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Fiber-Flax Machinery and Processing Operations in Oregon[1]

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INTRODUCTION

Flax is grown commercially for seed and fiber. The varieties grown for seed from which oil is extracted are generally short plants with many lateral branches. The fiber from the seed varieties is usually unsuitable for textile purposes, but it is used to a considerable extent for manufacturing paper. Varieties grown for fiber have fewer lateral branches and the plants grow to a greater height than seed flax. The fiber is longer and is suitable for the manufacture of linen. The seed is used principally for oil (linseed), just as is the seed of flax grown primarily for oil. The fiber of seed flax is a byproduct and conversely the seed of fiber flax is a byproduct.

Seed-bed preparation and the seeding of fiber flax are performed with the machinery available on most farms for such operations. All subsequent operations, such as pulling (harvesting), deseeding, retting, and scutching, are peculiar to fiber flax. In order to obtain a long

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fiber and as much fiber as possible, fiber flax is pulled rather than cut.

In the United States only a few thousand acres are devoted to fiber flax compared with several million acres annually planted to seed flax. Seed flax is harvested with a combine and the seed is sold in the same manner as is small grain. After pulling, the fiber flax must be deseeded, retted, and scutched before the fiber can be sold.

Fiber in the flax stalk is set in plant gums which must be dissolved with the aid of some organism or chemical to free the fiber. The practice in Oregon is to soak the straw in warm water in tanks for 3 to 6 days during which time a retting or rotting takes place which makes the woody portion of the straw brittle when dry, and loosens it from the fiber. In some flax-producing areas, as in Canada, the straw is spread on the ground where moisture from dews and rains rets it. The dry weather in Oregon during the pulling season is not suitable for retting the flax in this manner.

In the past, machinery for processing flax has been imported. Even prior to the outbreak of the war in 1939, considerable time was required to obtain a machine from Europe and it was necessary to construct repair parts locally. No local dealers sell or service foreign-made fiber-flax processing machinery. Moreover, production per worker with the equipment used was at times insufficient to enable local mills to compete with the low labor costs abroad. In view of these conditions it appears that an increase in the domestic production of fiber flax at prewar fiber prices depends largely on reduction in the cost of processing. If the growing of flax can be made more attractive to farmers, the quantity of fiber produced might become large enough to interest domestic machinery manufacturers in meeting the equipment needs of the industry.

All operations involved in harvesting, retting, and scutching, until recent years, have been performed by hand. The major developments in machines adopted by the industry for the harvesting and processing operations date back to the days immediately following World War I. This delay in the development and use of machinery was due in part to the type of agriculture practiced in the flax-producing countries and to the complexity of the industry which may be divided, roughly, into the following major parts: (1) Growing, (2) processing, (3) spinning, (4) weaving, and (5) marketing.

The peculiarities of the processing, spinning, and weaving machinery and methods are due in large measure to the physical characteristics of flax fiber. Also, each of the five major parts depends upon the others. The farmer must produce a crop of flax straw and get it to the mill in condition to be processed with available facilities. The processor, the spinner, and the weaver must likewise meet certain requirements or an unsalable material will result. It would appear desirable for the farmer or the processor to have a machine which would in one operation produce, at a profit, fiber suitable for manufacturing the several useful linen articles. Such short cuts are difficult to make due to the complexity of the industry and the physical characteristics of the fiber. For these reasons experienced persons are usually skeptical of new machines and methods designed to revolutionize the industry.

Fiber flax is a nonsurplus and noncompetitive crop in the United States. The bulk of all flax fiber and manufactured linen articles is imported. About 12,000 acres of fiber flax was planted in this country in 1941, the bulk of it in Oregon. This was probably the largest acreage since flax was replaced by cotton in the South Atlantic States following the development of the cotton gin. The average yield of pulled flax in Oregon is about 1.6 tons per acre. In 1941 the acreage represented approximately one-tenth of the amount required for fiber to meet normal domestic needs. The processing plants required for 100,000 acres would represent an industry of sizable proportions. Moreover, if domestic production increases, additional linen mills for spinning and weaving will doubtless be attracted to production centers.

An investigation of the mechanical phases of flax harvesting and processing was begun by the Bureau of Agricultural Chemistry and Engineering in cooperation with the Oregon Agricultural Experi-

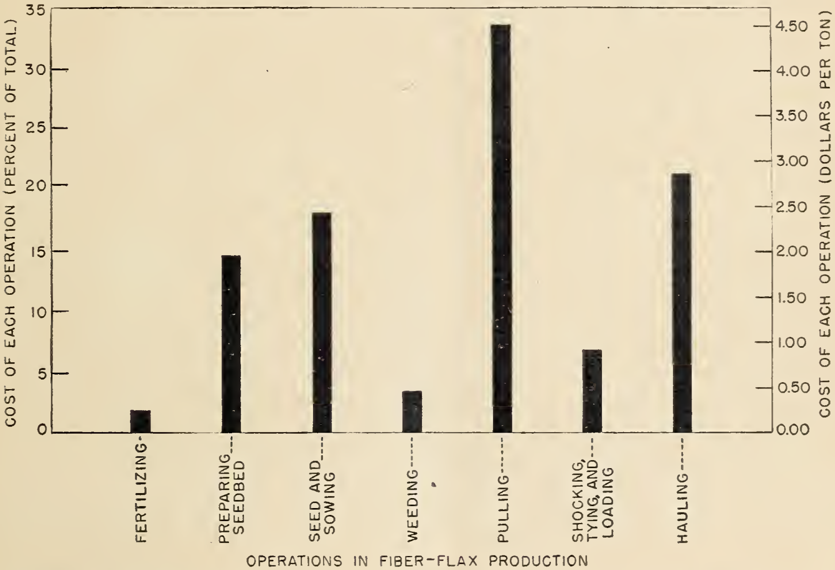

FIGURE 1.—Distribution of costs in producing fiber flax, excluding use of land.

ment Station and the Bureau of Plant Industry in 1938. A job analysis was made at the farm cooperative flax mills in Oregon to determine at what points in the chain of operations improvements in machinery would be most likely to cut costs. While pulling and processing operations for flax are peculiar to flax, the labor involved in all operations appeared out of line with that required for somewhat similar operations in other crops. For example, the total cost of pulling fiber flax is six to nine times greater than cutting and threshing wheat with a combine.

Figure 1 shows the distribution of costs of producing fiber flax in the period 1934 to 1936, based on studies made by the Oregon Agricultural Experiment Station and the Bureau of Plant Industry.

A general program of machinery development and improvement was begun as a result of the job analysis. Work in altering pullers and developing deseeders and tow cleaners was started immediately.

A representative of the Bureau of Agricultural Chemistry and Engineering visited several flax-producing areas in Europe and was instrumental in importing for experimental use some pieces of the most modern flax machinery in use at that time in Europe. Some of this new machinery now employed in Oregon performs with less labor per unit of production than do the old machines. Flax pullers and some processing machinery are manufactured locally. Several pieces of equipment developed by the Bureau have also been constructed by local machine shops.

THE FIBER-FLAX INDUSTRY IN OREGON

The Oregon Agricultural Experiment Station and the Bureau of Plant Industry have conducted investigational work on the agronomic and economic phases of fiber-flax production for a number of years. The experience of individuals associated with these organizations has been freely passed on to others interested in flax and contacts with linen mills have been maintained by the State flax industry (State penitentiary at Salem) for establishing prices. Although a report on operations at the Salem mill would reveal useful information, conditions there are not comparable with those in privately operated establishments. Therefore, data from the State flax industry mill are not included in this circular.

In 1936 three additional mills were erected with State and Federal assistance. These mills, located one each at Canby. Mount Angel, and Springfield, were leased by the State of Oregon to farm cooperatives which provide the machinery and operate the mills. The State flax industry mill at Salem had a rated capacity of 4,000 tons of pulled flax a year at the time the new mills were constructed. The other three were each designed for a capacity of 1.200 tons of pulled flax annually, making a total of 7,600 tons for all plants. With some exceptions, rated capacity was not attained at all mills prior to the crop year 1941 when the tonnage exceeded mill capacity at all four locations. Flax yields were low several seasons, particularly in 1938, and difficulty was experienced by some mills in obtaining sufficient acreage.

In 1939 there was apparently a low stock of flax fiber and linen goods at the principal trade centers. The supplies from Europe were cut off when these countries were occupied by the Germans. As a result fiber prices increased about 100 percent in 1940, greatly stimulating interest in the crop in the Willamette Valley.

Farm fiber-flax cooperatives established at St. Paul and Harrisburg, Oreg., each erected a mill for the 1941 crop and private individuals began the construction of mills in the Silverton and Eugene neighborhoods. All of the mills constructed in 1936 and the State flax industry enlarged their capacity by the installation of new retting tanks and storage sheds. Consequently, both the 1941 acreage and mill capacity were increased almost 100 percent compared to the acreage and capacity in previous years.

PROCESSING PLANTS

Processing plants in Oregon generally consist of a mill building where the straw is deseeded and scutched, concrete tanks or vats where it is retted, a drying field for setting up the bundles of retted straw to dry, storage sheds for the straw, a boiler room and fuel-storage building, and an office and hackling room. Scales for weighing the flax and the office and hackling room are usually under one roof. A dwelling for a watchman or manager is sometimes included in the group. Figure 2 shows a mill building, and figure 3 some storage sheds.

