Control Methods Used Against Destructive Western Barkbeetles

by

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INTRODUCTION

Statement of Purpose:

It is my purpose to explain all methods used in the western United States in the control of barkbeetles. This includes all methods used in actual control as well as all methods in the experimental stage. From this review of the possible control measures, conclusions will be drawn as to the future of barkbeetle control.

Importance of the Problem:

It is now becoming a better known fact that insects are definitely a primary enemy of the forests of our country. Formerly the layman recognized fire as the only agency from which it was necessary to protect the forests. Insects in the West kill more timber than any other agency including fire,(1) but they kill it in a less spectacular way so that it is not especially evident to the public. Estimates have been made which place the loss of forest resources due to insect damage at $200,000,000 annually,(2) and 85% to 90% of this is caused by barkbeetles.(3)

Over the entire ponderosa pine forests of Oregon, the estimated annual loss brought about by the western pine beetle, Dendroctonus brevicomis, is 0.75 per cent of the stand.(3) This amounts to 570,000,000 board feet of material which at a stumpage value of three dollars per thousand board feet would show a loss of $1,710,000.00 annually due to this one species of barkbeetle.

Reports of great epidemics are found where millions of dollars worth of valuable timber has been wiped out in a single year. One of these was the destruction of 1,400,000,000 board feet of merchantable white pine in Northern Idaho, in 1911-1913, by the mountain pine beetle, Dendroctonus monticolae.(3) Hopkins reports another epidemic in which the black hills beetle, Dendroctonus ponderosae, destroyed 1,000,000,000 board feet of timber over a ten year period.(4)

The genus Dendroctonus to which most of our destructive western forms belong have in the past thirteen years killed more valuable mature ponderosa pine than has been logged by the industry.(5) It is not necessary to emphasize farther the fact that barkbeetle control in the West must be improved and expanded to save our standing timber.

Information about the beetles:

These small insects commonly known as "barkbeetles" belong to the superfamily Scolytoidea which is divided into two families, Platypodidae and Scolytidae. Of the barkbeetles indigenous to the United States, one species belongs to the family Platypodidae and the other 550 species are of the family Scolytidae; consequently, barkbeetles are usually considered as the members of this family. The family is further divided into 70 genera, only a few of these are of economic importance in the West; Ips, Dendroctonus, Scolytus, Phleosinus and Pityophthorus are important. By far the most destructive genus is Dendroctonus which contains the important western pine beetle, mountain pine beetle, black hills beetle and the southwestern pine beetle, D. barberi.

Barkbeetles have an important appearance, being 1 to 9 mm. in length and ¼ to 2 mm. in width. They are cylindrical in form, and their color ranges from light reddish brown to black. The larvae are thick-bodied, always legless and white to cream colored with darker mandibles. The pupae are white when first transformed but gradually take on a yellowish color as they near the time of changing into the adult. The antennae, mandibles, legs, and wing pads are plainly visible on full-formed pupae. The eggs are very small, clear or pearly white, round or oval and varying in shape and size with the species.

The damage to the tree is begun with the construction of the egg tunnel. The methods of mating and egg tunnel construction are variable; however as a rule, with the important economic species the female mates and then begins construction of the egg tunnel. As she progresses she lays the eggs along the sides of the tunnel either singly or in groups, and usually sealing them in a small pocket or nitch. This tunnel is partly in the cambium, sometimes more of it being in the bark. If the tunnels are constructed in a horizontal position with the ground it can easily be seen that but a few females would be necessary to girdle the tree and hence destroy it. When the eggs hatch into young larvae they immediately begin to feed and progress away from the egg tunnel until they are fully grown.

THE WESTERN PINE BEETLE
(*Dendroctonus brevicomis* Lec)

(Above) Inner surface of bark showing egg galleries packed with boring dust and (insert) adults, pupae and larvae, all natural size.

(Below) Bark removed from infested ponderosa pine showing the typical winding egg galleries. Note the streaks of blue stain.

