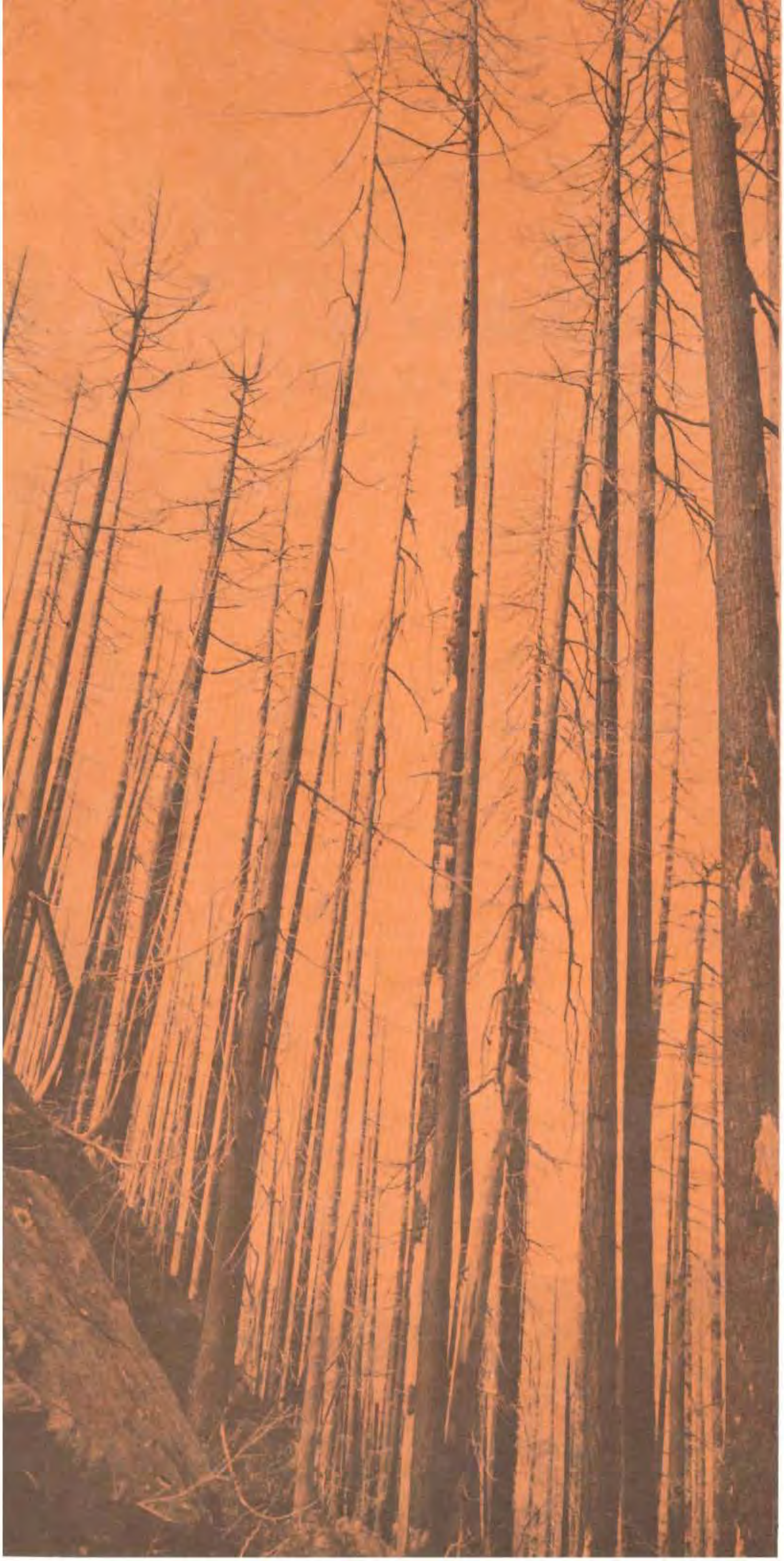

Losses in Fire-Killed Timber

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by
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Wild fires and escapes from operational burns caused an average annual kill of commercial timber in excess of 11 million cubic feet, in the Vancouver Forest District during the past 10 years. Kimmey and Furniss (1943) provide guidelines on the rate of deterioration of fire-killed Douglas-fir but their loss factors appear high for coastal British Columbia. No published information was found pertaining to losses incurred in products manufactured from fire-killed timber in the Northwest United States and British Columbia coastal stands.