Flax straw and fiber are highly inflammable. The mills are located in rural areas, and as a consequence the cost of fire insurance is high, especially if the buildings are closely spaced. For this reason, and because of the bulky nature of the straw and the use of open-air drying fields, 30 to 40 acres are needed for a plant with a rated capacity of 1,600 tons of pulled flax per year.

FIGURE 2.—Mill building where the deseeding and scutching operations are performed. Changes are being made in the design of such buildings to utilize the space more efficiently and to reduce the cost of construction.

The buildings used are frame, usually with metal roof and sides, at least for the mill building. The sheds may have metal roofs, shingles, or composition roofing depending upon prices of materials and other circumstances peculiar to the individual location. Metal or fire-resistant materials are preferable because of the protection offered against the spread of fire. The relatively humidity of the atmosphere is as low as 20 percent at times during the summer months; consequently the materials around the mills are dry and inflammable.

An adequate water supply and means of disposing of the retting water are essential. A flax mill with six tanks will use possibly 75,000 gallons of water a day during several months of the year, much of which must be disposed of as retting waste low in oxygen and high in acid. The water will kill crops if the fields are flooded with it; it has an objectionable odor and, in concentrated form, will kill animal and plant life in streams. The most practical means of disposal, other than dumping into a river as sewage or onto waste land, appears to be to provide two 8- or 10-acre shallow ponds and to use them during alternate years for storage of retting water and for crops. The retting water has some fertilizer value which becomes evident on plant growth the year after flooding. Some plants, such as ryegrass, will grow abundantly on the bank of an open ditch or pond full of this waste, indicating some possibility of using the retting water for deep-furrow irrigation.

The water in the tanks for retting is maintained at the desired temperature, usually 90° to 95° F., by heat from a boiler. Hot water or steam systems may be employed to heat water to the required temperature. In starting the retting of a tankful of flax, warm water of the desired temperature is admitted in sufficient quantity to

FIGURE 3.—Typical flax-straw storage sheds with north end and east side open; the prevailing wind during the rainy season is from the southwest. Such sheds are usually 56 feet wide, 240 feet long, and 18 to 20 feet high to the eaves.

submerge the straw. Some fresh water is needed from time to time in order to sustain bacterial action. Sufficient fresh warm water is usually added for a complete change during the ret for a particular tank, which is equal to the addition of 1 to 2 feet of fresh water daily. To maintain the temperature of the water in the tank the fresh warm water is admitted at the bottom, which displaces a like volume of retting water drained off from the top. At some mills a hot water boiler with storage tank is provided and the operator mixes water from this thermosiphon system with cold water to obtain the desired temperature. When steam is used, live steam is admitted under pressure in the water supply line to the tank in sufficient quantity to raise the water to the desired temperature. Valves are provided to regulate both water and steam at this point.

Shives and other waste material, such as hulls from the flax, are used as fuel. Due to the bulky nature of this material, a Dutch oven or some auxiliary firebox must be provided for the ordinary boiler. Shives make good fuel as they burn readily and have a heat content approaching that of some coal. More shives are produced than are needed for heating the retting water and probably almost enough to generate steam for all the power and heat required. However, electricity is used for power.

The retting tanks at each of the three original farm cooperative mills were erected as a unit of six tanks. Such a unit is illustrated in figure 4. Each tank is approximately 7 feet deep, 16 feet wide, and

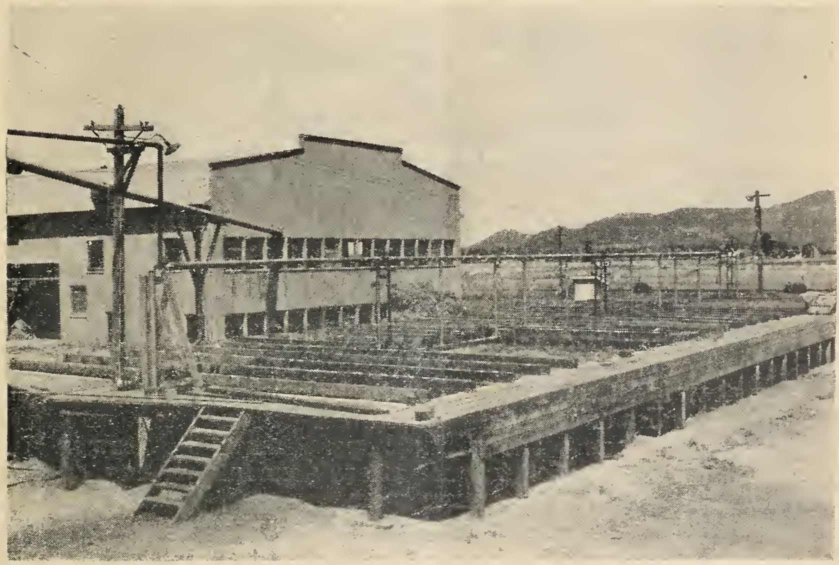

Figure 4.—A battery of six retting tanks surrounded by a catwalk. Note water supply pipe overhead and mill building in background.

40 feet long, inside dimensions. The arrangement is such that the battery is two tanks wide by three tanks long with overall dimensions of approximately 38 by 122 feet. Tanks are constructed of reinforced concrete with foundation at ground level or below depending upon drainage for depositing the retting water at individual mills. The tanks are open at the top, the battery has a catwalk around it, and hold-downs are provided in the walls for heavy timbers spanning each tank for holding the flax under water as illustrated in figure 5.

Some operators feel that the tanks should be 8 to 9 feet deep and constructed in a battery of eight. The bundles are set vertical in the tank and with long flax it is sometimes difficult to arrange two layers in a 7-foot depth. Some tanks recently constructed are 8 feet deep and 50 feet long. Others have been constructed to the usual size, but in a battery of eight. The exact size of the tank, except for the size of the crew required to fill and empty, seems to be of no great importance.

FIGURE 5.—Open tank showing how heavy cross timbers are held in place. Timbers are used over grates for holding the flax straw under water for retting. One of the tanks has been filled with straw, but the grates and timbers have not been placed.

FLAX-MILL OPERATIONS

Flax straw is delivered to the mills in Oregon in about the same condition in bundles as wheat or oat straw is delivered to a threshing machine on the farm. The principal operations on the straw in getting the fiber in condition for market are deseeding, retting, drying, and scutching. To perform these operations the following pieces of equipment are usually employed: Deseeder with double-needle binding apparatus, a thresher, a scutcher with breaker and tow shaker, 1 or 2 tractors, 1 or more trucks, 8 to 12 wagons, 1 or more single-needle binding units mounted on a truck bed for binding retted straw in the field, a tow baler, 1 or more bundle elevators for loading wagons at the deseeder and for emptying retting tanks, electric motors for the several machines totaling 40 to 50 connected horsepower, and 20 to 30 pitchforks.

The seasonal nature of the various operations in Oregon flax mills is such that a year or more may elapse before all the fiber from a particular crop is ready for market. Flax pulling usually begins early in July and may extend well into August. Since the rainy season in the Willamette Valley begins in September or October, not more than 3 months are available for the retting and drying during the year the crop is grown. Flax straw not retted during this period is stored until the following spring. Scutching is not commonly practiced with present equipment during the summer months when the humidity of the atmosphere is low, and the straw that is retted in the spring is again stored for scutching during the following winter. Due to high fiber prices caused by the war, some of the plants are beginning to scutch the year around, and this practice may become established.

Fiber flax is grown in Oregon under contract. Seed is furnished by the mills, advice given as to crop requirements, and the straw is graded as to height before it is pulled. In some cases mills have pulled the flax at a stipulated price per ton of straw, but this practice has been discontinued and most of the flax is now harvested with farm-owned machinery.

The market value of the crop for textile purposes under Oregon conditions depends to a large extent upon the length of the straw and freedom from weeds. There are three grades for the straw: No. 1, 30 inches or more in length; No. 2, 25 to 30 inches in length; and No. 3, less than 25 inches, or straw that contains a high percentage of weeds. Straw of grades 1 and 2 is suitable for retting and scutching, but No. 3 straw is usually made into green tow for upholstery or other similar uses. No. 3 straw may be pulled, cut with a binder, or mowed and handled as hay. Nos. 1 and 2 grades are pulled and handled in bundles.

Weeds are a source of endless trouble in fiber-flax straw, not alleviated by a dockage penalty. They remain in the straw as excess weight and some seem to toughen with the retting operation. Flax fiber is at times pulled from the gripping device in the scutcher along with weeds and it is almost impossible to clean weedy tow. A premium for weed-free straw, or in addition to dockage a penalty representing the cost of processing the equivalent weight of straw, have been suggested.

Flax straw is deseeded and retted as fast as these operations can be performed during the harvest season. It is impossible, with present equipment, to accomplish this task before the rainy season begins, and usually over half the crop must be stored as received from the farm. Flaxseed prices sometimes make it desirable to have the seed ready for market during the late fall and early winter months. When this occurs, the deseeding operations continue until the entire crop has been deseeded. While particular operations, such as retting and scutching, are seasonal, labor is employed the year round when mills are operated at capacity.