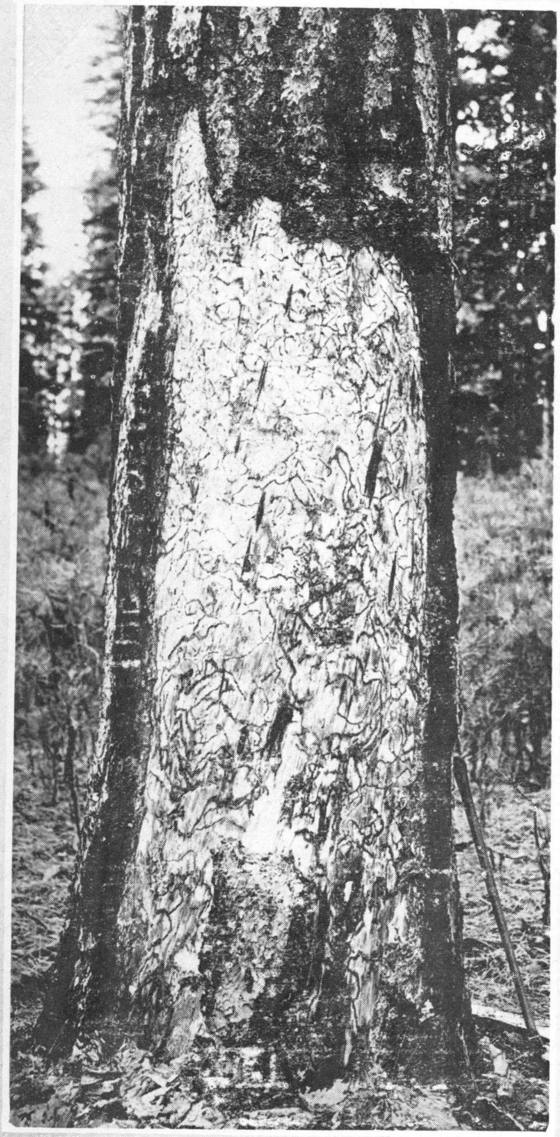


Fig. 1

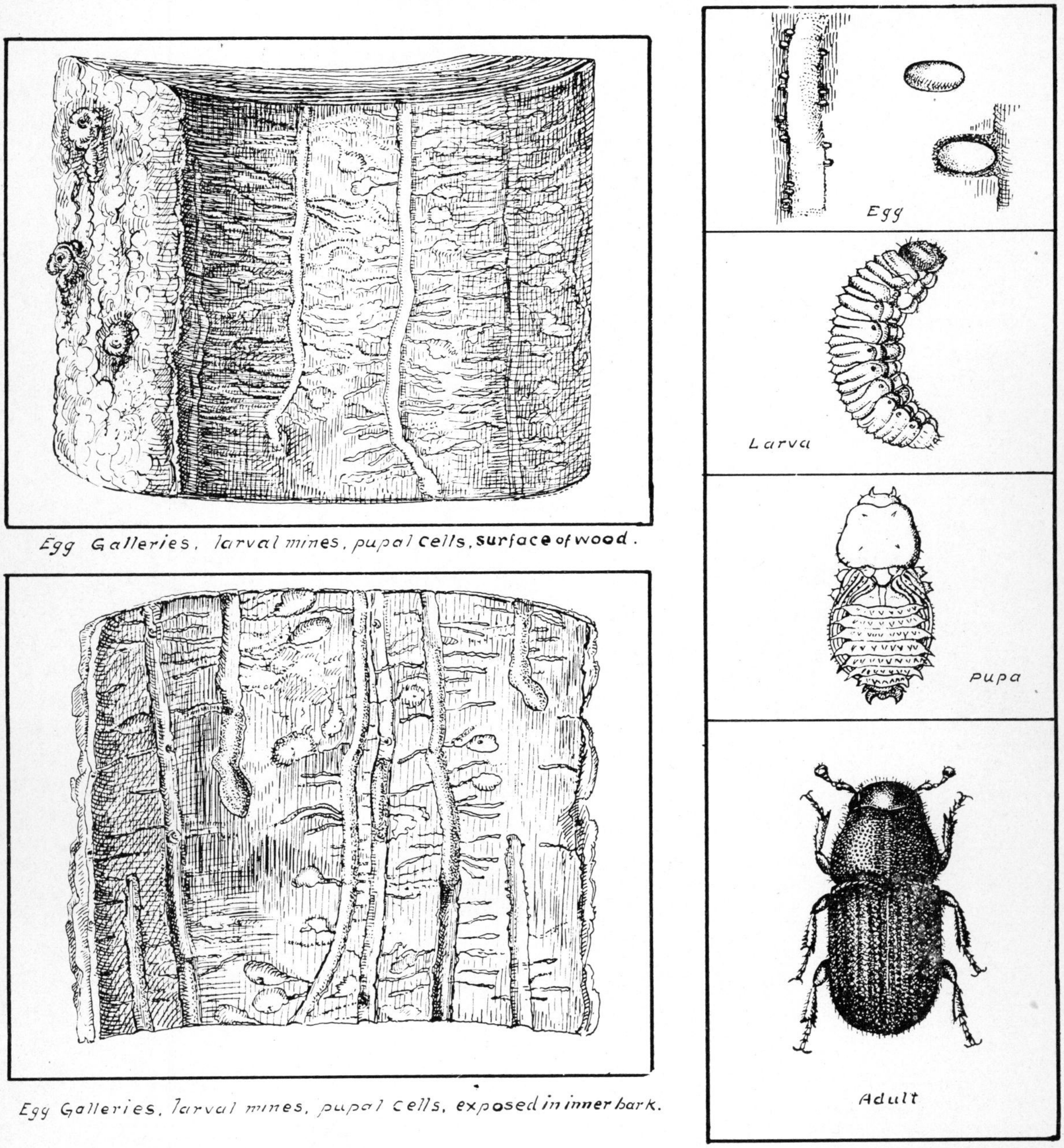
These larval mines may be either in the bark or in the cambium; if they are in the cambium and the egg tunnel is vertical they will girdle the tree if several broods are present. Pupation takes place at the end of the larval mine which may be either in the bark or the cambium. After the pupal period has expired and it is necessary for the beetles to emerge, they bore a tunnel out through the bark. Mating takes place again and the cycle starts over. Usually this cycle takes from four months to two years depending on the species and climate. The western pine beetle is peculiar in that it makes neither a horizontal or vertical gallery, but it makes a long winding egg tunnel which follows no certain pattern. (Fig. 1)

As a family Scolytidae are world wide in distribution, and in the United States some species are found over the entire country while others are limited to small areas. Some species of the family are restricted in distribution because of the limited distribution of their host tree which in turn is limited by climate and soil. An example of this is the jeffry pine beetle, Dendroctonus jeffri, which attacks only jeffry pine and which is found only in a limited area of extreme southern Oregon and northern California. However, most of our destructive beetles have more than one species of host tree or attack a tree which has a side distribution.

Dendroctonus brevicomis attacks Pinus ponderosa and

SEASONAL HISTORY of THE MOUNTAIN PINE BEETLE

Dendroctonus monticolae in Lodgepole Pine.



JAN. to JUNE	JULY	AUG.	SEP.	OCT.	NOV. DEC.
Parent adults Larvae Pupae a few young adults Larvae	Larvae pupae young adults. Some emergence	Adults emerge and attack. Eggs. a few young Larvae	Adults attack Eggs young Larvae	Parent adults Eggs Larvae	Parent adults Eggs Larvae

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Fig. 2

and Pinus coulteri primarily and rarely is found in Pinus lambertiana and Pinus contorta. Its range is from south central California north through Oregon, Washington and into British Columbia, also east through Idaho into western Montana and northwestern Wyoming.(3)

Dendroctonus monticolae attacks all species of the genus Pinus which are native to its range; it is also reported to attack engelman spruce and mountain hemlock. Its range includes British Columbia south through Washington, Idaho, Montana, Oregon, Wyoming, Utah, Nevada, Colorado, California, and parts of Arizona and New Mexico.

Dendroctonus barberi attacks Pinus ponderosa in the southwestern pine region which includes Arizona, New Mexico, Colorado, southeastern Nevada and southern Utah. (Fig. 2)

Dendroctonus ponderosae attacks many of the pines including Pinus ponderosa, P. contorta, P. flexilis and P. aristata, also some other conifers less commonly.

If it were not for the natural enemies of barkbeetles our forests would have been long since destroyed; however, nature has provided many restraining influences which may be divided into four groups; predators, parasites, climatic factors, and food robbers. The predators may still be divided farther into the following groups; insects, mammals, birds, arachnids, and others of minor importance. The insects include the very important predaceous beetles and ants which often destroy large percentages of the broods. The parasites of barkbeetles come under the following classifications; fungi, bacteria, nematodes, and insects.

