Project Number 81-Z3
Project Researchers: Tretheway/Matthews

ANNUAL REPORT

PROJECT NO. 81-Z3
BRUSH UTILIZATION STUDY
DENSIFYING AND TRANSPORTING BRUSH
FOR
CALIFORNIA ALMOND BOARD

By

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Chapter 1
INTRODUCTION

BACKGROUND

CH2M HILL has contracted with the Almond Board of California to conduct a feasibility study for size reduction, collecting, transporting, and marketing almond brush (prunings) from orchards in California. The study was conducted concurrently with a tub grinder test (Project No. 79-ZG) under the management of University of California, Davis Cooperative Extension. This report summarizes the findings of the CH2M HILL study (Project Number 81-Z3).

OBJECTIVES

The objective of the study is to identify a feasible and cost-effective method for removing, processing, and transporting almond brush from the orchard to potential buyers. The study includes the following activities:

- Evaluate commercially available semiportable densification (sizing) equipment that was not previously tested on almond brush.

- Help coordinate the required almond brush sizing tests. Monitor and analyze test results. Provide liaison between Almond Board, growers, and equipment vendors.

- Evaluate available transportation modes and loaders for each new sizing process or method tested.

- From results of the tests and evaluations, develop typical capital and operating costs for each feasible sizing process. Unit costs per sized ton and transportation costs to selected markets will be included.

- Update the market survey for sized almond prunings.

- Prepare a final annual report to include results of all testing and evaluations. The report will consolidate current and past studies and will include a recommended process for removing, processing, and transporting almond brush.

- Provide engineering consulting services where necessary for obtaining Federal and State funding/grants for developing the recommended brush sizing process for commercial use or for conducting detailed tests on a prototype machine.

- Witness other pruning sizing tests conducted independently by growers or other agricultural associations.

Chapter 2
SUMMARY

The following paragraphs summarize the results of the study.

PRUNINGS DISTRIBUTION AND DESCRIPTION

Approximately 350,000 tons of prunings are generated each year in California after removal of large limbs for firewood. Quantities average about 1 ton per bearing acre, the greatest amounts being found in the northern and central sections of the San Joaquin Valley. Pruning quantities are expected to increase by about 6 percent per year, with the largest increase occurring in the southern San Joaquin Valley.

PROCESSING PRUNINGS

Almond brush must be reduced in size to approximately 2-inch minus material to be marketable. These prunings are difficult to size because of high resiliency and small diameter. Average prunings are 6 to 10 feet long and 1 to 3 inches in diameter. Heat value varies according to moisture content and ranges from about 6,500 Btu per pound at 30 percent moisture to 5,000 Btu per pound at 45 percent moisture. Sized prunings (about 2-inch size) will have a bulk density from 15 to 20 pounds per cubic foot.

MARKETS

Processed (sized) almond prunings can be sold at a delivered price between $15 and $50 per ton depending on use, size, and moisture content. The greatest demand for sized almond brush appears to be as boiler fuel. About 20 to 30 biomass-fueled plants in California are in operation, under construction, or in the planning/design stages. Using sized brush for mushroom compost, alcohol production, soil additive, and charcoal, production appears promising. Sized prunings may someday serve additional markets such as animal feed, paper manufacturing, firelog manufacturing, particle board manufacturing, and animal bedding.

EQUIPMENT TESTS

Numerous types and pieces of orchard-side and in-row equipment were tested during 1979, 1980, and 1981. These included tub grinders, various types of loaders, self-propelled hammermills, a packer truck, a large log chipper, cotton module builders, a small demolisher, small shredders, forklifts, and trucks. These tests were conducted at Durham, Ballico, Snelling, Huron, Chowchilla, Cortez, Lodi, and Palo Alto.

PROCESSING OPTIONS

Three methods of brush size reduction processing are possible:

- In-row
- Orchard-side
- Orchard-side compacting with sizing at a central location

In-row processing involves the use of a continuously moving chipper, tub grinder, or hammermill. Custom in-row sizing eliminates the need for buckraking, but heavy equipment can damage roots and mature trees and interfere with other orchard activities. Collection of the processed material also presents problems.

Orchard-side sizing and equipment tested included hammermills, tub grinders, a chipper, and a demolisher. Rates as high as 8 tons per hour have been temporarily achieved, but sustained rates above 5 tons per hour appear to be unattainable until methods of feeding the machinery can be improved. Tub grinders appear most effective at present, but a new chipper has been developed and is being tested.

Equipment tested for compacting at orchard-side included a baler, a packer truck, and cotton module builders. Of the three, the module builder is the most effective. The 16-foot by 7-foot by 7-foot module it produces can be easily transported to a central location for sizing.

Once the modules are at a central location, they can be fed into tub grinders or demolishers. Tub grinders have been tested at 15 to 20 tons per hour. The modules must be reduced in size to be fed into the tub grinders. However, no efficient method of cutting modules so that the prunings can be fed into tub grinders has yet been developed.

COSTS

Preliminary cost estimates for delivery of sized almond prunings to a market within 30 miles are expected to be $35 to $50 per ton.

Costs of orchard-side equipment range from $60,000 to $240,000 and for a central location from $300,000 to $600,000. Cotton module builders can cost $30,000 to $60,000.

CONCLUSIONS AND RECOMMENDATIONS

The studies completed to date indicate that a cost-effective system to convert can be developed that will utilize almond brush into fuel for energy production.

Much of the required equipment is currently available and can be either used as is or can be easily modified.

It is recommended that an orchard-side module builder system be further developed and that a prototype central system that will receive brush modules and reduce the brush to a marketable fuel particle size be constructed. Also, module equipment manufacturers should be encouraged to further develop their equipment for almond brush densification.

The prototype central system may be partially financed with grant funds from the California Energy Commission or other State agencies.

Chapter 3
PROCESSING, HANDLING, AND TRANSPORTATION

Alternatives to the current practice of burning prunings in the orchards are needed for two reasons. First, air quality regulations may make open burning very difficult in the future. Second, open burning is a waste of available energy that can be recovered.

The process of converting almond prunings into usable biomass can be complex. The process has, therefore, been separated into a number of steps or stages to permit the discussion to proceed in an orderly manner. The stages are orchard location processing, transporation from orchards to a central location, central location storage and processing, and transportation to the buyer. A number of brush handling and processing options are possible within each stage. Figure 1 is a product flow diagram of possible options. The options at each stage are discussed in the following paragraphs.

ORCHARD LOCATION PROCESSING

Orchard location processing has been separated into two categories: in-row and orchard-side sizing. Possible types of equipment for each category are shown on Figure 1.

In-Row Sizing

In-row sizing equipment moves down every other tree row. This method eliminates buckraking brush to the ends of tree rows as is required with orchard-side sizing. Small chippers and mobile hammermills and shredders can be used in the tree rows.

Small Chippers

A small, hand-fed, self-powered chipper (similar to those used by municipalities for tree prunings) can be pulled by a truck, tractor, or bankout wagon. A chipper pulled by a truck or bankout wagon can discharge chips directly into the pulling vehicles. If a chipper is pulled by a tractor, the chips can be discharged directly into a trailer or to the ground. Chips on the ground can be picked up with an almond sweeper.

The advantages of in-row chippers are:

- A chipper can be moved through an orchard with a pruning crew.
- A chipper involves a low investment. Most other necessary equipment is probably available at almond orchards.