In general, the quantity of flax straw retted for the season determines the capacity of a mill under Oregon conditions. As previously stated the three farm cooperative mills erected in 1936 were designed for 1,200 tons of pulled flax per year with six tanks 7 by 16 by 40 feet in size. When the mills first began operations, retting was usually started in the latter part of April and stopped in September. On this basis, and with a 5½- or 6-day week, the mills operated at approximately their rated capacity when sufficient straw was available. As experience was gained and the price of fiber increased, retting was started earlier in the spring, continued later in the fall, and done in a 7-day week. In the fall of 1940, for example, each of two mills retted the equivalent of about 766 tons of pulled flax. In the spring of 1941, one of these mills retted straw from about 888 tons of pulled flax in six tanks, indicating a mill capacity of 1,650 tons or about 275 tons per tank. However, some straw was damaged by rains and much greater chances were taken on the weather for field drying, especially in the fall, than would have been taken with prewar fiber prices. These observations indicate a capacity of more than 200 tons per year for a tank 7 by 16 by 40 feet. It would be difficult to estimate the average capacity based on only two or three seasons, but available information shows that a mill with six tanks can process more than 1,200 tons.

Mill capacity can be increased by operating such machines as scutchers and deseeders on two or three shifts. However, machine capacity is generally in excess of tank capacity at the Oregon mills. A scutcher will scutch the equivalent of at least 9.5 tons of pulled flax per 8-hour day. If a machine is run 6 months on a 44-hour week, it will scutch retted straw from about 1,200 tons of pulled flax. Experience gained during the past few years indicates the possibility of scutching throughout the year. On this basis, one scutcher would handle each year's retted straw from about 2,400 tons of pulled flax, working one shift of 8 hours.

Deseeders of the type developed by the Department deseed approximately 15 tons of pulled flax per 8-hour day. With 3 shifts sufficient straw could be deseeded for a battery of 20 standard tanks. From this it would appear that scutching and retting facilities generally fix the capacity of a mill. It is assumed, of course, that a sufficient number of straw storage sheds and drying fields are provided.

PROCESSING COSTS

Three farm cooperative flax mills in Oregon have been in operation since 1936 and the officials have made many changes in procedure since that time in an effort to reduce costs. This process continues but information collected in 1938, 1939, and 1940 will give some idea of the cost of the several operations in getting flax fiber in condition for market.

Figures 6, 7, 8, and 9 indicates the movement of straw in the mills, depending upon the way it is handled. The recommended practice is illustrated in figures 6 and 8, where the deseeding and retting are done simultaneously. With this plan somewhat less than 50 percent of the crop is deseeded and retted the calendar year it is produced and the remainder the next spring. When it is desirable to get the seed on the market as soon as possible, over 50 percent of the crop is handled according to the plan indicated in figure 9.

Labor costs are indicated for specific operations involved in the several patterns. It was necessary therefore to obtain information on labor requirements for each operation. Such information is given in tables 1 and 2. Table 2 gives the total labor required for the operations under the four plans illustrated in figures 6 to 9, inclusive.

In reviewing these tables it should be remembered that the exact labor requirements vary widely, depending at times upon conditions not under the control of the management. In some seasons shed capacity is insufficient to accommodate a bumper crop and some of the straw must be stacked in the open until space is provided in existing structures. During seasons when rains occur late in the spring or early in the fall, extra labor is required to turn the bundles on the field to hasten drying. Also, during prolonged damp weather the regular drying field may be too small and some straw may have to be hauled to a rented field on a nearby farm.

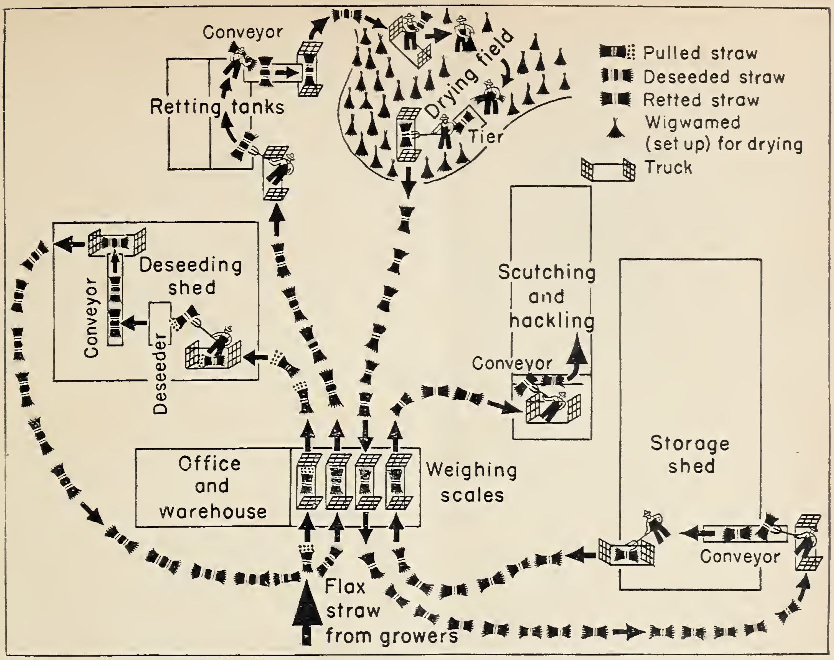

FIGURE 6.—One recommended way of handling flax straw, listed in the following order: Deseed, ret, store, scutch.

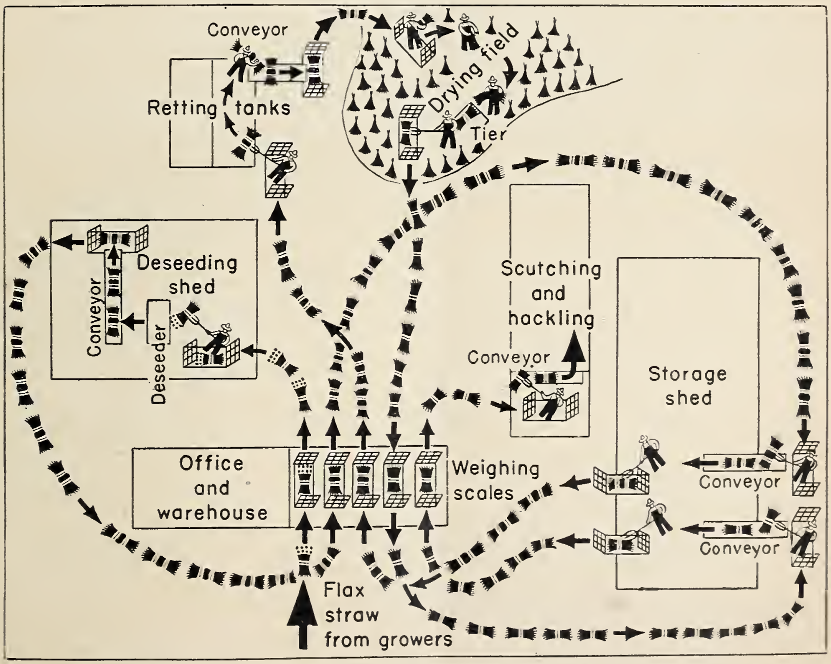

FIGURE 7.—Under the plan illustrated the straw is handled in the following order: Deseed, store, ret, store, scutch.

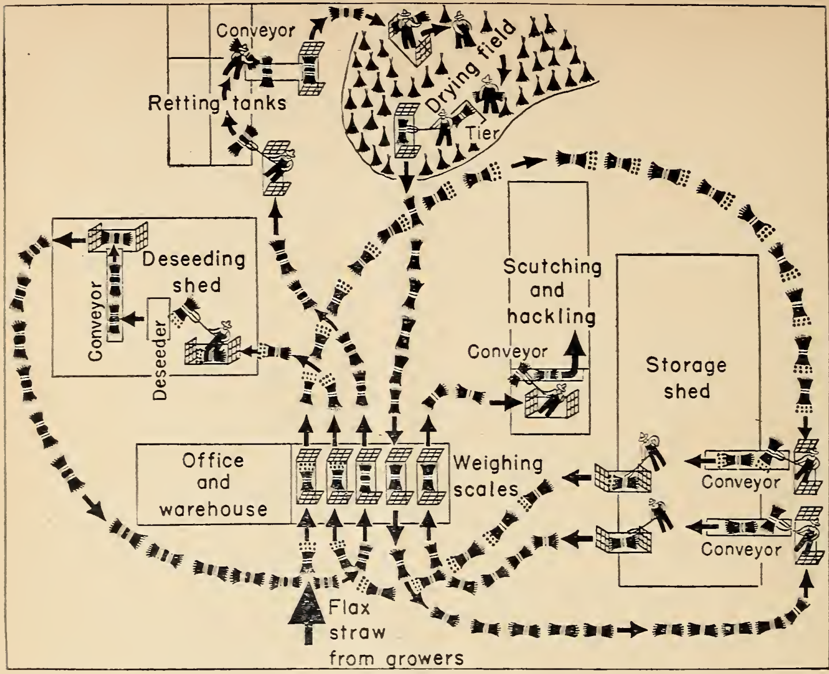

FIGURE 8.—Another recommended plan for handling flax straw is as follows: Store, deseed, ret, store, scutch.