Very little is known about parasitic fungi, bacteria, or nematodes, but many important insect parasites are known; most of them belong to the order Hymenoptera which includes the bees, wasps, etc. Climatic factors are the most important agencies in keeping the beetles in check, and have been known to control serious infestations in one season. Temperature, precipitation, wind, and snow are the agencies recognized under climatic factors; of these temperature is most important, for both excessively high and extremely low temperatures will destroy barkbeetles. Food robbers help control Scolytids in that they compete for the food supply, often consuming all of the available material and hence causing the larvae to die of starvation.

PRELIMINARY CONTROL WORK

The actual control of barkbeetles includes much more than the mere act of going into the field and destroying the insects. Many preliminaries and much planning must first be tended. The first step is the actual recognition of the infestation; the second step is the organization of the control project; the third step is the spotting of the infested trees.

Recognition of the infestation:

The first recognition of an infestation depends upon men directly in contact with the forests; usually the district ranger is most familiar with the conditions, especially within the boundries of the national forest. In some districts the ranger is required to make an annual report, late in the fall, of the insect conditions which prevail in his territory. Although this practice has not been adopted generally in region six, it seems that it would be the most efficient system in locating insect infestations, especially in the pine country where beetles are prevelant. The following report blank has been set up to be filled out by district rangers when an infestation is located: (6)

1. Date of report.
2. Name of forest officer making the report.
3. Species of trees infested and statement as to part of trees attacked.
4. Character of trees infested, whether large or small, old or young, healthy or sickly, fast or slow growing, etc.

5. Description of the area infested.
   a. Estimate of acreage infested.
   b. Legal subdivisions included in infestation.
   c. Names of drainages or portions of drainages involved.
   d. Map of infestation. (need not be detailed)
6. Estimate of amount of damage.
   a. Volume of infested timber per section, separated by species. Statement as to what portion of these infested trees will, in your judgement, fail to survive.
   b. Value and quality of timber infested and threatened.
7. Distribution of damage.
   a. Range of elevation.
   b. Exposures on which damage is concentrated.
   c. Occurrence of infested trees; single trees, groups, etc.
8. Description of the insects thought to be responsible for the injury. Send specimens of the injured or infested foliage, bark or wood, securely packed in a tight wooden or tin box to the regional office or insect station if there is any doubt as to species of insect doing the damage.
9. Miscellaneous information.
   a. History of the outbreak.
   b. Status of the infestation, namely whether it is increasing, decreasing or in a quiescent condition.
10. Recommendations of the reporting forest officer, particularly whether a more detailed insect survey by a specialist is needed, or whether control operations seem to be needed, or whether there is a possibility of disposing of the infested timber through administrative use or sale. (6)

From this information the regional office will decide whether further investigation by a specialist is necessary.

Organization of a control project:

It must be realized that each control project is different in nature because of its size, species of beetles, and geographical location, and consequently requires many different details in its administration. However, in 1933, region six issued a handbook for insect control which set up an outline for administration and organization plans on barkbeetle projects which should prove applicable to any situation.

The first consideration is the establishment of the boundaries of the area to be treated so that the size of the area, location of camps, etc. can be determined. A map should be constructed with the exact control area indicated on it.

The season during which the field work is to be undertaken is an important problem. In past years work has been carried on both in the fall and spring, and if necessary it can be successfully undertaken either season. There are several disadvantages and advantages for each season which might affect certain projects more than others. These are as follows:

Spring work has the following advantages:

1. More and better light for spotting and treating work.
2. Infested trees are easier to discover and spot.
3. Trees are easier to peel.
4. Trees are easier to burn.

Spring work has these disadvantages:

1. Frequently many beetles emerge and fly before the control operations can be completed.
2. The work may be cut short by the advent of unusually hot, dry weather because of the high fire danger and rapid emergence of the beetles.
3. Burning becomes more hazardous, hence more expensive as the season progresses.
4. The ground is usually soft and the transportation to the camps is difficult.

5. Other forest activities frequently open up about the same time as the control work and make it difficult for the personnel to give the insect control job the same amount of supervision and attention.

Fall work has the following advantages:

1. Most other forest work has closed down and better men and more supervision are more easily provided.
2. The beetles are destroyed before there is any emergence.
3. Some predators may escape destruction, which are burned in the spring work.
4. The transportation is easier except maybe very late in the fall.
5. If for some reason the work is not completed, the winter and spring periods offer opportunity for its completion.
6. The fire hazard is less.

Fall work has its disadvantages as follows:

1. The infested trees are often difficult to find.
2. The bark is harder to peel than in the spring work.
3. Frequently the trees are difficult to burn on account of snow and rain.
4. The camp may get caught in a heavy snow storm and make it difficult and expensive to move out men and equipment.
5. Late in the season, snow may increase the time in walking and working.(6)

The time of year when the infestation is discovered will be a factor, as well as these advantages and disadvantages, in deciding what season of the year field work will be undertaken.

Size of camps must be determined by finding how many laborers will be required to treat the area in a given length of time. If more than one camp is necessary it is less expensive and more efficient to have large camps. The following factors are considered when finding a location for the camp: central location in respect to the working area; general topography of the region; method of transportation; proximity to roads or trails; available water supply; and the intensity of the infestation. After the size of the camp is decided, the equipment for the camp must be listed and collected. This should be thoroughly inspected and checked because damaged or omitted camp necessities cause added expense and often much grief.

The personnel of a 23 man camp (this size is used as a sample because it is an economical size and fitted for most projects) includes one camp foreman, one cook, one flunky, one saw-filer, one spotting crew of three men, and sixteen woodsmen used in treating, whatever the method may be.

Other details of organization include transportation, wages, and communication. It is desirable to have telephone connections if at all possible; if not, short wave radio is now coming into general use.

Spotting:

The actual location and marking of the infested trees in the forest is known as spotting. This operation has almost become standardized in the West, and is carried on in almost the same manner on all projects. Minor variations in the process are caused by local conditions. The work in the field is done by three men; one compassman and two spotters who make a 100 per cent inspection of all the timber in the infested area. The timber is inspected in strips.

A ten-chain strip being covered at one time, the compassman runs a compass line down the middle and each spotter inspects five chains on each side of him. The compassman paces the distance, calling out "Tally one, tally two, etc.", and as bug trees are spotted and called out, he numbers them and plots them on his map. The spotters mark the tree on all sides by blazing, leave a numbered tag on it, and also write the number and their initials on the tree itself with timber crayon. This spotting crew should be made up of active, experienced men who are familiar with the various species of beetles and the outward characteristics of infested trees. Under average conditions approximately 320 acres should be covered in an eight hour day by one crew. The regulations set up by region six require the following records to be kept by each spotting crew:

1. Spotting record of individual trees. The data entered for each tree to be treated consists of:
   a. The number of the tree.
   b. Diameter.
   c. Number of 16-foot logs and board foot volume.
   d. Location of tree by forty and section.