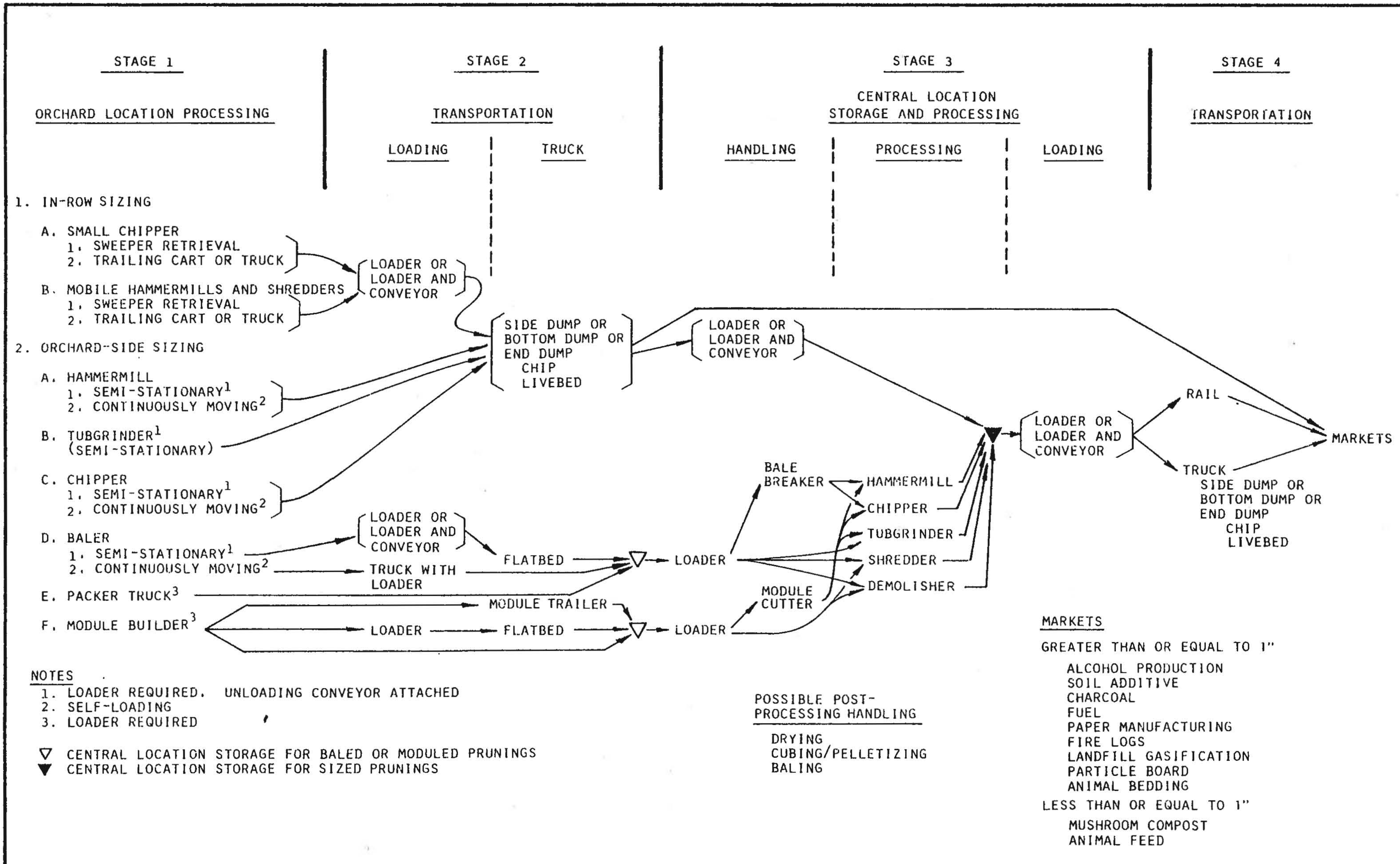

FIGURE 1
PRODUCT FLOW DIAGRAM

The disadvantages of in-row chippers are:

- Hand-fed chippers have low hourly production rates (1-2 tons per hour).
- Hand-feeding requires constant safety monitoring by supervising personnel.
- Some "stringers" (unchipped small branches) may pass through the chipper. The stringers must be separated from the chips before most buyers will purchase them.
- If the chips are discharged to the ground, not all will be swept. Those remaining could interrupt almond sweeping and hulling operations during the next harvest.
- Chippers require extensive maintenance and servicing. Servicing includes knife sharpening and changing.

Mobile Hammermills and Shredders

Mobile hammermills and shredders that move along tree rows grinding windrowed prunings have been tested on almond prunings. The machines tested discharge sized prunings directly to the ground to be swept up by almond sweepers. All of those tested required multiple passes over windrows to reduce all prunings to a 3-inch-minus size. If these units could be modified to discharge sized material into an attached trailer, pickup costs would be saved.

In-row hammermills and shredders have the main advantage of adapting proven and available processing equipment.

The disadvantages of in-row hammermills and shredders are:

- Some machines are heavy, and excessive soil compaction may damage tree roots.
- Low-hanging branches can be damaged by the machines. Some machines require much greater vertical clearance than a tractor or buckrake.
- Not all sized prunings can be swept from the orchard floor. The residual material could interrupt the sweeping and hulling operations during the next harvest.
- Rocks, dirt, and other inert material will contaminate the sized prunings and lower the market value of the prunings.

- Leaving the prunings in windrows could interfere with other orchard work such as spraying.

Orchard-Side Sizing

Six options are included in the orchard-side sizing category. All require buckraking the prunings to the end of tree rows, but all enable more rapid handling of the brush than does in-row sizing. They also allow more efficient scheduling of sizing equipment and, most important, do not interfere with other orchard work.

The six options considered feasible are:

1. Hammermill
2. Tub grinder
3. Chipper
4. Baler
5. Packer truck
6. Module builder

Table 1 provides comparative information.

Hammermill

A hammermill applies the principle of impaction to "shear" the prunings. Prunings are usually fed to a hammermill by a moving horizontal conveyor or vertically through a hopper. Hammers are arranged in rows on a rotating shaft and may be (1) fixed by locking discs, (2) welded or screwed to the shaft, or (3) allowed to swing on pins. Holes in a removable screen determine the size of the sized material. Hammermills are used extensively in the forest products industry.

Tub Grinder

A tub grinder is a hammermill that is force-fed by an open rotating tub. Hammers are usually of the swing type, and screens are interchangeable. Tub grinders have been used for many years to grind hay, alfalfa, and silage.

Chipper

A chipper uses rotating knives to cut prunings into small pieces. The replaceable knives are attached radially or axially to a moving rotor or drum. The clearance between the chipper anvil and the moving blades determines the size of the chips. Smaller chippers are used by municipalities for chipping tree limbs, and larger ones are used by forest products companies to make wood chips from entire trees.

Table 1
ORCHARD-SIDE SIZING EQUIPMENT
UNDER CONSIDERATION

Equipment	Estimated Cost	Estimated Horsepower	Estimated Rates (TPH)	Remarks
1. Hammermills				
a. Gruendler (small)	$ 60,000	200	0-5	1
b. Gruendler (large)	130,000	300	0-10	1
c. Jeffrey Design	175,000	250	0-15	1
2. Tub Grinders				
a. W.H.O.	80,000	250	0-6	2,3
b. Medallion (large)	110,000		0-8	2,3
3. Chippers				
a. Morbark Design	95,000	250	0-8	1
b. Morbark with Claw	120,000	300	0-8	1
c. Nicholson Wood Fuel Processor	240,000	500	0-20	2
4. Baler	25,000		0-5	1
5. Packer Truck	70/hour	250	1/2-3	2,3
6. Module Builder (16 foot)	35,000		0-10	2,3

Remarks:
1. Not available but under design or design review.
2. Available on market.
3. Tested during the study.

Baler and Packer Truck

The baler and packer truck use compaction to densify almond prunings. Balers use binding material to maintain compaction and are commonly used to bale hay and municipal solid waste. Balers designed specifically to handle almond prunings are not yet available. Packer trucks are used for municipal solid waste and do not use binding material. Compaction, in both cases, is accomplished with hydraulically operated rams.

Module Builder

The module builder also applies the principle of compaction to densify almond prunings. The module builder was designed for use in the cotton industry. Field tests using cotton module builders to compact almond prunings have been successful. Almond prunings can be compressed into 16-foot by 7-foot by 7-foot modules and transported using either a flatbed truck or a specially designed module trailer. Binding material is not required since almond prunings "knit" together when compacted.

Evaluation of Orchard-Side Options

Hammermills offer the advantages of durability, potentially high processing rates, and rapid adjustments to the size of material produced. However, they are not available for use in orchard-side sizing of almond prunings. The tub grinder has similar advantages except that it has not demonstrated that it will meet the processing rate of a force-fed hammermill. Tub grinders are available for immediate use. The tub grinder and hammermill can also be used to reprocess sized prunings and to grind almond hulls and other agricultural residues.

The chipper produces a high-quality sized material and can also achieve high processing rates. However, maintenance costs are expected to be higher than for hammermills because the knife edges must be sharpened often. Chippers for orchard-side and in-row sizing are under development and will probably be tested during the 1981-82 pruning season. Chippers, unlike the tub grinder or hammermill, can only be used for processing wood material.

The primary advantages of the baler, packer truck, and module builder over the other sizing machines are mobility and relatively low equipment cost. Low field processing rates are expected from a baler or packer truck.

With the exception of the module builder, none of the equipment tested to date at orchard side could be fed at the desired material processing rates. The highest rate for a chipper was achieved by horizontally force-feeding, using a support conveyor and an upper roller. The tub grinder, chipper, packer truck, and module builder require a loader. Prototype self-loading hammermills and chippers have not yet been manufactured. A prototype self-loading chipper has been developed and is undergoing testing. Potentially, the hammermill, chipper, and baler could be designed and operated as continuously moving units.

Prototypes of semistationary and continuously moving hammermills and chippers are being designed by various equipment manufacturers. The designs are based upon units that have reduced because of proximity to the prunings, and the machine can be operated continuously. If high-capacity equipment is used for field location processing, operational time is lost when the equipment is moved from orchard to orchard. Different types of equipment are:

- o Tub grinders
- o Chippers
- o Shredders
- o Demolishers
- o Hammermills

Large tub grinders have been tested with sections of modules. Large chippers are being field tested in the southern San Joaquin Valley during the winter of 1981-82.

Shredder prototypes that are large enough to be fed with modules are not currently available.

A demolisher that can be loaded with a 16-foot by 7-foot by 7-foot module may be tested during the winter of 1982. Large demolishers operate on the principle of counter-rotating shafts. The shafts have protruding studs that break up prunings. Demolishers are gravity fed and have been used successfully to grind municipal wastes.