High temperatures and below-normal precipitation resulted in extreme fire danger conditions in south-

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coastal British Columbia during the summer of 1967. In August, in the Taylor River valley, near Sproat Lake on Vancouver Island, fire burned over 6400 acres, of which 4400 acres were in commercial timber. Codes of the Canadian Forest Fire Behavior System (1970), calculated from the Sproat Lake weather station, indicated an extreme fire hazard on the day of the fire, i.e., fire weather index 35, build-up index 135 and drought code 574.

About 2000 acres of the burned timber were owned by MacMillan Bloedel Limited. As a result of legal implications, a sampling program was initiated in this timber to define the cause and extent of losses with time since the fire for Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and western red cedar (*Thuja plicata* Donn). Total losses recorded are probably pertinent only to the Taylor River site; however, the cause of damage and rate in breakdown of dead trees should be of interest to others responsible for salvage of fire-killed timber in the Douglas-fir region. When transcribing losses, shown in this report, to other fire sites, the following should be kept in mind. In burns of similar size, losses resulting from direct causes, i.e., physical consumption of wood and charring, are dependent in large part on the species composition and intensity of the fire. Losses resulting from indirect causes, i.e., increased breakage, insect damage and decay, vary among stands primarily in relation to the percentage of mortality and species composition.

Losses from direct causes at Taylor River were estimated to be equivalent to 6% of the total preburn inventory. Those from indirect causes were relatively minor during the first year following the fire, being confined to a degrade in peeler stock resulting from insect activity. Beyond the first year, losses in the log and in the product increased rapidly, particularly in the less decay-resistant western hemlocks; under existing economic conditions, it is doubtful if this species could be logged profitably beyond 4-5 years following the fire. Small diameter stems and upper-bole logs of Douglas-fir were also judged to be of little economic value by the end of this same period in time. Western red cedar showed little deterioration even 5 years after the fire.

STUDY AREA AND METHOD OF INVESTIGATING LOSSES

Stands examined were composed primarily of Douglas-fir (60%), western hemlock (20%) and western red cedar (15%). Most of the trees burned were mature but small and pole-sized immature trees were also killed. Site index for Douglas-fir varied from 60 to 140 on base 50 years. The area burned extended from elevations of about 200 to 2000 ft.

Extent of the burn was accurately established from color aerial photographs.

One hundred and eleven diopter prism (BAF 40) plots were randomly established within the burned mature timber to measure the percentage of mortaility, volume of the preburned inventory consumed or burned beyond recovery to the nearest 10%, and extent of charring for bark and wood. Gross and net volumes (gross volume less fire-consumed wood) were calculated for each plot; loss was expressed as a percentage of the gross volume.

Field surveys were undertaken by experienced personnel to estimate losses for additional breakage, i.e., breakage beyond that which would be expected in unburned timber. Four variables were used for correlations with the percentage of loss: tree diameter, topography, year of logging and tree species.

Insect infestation and penetration of wood decay fungi in killed trees were measured 2.5, 4 and 5 years following the burn. At 2.5 years, five sites representative of conditions in the mature timber were sampled. Twelve Douglas-fir, 4 western hemlock and 3 western red cedar trees were dissected in each site. Sample trees were felled and bucked according to normal cutting practices. An average of five stem cross sections were removed from the top and lower side of the stem adjacent to each cross section and the log surface was examined for insect attack. Holes in the sapwood were classified as to causal insect and quantified per square foot of log surface. Dendroctonus (an insect that mines in the phloem but does not enter the sapwood) egg

Fig. 1 - Portion of burned stand showing killed Douglas-fir and western hemlock.

Fig. 2 - Fire-consumed western red cedar. Cedar in the burned stands characteristically had numerous "dry faces" before the fire. →

galleries were also quantified. Each stem cross section was examined for decay at eight or more points around the circumference. The patterns of visible decay were recorded on "deterioration tree analysis sheets" and the stage of wood breakdown was categorized as advanced (wood could not be utilized even for pulp) or incipient (although subject to degrade, the wood still possessed sufficient strength to allow its use in one or more of the products: plywood, lumber or pulp). Sampling at 4 and 5 years following the fire was the same as indicated above, except that trees were removed from only two sites; 12 Douglas-fir, 12 western hemlock and 5 cedar trees were examined at each sampling period.