2. Maps of the sections covered by the spotting work on the scale of eight inches to the mile. This map shows the position of each bug tree by its number, and also trails, streams, roads, etc., which would help the treating crew locate the trees.

3. A spotting progress map which consists of a township map on the scale of one inch to the mile. On this map the number of trees to be treated on each 40 acres is entered.

4. A spotting progress record. This is a daily tabulation which shows the number of trees spotted each day, the acreage spotted each day, the total

amount of spotting completed, and the acreage still to be spotted.(6)

As mentioned before these spotting methods are standard in the West for most barkbeetle projects no matter what the actual field control method.

SOLAR HEAT METHODS OF CONTROLLING BARKBEETLES

Utilization of the sun's rays in exterminating barkbeetle broods was one of the first control methods to be used against these destructive insects. The following experiments and projects were carried on using this principle: Craighead's experiments in the East with *Cyllene caryae* in hickory logs(7); F. P. Keen's control work in the Kaibab National Forest, Arizona, dealing with *Dendroctonus ponderosae* in ponderosa pine during 1924-1925; J. C. Evenden supervised a project in the Bitterroot forest, Montana during 1926-1927, dealing with infestations of *Dendroctonus monticolae* in lodge-pole pine. One of the largest projects undertaken using solar heat as the killing agent was the work in Crater Lake Park during 1925-1926, and 1927, where 9,000 lodgepole pines infested with the mountain pine beetle were treated.

The principle underlying this method of control states that if an outside air temperature of 85 degrees *Fairenheit* can be obtained, the temperature beneath the bark of a tree exposed to direct sunlight will be from 110 to 130 degrees F.(8) This high range of temperature is usually hot enough to kill the broods under most conditions. The following table (Table I) shows the relationship of air temperature, bark temperature, and brood kill in an infested lodgepole pine log during a summer day.

Table I

Hour of the day	Air temperature in shade °F	Temperature under bark on top of the log in sun °F	Temperature under bark on top of the log in shade °F	Brood kill %
8 AM	58	60	58	0
9 AM	63	72	61	0
10 AM	68	79	65	0
11 AM	74	104	69	0
12 AM	80	110	76	28
1 PM	85	114	80	100
2 PM	85	122	86	--
3 PM	64	112	69	--
4 PM	61	90	66	--
5 PM	59	72	63	--

Control methods using solar heat are not applicable to thick-barked species such as ponderosa pine and sugar pine, but have been used on lodgepole pine and white pine. The various techniques in applying solar heat will now be discussed.

<u>Treatment without peeling the tree or log</u>:

This method is only applicable to small, thin-barked or young trees. The trees are felled into openings in a north and south direction so that the sun's rays will shine directly onto the trunk the greatest part of the day. The tree is limbed and topped above the infested area; the slash is either piled or scattered away from the trunk. After this preparation the trunks are left to the action of the sunlight for from two to five days; then they are turned half way over to expose the other side. This completes the treatment.(9)

This method of treatment proved successful in the control of Dendroctonus monticolae infesting lodgepole pine. An epidemic was stopped in Crater Lake Park and other successful projects using this method are recorded. However, it has been a failure in some instances where natural conditions were not suited to the method. Costs per tree were $1.22 as compared to $2.00 per tree by the burning method;(9) however, the costs are affected by factors peculiar to the stand being treated. Further data on costs will be found in Table II.

Solar heat with peeling:

A variation of the solar heat method is often used which includes the peeling of the logs. This variation is closely allied to the "peeling" method which depends on predators and exposure to kill the beetles. The bark is peeled and then laid in the sun to get complete kill of the brood. This is only necessary for Dendroctonus brevicomis which lives inside the bark and will usually continue to exist if the bark is merely stripped off.

When the method is properly carried out and weather conditions are favorable, almost complete control is obtained. However the cost is practically the same as that for the burning method used against D. brevicomis, because here all the bark must be peeled whereas in burning only about 50 per cent is removed. Therefore the only advantage lies in the reduction of fire hazard which is very often an important factor in control, especially in the southern range of the beetles.

CONTROL OF BARKBEETLES BY BURNING

Control of barkbeetles by burning has been accomplished in three different ways. First by partially peeling the bark from the logs and then burning the bark around the log. Second by burning the logs without peeling, either singly or in groups. And the third way is by spraying fuel oil on the logs and burning. These various methods will be discussed separately.

Partial peeling and burning:

At present this is almost the only method of barkbeetle control in use in the West. Partial peeling and burning is especially applicable to the control of *Dendroctonus brevicomis* infesting ponderosa pine, and is used exclusively in controlling this destructive insect. The heat from the burning either consumes or cooks all the broods in the bark.

The treating crew, usually of two men, locates the infested tree from the spotter's map. The tree is felled up the hill or down the slope, never with the contour because too great a fire hazard is brought about when the tree lies in a position across the slope. Stumps should be cut low enough to include all the attacked bark, and often it is desirable to fall the tree on poles or branches to keep it entirely off the ground. The tree is limbed and topped, with care being taken to remove the limbs close to the trunk. All of the infested bark on the top of the log and well down on the sides is removed and stacked along the log. The tree is then ready for burning; this is a process which takes some practice to master. During fire weather a fire line is constructed around the tree to insure against the spread of fire to adjoining stands. In wet weather all of the limbs and tops are placed on or around the trunk to insure a sufficient amount of heat to destroy the broods, whereas in warm, dry weather all of the slash is piled outside of the fireline and the bark of the tree will burn readily enough to kill all of the beetles. It is this process which requires skill, for just enough slash is needed to create a hot enough fire to kill the beetles while too much may bring about serious loss to the surrounding stand of timber. This method brings about complete mortality in the broods when properly carried out. Cost figures will be found in Table II.

<u>Control by burning without peeling</u>:

This method has been successfully used in forests where the trees are small and the infestations heavy. The advantages of this way of burning over the previously discussed method is the great reduction in cost of treatment.

The trees are felled in piles as much as possible with the logs parallel and a large amount of inflamable material beneath them to insure a complete burn of the bark. Peavys can be used on small logs in getting them in place in the pile. The limbs and tops are usually thrown back over the pole to help create a hotter fire. As would be expected, this creates a large fire hazard due to the actual size of the burning fire. Consequently, this method is used only out of the fire season; however, on some projects it is used at will, because the infestation is so heavy that most of the surrounding trees are felled for treatment. In this method, as well as all others using fire, great precaution must be exercised in protecting the surrounding green timber.