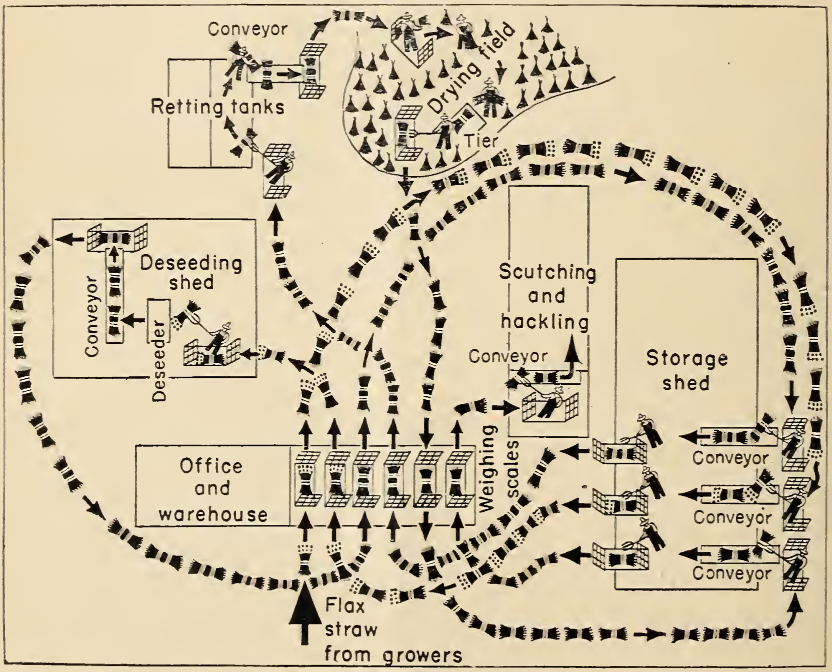

FIGURE 9.—A fourth way to handle flax straw is as follows: Store, deseed, store, ret, store, scutch.

TABLE 1.—*Approximate labor requirements for the various operations in processing fiber flax at Farmers' Cooperative Mills in Oregon, 1938, 1939, and 1940*

Operation	Mills	Usual crew	Observed material handled	Labor requirements: Total	Labor requirements: Per ton of pulled flax
	Number	*Men*	*Tons* [1]	*Man-hours*	*Man-hours*
Unloading in shed from farm	2	2–5	42.01	43.41	1.03
Loading in shed for deseeder	3	2–4	42.19	38.87	.92
Deseeding: [2]					
Whipper	1	10	41.92	188.63	4.50
Belgian	2	7	98.10	418.30	4.26
Experimental No. 1	1	7	94.66	323.98	3.42
Experimental No. 2	1	7	331.10	1,133.00	3.40
Unloading in shed from deseeder	2	2–5	49.07	52.00	.72
Loading in shed for retting	2	2	14.66	16.37	.76
Filling retting tanks	3	3	230.37	316.63	.94
Emptying retting tanks	2	3	108.66	98.71	.62
Hauling to drying field and unloading	2	3	95.53	52.40	.38
Firing boiler and retting	2	2	2,007.78	524.00	1.78
Cutting bands and setting up	2	4–6	65.82	112.13	1.16
Tying bundles on drying field	2	2–4	60.60	120.47	1.07
Loading and hauling from field	2	2–4	75.04	94.47	.68
Unloading in shed from field	2	2–4	58.14	63.08	.59
Loading in shed for scutcher [3]	3	2–3	47.86	58.05	.65
Unloading at scutcher [3]	1	1	12.10	6.67	.30
Scutching	2	8	100.25	1,240.00	6.68
Hackling	3	3	19.26	695.00	2.52

[1] Weight of pulled, deseeded, and retted straw or fiber, depending upon the operation involved.
[2] Labor for deseeding adjusted for direct comparison of different machines. Some plants used an elevator for loading deseeding bundles and others did not. The thresher was connected directly with the deseeder at one location and a man was used at another for feeding the thresher.
[3] Included in scutching.

TABLE 2.—*Approximate labor requirements in processing a ton of pulled flax at farm cooperative mills in Oregon, 1938, 1939, and 1940*

Operation	Plan No. 1	Plan No. 2	Plan No. 3	Plan No. 4
	Man-hours	*Man-hours*	*Man-hours*	*Man-hours*
Unloading in shed from farm			1.03	1.03
Loading in shed for deseeding			.92	.92
Deseeding [1]	3.82	3.82	3.82	3.82
Unloading in shed from deseeder		.72		.72
Loading in shed for retting		.76		.76
Filling retting tank	.94	.94	.94	.94
Emptying retting tank	.62	.62	.62	.62
Hauling to drying field and unloading	.38	.38	.38	.38
Stoking boiler and retting	1.78	1.78	1.78	1.78
Cutting bands and setting up	1.16	1.16	1.16	1.16
Tying bundles on drying field	1.07	1.07	1.07	1.07
Loading and hauling from field	.68	.68	.68	.68
Unloading in shed from field	.59	.59	.59	.59
Loading in shed for scutcher	(2)	(2)	(2)	(2)
Unloading at scutcher	(2)	(2)	(2)	(2)
Scutching	6.68	6.68	6.68	6.68
Hackling	2.52	2.52	2.52	2.52
Miscelleneous (estimated) [3]	1.00	1.00	1.00	1.00
Total	21.24	22.72	23.19	24.67

[1] Average Belgian and Experimental No. 2. See footnote,[1] table 1.
[2] Included in scutching.
[3] Handling tow, turning bundles to dry during damp weather, setting up down bundles on drying field, hauling shives, etc.

Referring to table 2, labor requirements range from 21.24 to 24.67 man hours per ton of pulled flax depending upon the way it is handled at the mill. The tonnage processed under plans 1 to 4 varies from year to year and from mill to mill and insufficient information is available to indicate a reliable average. However, over a period of years with equipment now in common use the average number of man hours would probably approximate that indicated for plan 3. The exact labor cost will, therefore, depend upon the wages and the percentage of the crop handled under the several plans.

Prior to 1939, workmen were employed in the cooperative mills on a piecework basis, by the hour, or on salary, depending somewhat on the job to be done and the circumstances involved. One mill operated on piecework except for the manager, bookkeeper, fireman or watchman, and extra labor needed in stacking straw during the harvest season.

At other mills hourly wages were most common except for scutching and hackling. For these operations the men at all three mills were usually paid by the pound of fiber produced. Piecework, hourly wages, and salaries all prevailed, but labor pay for the 1941 crop was generally on an hourly basis (50 to 60 cents) except for the manager and the clerical employees.

In 1938 and 1939 one of the farm cooperative mills operating on a piecework basis paid $3.25 per ton for deseeding on a deseeded-straw basis, $1.20 for retting, $2.50 for field drying, 2¼ cents per pound of fiber for scutching, and 1 cent per pound for hackling. On a pulled-flax basis these figures approximated $2.05 for deseeding, 82 cents for retting, $1.70 for drying, $3.58 for scutching, and $1.43 for hackling. With 50 cents per ton of pulled flax added for the cost of firemen and 30 cents for extra labor, including stacking straw in the sheds, the total labor cost approximated $10.36 per ton of pulled flax.

In operating on a piecework basis some employees earned more than others on the same job. Earnings also varied with the type of work involved. In hackling, the men hackled on an average of 440 pounds of fiber per 8-hour day, indicating an hourly wage of 55 cents. In deseeding in 1939 with an experimental deseeder developed by the Department, a crew earned as much as 60 cents per hour at times when the flax was unloaded at the machine directly from the farm. However, for the crop years 1938, 1939, and 1940 the workmen earned about 40 cents per hour.

In addition to labor, the overhead cost is sizable especially if the mill is not operated at capacity. Three of the farm cooperatives were erected with relief labor, one on contract, and one with local labor hired as the need arose. Also, no two are exactly alike. For these reasons an accurate appraisal is difficult to make. It would appear, however, that a mill with six tanks and all necessary buildings and machinery represents an investment of $50,000 to $60,000 at prewar prices. The cost of mills constructed since the war began ranges from approximately $75,000 to $100,000. However, most of these have 12 retting tanks instead of 6, and some additional buildings and fire-fighting equipment.

In listing the cost of various facilities for the three original mills it would appear that buildings represent an investment of $30,000 to $35,000; land $2,500 to $3,500; machinery $10,000 to $12,000; tanks $5,000 to $6,000; boiler and water system $2,500 to $3,500. In this appraisal the assumption is made that the buildings, tanks, and water system will last 20 years and machinery 5 years. On this basis, and with 6 percent interest on the average investment, the fixed cost will vary from about $5,275 to $6,425 a year, depending on the initial cost of the mill. To this fixed overhead must be added the manager's salary, clerical work, power, light, gasoline, lubricants, twine, machinery repairs, supplies, insurance, and a host of small items which may range from $4,000 to $6,000 per year. A further assumption is made that the mill in question processes 1.200 tons per year of pulled flax. On this basis all overhead items might be expected to range from $4.40 to $5.35 per ton; operating expenses and management $3.33 to $5 per ton; and labor $10 per ton. This indicates that about $17 to $20 per ton were required to process fiber flax under Oregon conditions in the period 1938 to 1940.