Large hammermills that can be force-fed prunings are not available at this time.

Table 2 shows required hourly equipment capacities (sizing rates) for specified processing season lengths, work day lengths, and tonnage.

TRANSPORTATION FROM CENTRAL LOCATION TO BUYERS

Grower or growers association trucks could be used to transport sized material from a central location to buyers. If larger quantities or long distances are to be considered, commercial trucking companies can provide the required transportation services. Rail cars could be used for long distance transportation of large quantities.

proven satisfactory in logging operations, and all have some form of self-feeding capability. Semistationary equipment will need buckrakes to push brush to the self-feeding mechanism.

TRANSPORTATION FROM ORCHARD LOCATION

Transportation of prunings from the orchard location to the buyer or to a central location may be accomplished by (1) packer trucks, (2) bulk material trucks or truck trailers (for sized material), (3) module trailers, and (4) flatbed trucks for hauling baled or moduled material.

A number of trailer options exist if the prunings have been sized by chippers or hammermills. They include side-dump, bottom-dump, and end-dump configurations. End-dump, live-bed trailers are the best way to transport the prunings. Prunings tend to "bridge" when dumped from side- or bottom-dump trailers.

CENTRAL LOCATION STORAGE AND PROCESSING

A central location should be included in a plan for marketing sized almond prunings for a number of reasons.

- To coordinate transportation between the various points where field location processing may be occurring.
- To store enough baled or moduled prunings to permit the efficient operation of large capacity sizing equipment (and associated support equipment).
- To dry the baled or moduled prunings prior to sizing.
- To produce a wider variety of products by reprocessing with stationary equipment.
- To schedule deliveries of sized prunings to buyers over an extended time.

Off-loading equipment is required at the central location. The equipment will be determined by the product form(s) being delivered and the type of trailer(s) used. Skip loaders, conveyor belts, receiving pits, and screens may be required. Equipment for off-load prunings at a central location could be used to load transportation vehicles.

It is economically feasible to operate sizing equipment that has production rates (capacities) up to 20 tons per hour at a central location for two reasons: Average loading time is

Table 2

REQUIRED HOURLY EQUIPMENT CAPACITIES[1]

FOR SPECIFIED PROCESSING SEASON LENGTHS, WORK DAY LENGTHS, AND TONNAGE

	30-Day Season				60-Day Season				90-Day Season			
		Capacity Required For				Capacity Required For				Capacity Required For		
Length of Work Day	Available Hours	5,000 Tons	10,000 Tons	20,000 Tons	Available Hours	5,000 Tons	10,000 Tons	20,000 Tons	Available Hours	5,000 Tons	10,000 Tons	20,000 Tons
(hours)		----(tons per hour)----				---(tons per hour)----				----(tons per hour)----		
24	720	6.9	13.9	27.8	1,440	3.5	6.9	13.9	2,160	2.3	4.6	9.2
16	480	10.4	20.8	41.6	960	5.2	10.4	20.8	1,440	3.5	6.9	13.8
12	360	13.9	27.8	55.6	720	6.9	13.9	27.8	1,080	4.2	8.3	16.6
8	240	20.8	41.7	83.4	480	10.4	20.8	41.7	720	6.9	13.9	27.8

[1] If equipment is operated at 80 percent of rated capacity, increase all values by 25 percent.

Chapter 4
SUMMARY OF EQUIPMENT TEST FINDINGS

Fifteen equipment tests involving different types of equipment for removing almond prunings from orchards and converting the prunings into marketable products were conducted and evaluated. The focus was on farm equipment that could be easily modified. The goal was to identify low-cost, available alternatives to replace current burning practices. The first equipment test was conducted in 1979. The tests have been separated into three general categories for evaluation:

- Equipment operated in an orchard (in-row)
- Equipment operated at the side of an orchard (orchard-side)
- Methods that combine orchard-side compacting with processing (sizing) at central locations

Appendix A includes a listing of equipment tests. Reports for each test were delivered to the Almond Board following each test.

1979 AND 1980 EQUIPMENT TESTS

Orchard-side and in-row equipment were tested during 1979 and 1980. Tub grinders, various types of loaders, self-propelled hammermills, a packer truck (municipal garbage truck), and a large log chipper were evaluated. The findings were:

- Tub grinders operated at orchard-side could not be fed prunings fast enough to obtain average production rates exceeding 5 dry tons per hour. Because of operating expenses, the average cost of the sized prunings exceeded the prices offered by potential buyers.
- Self-propelled hammermills and similar in-row equipment could not achieve production rates exceeding 3 tons per hour. Average costs per ton were high because hourly expenses exceeded $100. In addition, the sized prunings were left on the ground by the equipment. It was necessary to go back through the orchard with a sweeper to pick up the material.
- Packer trucks could not be loaded quickly with prunings and were also limited by the small quantity of prunings that could be transported in one load. As a result, average costs per ton for compaction and transportation were high.

- o The log chipper was large enough to chip all sizes of prunings fed into it. The production rate was low because loading was slow. As a result of the test, the equipment manufacturer redesigned the feed mechanism, and a new model has been constructed.
- o A method of compacting prunings prior to loading the prunings into sizing equipment is required if average hourly production rates are to be increased.

1981 EQUIPMENT TESTS

Equipment tests conducted during 1981 began early in March. Three objectives were established for the tests:

- o Continue testing tub grinders and other sizing equipment at orchard-side.
- o Test cotton module builders to see if almond prunings could be compacted into large modules (bales).
- o Continue evaluation of in-row sizing equipment.

The results of the 1981 equipment tests have been separated into five categories: (1) increasing average production rates of sizing equipment by feeding compacted prunings; (2) module building; (3) module handling and transport; (4) cutting modules; and (5) in-row sizing equipment.

Increasing Production By Feeding Compacted Prunings

Tests with two different types of equipment showed it is possible to increase hourly production rates significantly if compacted prunings are fed.

Large tub grinders fed with loosely piled prunings achieved average rates of 3 to 6 dry tons per hour. However, hourly rates of 15 to 20 dry tons were achieved when sections of modules were fed into the tub grinders. The production rate of a wood demolisher was doubled from about 4 to 8 tons per hour by feeding compacted prunings.

Module Building

Cotton module builders can be used to compact almond prunings into 16-foot by 7-foot by 7-foot modules. The following was learned:

- o Module builders can be loaded easily using front-end or grapple loaders. Large front-end loaders load prunings faster than grapple loaders, however.

- Modules of prunings can be unloaded in about 15 seconds.

- Prunings knit together well when compacted, and binding is not required to hold the modules together.

- Module builders with a floor (bottom) can compact prunings to greater densities than can module builders without floors.

- Minor design modifications to cotton module builders may be required if they are continuously used to compact almond brush. Possible modifications are heavier gauge metal in the sides and bottom, larger capacity hydraulic pumps and cylinders, stronger unloading chains, and a redesigned ram assembly.

- More densely compacted modules can be made with green (high moisture content) prunings than with dry prunings. Green prunings knit together more tightly because they are more pliable.

- Prunings less than 10 feet long can be loaded into module builders faster than longer prunings.

Module Loading and Transport

After modules of prunings are made, they may be left at the orchard-side or transported to a central location for storage. They can be easily transported using module builders, module trailers, flatbed trucks, or flatbed trailers.

Module trailers are presently used to move cotton modules from the field to the cotton gin and are self-loading. Large forklifts or loaders will be needed to load modules on trucks or trailers, however.

Modules may be loaded individually or stacked on trucks and trailers. If loaded individually, only tie-down ropes are required to hold them in place. If modules are stacked, stakes should be placed along the sides of the truck or trailer for faster loading and to keep the modules from shifting during transport.

Cutting Modules

Modules of almond prunings must be cut into three or four smaller sections before the prunings can be fed into existing sizing equipment. New equipment that can be loaded with entire modules must be designed if an inexpensive way to make modules smaller cannot be found.

It is difficult to use hand-held chainsaws to cut modules because the saws are cumbersome and slow. Shears or cutters used in the metal fabricating or paper manufacturing industries are not adaptable. Tree topping and hedging equipment and large circular saws will not work because the required depth of cut is too great.

Agricultural engineers are now attempting to design module cutting equipment that overcomes the limitations of hand-held chainsaws while retaining the chainsaw principle.

In-Row Sizing Equipment

Chippers, small shredders, and baling equipment were tested during 1981. Existing in-row sizing equipment needs to be modified before any can be used to size almond prunings and produce a marketable product.

Experimental work is likely to continue because there is a great deal of grower interest in equipment that will be feasible for in-row use and for smaller quantities of prunings. Efforts will be directed toward reducing the amount of labor required (by incorporating self-feeding mechanisms) and to design equipment to discharge sized material to trailers rather than the orchard floor.

Hay balers modified to bale prunings are being assembled by the agricultural engineering department of one university, and some farm equipment distributors will experiment with new round balers. Small bales of almond prunings would not require cutting before being fed to tub grinders and chippers.