In lodgepole pine control operations, horses have been used to skid the logs out into an opening to be piled where they may be burned without injuring any standing timber. This has resulted in an actual saving of man labor in the handling of the logs, and has permitted the burning of the trees in larger piles, but has materially increased the cost of the operation because of the rent on the teams. Records show that 50 per cent of the cost of treatment by this method is due to moving of the logs and the brush piling.(10)

This method of burning without peeling insures a 100 per cent mortality of the broods when the field treatment is properly executed, i.e., the bark on the entire infested area of the log must be consumed or deeply charred. In actual field operations 100 percent mortality has been obtained. When the field conditions are suited to this method, the costs are favorably low compared to other methods of control. Detailed cost accounts will be found in Table II.

Control by burning with the use of oil:

This method of using oil to aid burning in controlling barkbeetles seems to be one of the most promising developed yet. It is comparatively economical, quick, and causes no fire hazard. The actual work is described by Keen as follows:

"The trees were felled in such a position as to raise them off the ground and clear of brush and green timber. They were then limbed and the top cut off at the end of the infestation. A small fire was started on the base of the log, a spray stream of oil directed against it, and the fire carried up one side of the bole and down the other. The log was then given a quarter turn, and the unburned sides treated in the same way. One man with a shovel followed the burner and extinguished any fire which dropped to the ground. By never allowing any ground fire to start, the escape of fire and scorching of nearby trees was almost entirely avoided. It was considered that the log had been adequately burned when the bark scales showed white ash margins. Within five or ten minutes the fire was completely out, only the bark was scorched, and the beetles were killed."(11)

The burning equipment used on the project consisted of a five gallon back-pack pump, similar to the standard pump required for fire protection, fitted with a three foot extension and a nozzle designed to vary the character of the oil stream. Ordinary fuel oil with a gravity of 27 and a flash point of 225 degrees F. was found to be the most satisfactory both from the standpoint of slowness of burning and cost.(11)

A variation of this method is used in short stands of trees such as sub-alpine types which have a relatively short trunk. An extension is placed on the nozzle which allows the standing trees to be treated up the trunk to a height of 28 feet. This method was used in the Wyoming National Forest with considerable success; they obtained 96.1 per cent effectiveness. However, they found that it was impossible to estimate the height of an infestation from the ground.

Cost of the work when the trees were felled was $.68 to $1.00 per tree depending upon the thickness of the ground cover, the extra fire precaustions necessary, the distance from the oil supply, and the ability of the crew to adapt the method to each particular situation.(11)

PEELING AS A METHOD OF CONTROLLING BARKBEETLES

This method of barkbeetle control is only applicable to certain species of bark beetles that spend their entire pupal and larval stage in the cambium of the tree. The actual control is obtained by peeling the bark from the trees which exposes the beetles to the elements and to predators. Species such as Dendroctonus monticolae and Dendroctonus ponderosae have been successfully controlled in Colorado, Utah, Arizona, Idaho, and Montana by use of peeling.(10)

The actual field work involves the felling of the trees across each other so that they will be off the ground, allowing the bark to be peeled. Two-man crews work in falling and peeling the trees. As a rule axes are used in peeling; however, spuds and other special tools have been used on some projects. The slash and bark are left scattered around the area or may be piled with the idea of burning later in the season. This adds expense to the operation.

On the Kaibab National Forest in 1925, 97 per cent of the broods were destroyed by peeling. It is generally considered that there is complete control by this method when it is used judiciously in the correct situations.(2) Comparative costs for this method will be found in Table II.

Some specific cases have shown that from 3.7 to 6.1

trees may be treated per day for each man on the treating crew; this varies according to the size of trees and the height of infestation.

In certain special cases when the beetles have not attacked more than seven or ten feet from the ground the bark may be peeled with axes or spuds without falling the trees. This materially reduces the cost of treating.

CONTROL OF BARKBEETLES WITH OIL SPRAYS

The destroying of barkbeetles with the use of oil sprays is one of the newer methods of control which is still in the experimental stage. All of the work along this line has been carried on by G. S. Hensill, J. M. Miller, J. E. Patterson, K. A. Salman, and G. R. Struble of the Berkeley, California, laboratory of the Division of Forest Insect Investigation in conjunction with the Standard Oil Company of California. Most of the work was carried on with Dendroctonus brevicomis in ponderosa pine; however, other barkbeetles such as Dendroctonus jeffreyi and Ips confuses were used in some experiments.

The field work consisted of falling the trees, limbing them and removing the tops. Then the oil was sprayed on with an ordinary fire fighter's back pump. All available grades of oils were used in the tests, but the following mixtures gave the best results:

1. Diesel oil of 27° A. P. I. gravity with crude flake napthalene at the rate of three-fourths pound per gallon. This spray costs about ten cents per gallon. It should be mixed while warm and should be protected from low temperatures.

2. Diesel oil (same grade as above) two parts, stainless creosote one part, lubricating oil, S. A. E. 30 viscosity, one part. The cost is about 30 cents per gallon.

3. Diesel oil (same grade as above) with paradichlorobenzene at the rate of 45 grams per gallon. This gave good results in the 1934 tests.

To compete with other methods of bark beetle control this method must give satisfactory control of the insect. It

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must have a reasonable cost and must be applicable to field conditions. It has the one big advantage of causing no fire hazard, which is important, especially in the southern range of the beetles where the fire season is long.(13)

The mortality of Dendroctonus brevicomis in ponderosa pine was found to range from 18 to 80.4 per cent; while it was concluded that 60 to 70 per cent control may be expected under relatively favorable summer conditions. Results with other species were variable, ranging from satisfactory to unsatisfactory. Several limiting factors were recognized which control the effectiveness of this method; they are the following:

1. Thickness of the bark: Some sugar pines were treated with bark as thick as five inches; results were unsatisfactory. While the same species of beetles attacking thin-bark lodgepole pine were successfully treated. This would indicate that the penetrating oil has more effect on broods in thin-barked trees than thick-barked.

2. Brood resistance: Laboratory tests showed considerable variation in the resistance of individuals and brood stages to the action of oils and oil mixtures.

3. Temperature: The treatment was not effective at temperatures below 50 degrees F. However, exposure of sprayed bark to that temperature for 21 days, followed by exposure to 70 degrees F. for a week, resulted in a satisfactory kill of brood.

4. Moisture: High water content in the phloem of infested trees interfers with the penetration of the oil in to the broods. Especially in newly attacked trees it was hard to get control due to this factor.