STRAW YIELDS

Straw yields influence greatly the success of a flax mill. While many factors beyond the control of the management, such as length of straw, weeds, rainfall, soil type, and fertility, influence the fiber-straw ratio, careful handling seems to pay dividends. From the time the flax is pulled until it is marketed, care must be taken to keep the straws in the bundle, or fiber in the hank, parallel to prevent excess waste at each succeeding operation. If the bundles of pulled flax are sloppy, more straw will be combed out in deseeding, less tonnage will be put in each tank, and there will be more waste of retted straw in handling than if they are neat and the root ends even. If reasonable care is not exercised in evening up the root ends of the retted straw when fed to the scutcher, the percentage of tow may be excessive. While constant attention to such details is not conducive to large-capacity operations, careful handling is essential for a profitable and thriving flax industry based on prewar fiber prices.

Referring to table 3, the weight of pulled flax is reduced 30 to 33 percent in deseeding, over half of which is seed. The seed, including dockage, averages about 6 bushels per ton of flax. In retting the deseeded straw loses from 20 to 33 percent. After scutching only the fiber and tow remain, representing about 11 to 15 percent of the weight of the retted straw in line fiber and 6 to 10 percent for tow. Figure 10 shows similar proportions graphically.

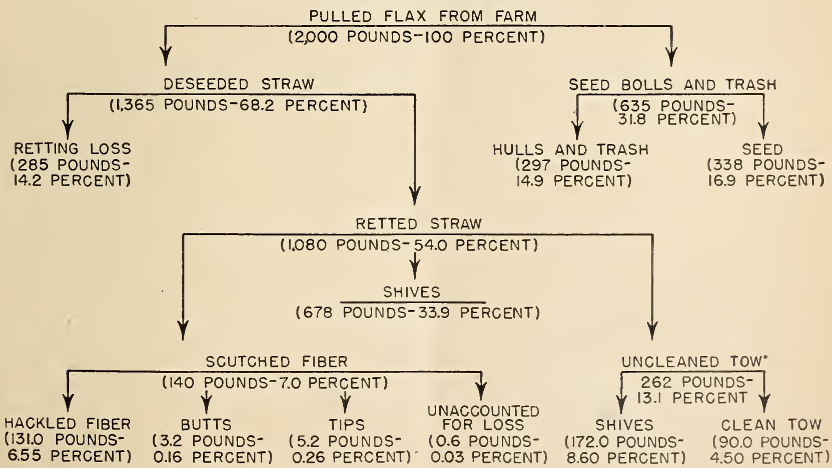

FIGURE 10.—Approximate fiber-flax straw yields based on the crops of 1938, 1939, and 1940.

The fiber-flax crop was not exceptionally good during the period 1938 to 1940, especially in 1938, and the yields of line fiber may be lower than an average over a long period of years for all mills. Weather conditions during the 1941 growing season were ideal for flax and fiber yield ran over 10 percent on some lots of pulled flax. However, excellent straw and careful handling are necessary to obtain a line fiber yield of 10 percent with present equipment.

FLAX MACHINERY

Pullers

A large number of patents have been obtained on flax pullers but only three or four have been developed to the stage where the machines have been manufactured and used.

Table 3.—*Proportion of flax straw or fiber remaining after each process at cooperative flax mills in Oregon in 1938, 1939, and 1940*

Process	Quantity processed	Straw or fiber		Other products					
		Total	Proportion	Name	Total	Proportion	Name	Total	Proportion
	Tons	*Tons*	*Percent*		*Tons*	*Percent*		*Tons*	*Percent*
Deseeding	1,990.11	1,349.27	67.8	Seed	327.9	16.4			
	736.00				125.3	17.0			
	1,034.70	730.10	70.6		175.2	16.9			
	1,157.43	768.70	66.4		201.8	17.4			
	652.42	451.56	69.2						
Average			68.25			16.9			
Retting	743.44	587.58	79.04						
	292.27	226.38	77.46						
	530.23	419.70	79.15						
	523.33	418.70	80.00						
Average			79.09						
Scutching	242.03	27.50	11.36	Tow [1]	21.4	8.8			
	155.50	19.26	12.39		13.6	8.7			
	418.70	46.05	11.00		42.3	10.1			
	293.01	43.28	14.77		17.62	6.0			
	265.28	34.92	13.15		20.75	7.8			
	412.60	60.18	14.59		33.29	8.1			
Average			12.93			8.3			
Hackling	53.44	49.74	93.08	Butts	1.58	2.96	Tips	2.12	3.96
	80.85	75.58	93.48		1.84	2.28		3.43	4.24
	21.58	20.11	93.19		.57	2.64		.90	4.17
	39.93	37.89	94.90		1.19	2.98		.85	2.12
Average			93.60			2.70			3.70

[1] Does not include tow from loose retted straw or green tow from straw pulled out at deseeder.

A machine developed in Canada many years ago was tried out in Michigan and later in Oregon. The State flax industry constructed a number of these machines and they have been used for pulling the Oregon fiber-flax crop for a number of years. Pullers of the type developed in Belgium and introduced in Oregon in 1939 by the Bureau are replacing the old machines. A puller developed by a local shop is also in use.

The new pullers are of simpler design and usually give less trouble in the field than their predecessors, but the old machines turn out a bundle with evener root ends than the Belgian type. Well-rooted weeds and grass are more likely to pull through the gripping belts of the Canadian than the European machines which is usually a desirable feature. While each type has its advantages and limitations, pullers have not been developed to the stage comparable with that of most other farm machines.

The Canadian machine pulls a swath 3 feet wide in three throats with three pair of gripping belts as indicated in figure 11. The pulling units are set at an angle of about 45° and in such a position as to pull the plants out of the ground and convey them upward and rearward to a binding unit. The straw remains in a vertical position until the bundles are formed and tied. The narrow 1-foot

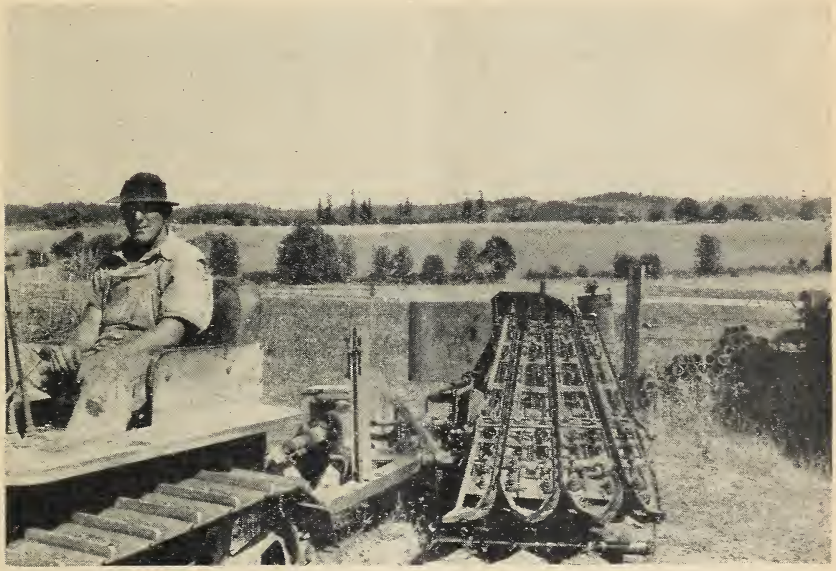

FIGURE 11.—Canadian-type flax puller with covers removed showing belts, tension and guide rollers.

swath, pulled in each throat, and the vertical position of the straw for binding tend to produce a bundle with fairly even root ends. The large number of spring-mounted rollers for holding the gripping belt together under sufficient tension to do the job, and the necessity for small pulleys at the top to narrow the unit down to the throat width of the binder are sources of endless trouble.

The European machine employs two wheels for pulling, tilted backward from the vertical about 20°, one ahead of the other in parallel planes transverse to the direction of travel but on offset axes. The rims of these wheels are rubber faced and the wheels are driven in opposite directions. Rubber belts, one belt for each wheel but not surrounding it, contact a portion of the circumference and the flax is gripped between the belt and the rubber-covered rim for pulling. This type of machine is shown in figure 12. The wheel and belt assembly is such that the two sheets of pulled flax are brought together near the top of the wheels where the belts and the rims part. An auxiliary belt is employed for moving the flax to one side from this point into the throat of a binder unit placed substantially horizontal as on a grain binder.