Chapter 5
PRELIMINARY COST ESTIMATES

Preliminary cost estimates, at 1981 costs, for sizing almond prunings are developed in this chapter. Costs are estimated for sizing prunings at both orchard and central locations. Costs, including transportation to buyers, are expected to be:

- o Orchard Location: $35 to $46 per ton
- o Central Location: $24 to $27 per ton

ORCHARD LOCATION SIZING COSTS

Preliminary hourly cost estimates for eight pieces of equipment are shown on Table 3. Total hourly costs for sizing equipment range from $40 per hour to more than $120 per hour. In-row shredding equipment, packer trucks, and balers are not included because of high costs per ton or lack of workable design. Module builders are discussed later in this chapter.

The methods and assumptions used to calculate the costs are described in the following sections. Total costs are the sums of fixed and operational expenses. Fixed costs are costs associated directly with the cost of the equipment, expected operational life, and interest charges. Costs of operation are costs incurred on an hourly basis for operators, fuel, and repairs.

Fixed Costs

Fixed costs are the sum of (1) the annual cost of equipment ownerships as determined by the capital recovery depreciation method (CRD) and (2) taxes, insurance, and shelter (TIS).

The CRD method of calculating an annual cost depends upon three parameters: the salvage value, an interest rate, and an operational lifetime. Given assumptions about these three parameters, the annual equipment cost is calculated as follows:

$$\text{Cost} = (PC - SV)(\text{PDV factor}) + (I)(SV)$$

where: PC = purchase cost

SV = salvage value

Table 3
ANNUAL AND HOURLY EQUIPMENT COSTS
FOR ORCHARD LOCATION EQUIPMENT

Costs	Gruendler (Small)	Gruendler (Large)	Jeffrey Design	W.H.O. Tub Grinder	Medallion Tub Grinder	Morbark Design	Morbark With Claw	Nicholson Fuel Processor
	Equipment							
Purchase Cost	$ 60,000	$130,000	$175,000	$ 80,000	$110,000	$ 95,000	$120,000	$240,000
Annual Fixed Costs								
CRD[1]	10,000	21,600	29,000	13,300	18,200	15,800	19,900	39,800
TIS[2]	1,200	2,600	3,500	1,600	2,200	1,900	2,400	4,800
Total	$ 11,200	$ 24,200	$ 32,500	$ 14,900	$ 20,400	$ 17,700	$ 21,300	$ 44,600
Hourly Fixed Costs[3]	11	24	33	15	20	18	21	45
Hourly Operation Costs								
Labor	8	8	8	8	8	8	8	8
Fuel[4]	13	19	16	16	13	16	19	32
R&M[5]	4	9	12	5	7	6	8	16
Truck[6]	-	15	15	15	15	15	15	15
Subtotal	36	75	84	59	63	63	71	116
Management/Overhead	4	8	8	6	6	6	7	12
TOTAL	40	83	92	65	69	69	78	128

[1]Capital recovery depreciation.

[2]Taxes, insurance, and shelter.

[3]Based on 1,000 hours per year.

[4]Medallion tub grinder fuel consumption is 11 gallons per hour. Fuel consumption of other equipment estimated by specifying fuel consumption of .07 gallon per hour, per horsepower, for three-fourths of rated horsepower.

[5]Repair and maintenance.

[6]See Table 5.

[7]Specified as 10 percent.

PDV factor = discounting factor based upon operational life and interest rate

I = interest rate

The set of assumptions for equipment costs was:

- o Salvage value of 25 percent of purchase cost
- o Interest rate of 15 percent
- o Equipment life of 15 years

Total annual costs are divided by the number of operational hours in a year to calculate an hourly fixed cost. All equipment is assumed to be operated for 1,000 total hours per year.

Annual TIS costs are specified as 2 percent of purchase cost.

Operating Costs

Operators' wages for each type of equipment are identical. Fuel consumption costs are varied by horsepower unless actual consumption figures were available. The total expense for repairs and maintenance (R&M) was set to be equal to the purchase cost. The total R&M expense was then divided by the operational lifetime (in hours) to determine an hourly cost.

Additional Equipment Costs

Additional equipment that is required to support brush sizing activity is shown on Table 4. This equipment is common to many of the sizing methods and is added to sizing costs shown on Table 5.

Total Sizing and Handling Costs

Table 5 summarizes total estimated costs per ton for sizing and transporting almond prunings to a buyer. The costs are shown per ton of prunings sized at different hourly production rates. Wet tonnage delivered cost ranges from $17 to $37 per ton. Dry tonnage delivered cost ranges from $21 to $46 per ton. Costs do not include allowances for supervision, maintenance, and delays.

Costs for buckraking prunings to the end of rows have not been included because buckraking occurs during brush burning as well. Buckraking from brush piles at the end of tree rows is assumed to be required for all methods. This may not be valid for all equipment in subsequent analyses but has been retained for these preliminary estimates.

Table 4
COSTS OF ADDITIONAL EQUIPMENT

1. Truck tractor

Purchase price	$40,000
CRD (annual cost)	5,100
TIS (annual cost)	800

Hourly cost (1,000 hours per year)	$ 5.90
Operator	8.00
Fuel	16.00
R&M	2.70
Total Hourly Cost	$32.60

Truck cost per equipment operation hour is approximately $15 per hour if equipment is being moved one-third of the time.

2. Buckrake (including operator) $20 per hour

3. Loaders for the tub grinders and the fuel processor are estimated to cost $32 per hour (including operator).

4. Transportation costs for sized prunings

Waiting and loading costs per ton	$ 1.50
Transportation (30 miles @ $.18 per mile)	5.40
Total	$ 6.90

Table 5
PRELIMINARY COST ESTIMATES FOR SIZING ALMOND PRUNINGS AT ORCHARD LOCATIONS AND TRANSPORTING DIRECTLY TO BUYERS

		Cost Per Ton					
Equipment	Rate (Tons Per Hour)	Buckrake[1]	Loader	Sizing	Transport to Buyer[2]	Wet Tonnage Delivered Cost[3]	Dry Tonnage Delivered Cost[3,4]
Hammermills							
Gruendler (small)	5	4	-	8	7	19	24
Gruendler (large)	5	4	-	17	7	28	35
	10	4	-	8	7	19	24
Jeffrey Design	5	4	-	18	7	29	36
	10	4	-	9	7	20	25
Tub Grinders							
W.H.O.	6	3	5	11	7	26	33
Medallion	4	5	8	17	7	37	46
	8	3	4	9	7	23	29
Chippers							
Morbark Design	4	4	-	17	7	28	35
	8	3	-	9	7	19	24
Morbark With Claw	4	4	-	20	7	31	39
	8	3	-	10	7	20	25
Nicholson Fuel Processor	10	4	3	13	7	27	34
	20	2	2	6	7	17	21

[1] Two buckrakes if rate is 10 to 20 tons per hour.

[2] Loading, mileage, and waiting time included.

[3] With the exception of tub grinders, costs shown reflect opinions of suppliers only and are not based on study test data. Costs appear for information purposes only.

[4] Weight loss of approximately 25 percent.

Costs in common to all methods are a truck to move the semi-stationary equipment from location to location and transportation of sized prunings to buyers. Transporting directly to buyer would save all costs of a second handling at a central location but could also increase the coordination costs for operators. Growers suggested a $5 to 7 per ton range for transportation costs given a 20- to 30-mile hauling distance to the buyer.

CENTRAL LOCATION STORAGE

Initial transportation costs may be reduced to approximately $4 per ton if sized prunings are transported to a central location for open-air drying and storage. The effect, due to double handling, is to increase costs above the costs of shipping directly (see Table 5):

	Wet Rate (Tons Per Hour)	Dry Tonnage Cost	Tonnage Cost	Transport To Buyer	Total
Gruendler (small)	5	$16	$21	$7	$28
Gruendler (large)	10	16	21	7	28
Jeffrey Design	10	17	22	7	29
W.H.O. Tub Grinder	6	23	30	7	37
Medallion Tub Grinder	8	20	26	7	33
Morbark Design	8	16	21	7	28
Morbark With Claw	8	17	22	7	29
Nicholson Fuel Processor	20	14	18	7	25

However, if sized prunings are dried and stored at a central location before shipment to buyers, the material could also be reprocessed to meet buyer needs. For example, it could be reground in a stationary hammermill if buyers requested small sized material (e.g., 1/2 inch minus). The densified prunings could also be pelletized, cubed, or baled prior to shipment. Costs for this additional processing are estimated to range upwards from $4 per ton.

CENTRAL LOCATION SIZING COSTS

A preliminary cost estimate for converting almond prunings to boiler fuel at a central location is presented in this section. Module builders are utilized in field locations to initially compress almond prunings into 16-foot by 7-foot by 7-foot modules. The modules are transported to a central location where they are processed. Costs are shown on a dry-ton basis.

The system will include a module cutter, tub grinder, and screen. A module cutter will be required if a tub grinder is used because existing tub grinders cannot be loaded with a whole module.

For this system, four steps have been identified for converting almond prunings into a useful product: (1) compress the brush into modules, (2) move the modules to a central location, (3) reduce the prunings to 3-inch chips (sizing), and (4) transport the sized prunings to a buyer.