To avoid including charcoal in the residue sent to the pulpmill, all logs with charred wood faces were rejected by the sawmill and sold on the open market. Essentially all losses incurred in products manufactured from logs reaching the sawmill were, therefore, the result of attack by insects and wood decay fungi. Losses were categorized in terms of products produced on the basis of species and grade of peelers, saw logs and pulp. In defining decreased value from pulp production, consideration was given to type of decay, increase in fines, low yields because of the low density of decayed wood and low alpha cellulose content, poor pulp grades caused by dark color and reduced strength, poor running properties on the paper machines and an increase in consumption of alkali.

In the analysis, losses were divided into those resulting from direction causes (wood physically consumed or burned beyond recovery) and from indirect causes (breakage, insect damage and decay).

DIRECT LOSSES IN LOG VALUE

The dry conditions before and at the time of the fire, the continuous fuel and the steep topography combined to produce an extremely hot burn (Fig. 1). Small trees and snags were consumed; 17% of the preburn inventory of cedar and 4% of hemlock were lost in this manner. Eighty-four per cent of the mature trees were killed outright.

Besides charred knots, charred bole wood (Fig. 2) was found on all tree species. One per cent of Douglas-fir stems, 20% of hemlock and 50% of cedar (characteristically having numerous "dry faces" as well as thin bark) had some degree of wood charring. As indicated earlier, charred logs were not accepted by the sawmill; consequently, this material, estimated at 5% of the postburn inventory, was degraded and sold on the open market.

A volume estimated to be equivalent to 6% of the total preburn inventory was lost to these direct sources of damage. Also, the majority of trees in the burn had charred knot faces and required special handling to prevent this charcoal from reaching the pulpmill; the costs incurred were not included in the estimate of losses.

Much of the immature timber killed by the fire would have been merchantable at rotation age, but at the time of the fire was not large enough to be economically salvageable. These trees will be destroyed by insects and decay before they can be removed profitably and must be considered a total loss; 18% of the preburn inventory was involved.

Also included under direct charges are administrative and management costs accruing to changes in utilization plans. These vary directly with the operator and characteristics of the burn; consequently, they are not detailed here.

INDIRECT LOSSES IN LOG VALUE

Breakage

Additional falling and yarding breakage attributable to the fire kill, i.e., breakage above the 5% generally expected in an unburned stand, is presented in Table 1. Most of the damage occurred in the upper stem, i.e., in low value logs. Two years following the fire, extra breakage was estimated at 1.5%, at 3 years, 7% and at 4 years, 16%. In addition to this unrecoverable breakage volume, considerable numbers of trees broke into pieces sufficiently long for short logs. This material incurred extra handling costs for the large number of short pieces, additional trim for broken ends, split peelers and short lengths of lumber.

Insects and Decay

Besides causing a serious degrade in products produced from infested timber, insects are directly related to rate of initial deterioration by providing holes in the bark through which decay fungi gain direct and early

Table 1. Falling and yarding breakage attributable to fire killing (additional to normal breakage estimated at 5%) for slope type and tree species in mature stands.

Slope type	Tree species[a]	Years since fire, additional breakage (%) 0-1	1-2	2-3	3-4
Flat to average	F	0	0	5	10
	H	0	0	10	15
	C	0	0	3	6
Average to extreme	F	3	5	10	15
	H	5	8	15	20
	C	5	8	12	18
Extreme	F	5	8	15	25
	H	5	8	17	27
	C	5	8	12	18

a F = Douglas-fir; H = western hemlock; C = western red cedar access to wood tissues.