The new machines pull a swath 3 feet wide divided in two throats. Thus, an 18-inch strip is pulled by each wheel compared with a 12-inch strip for each pair of gripping belts on the Canadian puller. As the machine is moved across the field the flax straw is bent forward slightly and guided to the throats by dividers. As the machine moves over the field the leaning plants are caught between the rubber-covered surfaces of the revolving wheels and the belts. The forward

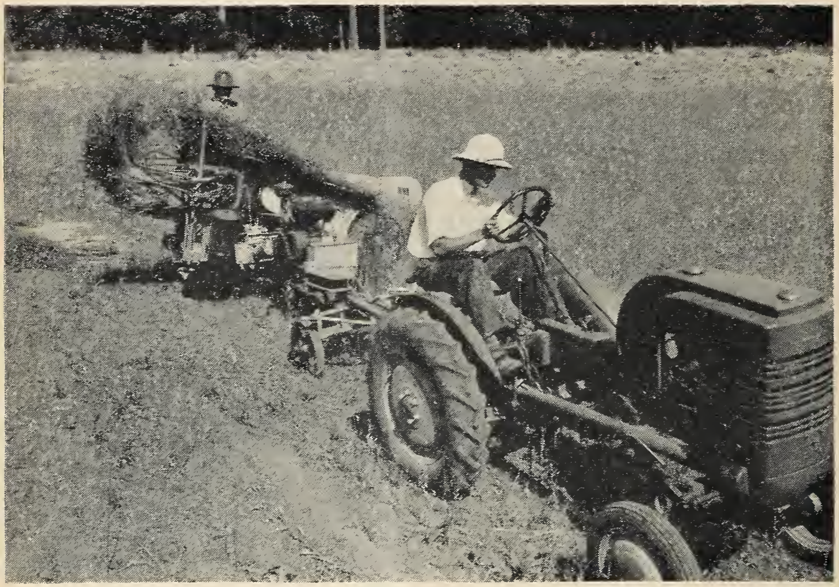

FIGURE 12.—A European-type flax puller equipped with gasoline engine for operating all moving parts. The binder is set vertically on this machine for experimental purposes.

motion of the machine and the upward movement around the circumference of the wheels uproot the plants. The wide throat and the binding of the bundles in a substantially horizontal position are not conducive to making the root ends even. A butter of the type used on grain binders does not work well on the flimsy root ends of pulled flax straw. The binder on a Belgian-type puller was set in a vertical position for experimental purposes and used on the 1941 crop with encouraging results in obtaining better bundles.

A crew of one or two men operates the Belgian-type puller and two or three men are needed for the Canadian type, including the tractor driver. Both types of pullers are operated by the power take-off from a tractor but on the Belgian machine some operators prefer a separate engine. A 5-horsepower gasoline engine provides sufficient power for operating all moving parts.

The rubber on the gripping wheels wears and considerable tension on the belts is required, under some crop and field conditions, to pull the flax. In such cases the flax straw is damaged, resulting in overretting of the damaged portion. To overcome this difficulty, an experimental machine has been constructed with pneumatic tires on the pulling wheels. By regulating the air pressure in the tires it is hoped that damage to the straw will be eliminated.

A machine with a 3-foot swath operated at 3 miles per hour should pull about 9 acres per 10-hour day. It is seldom, however, that a puller covers this acreage, and 4 to 5 acres is considered a good day's work. Down flax or damp straw cause trouble by winding on the moving parts, and weeds are a source of considerable trouble.

Figure 13.—Deseeding flax straw from experimental plots with a "whipper."

Deseeders

Many kinds of machines for deseeding flax have been used. The "whipper" and the comb-type deseeders have been common in Oregon. The whipper is made up of a pair of parallel shafts mounted in a frame with steel crushing rollers on the ends of the shafts protruding from the frame. Power is applied to one shaft mounted in fixed bearings. The rims of the crushing rollers mounted on the second shaft are held against the drive unit by a spring-mounted bearing and rotated by friction. The rotation is such that the surfaces in contact move downward. A deseeder of the whipper type mounted on sled runners for use in the field in deseeding small plots of flax is shown in figure 13.

In operation, a man faces each pair of rollers and receives a bundle of flax with the band removed. He fans out the seed ends of the bundle and passes it downward between the rollers two or three times to remove or crush all of the bolls and liberate the seed. In performing this operation rapidly the crushing rollers appear to be whipped, or slashed.

For flax-mill operation a whipper is set over a conveyor for conveying the seed to a threshing machine and tables are provided on each side of the machine. The bundles of pulled flax are placed on one table where bands are cut and the other table is used to receive the deseeded bundles. A binding apparatus with two needles is placed at the end of one table in which the deseeded straw is bound ready for the retting tank. Two ties or bands are used because the wet retted straw can be handled to better advantage with two ties than with one.

A crew of 10 men is usually employed to operate a whipper when the straw is delivered to the machine directly from the field. The crew is made up as follows: 1 pitcher, 1 band cutter, 2 whippers, 2 eveners, 1 binder, 2 loaders, and 1 sack sewer. When it is necessary to haul the straw to the machine from the shed, additional men are needed. With good dry flax and an experienced crew this machine will deseed 15 tons of pulled flax per 8-hour day. However, a whipper is usually rated at 1 ton of deseeded flax per hour which is the equivalent of about 12 tons of pulled flax per 8-hour day, sufficient to fill 1 standard retting tank.

A comb-type deseeder imported from Europe was introduced in Oregon for use by the cooperative plants soon after these mills were erected. Because of low capacity and mechanical difficulties these machines were generally discarded in favor of the home-made whipper. One comb was used in the machine and the gripping device consisted of two ribbed-rubber belts between which the straw traveled past the comb. Numerous spring-mounted rollers were employed to hold the belts together for gripping the flax straw. Corrugated rollers were mounted in a seed hopper for crushing the seed pods combed from the straw, but some auxiliary threshing and seed-cleaning device was needed.

In operation the bands of the pulled-flax bundles were cut, the straw was spread in a thin layer and fed to the machine in such a manner that the seed ends moved across the path of the comb. The comb was actuated by a crank with mechanism provided to raise the comb above the flax, allow it to enter the straw, and then move rearward to comb off the seed pods. The deseeded straw was again assembled in bundles and tied with two bands for retting. The material combed out consists of some straw, seed pods, and loose seed.

In 1939 a new type European deseeder which combs both the seed and the root ends of the straw was introduced. The combs resemble heavy forks mounted on cranks with the handle held in such position that the fork teeth travel in the path of an ellipse. The comb teeth for the root ends of the straw are widely spaced and those on the seed end narrowly spaced to comb out the seed pods. Straw combed on both ends is easier to set up on the drying field than either straw from the whipper or from a machine which combs only the seed ends. The root-end comb removes some dirt and weeds, but two combs naturally pull out more straw than one. A device comprising a wheel with pneumatic tire and a heavy rubber belt serves well on the Belgian machine for gripping the straw as it is combed.

In 1938 the Bureau began the construction of an experimental machine in which a wheel with concentric grooves and steel cables was used for gripping the straw. A revolving drum comb assembly in which the comb teeth are held in a substantially vertical position was employed. The gripping device was discarded but the revolving comb idea had certain advantages over a single forklike comb. With three or four combs in a drum it was possible to increase the speed of the gripping device for higher capacity and maintain a relatively low comb speed.

As a result of these findings a second deseeder was constructed in which both ends of the straw are combed. On this machine each drum is rotated on a stationary shaft to which is keyed sprockets with the same number of teeth as corresponding sprockets on the comb shafts mounted in the revolving drum near its rim. Both pairs of sprockets, one on the stationary shaft and one on the comb

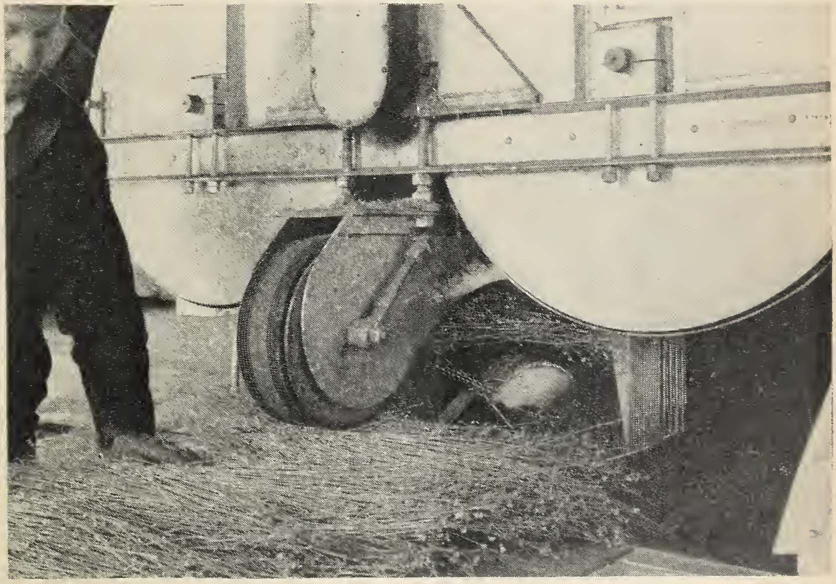

FIGURE 14.—An experimental deseeder which combs both the seed ends and root ends of the straw.

shaft, are connected together by roller chain. With this arrangement of parts the teeth always point in the same direction as the drum assembly revolves and on the downward stroke they enter the flax near the gripping device. The direction of rotation of the drum for combing the seed ends of the straw is opposite to that for combing the root ends. The double-comb machine is shown in figure 14.