The estimated costs in dollars per ton are:

	Tub Grinder
Module Building	$ 4.25
Module Moving	3.75
Sizing	10.30
Management/Overhead	1.80
Transportation	6.90
	$27.00
Capital Cost	$305,000[1]
Average Sizing Rate	17.5 TPH

[1]Includes module cutter and screen units.

The costs presented above are based upon three types of information:

- Equipment test data. These data were used to estimate production rates, manpower requirements, equipment requirements, and fuel consumption. The data were assembled over a 20-month period when a variety of equipment was operated under actual field conditions.
- Projected engineering estimates for costs of new equipment, production rates, and costs of operation.
- Equipment lease and purchase costs. This information was provided by equipment manufacturers.

Estimates of costs are based upon leasing equipment, hiring custom operators, or purchasing new equipment. Estimates are based upon 200 work hours per month.

Step 1: Module Building Costs

Three pieces of equipment are required for the first step in converting almond prunings to boiler fuel. A module builder is pulled and powered by a wheel tractor. A tractor fitted with front-end loader is used to load the module builder with prunings. Two people will be employed at this step. The production rate is nominally 8 tons per hour.

	Monthly Cost
Tractor Rental (with loader, includes fuel)	$1,400
Tractor Rental (including fuel)	1,200
Module Builder Rental (including repair)	1,200
Labor (2 men, 200 hours, $7.50 per hour)	3,000
	$6,800
Cost per Ton (1,600 tons per month)	$ 4.25

Step 2: Module Moving Costs

Modules will be moved from orchards to a central location using a cotton module trailer.

Custom operator moving 8 tons per hour, $30 per hour.

Cost per Ton $ 3.75

Step 3: Sizing Prunings

Sizing equipment will be loaded with a large front-end loader. Module cutter, tub grinder, and screen operation costs are based upon the capital recovery depreciation method discussed earlier in this chapter.

This step has been divided into five parts. The first four parts are loading sizing equipment, cutting modules (required for tub grinder operations), and sizing costs for a tub grinder. A sizing cost summary is the last part of Step 3. Cost estimates are based upon a production rate for the tub grinder of 17.5 tons per hour. It is assumed that 10 percent of all sized material produced by the tub grinder must be re-sized to guarantee a marketable product. This reduces the average rate for the tub grinder to 17.5 tons per hour from 20 tons per hour.

Loading Costs

One large front-end loader is required for module handling. Approximately 8 to 10 modules must be moved from storage each hour to supply the module cutter. The loader must also load the small (cut) modules into the tub grinder.

	Tub Grinder (Monthly Cost)
Loader Rental (includes repair)	$2,500
Fuel (10 gph @ $1.20/gal) With Tub Grinder (100 hr/mo)	1,200
Labor ($7.50/hr) With Tub Grinder (100 hr/mo)	750
Total Monthly Cost	$4,450
Hourly Cost	$44.50
Cost per Ton (1,750 tons)	$ 2.50

Cutting Modules

Modules of almond prunings will be approximately 16 feet by 7 feet by 7 feet and will probably weigh from 6,000 to 8,000 pounds. The modules must be cut into three smaller modules before the prunings can be loaded into a tub grinder. A module cutter is estimated to cost $135,000 and is assumed to be powered by a wheel tractor. A module cutter has not been designed, however, and the estimated cost represents an average of equipment manufacturers' cost suggestions.

Module Cutter (Purchase for $135,000)

Hourly Fixed Cost[1]	
Module Cutter	$25.00
Tractor	10.00
Hourly Operation Costs[1]	
Labor	7.50
Fuel (3 gal/hr @ $1.20 per gal)	3.60
Repair	3.30
Total Hourly Cost	$49.40
Cost per Ton (17.5 tons/hr)	$ 2.80

[1]See Appendix B for calculations.

Tub Grinder Sizing Costs

Since a 3-inch-minus chip size is required to guarantee the sale of sized prunings, the prunings must pass through a screen following grinding. Oversize material will be reground. A production rate of 20 tons per hour is used for the first grinding; 15 tons per hour is used for regrinding. The average sizing rate will be about 17.5 tons per hour if 10 percent of the volume is oversize, removed by the screen, and reloaded into the tub grinder. Equipment tests showed it was difficult to load a tub grinder with sized prunings at average rates exceeding 15 tons per hour.

A screen is estimated to cost $60,000 and is assumed to be powered by a wheel tractor. A screen has not been designed, however.

Tub Grinder Hourly Fixed Cost[1]	$20.00
Screen Hourly Fixed Cost[1]	11.00
Tractor Hourly Fixed Cost[1]	10.00
Hourly Operation Costs[1]	
Labor	
Tub Grinder	7.50
Screen	-
Fuel	
Tub Grinder (11 gal/hr @ $1.20)	13.20
Tractor (3 gal/hr @ $1.20)	3.60
Repair and Maintenance	
Tub Grinder	5.30
Screen	1.70
Truck Tractor	15.00
Total	$87.30[2]
Cost per Ton (17.5 tons)	$ 5.00

[1]See Appendix B for calculations.

[2]Costs do not include allowances for supervision and delays.

Sizing Cost Summary

Total estimated sizing costs for the tub grinder operation are:

	Hourly Cost	Cost Per Ton
Tub Grinder		
Loading Costs	$ 44.50	$ 2.50
Module Cutter	49.40	2.80
Tub Grinder and Screen Costs	87.30	5.00
Total	$181.20	$10.30

Step 4: Transportation to Buyer

Loading	
Cost per Ton	$1.50
Transportation	
30 miles at about $.18/ton mile	
Cost per Ton	5.40
Total Cost per Ton	$6.90

Total Costs

Total cost per ton is the sum of costs for each step and includes a management/overhead cost of 10 percent:

	Tub Grinder ($ per ton)
Module Building	$ 4.25
Module moving	3.75
Sizing	
Cutting Modules	2.80
Loading Modules	2.50
Sizing Modules	5.00
Management/Overhead (10%)	1.80
Transportation	6.90
	$27.00

TRANSPORTATION - GENERAL

As shown in the preceding cost analyses, transportation costs make up a significant part of total costs. Highway transportation can be accomplished by (1) contract haulers, (2) using purchased equipment, and (3) using equipment that is presently owned by grower associations and association members. Railroads could be used for larger shipments over longer distances.

The transportation equipment requirement for delivering sized prunings to buyers from orchard locations would be a truck tractor and either two sets of double trailers or two large single trailers.

Contract Haulers

During November 1980, the California Public Utilities Commission provided commercial truck transportation rates for wood chips. The rates are expressed in terms of dollars per unit of carriage equipment for a specified number of miles. A unit of carriage equipment is either a single truck or a single trailer. Wood chip costs per carriage unit for 20, 50, and 100 miles were $45, $94, and $165, respectively. Costs per ton by trailer capacity and distance are:

Trailer Length (feet)	Trailer Capacity (units)	Trailer Capacity (tons)[1]	Cost Per Ton To Deliver		
			20 Miles	50 Miles	100 Miles
22	8	12.8	3.52	7.34	12.89
40	14	22.4	2.01	4.20	7.37
45	16	25.6	1.76	3.67	6.45

[1] Chip density of 16 pounds per cubic foot.

These costs are equivalent to a range of approximately 6 to 18 cents per ton mile depending on carriage unit capacity and distance. Additional transportation costs could be incurred for standby charges.

Use of Purchased Equipment

According to Sacramento area equipment dealers, the cost of a used truck-tractor (3-axle, 10-13 speed, 350 hp diesel) will be between $15,000 and $50,000 depending on condition. The prices for new truck tractors range from $55,000 to $70,000. Chip trailer prices range from $20,000 to $25,000. "Live-bed" trailer prices were in the $34,000 to $36,000 range. If an investment in highway transportation equipment were made, costs could approach contract hauling rates only if the equipment were used throughout the entire year.

Use of Presently Owned Equipment

The third highway transportation method is to use equipment presently owned by growers or grower associations. However, it is unlikely that there is enough equipment to transport sized material. It is, therefore, recommended that growers or grower associations considering starting brush sizing operations consider contract haulers for at least the first few years.

Railroad Transportation

Rail cars could be used to ship larger volumes of sized material from central storage locations to buyers if sidings and material handling equipment were available. Railroad industry representatives provided shipping cost information that was used to calculate the following costs:

Shipment	Cost in Dollars Per Ton To Deliver 20 Miles	100 Miles	300 Miles
Carload[1]	8.00	9.00	14.00
Unit Train[2]	3.00	5.00	10.00

[1]Carload of 40 tons.

[2]At least 50 carloads moved at one time.

SIZING COSTS BASED ON LEASED EQUIPMENT

This section comments on leasing equipment. Individuals who do not wish to make a large capital investment may consider this option. Sizing costs per ton are estimated to be approximately equal for the two options of leasing or buying equipment. Estimated costs per wet ton (including transportation) range from $23 to $34. Estimated costs depend on number of days worked per month, number of hours worked per day, and hourly sizing (production) rates.

