling/storage	$ 300,000
250 Mbf dryer @ 60¢/board foot capacity	150,000
Three 20 Mbf kilns @ $2.70/board foot capacity	162,000
Two forklifts 4,000 pounds propane $12,500 each	25,000
	$ 637,000
Land, improved 8 acres $12,500/acre	$ 100,000
Buildings	
Primary plant 40′ × 70′ = 2,800 square feet @ $24/square foot	$ 67,000
Secondary plant 40′ × 150′ = 6,000 square feet @ $24/square foot	144,000
Boiler 40′ × 40′ = 1,600 square feet @ $12.50/square foot	20,000
Air dry lumber storage 40′ × 60′ = 2,400 square feet @ $12/square foot	29,000
	$ 260,000
Total Investment	
Machinery: Primary plant	$ 173,000
Secondary plant	530,000
Total	$ 703,000
Dryers, Kilns, and Boilers	$ 637,000
Buildings	260,000
Total	$ 897,000
Land	$ 100,000
Grand Total	$1,700,000

The estimated installed cost for the plant layout shown in Figure 3 is given in Table 2. Costs are those of October 1982.

Economic Analysis

After a proposed plant is designed, the engineering data must be translated into economic terms. A cash flow analysis is made with the economic data. If the CFA shows that the plant specifications are met or exceeded, the proposed plant design will be accepted. If the design does not meet the specifications, a new design must be made and tested.

A number of assumptions and techniques are used with the CFA program:[1]

- A 10-year plant life: In 10 years the assets will be presumed sold for their remaining undepreciated value. The working capital will be returned.
- Investment: The internal rate of return (IRR) is based on the entire investment. The source of this investment, whether borrowed or equity capital, is not considered.
- Taxes: The maximum Federal corporate tax rate of 46 percent will be used without any tax sheltering. Investment tax credits will not be used. State and local taxes are taken as fixed costs.
- Depreciation: The 1981 accelerated depreciation allowances are used with 5-year writeoff for machinery; 15 years for buildings, kilns, and boilers; and no depreciation for land.

The economic data, costs, and revenues are shown in Table 3. Sawmillers near the new System 6 blank plant will purchase marginal quality white oak bolts (Reynolds and Araman 1983) for $39 per cord. This is equivalent to $85 per Mbf by the ¼-inch International scale, as there are 2.2 cords per Mbf, bolt scale. The sawmillers can saw two cants per bolt profitably at $50 per Mbf, bolt scale. Hauling costs from sawmill to the blanks plant will average $15 per Mbf. Bolt and cant scale are the same. The cant cost at the blank mill will be $85 + $50 + $15 = $150 per Mbf. Because the white oak bolts are of small diameter, the ¼-inch International scale underestimates the quantity of boards that can be made. Research for this paper showed a 28-percent overrun from bolt/cant scale to boards. Thus the 15.7 Mbf per shift board requirement becomes a 12.3 Mbf per shift cant requirement (15.7 ÷ 1.28 = 12.3).

Table 3. Annual operating costs and revenues

	Item	Year 1	Years 2–10
Costs:	Variable		
	Cants $150/Mbf × 12.3 Mbf/day × 240 days/year	$ 221,000[a]	$ 442,000
	Labor 45 workers @ $6/hour + 2 @ $10/hour	435,000[b]	580,000
	Supplies: 1.5 percent of sales	26,000[b]	35,000
	Utilities: 2.0 percent of sales	35,000[b]	46,000
	Selling expenses: 5.0 percent of sales	58,000[a]	116,000
Costs:	Fixed		
	Management and administrative (2 executives; 1 secretary)	80,000	80,000
	Insurance: 2½ percent of value = $1,600,000	40,000	40,000
	Maintenance: 10 percent of equipment cost = $1,340,000	134,000	134,000
	Total	$1,029,000	$1,473,000[c]
Revenue:	Frame blanks: 1,550,000 ft² × $1.00	775,000[a]	1,550,000
	Clear blanks: 450,000 ft² × $1.70	383,000[a]	765,000
	Total: 2,000,000 ft² × $1.16	$1,158,000[a]	$2,315,000

[a]Half of years 2–10 production.
[b]Seventy-five percent of years 2–10 costs.
[c]64 percent of sales.

Plant construction, manpower, hiring, and training will start at the beginning of year 1. By the end of the year, production will be at the design rate. Because of training and construction delays, only half of a normal year's production will be made in year 1; but 75 percent of the normal year's costs for labor, supplies, and utilities will be incurred in year 1. Only 50 percent of the normal year's cant costs and selling costs will be incurred in year 1, but all the normal year's fixed costs will be incurred.

Working capital is required to purchase and maintain a 36-day supply of cants on hand ($66,000). The blanks customers will have 30 days to pay for the blanks so an accounts receivable working capital of $190,000 will be needed. Only $128,000 of working capital will be required during the first year because production will be only half of that projected. The other half of the total working capital ($256,000) will be committed at the beginning of year 2.

The capital investment is shown in Table 2. Machinery totaling $703,000 will be depreciated in 5 years; kilns and boilers totaling $637,000 will be depreciated in 15 years, as will buildings totaling $260,000. The $100,000 in land and improvements will not carry any depreciation. The capital investment totals $1,828,000 which is $1,700,000 of real capital plus the first year's working capital at $128,000.

The CFA shows an IRR of 21 percent. Thus both the maximum capital investment of $2,000,000 and the required 20-percent minimum rate of return have been met. The proposed design is acceptable.

Summary

Three independent factors must be considered when a System 6 plant is designed:

- Investment: What is the maximum amount of investment capital available and what is the minimum rate of return this investment must earn?
- Blanks: There are 148 different standard-size blanks by quality, thickness, and length. What are the quantity requirements for each of these blanks?
- Raw material: What quality and quantity of small-diameter, low-grade hardwood is available; what will it cost; and what will be the yield in required blanks?

The System 6 plant designer's problem is to find a design that will satisfy the blank demands using the available raw material while staying within the prescribed investment limits.

The demand for blanks can be estimated from the total furniture and kitchen cabinet industry demand as found by Araman et al. (1982) or for a particular part of the industry. In this paper the second method was used (Reynolds and Araman 1983).

A study of the raw material is necessary to find the yield of the required blanks. Raw material costs are also needed. In this paper we used the results of a study using white oak thinnings to produce frame blanks (Reynolds and Araman 1983).

A System 6 plant design is then roughed out. Machinery, kilns, buildings, land costs, etc., are estimated. This data is put into economic terms and a CFA is made. If the results of the CFA show that the design meets or exceeds the investment requirements, then this plant design is practical.

This System 6 plant design method is an iterative technique. A design is made and tested. If the design meets or exceeds the economic requirements, it is acceptable. Additional designs can be tested to determine whether a better one exists. If the design is unacceptable, changes will have to be made to reduce costs and investment or to improve earnings. In a companion paper[1] the CFA is fully explained.

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