Costs were computed from 142 trees which were treated with 1,176 gallons of oil. $3.39 was spent per thousand board feet which is not a reduction over the usual burning method.

CONTROL OF BARKBEETLES BY THE USE OF TRAP TREES

This method calls for the placing of trees in certain areas to be used as traps, i.e., the broods of barkbeetles are attracted to the freshly cut trees instead of the valuable standing timber, after the traps are thoroughly infested they are treated to destroy the broods; usually by burning. As yet this method has not proven applicable except in a specialized case such as maintenance control. Keen says the following about the use of trap trees:

"This method has been tried out extensively, both on commercial and experimental projects, but so far without marked success. Although many injurious barkbeetles are attracted to the traps, they do not absorb any large proportion of the destructive beetles present on an area, nor prevent the attacking of healthy trees in the vicinity. Moreover, the cost of preparing and later treating the trap trees is greater than that of treating the infestation in the scattered standing ones. This method, therefore, has not as yet produced results which would justify its general recommendation and adoption."

No specific costs or results are given for this method, but from the above statement it is obvious that they are high and unsatisfactory.

TREE MEDICATION (POISON) AS A METHOD
OF CONTROLLING BARKBEETLES

For over 100 years the injection of chemicals into the sap stream of plants has been experimented with, for various purposes such as preserving the wood, dying the wood and controlling disease.(15) Only in the last 10 or 20 years has this method been used experimentally against insects.

When used against barkbeetles, no attempt is made to keep the tree alive; the poison is injected into the sap stream in large enough quantities to kill the mature and immature forms of the beetles present in the cambium. The actual injection of the chemical into the sap stream has been one of the problems experimented with in the last few years. Bore-holes and girdles have been used some, but a quicker and more even distribution has been obtained by the following field methods worked out by J. C. Evenden, H. J. Rust, R. A. St. George, and D. De Leon in the Kaniksu and Coeur D'Alene National Forests.(14) This method is known as the "saw kerf rubberized collar" type of tree injection:

"In preparing the tree for this type of injection two paralled saw cuts approximately three inches apart are made completely around the tree, as nearly horizontal as possible, and just above the butt swell of the tree. The upper cut should penetrate the wood from $\frac{1}{4}$ to $\frac{1}{2}$ inch so that the solution may readily enter the water carrying vessels of the freshly cut xylem. The lower saw cut barely penetrates to the wood and is made to facilitate peeling the bark in a narrow strip where the collar is to be attached.

After the band of bark has been removed, the wood surface is scraped slightly to permit a tight, leak proof application of the collar, and a narrow strip of bark is removed perpendicular to and above the peeled band, where the ends of the collar are joined and fastened to the tree. The collar material is then attached around the tree by means of tin strips and shingle nails, and the ends of the collar are overlapped and nailed to the tree in the same manner. The bottom of the collar should be just below and as near the upper saw cut as possible so that all of the solution will be utilized. Following this operation the poison solution is poured into the collar, which stretches sufficiently to hold the desired amount."(14)

Ten different poisons have been experimented with over a course of years: all except copper sulphate, sodium arsenate, and zinc chloride have been discarded because of their ineffectiveness or their extreme toxicity. Bedard reports copper sulphate ($Cu\ SO_4\ 5H_2O$) to be most suited in regards to cost, effectiveness, and ease in handling (14): however, Craighead considers zinc chloride ($Zn\ Cl_2$) most suitable because it will not corrode metal fasteners if the tree is utilized later.(15)

Two-man crews carry on this work in the field with the following equipment: docking saw, 2-inch wood chisel, collar material, tin strips, shingle nails, pack frame and water can, light hammer, mixing bucket, knife, and the poison. One reason that his method has been found unsuccessful in other regions is the rapid rate of spread of blue stain fungus in warmer climates. The distribution of the poison and resultant mortality are apparently governed by the development of the blue-stain fungus. Blue-stain development in turn is dependent upon the time elapsing between attack by the beetles and the injection of the poison, the density of the wood, the temperature, and the intensity of infection. Due to this factor and other physiological functions of the tree the successful introduction of chemicals into trees is limited to those in which the attack is not over 90 days old. This necessarily limits the time of injection to late summer and early fall. The actual mortality of the beetles was found to be over 90 per cent when the above methods were used. This is a sufficient amount to control an epidemic. Complete cost records were kept which showed a very favorable comparison with the decking and burning method now used in Idaho and Montana. Costs per tree were $4.12 by tree medication and $6.13 by decking and burning.(14) The fact that no fire is involved is a decided advantage in favor of this method.

When the trees are treated in this manner, the chemicals act as a preservative to the heart wood which would make it possible to salvage the treated logs for a much longer time after treating than would ordinarily be possible under the usual method of control.(16)

CONTROL OF BARKBEETLES WITH ELECTRICITY

The only experiments along the line of control with electricity were carried on in 1919, by W. J. Chamberlin in southern Oregon. Through the cooperation of the California-Oregon Power Company various field tests were attempted. The general method used was girdling the tree in two places at varying distances apart. Chains were wrapped around the trees where they were girdled and the two terminals were attached to the chains whose wires led through transformers to the nearby power lines.

The problems involved were the determination of the distance apart to place the terminals, the length of time the current should be applied, the most effective voltage and amperage required, and the necessary physiological condition of the tree. The following tests were made and the trees were examined for results:

Distance apart of terminals	volts	length of time applied	results
6 feet	500	17 min.	No beetles killed.
6 feet	2300	not given	Beetles dead about 6 inches from each terminal.
2.5 feet	2300	15 min.	Beetles dead between terminals.
8 feet	11,000	not given	Only a few killed.
35 feet	11,000	not given	The ground was used as the lower terminal; no results
28 feet	11,000	15 min.	All killed for four feet below the upper terminal.

As the above incomplete tests show the method was not fully investigated and as far as tried did not show much promise as a control measure, however, if extensive laboratory tests could be carried on with infested portions of trees, the conditions necessary for control could be accurately worked out. Even with this data the method could not be considered applicable in the field until certain limitations such as the source of electricity and costs of application were overcome.(17)

LOGGING USED IN THE CONTROL AND PREVENTION OF BARKBEETLE ATTACKS

The control of barkbeetles with this method as a rule primarily involves the logging of the infested trees, and secondarily of either destroying the broods by burning the slabs at the mill, submerging the logs in ponds, or taking the logs completely away (20-25 miles) from any timber. It seems that some practice involving logging is the ideal method of controlling the beetles because it wastes no timber and should incur only a small treatment cost as compared with the methods mentioned before.

