Chip pile storage—a review of practices to avoid deterioration and economic losses

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Chip pile storage began in the 1950s with the use of wood products residuals as a major source for pulp chips. Storage was required to handle the intermittent flow of chips to the mills. Chip piles were also used to build inventory for periods of the year when wood delivery was low, such as in the winter and rainy seasons. In the early years of using chip pile storage, there were catastrophic losses of chip piles as a result of high temperatures and even fire. Numerous studies have determined the mechanisms that cause this deterioration, and methods have been developed to control the deterioration and reduce economic losses. Part of this inventory strategy includes equipment that has been specifically designed for storing and handling chips. This summary brings the past work together into a prescription for chip pile management that can be adapted to any mill that stores chips.

Keywords: Chips • Outdoor storage • Temperature • Decay

Given the current technology and equipment available for storing chips and the knowledge of how chips are deteriorated in a pile, there is no reason that a mill should find itself in the situation where a chip pile has heated to high temperatures and, at worst, is burning in the interior (*1-3*). The mechanisms of deterioration have been thoroughly studied in North America and Europe (*4-8*).

Sequence of temperature rise

The sequence of events that would lead to such a catastrophic loss can be tracked using temperature as an indicator. In Fig. 1, the temperature profile for several types of piles is plotted. Note that the key variables are pile height and the degree of compaction. Let us follow the development of these temperature curves.

First 5-7 days

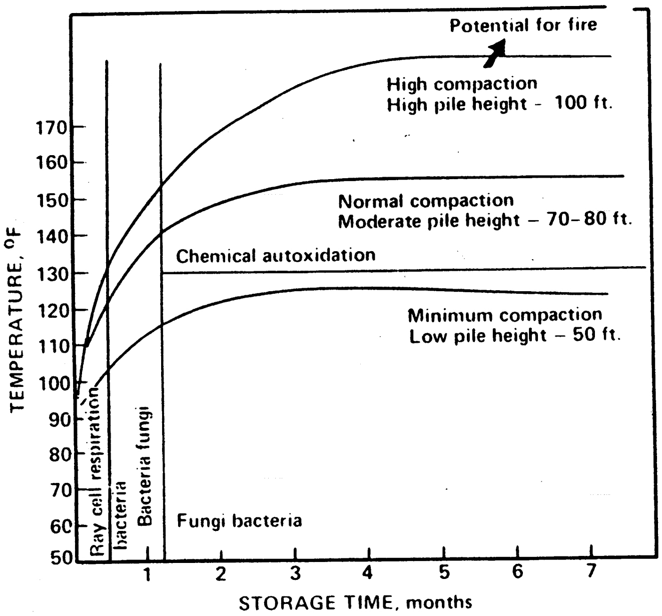
Living cells are contained in the bark, foliage, and wood when the tree is cut. These cells remain viable for long periods of time when the wood is stored in log form (*8, 9*). They live for up to six months under certain conditions. Most of the bark and foliage is removed when the tree is prepared for pulpwood, except in whole-tree woods chipping.

When wood is chipped and placed in a pile, the living cells in the wood rays (also called parenchyma) respire in what amounts to an attempt to heal the tree. Oxygen is consumed and heat is released. This heat generation provides good growth conditions for bacteria, which feed on the extractives in the wood—particularly the starches in hardwoods such as aspen, alder, and the tropical hardwoods (*10-12*). At the end of a 7-14 day period, it is not unusual to find that the temperature in a chip pile has reached 120°F. This is true for conifers and hardwoods. The rate of heating is influenced by the rate of pile construction and the freshness of the wood. At the extreme, tropical hardwood and whole-tree chip piles have been reported to heat rapidly to temperatures of 120-180°F in 5-7 days. Some rapidly developing molds have been reported to have developed in this short period of time, but this is not enough time for the wood rotting fungi to develop, and at this high temperature, they will not grow well.

Next 1-4 weeks

The events that occur in this period are largely influenced by the factors that limit air circulation in the pile. Tall piles and piles that have been compacted by either tractor activity or the presence of large amounts of chip fines and

1. Mechanisms of pile deterioration.



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sawdust have low air circulation rates (*13*). Therefore, the heat that is developed in the pile dissipates slowly. Once the temperature reaches 140–160°F, a chemical reaction occurs in which the acetyl group attached to each cellulose molecule is cleaved from the chain forming acetic acid (*14*). This reaction produces heat and raises the acidity of the pile. The increased heat, of course, drives this reaction even faster if it is not dissipated, releasing more acid.