Wallis *et al.* (1971) present a detailed accounting of the damage present in logs caused by insects and decay 2.5 years after the fire. Ambrosia beetles, cerambycids (primarily *Tetropium*) and siricids were responsible for most of the damage to timber attributed to wood borers in the Taylor River burn. Ambrosia beetle populations built up rapidly after the fire, reaching epidemic levels in the first 2 years; some new attacks in Douglas-fir were noted in the third year. Sixty per cent of Douglas-fir and hemlock were infested in the first year and over 90% by the second year. By the end of the infestation, the number of ambrosia beetle holes per square foot was 2.2 and 1.0 for Douglas-fir and hemlock, respectively.

Cerambycid and siricid attacks were lighter than expected in the first year but built up rapidly thereafter; by the third year, essentially all Douglas-fir and hemlock trees had been attacked by one or more of the wood boring insects; the number of holes per square foot was 2.5 and 2.2 respectively. No new attacks by these insects were found after the second year following the fire; however, an increase in the number of large holes attributable to siricids occurred during the third year because of emerging adults.

During the first 2 years following the fire, insect attacks were confined to the sapwood (average width was 1.5 inches for Douglas-fir, 2 inches for hemlock and 1 inch for cedar). In the third year, the large round-headed borer, *Ergates* (Fig. 3), infested the dead Douglas-fir and, along with earlier established cerambycids, by the fifth year had penetrated the heartwood more than 3 inches. At this latter period, *Ergates* larvae had reached sizes of up to 2 inches in length; activity of this insect will undoubtedly continue and sizes up to 3 inches in length (3/4 inch wide) can be expected.

Wood borer attack in mature red cedar was much less common than in Douglas-fir and hemlock. Less than one-half of the trees were infested and the number of holes per square foot was only a third to a fifth of the number found in the other two tree species.

Bark beetle (*Dendroctonus pseudotsugae*) were present throughout the burn. However, salvage operations, which commenced shortly after the fire, removed much of the brood and helped to keep the population small.

Decay during the first year following the fire was not sufficient to be of concern to those responsible for utilization of the burned timber. However, a number of wood decay fungi became established in the sapwood during this period so that by the middle of the second year, 36 and 51% of the sapwood (12 and 24% of the total tree volume) of mature Douglas-fir and hemlock, respectively, were visibly decayed. Approximately one-third to one-half of the decayed wood was judged to be of no value even for pulp.

By the fourth year following the fire, wood decay fungi had penetrated to the depth of the sapwood and were well established in the heartwood; 40 and 52% of the total tree volume of mature Douglas-fir and hemlock, respectively, were infected. By the fifth year, economic salvage of hemlock would be questionable, with 75% of the total volume decayed. Large butt logs of Douglas-fir still contained utilizable material 5 years following the fire; 42% of their volume were decayed

Fig. 3 - Large, round-headed wood borer, Ergates, infesting dead Douglas-fir.