The leasing option minimizes the amount of investment required to begin operations. The financial incentives provided by each option (investment tax credits and depreciation if equipment is purchased or deductible business expenses if equipment is leased) will be unique to each grower or organization.

Chapter 6
ALMOND PRUNINGS SURVEY

ALMOND ACREAGE

There is in excess of 300,000 bearing acres of almonds in California. Principal growing areas are the Sacramento and San Joaquin valleys and San Luis Obispo County. Most fruit and nut crop acreages are reasonably stable because of the length of time trees and vines will bear. However, almond acreage (bearing plus nonbearing) has been increasing significantly over the past decade.

Table 6 summarizes acreage data for California by area and county for 1975 through 1979. The increase in California's bearing acreage was 3.5, 6.5, and 11.0 percent in 1976, 1977, and 1978, respectively. A 6.3 percent increase occurred in 1979. The largest increase in bearing acreage occurred in the southern San Joaquin Valley (where bearing acreage more than doubled over the 5-year period). The only area showing a decline in bearing acreage over the 5-year period was the southern Sacramento Valley.

Data on average orchard size are not available, but sizes range from 10 to 4,000 acres. The larger orchards are generally located in the San Joaquin Valley.

PRUNING QUANTITIES

University of California research personnel[1] suggest that approximately 1.3 tons[2] of pruning material are removed annually from each bearing acre in California. It is estimated that about 25 percent of the total prunings are first removed as firewood.

Table 7 summarizes by area estimated available quantities of wet (35 percent moisture) and dry (10 percent moisture) prunings that will remain after firewood removal. The estimate is the sum of bearing and nonbearing acreage shown in Table 6 multiplied by an estimated pruning yield. As indicated, the amount of material available in dry form is about 25 percent less than the amount that must be actually handled in the orchards.

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[1]Knutson, J., G. Miller, and V. Osterli (1078). "Crop Residues in California - Some Factors Affecting Utilization," Division of Agricultural Sciences, University of California, Leaflet 2872.

[2]Moisture content 25 to 45 percent. Average moisture content 35 percent.

Table 6
BEARING AND NONBEARING ALMOND ACREAGE IN CALIFORNIA
1975-1979

Area & Associated Counties	1975 Bearing	1975 Non-Bearing	1976 Bearing	1976 Non-Bearing	1977 Bearing	1977 Non-Bearing	1978 Bearing	1978 Non-Bearing	1979 Bearing	1979 Non-Bearing
No. Sacramento Valley										
Tehama	4,615	1,182	4,767	1,289	5,241	994	5,144	545	4,961	561
Glenn	6,552	3,543	6,568	3,857	6,990	3,707	6,969	1,747	8,236	1,400
Butte	25,783	5,511	26,768	5,202	28,176	3,998	30,155	2,359	31,497	3,124
Subtotal	36,950	10,236	38,121	10,348	40,407	8,699	42,268	4,651	44,694	3,124
So. Sacramento Valley										
Colusa	14,063	510	14,158	500	14,323	445	14,056	545	14,394	275
Sutter	6,348	350	5,468	531	5,636	473	5,199	317	5,134	428
Yuba	1,882	310	1,938	306	1,968	265	2,101	131	1,927	0
Yolo	11,787	451	11,877	436	12,067	336	12,117	295	9,868	248
Sacramento	46	0	56	0	46	0	39	0	39	0
Solano	3,652	401	3,541	415	3,445	455	3,375	375	3,360	318
Subtotal	37,778	2,022	37,038	2,188	37,485	1,974	36,887	1,663	34,722	1,269
No. San Joaquin Valley										
Contra Costa	3,708	9	3,599	1	3,472	0	3,313	9	3,242	9
San Joaquin	27,282	6,194	27,590	4,302	26,628	5,561	29,658	3,153	30,862	2,645
Stanislaus	31,897	8,062	34,323	7,269	35,842	6,609	37,802	5,239	41,819	11,127
Subtotal	62,887	14,265	65,512	11,572	65,942	12,170	70,773	8,401	75,923	13,781
Central San Joaquin Valley										
Merced	37,772	8,321	40,428	7,480	43,646	6,116	40,614	6,533	42,065	5,949
Madera	12,413	8,212	13,766	8,248	12,882	5,464	17,293	4,042	19,473	2,898
Fresno	15,062	6,337	14,623	7,039	17,076	6,636	21,159	4,320	23,178	2,501
Subtotal	65,247	22,870	68,817	22,767	73,604	18,217	79,066	14,895	84,716	11,348
So. San Joaquin Valley										
Kings	2,728	3,018	2,928	3,413	4,041	2,825	4,824	2,405	4,603	132
Tulare	4,280	3,917	4,343	4,352	4,735	4,299	7,878	1,852	9,515	1,897
Kern	29,587	24,199	32,258	24,640	39,527	18,944	53,997	8,316	60,531	3,174
Subtotal	36,595	31,134	39,529	32,405	48,303	26,068	66,699	12,573	74,649	5,203
Coastal										
San Luis Obispo	7,213	65	6,430	11	6,433	7	6,394	9	6,394	1
All Others	1,278	0	1,294	5	1,243	5	1,505	11	1,504	11
State Totals	247,948	80,592	256,741	79,296	272,417	67,140	303,592	42,203	322,602	34,737

Table 7
ESTIMATED ACREAGES AND PRUNINGS BY AREA

Area	Approximate Acreage	Estimated Wet Tonnage	Estimated Dry Tonnage
Northern Sacramento Valley	47,000	49,000	35,000
Southern Sacramento Valley	36,000	37,000	27,000
Northern San Joaquin Valley	90,000	94,000	68,000
Central San Joaquin Valley	95,000	99,000	71,000
Southern San Joaquin Valley	80,000	83,000	60,000
		362,000	261,000

PRUNING PRACTICES

Based on a sample survey of almond growers and orchard visits, the following pruning practices were found to be common throughout the industry.

1. Pruning crews vary from 4 to 10 people. Crews are usually contracted. One man can properly prune about 10 mature trees per hour. At this rate, a 10-person pruning crew (8 pruning, 2 handling prunings) can work at a sustained rate of about 1 acre per hour (based on an average of about 75 to 80 trees per acre).

2. Prunings are usually piled in alternate tree rows. The piles have an average height of about 3 to 4 feet and a width of about 6 feet. The prunings are normally buckraked into larger piles at the side of the orchard or to the nearest clearing within the orchard for burning. Burning periods are controlled by local authorities and burning is usually not completed until the following spring. Tilling of shredded prunings into the soil is practiced in some areas but is not common.

3. Pruning can start as soon as harvest is completed, but the pruning season normally begins in early November and continues until the following February.

4. About one-fifth of the limbs of a full-grown tree are pruned. The larger limbs (2 to 4 inches in diameter) below a height of 8 feet are removed.

Smaller limbs (usually less than 2 inches in diameter) are pruned from the entire tree to maintain symmetry and stimulate growth upward and outward.

Actual pruning practices and pruning rates will vary according to grower, tree variety, age of tree, orchard size, tree spacing, weather, size of pruning crews, and the amount of pruning done the previous year. Older and diseased trees are often removed from an orchard during pruning. From 3 to 8 percent of all mature trees are removed each year.

ALMOND BRUSH CHARACTERISTICS

A typical pruned limb from an almond tree is 6 to 10 feet long and 1 to 3 inches in diameter. However, limbs up to 20 feet long may be pruned. Larger limbs (2 to 6 inches in diameter) and whole trees are generally cut into firewood.

Almond prunings are very resilient when green, and therefore difficult to handle. During equipment tests, almond prunings having a maximum length of 6 to 8 feet could be loaded into module builders faster than prunings over 12 feet long. Shorter prunings could also be compacted into modules that had greater density at the ends of the module.

The bulk density of unprocessed prunings varies according to moisture content and size of limbs. Piles of green prunings have a density of about 1/2 to 3/4 pound per cubic foot. Previous estimates have placed the density as high as 3 pounds per cubic foot. Green prunings that are chipped to a 2-inch size will have a density of between 15 to 20 pounds per cubic foot, depending on moisture content.

The moisture content of freshly cut almond prunings ranges from 40 to 50 percent. Prunings left in the open for 30 to 45 days were found to have a moisture content of about 36 percent. The moisture content of prunings stored in the open for 5 or 6 months can be as low as 13 percent. Even lower moisture content can be reached if prunings are sized before storing.

The heat value of almond prunings is inversely proportional to moisture content. Green prunings will have a heat value of about 5,000 Btu/lb while drier wood (about 30 percent moisture) will have a heat value of about 6,500 Btu/lb.

Prunings consist primarily of volatile matter, fixed carbon, and ash. Hydrogen, oxygen, and traces of sulfur and nitrogen are present. Most of the nitrogen can be found in the leaves. The bark contains sulfur. Contamination from chemical sprays, dirt, dust, and other inert material can lower the market value of sized prunings.