Some trouble was experienced with the chains and a third machine was constructed in which gears were used to maintain the fixed relation of the comb teeth. The center gear is stationary and is connected to gears on each comb shaft by idler gears attached to the drum. The comb shaft gears and the fixed gear, of course, have the same number of teeth.

It was also found that the comb assembly represented a large part of the cost of construction. For this reason the third deseeder was constructed to comb only the seed ends of the flax. The design also simplified the drive. This deseeder is shown in figure 15. A working drawing of the comb assembly may be obtained from the Bureau of Agricultural Chemistry and Engineering.

The capacity of the improved deseeders described depends to a large extent on the condition of the straw and the ability of the crew to feed the machine continuously at capacity. For individual loads of flax these machines have been observed operating at 2.5 tons of pulled flax per hour. One crew is reported to have obtained 18 tons of deseeded flax in 8 hours which is approximately 3.3 tons of pulled flax per hour. It would be physically impossible to maintain this

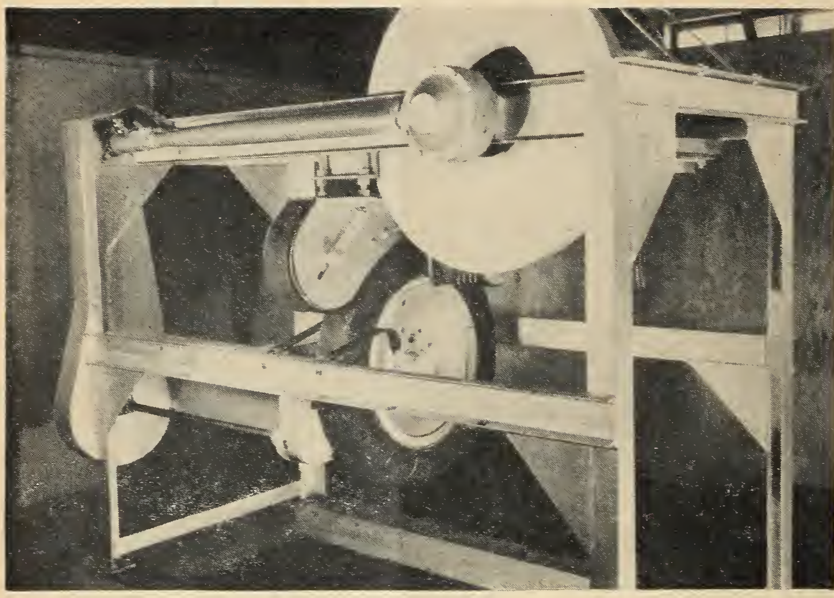

FIGURE 15.—Experimental deseeder which combs only the seed ends of the flax straw.

capacity for any great length of time, but the machines might approach it with an automatic feeding device for removing the ties and for spreading the bundles.

With an increase in the capacity of deseeders, loading the deseeded bundles became arduous. A bundle elevator was therefore developed for the job; it works quite well and is being adapted by the mills. A working drawing may be obtained from the Bureau of Agricultural Chemistry and Engineering.

The root ends of flax straw are difficult to make even, especially when the seeds are on or after the straw is retted. When a deseeder is used which combs both the root ends and seed ends the straw is substantially parallel and it is relatively easy to even the root ends at this point. Since bundles with even root ends are very desirable an attempt was made to develop a device for this purpose. In constructing the machine a butter was installed at the lower edge of a table tilted at about 45° over which the straw moves from the deseeder to the binder. The rather crude first attempt showed some promise and work in developing the device, shown in figure 16, is being continued.

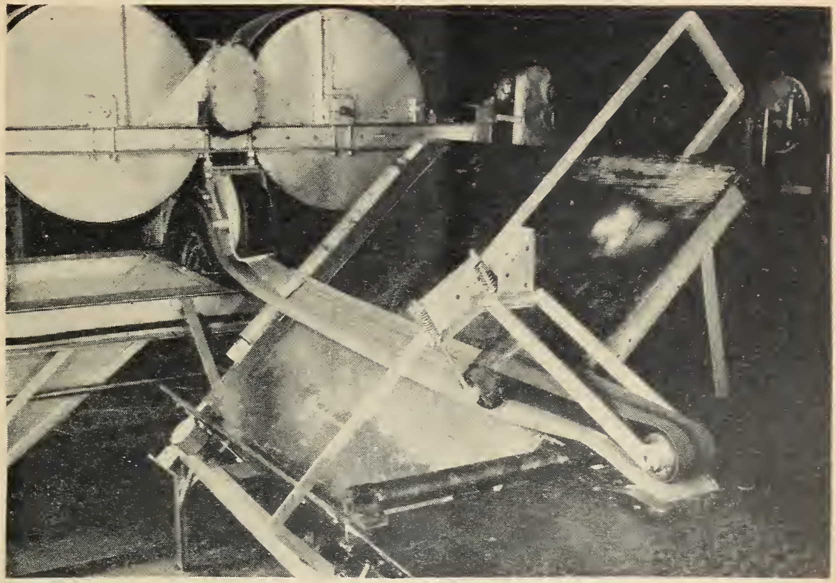

FIGURE 16.—An experimental butter for evening the root ends of flax straw. The board on the lower edge of the slanting table is actuated by a crank which causes the board to strike the root ends of the straw repeatedly as the straw moves across the table from the deseeder to the binding unit.

SCUTCHERS

The purpose of scutching is to remove the woody part of the plant and leave as much of the fiber unbroken as possible. To accomplish this it is desirable to first break the woody portion of the straw into short pieces and scrape or flail the shives free from the fiber.

Observations made at the Oregon flax mills, previously referred to, indicated the desirability of changes in design of scutchers in use in order to reduce the percentage of tow. Tow is a relatively low-priced product and it is difficult to clean. While many of the weak fibers are broken in hackling and reduced to tow, the tow from both the hand and machine hackles can be spun without any extra cleaning operation. Hand hackling is illustrated in figure 17, and machine hackling in figure 18.

In an effort to increase the line-fiber yield a machine was designed and constructed in which the flax straw was fed to the scutching rotors on the rim of a wheel. With this arrangement the flax was progressively lowered and withdrawn from the rotors to permit the blades to strike the fiber at different points on each revolution of the rotors. One unit of this machine is shown in figure 19. While the machine showed some promise it was apparent that the woody portion of the straw would have to be broken more effectively than was possible with conventional types of breakers. A new type breaker was developed and used with this scutcher with encouraging results.

This breaker consists of three fluted rollers mounted near the rim or periphery of a drum with the rollers geared to mesh with but not

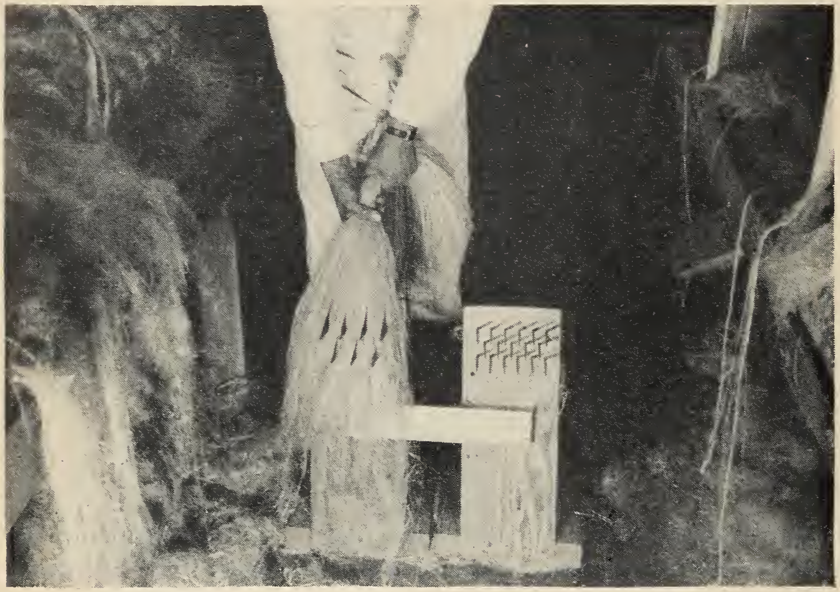

FIGURE 17.—Hand hackling or combing scutched line fiber.