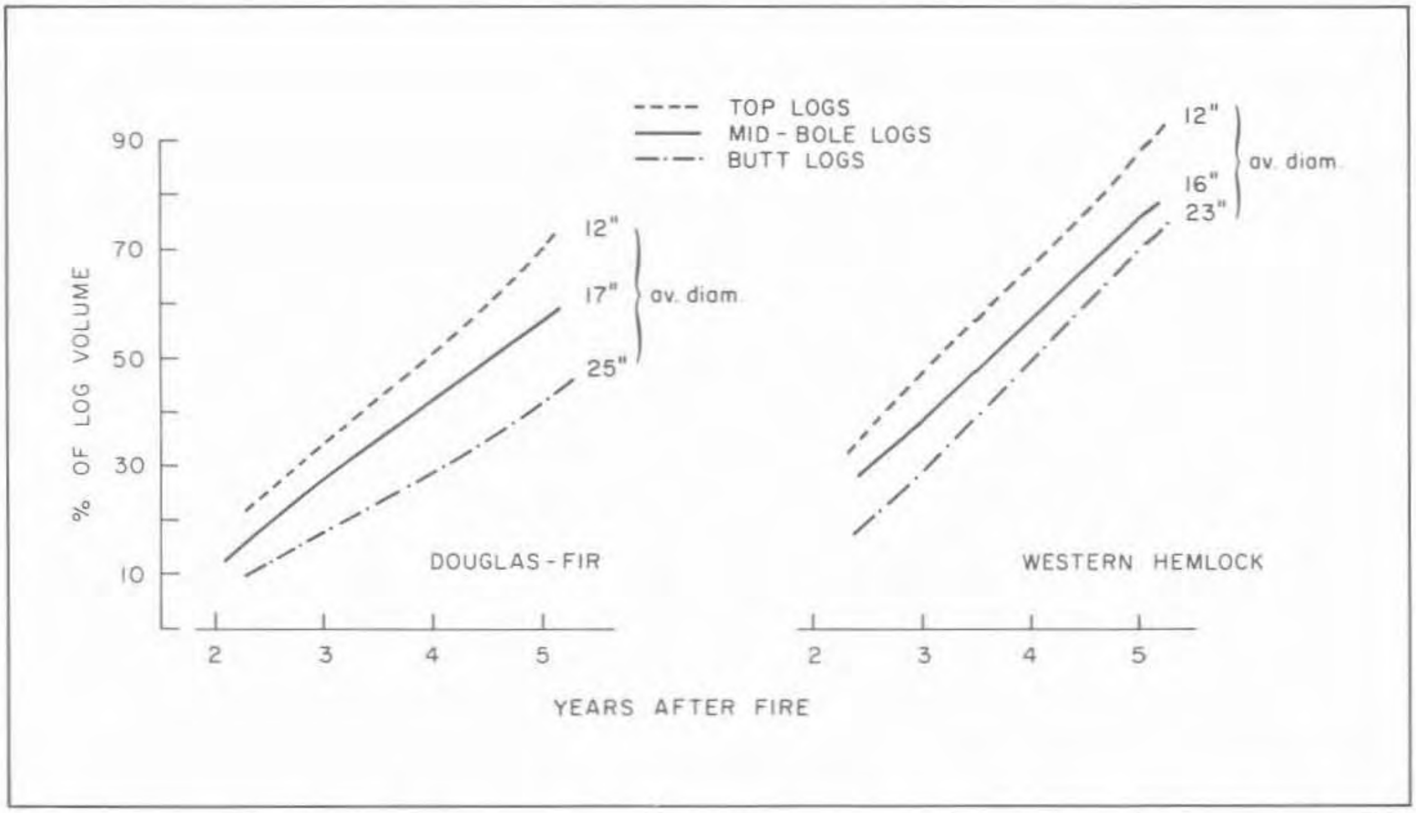

Fig. 4 - Percentage of the total log volume of mature Douglas-fir and western hemlock decayed 2.5 to 5 years after fire-killing.

Fig. 5 - Advanced brown cubical decay in upper-bole log of Douglas-fir 5 years after fire killing. →

Fig. 6 - Extensive rot in upper-bole log of Douglas-fir (left) 5 years after fire killing compared to the almost total absence of decay in western red cedar (right) killed in the same burn.

(Fig. 4). Small upper bole logs had 70% of their volume decayed at 5 years (Fig. 5) and were of little economic value. The percentage of decay volume considered unmerchantable even for pulp increased with increasing time since the fire; at 5 years, 60% of the decay volume were placed in this category.

Decay reduced the percentage of sound wood volume most rapidly in the small diameter trees and upper-bole logs. As early as 2.5 years after the fire, 25 and 40% of the volume of the top logs of mature Douglas-fir and hemlock, respectively, were visibly decayed (Fig. 5). By the fourth year, with over 50% of the volume decayed, economic salvage would be doubtful.

Even as late as the fourth year following the fire, decay was relatively minor in the bottom 3-4 ft. of the bole, particularly of Douglas-fir. It is important to note, therefore, that any attempt to estimate decay progression in standing trees by sampling the lower bole could be quite meaningless.

Fungal attack in mature cedar, even 5 years after the fire, was confined to staining and minor decay in the sapwood (Fig. 6). Losses were not considered to be of economic significance.

MILLING LOSSES

Degrade in the products manufactured from fire-killed timber was minor during the first year following the burn; degrade in peeler stocks because of insect attack started toward the end of the first year. However, damage increased rapidly thereafter; both direct and indirect losses were recorded.

Most of the direct losses occurred at the barkers, where sapwood with advanced decay was removed and burned along with the bark. Some advanced decay reached the chippers and disintegrated into fines. These fines passed through the chip screens and were burned, plugged the screens, or passed to the digesters, causing a reduced yield of pulp and an increase in the consumption of chemicals to maintain quality.