PRECLEANER TWIGS

Precleaner twigs are small sticks and twigs that are separated from the almonds prior to removing the hulls. The twigs are a marketable byproduct. During 1981, moduling tests were conducted on precleaner twigs. The twigs could be compacted into modules and transported easily. As a result of the tests, some of the 1981 crop year precleaner twig production will be sold for boiler fuel.

Additional screening machinery may be needed at some hulling plants to ensure precleaner twigs are free of foreign material (e.g., glass, rocks, scrap metal). Almond shells, fine particles of shell, and small pieces of almond hull are produced during hulling operations. These are also satisfactory biomass fuels and should be considered useful byproducts.

Chapter 7
MARKETS FOR ALMOND BRUSH

Following are the most promising uses for almond brush:

1. Fuel
2. Soil additive
3. Charcoal
4. Mushroom compost
5. Alcohol production

Other uses recognized at this time but which are not as promising include animal feed, paper pulp, fire logs, animal bedding, and landfill biogasification.

PROMISING USES FOR ALMOND BRUSH

Fuel

Probably the greatest market for almond brush now and in the future will be as fuel for direct combustion or gasification. Figure 2 shows the many methods by which almond prunings can be converted into usable energy. (Landfill gasification and animal feed are also shown.)

Table 8 compares the estimated cost and heat value of residual oil, coal, gas, and dry densified almond prunings. Heat values do not include combustion losses.

Table 8
COMPARISON BETWEEN PRIMARY FUELS AND ALMOND PRUNINGS

Fuel	Heat Value Btu/Lb or Ft^3	Cost	
		Unit Cost	¢/MBtu
Residual Oil	18,500	$0.8/gal	0.60
Coal	10,000	$45/ton	0.23
Natural Gas	$1,000/ft^3$	4.50/mcf	0.45
Almond Prunings (dry)	6,000	$25/ton	0.21

Assumption

Coal price is F.O.B. Sacramento using Utah coal.

As shown in Table 8, almond prunings are competitive with current sources of energy. Burning prunings will result in emission levels that will be far below either coal or residual oil because of the insignificant amounts of sulfur and nitrogen in wood.

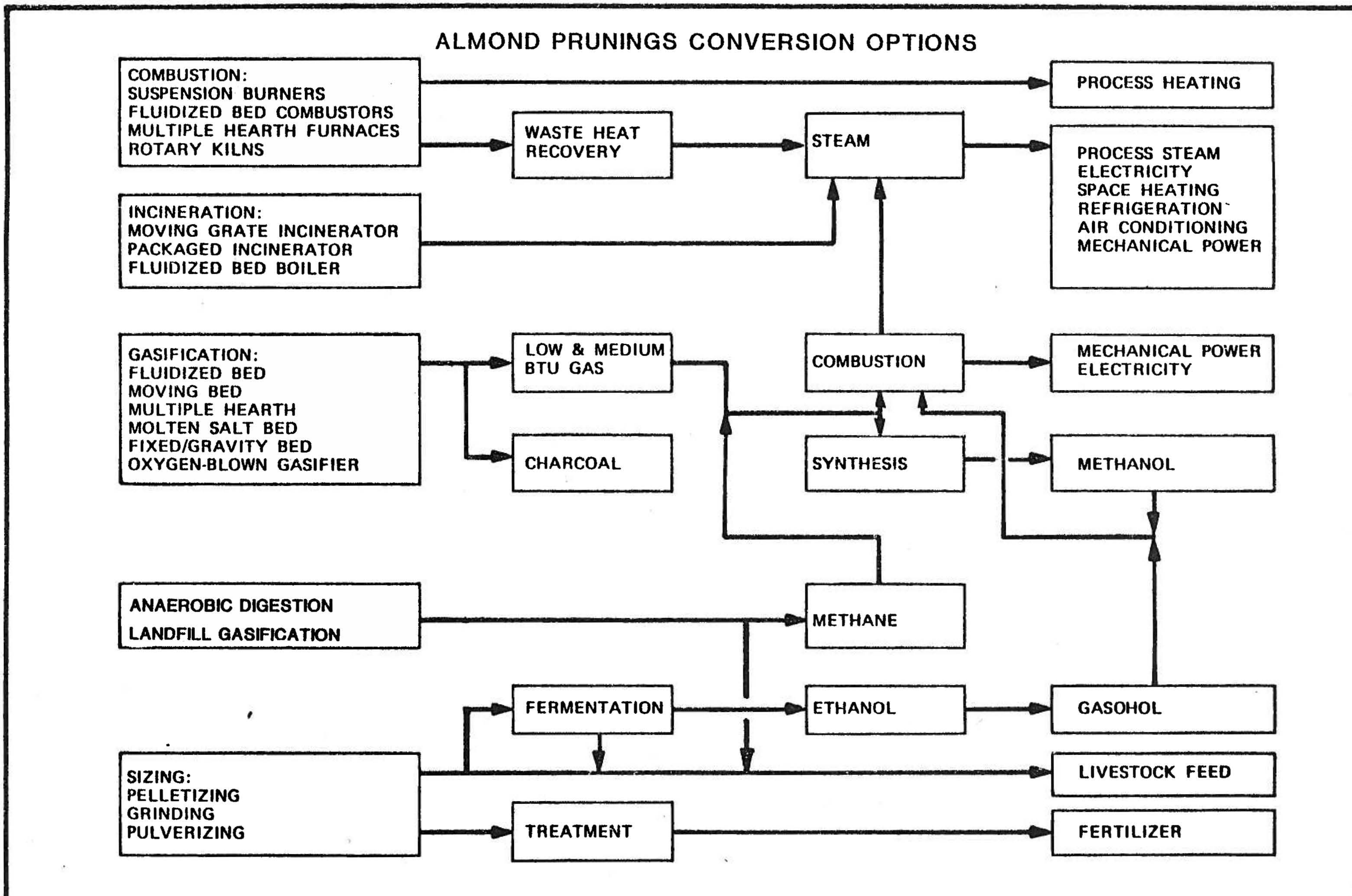
ALMOND PRUNINGS CONVERSION OPTIONS
COMBUSTION:
SUSPENSION BURNERS
FLUIDIZED BED COMBUSTORS
MULTIPLE HEARTH FURNACES
ROTARY KILNS
PROCESS HEATING
WASTE HEAT RECOVERY
STEAM
PROCESS STEAM
ELECTRICITY
SPACE HEATING
REFRIGERATION
AIR CONDITIONING
MECHANICAL POWER
INCINERATION:
MOVING GRATE INCINERATOR
PACKAGED INCINERATOR
FLUIDIZED BED BOILER
GASIFICATION:
FLUIDIZED BED
MOVING BED
MULTIPLE HEARTH
MOLTEN SALT BED
FIXED/GRAVITY BED
OXYGEN-BLOWN GASIFIER
LOW & MEDIUM BTU GAS
COMBUSTION
MECHANICAL POWER
ELECTRICITY
CHARCOAL
SYNTHESIS
METHANOL
ANAEROBIC DIGESTION
LANDFILL GASIFICATION
METHANE
FERMENTATION
ETHANOL
GASOHOL
SIZING:
PELLETIZING
GRINDING
PULVERIZING
LIVESTOCK FEED
TREATMENT
FERTILIZER

FIGURE 2

Almond prunings can also be fired in low temperature combustion processes. As a result, the emission levels of nitrogen oxides will be lower than from the combustion of natural gas. Ash disposal problems will be less significant than for coal but greater than for oil and gas.

The only significant environmental problem with the combustion or gasification of almond prunings is the high level of particulate emissions. These emissions cannot be captured satisfactorily using conventional methods such as baghouses and precipitators.

About 12 lumbermills and 3 food processing plants in California are presently using biomass fuels to generate electricity or steam. About 12 other biomass-fueled plants are being designed or are under construction in California. The major source of fuel for these plants is site-generated wood wastes. However, most of the new plants will be located close to or within almond growing areas.

Table 9 lists processing plants that are potential users of sized almond prunings because of proximity to almond orchards.

Table 9
POTENTIAL USERS OF ALMOND BRUSH FOR FUEL

Location	Owner	Plant Size	Year of Operation
Antioch	Louisiana Pacific	1,100-1,300 tpd	1982
Oroville	Louisiana Pacific	30-45 MW	1984
Standard	Louisiana Pacific	3 MW	1982
Madera	California Power & Light	1,000 tpd	1982
Sacramento	IMOTEK, Inc.	750 tpd	1982
Sacramento	State of California	240 tpd	1982
Stockton	Diamond/Sunsweet	750 tpd	1980
Modesto	Tri-Valley Growers	1,000 tpd	1981
Dinuba	Wickes Forest Products	5 MW	1981

Almond prunings will have to compete with site-generated wastes in all cases except for the California Power & Light and State of California installations.

The demand for biomass fuels and especially wood wastes is expected to continue to grow. An estimated 120 million dry tons of biomass wastes are generated each year in California. Of this amount, roughly 30 million tons are available for fuel (including the 350,000 tons of almond prunings). The California Energy Commission estimates that 1.5 million tons of biomass are now used annually for fuel in the State.