The first report of the use of this method is in 1907-1908, when Mr. W. D. Edmostron on an estate near Idaho Springs, Colorado, cut 240 thousand board feet of infested timber and sent it to the mill. There it was manufactured into lumber, and the infested slabs burned. This work was very successful in cleaning up the infestation, and was carried out not only at no expense to the owner, but the lumber was disposed of at a net profit of approximately $5.00 per thousand board feet.

The Arrowhead logging company in 1922, placed some barkbeetle infested poles in water to prevent the escape of the beetles to surrounding timber, but they found that the beetles were not killed after several days or several weeks of submergence. Later some experiments were carried on with the submergin of the western pine beetle. It was decided that it is quite possible that many logs would always float with one side exposed to the air, and that some of the beetles would escape from this portion of the log; it might also require more than five weeks to kill those broods which were submerged.

Another example of logging as a control method was carried out as follows. Mr. J. C. Evenden was asked by the Boise-Payette Lumber Company to make an investigation of their timber because some of it was being destroyed by barkbeetles. He found a 17 to 18 per cent loss of trees on one certain area where the attack seemed to be localized. After a careful study he made the following recommendations which were approved by the company:

1. Hot logging should be practiced, and that during May, June, July, and August, logs were not to be left in the woods longer than four weeks.

2. The operation should be continuous until its completion. This would provide a supply of freshly cut logs for the beetles to attack upon emergence from standing trees.

3. At the close of the operation, a proper disposition of all chunks, cull logs and large tops should be made as follows:

a. Material should be peeled and the bark burned after the beetles have attacked and before they emerge. (This would not be necessary if there were no attacks).

b. After the attack, slash should be piled upon this material and the logs etc. severely scorched.

4. The year following the close of operations a careful examination should be made of the timber stands adjacent to the project, and any existing infestations should be promptly treated.(19)

This plan was carried out by the logging company and proved very successful. Most of the beetles attacked the freshly cut logs and were taken to the mill where they died or were destroyed. The next season found only one tree on the entire area that was infested with the beetles.

Another angle to the use of logging in controlling barkbeetles is a prevention measure designed to remove the trees most susceptible to barkbeetle attack and in this way insure against epidemics.

The relative susceptibility to barkbeetle attack as worked out by Keen is one of the major factors in promoting this method of barkbeetle control.

"The classification of ponderosa pine trees according to relative susceptibility to beetle attack, has been worked out by F. P. Keen, Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine, Portland, Oregon. Mr. Keen's system is of great value in determining, in partially cut stands, the trees which show high resistance to Dendroctonus brevicomis. Such trees may be left for future cuttings. His classification is explained in full below:

There are four age groups, and within each, four vigor groups.

Age Groups

Trees are first divided into four age groups--young, immature, mature, and overmature. In average site IV ponderosa pine stands of the Pacific region, the characteristics of these age groups are as follows:

1. Young. Age: Usually less than 75 years. D.b.h.: Rarely over 20 inches. Bark: Dark grayish-brown to black, deeply furrowed, with narrow ridges between the fissures. Tops: Usually pointed, with distinct nodes. Branches: Upturned and whorls.

2. Immature. Age: Approximately 75 to 150 years. D.b.h.: Rarely over 30 inches. Bark: Dark reddish brown, with narrow, smooth plates between the fissures. Tops: Usually pointed, but with nodes indistinct. Branches: Mostly upturned and in whorls for upper half of crown.

3. Mature. Age: Approximately 150 to 300 years. D.b.h.: Rarely over 40 inches. Bark: Light reddish brown with moderately large plates between the fissures. Tops: Pyramidal or rounded. Branches: Upturned near top, those of middle crown horizontal, lower ones drooping; whorls incomplete.

4. Overmature. Age: More than 300 years. D.b.h.: Usually of large diameter. Bark: Light yellow, the plates usually very wide, long, and smooth. Tops: Usually flat and making no further height growth. Branches: Mostly drooping gnarled, or crooked.

In dividing trees into these four general age groups, more weight should be given to relative maturity, or what might be called 'physiological age', than to exact age as indicated by annual rings. Some trees growing under favorable conditions, particularly on good sites, retain their youthful appearance and vigor much longer than do trees that have been forced to struggle against unfavorable environmental conditions, such as those on poor sites. Since trees must be judged largely on the basis of external appearances, those having all the outward characteristics of a given age group should be classed in that group, even though they are actually somewhat younger or older than the designated age limits.

The distinction between Groups 1 and 2 is based largely on color and roughness of bark. While both are sometimes called 'bull pines' or 'blackjacks', only the Group 1 trees have the rough black bark which is so typical of juvenile growth. The change from Group 1 to Group 2 takes place at approximately 75 years of age in the site IV stands of southern Oregon. At that age there is a slowing down in the rate of height and diameter growth, narrow plates appear between bark fissures, and the bark starts to take on the reddish-brown color characteristic of maturity. Suppression in the seedling stage may greatly extend the period of juvenile growth and advance subsequent age limits. The distinction between mature and over-mature trees, Groups 3 and 4, is more difficult to recognize, and involves character of crown as well as bark differences.

Vigor Groups

In judging the relative vigor of different trees of a given age, the size of crown and abundance of foliage are probably the best outward indicators. Therefore, each age group is further subdivided into four sub-groups based upon relative crown vigor. These are designated by letters A to D as follows:

A.--Full, vigorous crowns, with a length of 55 per cent or more of the total height, and of average width or wider; foliage usually dense; position of tree isolated or dominant (rarely co-dominant); diameters large for age.

B.--Fair to moderately vigorous crowns with average width or narrower, and length less than 55 per cent of the total height; either short wide crowns or long narrow ones, but neither sparse nor ragged; position, usually codominant but sometimes isolated or dominant; diameters above average for age.

C.--Fair to poor crowns, very narrow and sparse or represented by only a tuft of foliage at the top; foliage usually short and thin; position usually intermediate, sometimes codominant, rarely isolated; diameters below average for age.

D.--Crowns of very poor vigor; foliage sparse and scattered or only partially developed; position suppressed or intermediate; diameters decidedly subnormal, considering age.

By combining the four age sub-groups with the four sub-groups of crown vigor a total of 16 classes was obtained which could be analyzed for relative susceptibility.

Application to Marking Practice

Susceptible Types.--This group includes all trees with C and D crowns, and, according to relative risk from higher to lower, the tree classes belonging here appear in the following order: 1D, 2C, 4C, 3C, 1C, 3D, 4D, 2D.