Most veneer peeled from logs fire-killed for more than a year contained insect damage and decay pockets (Fig. 7) and was automatically degraded to core stock (Table 2). By the end of the third year following the burn, most of the sapwood was decayed and was no longer of value for veneer stock.

Table 2. Percentage of the dollar value of peerlers and sawlogs estimated to have been lost as a result of insect and decay damage 2, 3 and 4 years after the timber had been killed by fire.

Grade	Species	Years from burn 2(1969)	3(1970)	4(1971)
		per cent loss in dollar value[a]		
Peelers				
No. 1 and 2		7	8	10
No. 3		11	12	14
No. 4		4	6	10
Core logs		4	7	15
Sawlogs	Douglas-fir	7	11	14
	hemlock	8	13	21

a loss in value of logs that reached the mill.

Lowering of the sawlog grades and loss of an overseas market for the affected timber during the first 2 years following the fire was attributable, for the most part, to insect activity. Most fungi that invaded the sapwood caused brown rot, i.e., primarily cellulose and hemicellulose tissues were destroyed. These fungi caused a rapid loss in the strength properties of wood so that by the third year following the burn, the majority of the affected material was no longer suitable for structural lumber. Estimated loss in percentage of dollar value of lumber produced from the fire-killed timber arriving at the mill is shown in Table 2.

SUMMARY AND CONCLUSIONS

Magnitude of losses occurring following fire kill in mature timber is directly related to the extent of the burn, intensity of the fire, tree species and rate of salvage. Where the fire is relatively cool or the timber affected is thick barked, e.g. Douglas-fir, and salvage is completed in the first year, losses in all probability will be of minor consequence. Where a fire is hot and salvage is delayed, consideration must be given to both direct and indirect losses.

Direct losses result from the physical consumption of trees, in total or in part, and, depending on the size of the timber, may account for up to 10% of the preburn inventory. Direct losses during milling occur primarily at the barkers, where advanced sap rot is lost with the bark, and at the chippers where advanced decay is reduced to fines with its attendant problems.

Indirect losses arise from increased breakage, insect and fungal activity and product degrade. These losses will be minor during the first year, increasing relatively rapidly thereafter. By the fifth year after the burn, economic utilization of species such as hemlock will be in question and utilization of moderately decay-resistant species, such as Douglas-fir, will be confined to the butt log of large trees. Small diameter trees and small top logs will have little value by the end of the

Fig. 7 - Ambrosia beetle holes and fungal stain in Douglas-fir plywood.

fourth year because of increased breakage and extensive decay.

Following large burns, a significant buildup in wood borer and bark beetle populations can be expected in dead and dying trees. Early salvage contributes to a reduction in these populations through the removal of young broods before they emerge. Where salvage is delayed, heavy attacks on burned trees will occur from increased populations and migrations from surrounding areas.

Degrade in products manufactured from the fire-killed trees will be minor in the first year, being confined to peeler grades. However, with increased insect and decay activity, losses will multiply rapidly thereafter; face veneers will be degraded to core stock, infested saw timber will be prohibited on the export market, structural grades will be lowered because of reduced strength, and increasingly higher volumes of peeler and lumber grades will be consigned to pulping.

In summary, the forest manager should consider the following in weighing his decisions concerning the salvage of fire-killed timber:

1. Because of the rapid progression of deterioration, utilizable fire-killed timber should be salvaged immediately.
2. Most of the volume of small diameter trees will be lost to decay within 3 to 4 years following the fire; stands with a high percentage of this material probably should be salvaged first.
3. In contrast to 2, the first and most severe product degrade will be peeler grades as a result of insect attack.
4. Where there is a choice, stands with a high percentage of decay susceptible species, e.g. western hemlock and the true firs, should be salvaged before stands containing decay resisting species such as Douglas-fir and western red cedar.
5. Consideration might be given to felling fire-killed trees even though they can not be removed immediately, to reduce the increased breakage and because deterioration of logs touching the ground is apparently slower (Smith *et al.* 1970).
6. Leaving large patches of dead timber adjacent to healthy stands will increase the risk of mortality in the green trees through migration of insects from the killed timber.

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