Soil Additive

There is a market for soil additives for home, commercial, and agricultural use. Soil additives are usually derived from lumber mill wastes. Processed coffee grounds, nut shells, and fruit pits are sometimes used for this purpose. Additives presently sell for about $20 to $35 per ton at retail outlets. Prunings can compete with lumber mill wastes as long as transportation costs are low. However, unlike most lumbermill wastes, prunings will require sizing. There is no estimate at this time of the probable market for sized prunings as a soil additive.

Charcoal

Almond prunings could be used as raw material for charcoal plants in California. One such charcoal manufacturing plant is owned and operated by Clorox-Kingsford in Elk Grove, only a short distance from the almond orchards in the northern San Joaquin Valley. Another plant is located in Milpitas, California. Both plants require about 100,000 tons of raw material annually. A source of raw material is needed for these plants because currently used raw material is being diverted to a new cogeneration facility. Almond prunings could be substituted as the raw material supply for the charcoal plants.

Mushroom Compost

Mushroom growers in California currently use about 400,000 tons of compost each year. Wheat straw is the primary local raw material used, and prices paid by mushroom growers are high because of competing uses for straw and transportation costs. Mushroom growers are paying an average of $50 per ton for straw. Most mushrooms are grown along the Pacific Coast, and the growing areas are not close to wheat acreages or almond orchards. Transportation cost will be a factor in the use of prunings as a substitute for wheat straw.

Prunings must be reduced to 1-inch-minus size for use in mushroom composting. The effect of almond chemical sprays on mushrooms is being evaluated at this time under another research project funded by the Almond Board. So far, there appears to be no problem as long as spraying does not occur immediately before pruning.

Alcohol Production

Almond prunings consist primarily of lignocellulose, the single largest source of polysaccharides (carbohydrates) in plants. Polysaccharides can be converted into sugar; the sugar can then be converted into alcohol using an acid hydrolysis process.

Alcohol demand is increasing rapidly, almost in proportion to the rise in cost of natural gas and gasoline. However, converting prunings into alcohol will be more costly than converting biomass having high sugar or starch content. However, plants with high sugar and starch content are already in high demand for use as food and animal feed.

It is estimated that 1 ton of sized prunings can provide from 55 to 65 gallons of ethanol and about 7 to 9 gallons of methanol. The California Energy Commission estimates that annual alcohol consumption in California may be as high as 100×10^{12} Btu by the year 2000. This would be equivalent to about 10,400,000 tons of almond brush (assuming a 60 percent conversion efficiency).

OTHER USES FOR ALMOND BRUSH

Prunings are high in carbohydrates and can be substituted for animal feed. However, the process of preparing the prunings for feed will be costly, and the product will not be competitive with existing feed supplies such as grains. Grains are also higher in protein content.

Prunings could be used for production of low grade paper products. However, the impurities in the bark and inert materials will limit usefulness. In addition, delivered costs of prunings could be higher than wood chips since paper manufacturing plants are located along the coast or in lumber producing areas. Delivered costs of prunings will also be high compared to wood chips used for the manufacture of fire logs.

The high cost of sizing and transportation also places prunings at a disadvantage to traditional supplies of animal bedding.

Landfill bio-gasification is still a fairly new concept. Burial and bio-gasification of municipal wastes is used to produce a salable methane gas. Prunings would have to compete with municipal solid wastes that are in ample supply within urban areas of California.

Despite the drawbacks mentioned above, there is no reason to write off prunings as a future substitute for the current raw materials used in these processes. The eventual usefulness will depend upon the scarcity of the primary supply of raw materials.

APPENDIX A

All the tests and demonstrations conducted since November 1979 are listed in Table A-1 below.

Table A-1
CALIFORNIA ALMOND BOARD
EQUIPMENT TESTS

Date	Location	Equipment
November 24, 1979	Palo Alto	Tub grinder
March 18, 1980	Diamond-Sunsweet Lockeford	Farmland loader, Wastequip loader, W.H.O. tub grinder, Farmhand tub grinder
March 26, 1980	Tenneco West Snelling	Medallion tub grinder, Heinrichs, Leydig/Condon, Noell & Sons, W.H.O. tub grinder, Wastequip loader, IMT grapple loader
April 1, 1980	Frish Ranch Lodi	Royer Woodsman
November 6, 1980	Cortez Growers Ballico	Nicholson Ecolo chipper
March 5, 1981	Tenneco West Chowchilla	Barko loader, Medallion tub grinder, Vermeer demolisher International loader, CMC module builders, Taylor module builder
March 17, 1981	Dempsey Ranch Durham	Small chipper
March 24, 1981	Tenneco West Chowchilla	Taylor module builder, CMC module builder, Barko loader, Case loader
April 7, 1981	Heppner Ranch Winton	Taylor module builder, Michigan loader
April 15, 1981	Tenneco West Snelling	Taylor module builder, Hyster forklift
May 13, 1981	Northern Merced Hulling Association Ballico	Homelite chainsaw

Table A-1 (Cont'd)
CALIFORNIA ALMOND BOARD
EQUIPMENT TESTS

Date	Location	Equipment
May 20, 1981	Northern Merced Hulling Association Ballico	Stihl chainsaw
May 29, 1981	Northern Merced Hulling Association Ballico	Stihl chainsaw
June 16, 17, 1981	Northern Merced Hulling Association Ballico Tenneco West Snelling	Medallion tub grinder, Michigan loader, Taylor module builder, Caterpillar loader, International loader, Webb module trailer, Kimball Toppers hammermill, Marwald flail chopper
August 19, 1981	V. Thomas Ranch Huron	Haybuster tub grinder, Taylor module builder, International loader, Case 950 loader with Tink loading attachment, OMC roll baler, Cal Poly baler, Cal Poly brush feeder

APPENDIX B

This technical appendix contains information supporting the costs in the central location sizing cost section of Chapter 4. The assumptions needed are shown in the following table. Calculations of hourly equipment fixed costs and repair and maintenance costs follow the table. Preliminary cost estimates for a screen follow the calculations.

Table B-1
ASSUMPTIONS NEEDED FOR COMPARATIVE COST ANALYSIS

	Tub Grinder	Module Cutter	Screen
Working Hours per Year	2,000	2,000	2,000
Machinery Availability	50%	50%	50%
Equipment Life (years)	15	15	15
Acquisition Cost	$110,000	$135,000	$60,000
Taxes, Insurance, Shelter (% of Acquisition Cost)	2%	2%	2%
Salvage Value (% of Acquisition Cost)	25%	25%	25%
Interest Rate	15%	15%	15%
Average Capacity (tons per hour)	20	20	20
Labor Rate ($ per hour)	$7.50	$7.50	$7.50
Fuel Cost ($ per gallon)	$1.20	$1.20	$1.20
Brake Horsepower	450	--	--
Labor (number of people)	1	1	--
Fuel Consumption (gallons per hour)	11	--	--

HOURLY EQUIPMENT FIXED COSTS

The capital recovery depreciation method for estimating annual equipment costs is based upon the following equation:

Annual Cost = (PC-SV) (PDV factor) + (I) (SV)

Where: PC = purchase cost
SV = salvage value
PDV factor = present value factor (Depends upon expected equipment life and interest rate)
I = interest rate

Dividing annual cost by annual hours of operation gives hourly equipment cost.

Annual taxes, insurance, and shelter (TIS) are estimated at 2 percent of acquisition cost. TIS divided by annual hours of operation gives hourly TIS cost. The sum of hourly equipment cost and hourly TIS cost is hourly fixed cost. The annual and hourly fixed costs for the tub grinder, module cutter, and screen are:

Tub Grinder

(\$110,000 - \$27,500) (.17102) + (.15) (\$27,500) =	\$ 18,200
+ TIS	2,200
Annual Total	\$ 20,400
Hourly Cost	\$ 20.00

Module Cutter

(\$135,000 - \$33,750) (.17102) + (.15) (\$33,750) =	\$ 22,400
+ TIS	2,700
Annual Total	\$ 25,100
Hourly Cost	\$ 25.00

Screen

(\$60,000 - \$15,000) (.17102) + (.15) (\$15,000) =	\$ 9,900
+ TIS	1,200
Annual Total	\$ 11,100
Hourly Cost	\$ 11.00

REPAIR AND MAINTENANCE COSTS

Hourly repair and maintenance costs are calculated as equal to the estimated capital cost of equipment subject to wear, divided by the total hours of use.

Tub grinder: (\$80,000/15,000)	\$ 5.30 per hour
Module cutter: (\$50,000/18,000)	\$ 3.30 per hour
Screen: (\$25,000/15,000)	\$ 1.70 per hour

SCREEN
PRELIMINARY COST ESTIMATE
10-13-81

	1981 Costs
Disc Screen	$10,000
50 HP Hydraulic Pump and Power Pack	10,000
Conveyors and Hydraulic Drives	5,000
Trailer Chassis	7,000
Instrumentation/Steel/Electrical/Piping (x 0.12)	3,000
Fabrication/Erection (x 0.60)	15,000
Freight, Insurance, Taxes (x 0.08)	2,000
Engineering (x 0.06)	3,000
Contingencies (x 0.10)	5,000
Grand Total	$60,000