Intermediate Types.--This group takes in trees with B crowns in the three older age classes. From higher to lower risk in this group, the order is as follows: 4B, 3B, 2B.

Resistant Types:--This group, on the average, is resistant to beetle attack and therefore comprises the best trees to leave in the reserve stand as far as pine-beetle risk is concerned. From the poorest risk to the best, these classes are as follows: 1B, 4A, 3A, 2A, 1A. All except class 4A are types of trees which are normally left under present Forest Service marking policy."(18)

The United States Forest Service now uses Keen's classification in their marking for timber sales. This use indicates a definite step forward in the use of logging in the control of barkbeetles.

MAINTENANCE CONTROL FOLLOWING BARKBEETLE CONTROL PROJECTS

It must be realized that no method of controlling barkbeetles has as yet been developed which is absolutely permanent. Consequently after money is spent on controlling an infestation, a check-up should be made the next year or two to treat any missed trees or any new areas of infestation. This is called maintenance control.

This has often been entirely neglected, or when it has been carried on, no set method has been followed. On some projects one or two regular fire guards travel through the area and treat the trees as they find them.

This is more or less a problem which must be adapted to local conditions. However, it should always be considered an important part of a barkbeetle control project.

CONCLUSION AND SUMMARY

1. The problem of controlling barkbeetles in the West is an important one. The losses pointed out earlier in this paper show that economically it is necessary to minimize this damage to our forests. Toward this end several methods of control are now in use and others are in the experimental stage.

2. More educational work should be carried on among men in the field so that they can be more proficient in recognizing infestations. It is always important that the infestation be observed soon after attack; when this is possible epidemics are often avoided.

3. Spotting work is now almost a standardized process, however, it must be kept in mind that adaptations to local conditions often save time and expense.

4. The solar heat methods of barkbeetle control are adaptable to thin-barked species or to young stands which have thin bark. This method has proved useful under certain conditions and it should continue to be considered when local conditions are suitable because it is a comparatively inexpensive method.

5. As stated before the practice of partial peeling and burning or piling and burning are the methods now in most general use, especially against *Dendroctonus brevicomis*. Up to the present time these methods have given the maximum control with the minimum cost. Yet, the cost is still prohibitive to the average private logging company.

The use of oil in burning is one of the newer adaptations of the burning method and as yet has been tried very little. It has the advantage of being cheaper than partial peeling and burning because it is not necessary to peel any of the log and in wet weather no time is wasted in starting the fire. Another distinct advantage is the decrease in fire hazard, for if the control is carried on as described above, the surrounding timber should not suffer. I believe that this is one of the methods which will be used in the near future for barkbeetle control.

6. Peeling of the bark as a control for barkbeetles is more or less one of the old standbys in barkbeetle control, and is still considered one of the most successful controls when used under the proper field conditions. However, it also is too expensive for wide, general use.

7. The use of trap trees in controlling barkbeetles has not proven successful as yet. The beetles will attack the traps, but so many trees would be necessary to attract all of the beetles that it would not be feasible.

8. The experimental work with the use of oil sprays in the control of barkbeetles has not proven satisfactory. The high cost of application and the uncertain results obtained mark this experimental method as unsatisfactory.

9. From the extensive experiments carried on with tree medication it seems that it is a less expensive and just as an effective method as the control methods now in general use. Cost figures show that it is cheaper mainly due to the

saving in labor because the trees need not be felled. It must be kept in mind that this method is only adaptable to the northern part of the beetle's range due to the activity of blue-stain fungus which stops the flow of the chemicals. Also the beetles must spend their larval and pupal stages in the cambium to make the method effective. Despite these limitations this method will probably find its place in Washington, Idaho, and Montana, against Dendroctonus monticolae and Dendroctonus ponderosae.

10. If electricity is to be used against barkbeetles it will be rather far in the future after many difficulties have been overcome.

11. The use of logging in controlling actual infestations is the only real way in which the timber is not partially or entirely wasted, yet this is a little known practice in the pine areas of the West. It is possible that an education program along this line, for large and small pine operators, would bring about a more general use of this method. I believe that small "gypo" outfits could contract for areas of infested timber and operate at a profit as well as save money for the timber owner.

The real hopes of minimizing the loss from barkbeetle damage rests in the selection of the trees susceptible to barkbeetle attack and selectively logging these trees. F. P. Keen has made an extensive study of barkbeetle susceptibility which is explained above. With the use of Keen's classification the United States Forest Service is advocating the cutting of the most susceptible trees when sustained yield is being practiced.

12. With the use of the above mentioned methods some inroads are being made against barkbeetle damage, but we can still, and must, improve these methods and reduce the costs of control.

COMPARATIVE COSTS OF CONTROL METHODS

Table II

Control Method	Average size of tree DBH	Ht.	Vol.	Rate of Treating per treater per day Tree	Vol.	Average cost Per tree	Per M
<u>Peeling standing trees at base only</u> (Pinus contorta)							
Small trees (5 ft. Infesed)	12"	30'	100	20.0	2000	$0.40	$4.00
Medium-sized trees (10 ft.)	20"	70'	300	8.0	2400	$1.00	$3.34
<u>Solar heat without peeling</u>							
Small trees	12"	30'	100	10.0	1000	0.80	8.00
Medium-sized trees	20"	70'	300	6.0	1800	1.33	4.45
<u>Burning without peeling</u>							
Small trees (in groups)	12"	30'	100	10.0	1000	0.80	8.00
Small trees (not in groups)	12"	30'	100	6.0	600	1.33	13.33
Medium-sized trees (in groups)	20"	70'	300	5.0	1500	2.00	5.34
<u>Peeling without burning</u>							
Small trees	12"	30'	100	8.0	800	1.00	10.00
Medium-sized trees	20"	70'	400	5.0	2000	1.60	4.00
Large trees	30"	100'	1500	2.0	3000	4.00	2.67

	DBH	Ht.	Vol.	Tree	Vol.	Per tree	Per M
<u>Burning</u> <u>(with peeling)</u>							
Medium-sized trees	20"	70'	400	4.0	1600	$2.00	$5.00
Large trees	30"	100'	1500	2.0	3000	4.00	2.67
<u>Solar</u> <u>heat</u> <u>with</u> <u>peeling</u>							
Medium-sized trees	24"	90'	1000	1.7	1700	4.70	4.70
<u>Tree</u> <u>Medic-ation</u>							
Small and Medium trees	18"	60'	700	6.14		4.12	5.88

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