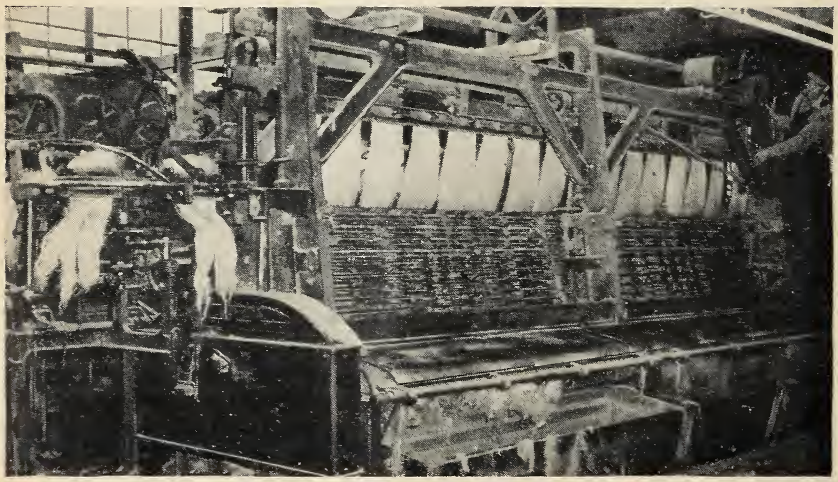

FIGURE 18.—Machine hackling of line fiber. The hanks of fiber are automatically lowered to belts on which are mounted horizontal bars carrying pins for combing the flax. As the hanks are lowered, withdrawn, and moved forward, progressively closer spaced pins are encountered.

touch stationary concave teeth arranged around a part of the rotor assembly. By a combination conveyor and gripping device flax straw is fed to the breaker in a continuous mat at right angles to the axis of the drum so as to pass between the fixed concaves and the rotating drum. As the straw emerges from the unit a transfer is made in the grip and the unbroken ends are engaged by a second breaking unit which rotates in the opposite direction. Figure 20, *A* illustrates one of the fluted rollers of the breaker-scutcher, and figure 20, *B* shows the feed end with only a part of the concave assembly in place. Trouble was experienced with the transfer on the breaker and the two units were separated for mounting, one each ahead of the gripping wheels on the scutcher previously referred to. With this arrangement the tips or seed ends of the mat of straw are broken and scutched and then the root ends. This machine did an excellent

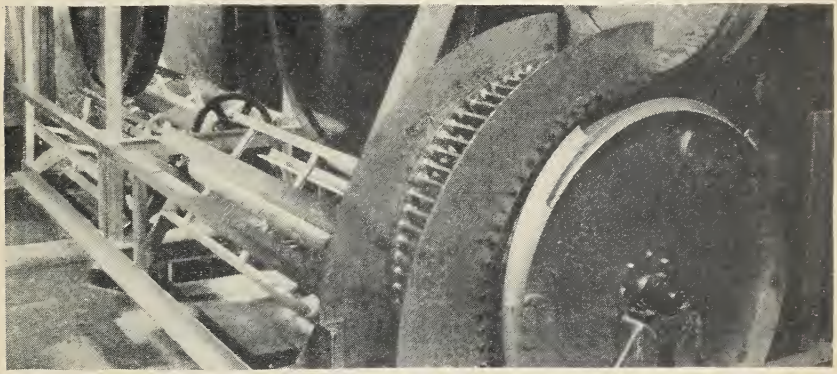

FIGURE 19.—An experimental scutcher under construction which lowers the flax into and withdraws it from the scutching rotors.

job of scutching but was unsuitable for large-scale tests under flax-mill conditions because of mechanical imperfections. It did, however, demonstrate the possibilities of increasing the yield of line fiber with a corresponding decrease in tow. Line-fiber yields as high as 20 percent of the retted straw were obtained in shop tests.

Tow Cleaners

Tow (tangled fiber which accumulates from the scutching operation or the fiber from tangled retted straw) is difficult to clean. However, it has some value. Yarn from tow serves well in manufacturing toweling and coarse fabrics where tensile strength is of no great importance. So far no machine has been developed which will clean the tow to the entire satisfaction of local spinners except possibly the wheel used in Europe for many years for scutching line fiber. Cleaning tow on the wheel is a slow and laborious job.

A tow-scutching machine developed in Germany a number of years ago has been used for cleaning tow in Oregon. One of these machines is also said to be used in Canada.

A machine known as a tow shaker has been used for a long time in Oregon for shaking out loose shives from the tow. This partly cleaned tow was then baled and hauled to a central location for scutching. With an increase in the number of flax mills in the State, the German machine previously mentioned proved inadequate.

Tow shakers of the European type originally used in Oregon were not very effective in removing the loose shives. A shaker developed by the Bureau of Agricultural Chemistry and Engineering has

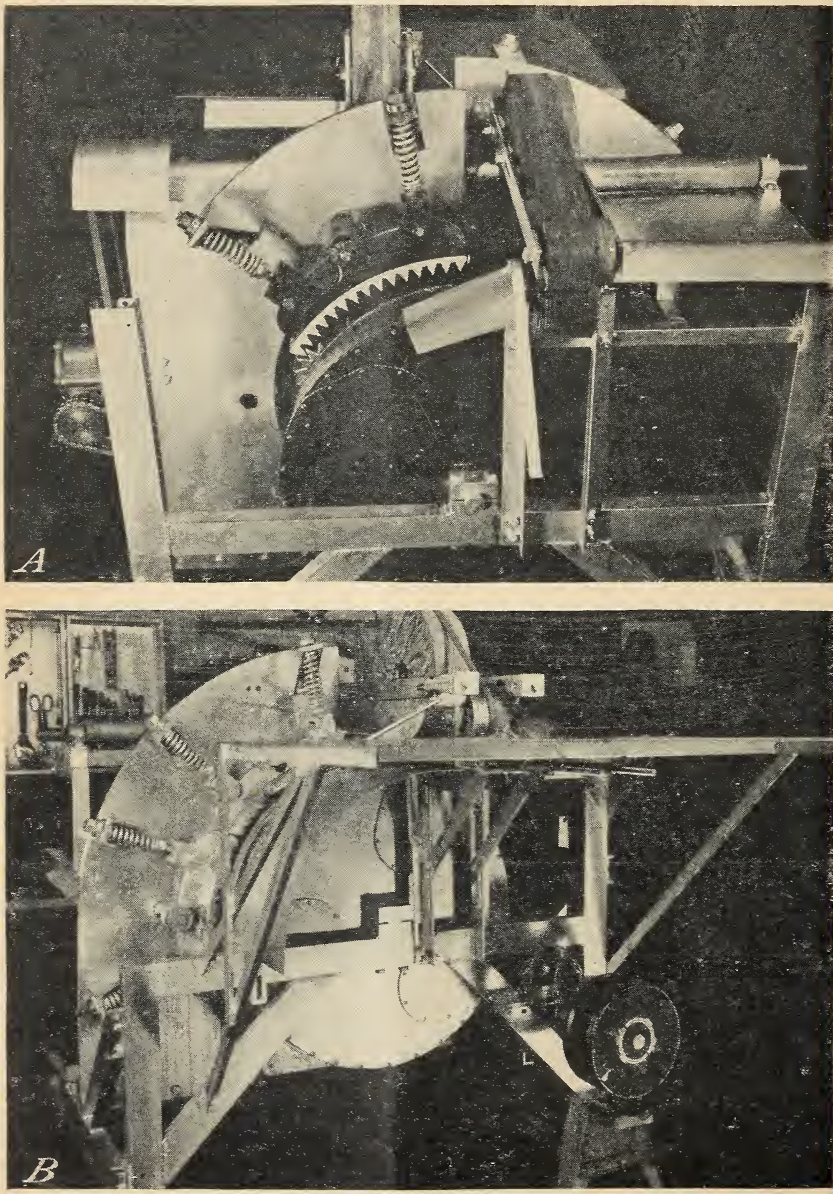

FIGURE 20.—*A*, one of three fluted rollers in drum of the breaker-scutcher shown meshed with spring-mounted concave; *B*, feed end of breaker-scutcher.

proved to be more efficient and is now in general use. It differs from the old machines principally in that the pins are longer and the machine is larger, making it possible to obtain a thin layer of tow for the pins or agitators to work on.

With an efficient tow shaker available it appeared possible that repeated crushing and a violent shaking for liberating the shives might effectively clean the tow. A combination of reciprocating breakers and tow shakers has been designed which offers some promise in cleaning the tow as it accumulates. A satisfactory tow cleaner for each mill would greatly reduce handling costs and enable the mills to market the tow in the same manner as scutched line fiber.

SUMMARY

About 12,000 acres of fiber flax was grown in the United States in 1941, chiefly in Oregon. The flax produced was only about one-tenth of the amount needed to meet normal peacetime demands. The war has restricted trade channels, thereby creating a demand for home-grown flax for fire hose and other essential linen articles for our armed forces.

Three flax mills were constructed in Oregon in 1936 with State and Federal assistance for operation as farmers' cooperatives. This expansion increased the rated capacity of Oregon mills from about 4,000 to 7,600 tons of pulled flax per year. New mills constructed in 1941 and additions to existing mills further increased processing facilities in Oregon.

A greater amount of labor is required for processing fiber flax than for most other field crops. Information obtained at Oregon mills in 1938, 1939, and 1940 indicates that from 20 to 25 man hours are expended per ton of pulled flax in getting the fiber and seed in marketable condition.

Flax-mill operations in Oregon are seasonal but labor is employed throughout the year. The capacity of a mill depends largely upon its retting capacity. Two or more shifts can be utilized for operating machinery but the retting (rotting) is a biological process generally done during the summer months to permit field drying of the water-retted straw. Under Oregon conditions, from 200 to 250 tons of flax straw, pulled-flax basis, can be retted in each 7 by 16 by 40-foot tank. Each mill usually has from 6 to 12 tanks.

Machines for harvesting and processing, including pullers, deseeders, and scutchers, have been imported. There have been no local dealers selling or servicing flax machinery. Imports of machinery from Europe have been cut off due to the war and local firms are now in production. Several pieces of equipment developed by the Bureau are being produced by local shops.

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