One month and beyond

While acetic acid is not a strong acid, its presence in large quantities causes deterioration of wood by attacking the cellulose molecule to shorten the length of the molecule. This has the effect of reducing the pulp yield and strength once the wood is removed from storage and is used in the mill. The increase in acidity and heat darkens the wood, and it eventually crumbles as if actually burned. Figure 2 shows some samples removed from a fairly low (only 40 ft tall) but highly compacted chip pile. The pH of the darkened chips is 5.0 and 3.5 respectively. At this low pH, the chips consume as much as 30–40 grams of 0.1-*N* sodium hydroxide per gram of wood to neutralize them. This expression of acidity is referred to as the buffering capacity (*15*). This means that an equivalent amount in kraft cooking liquor will be consumed before pulping can even begin. In normal practice, use of large quantities of these badly deteriorated chips would upset cooking by consuming most of the chemical before the fresh chips could begin cooking, resulting in low yields and high pulp-screen rejects. Some mills have uncovered these darkened chips and in error assumed that the pile had caught fire because of the dark, crumbly nature of the chips. The result is almost as severe as a fire, and such chips are not worth trying to use even in small quantities.

Again, depending on compaction and heat release, the pile temperature can follow several paths. The somewhat individual nature of chip piles is most evident at this point. The conditions that lead to higher temperatures and eventual actual combustion seem to often involve such factors as layers of fines trapped in the pile, pockets of hardwood chips buried in the pile, highly compacted areas around roads leading to the top of the pile or around reclaim areas that are themselves seldom reclaimed, and tall piles built rapidly with no rotation of the inventory. The mechanisms that lead to high temperatures above 180–200°F are assumed to be exothermic chemical autoxidation reactions of the cellulose at low pH. Biological organisms have low tolerance to these temperatures. In addition, there is indication that wood exposed to temperatures in the range of 200–300°F undergoes slow pyrolysis. After a time, the heat of pyrolysis cannot be dissipated to the surroundings, and the temperature rises to the point of ignition (*14*). These conditions can exist in a chip pile if temperatures are not controlled. This also explains why wood frame and paneling in a house catches fire more easily and often unexpectedly when exposed to the constant high temperature of a wood-burning-stove pipe or free-standing fireplace. The prevention of high temperatures and emergency measures to reduce temperatures will be discussed later.

Thus, the mechanisms that lead to temperature build-up are complex and follow a sequence that depends on many factors such as wood freshness, species, pile height, compaction from fines layering, tractor activity, and season of the year. The role of rapidly developing organisms (mold and bacteria) and living ray cells dominates the early stages of deterioration. At higher temperatures, chemical reactions are most active. In low-height and uncompacted piles, the numerous wood-rotting fungi are able to slowly deteriorate the chips after the initial heating period or when temperatures drop below 120°F, where the fungi can more actively grow (*2, 6–8*).

2. Comparison of fresh and heat/acid deteriorated chips. In the background are fresh chips. The small pile of chips on the left was exposed to temperatures in excess of 175°F for a period of 3–4 weeks (pH = 4.5; buffer capacity = 10–15 mL of 0.1-*N* NaOH). The chips on the right were exposed to these temperatures for 6–8 weeks, are a dark color, and have a strong acetic acid odor (pH = 3.0; buffer capacity = 30–35 mL of 0.1 *N* NaOH).

By-product recovery

Mills in the Southern U.S. that are using coniferous species with high enough resin contents are concerned with the yield of tall-oil and turpentine (*16, 17*). These materials are of significant value, and efforts to retain these extractive-based materials usually have a high return. Losses of resinous materials occur rapidly in chip piles, as shown in Figs. 3 and 4. Within 4–8 weeks, 60–80% of the yield of by-products is lost. Turpentine is lost more rapidly than tall oil. The only commercially feasible way to prevent these losses is to shorten the rotation cycle or, as proposed by Springer, maintain a stand-by pile while using the rest of the fresh chips (*18*). Landry has proposed a method for tracking the potential recovery of by-products and monitoring the losses due to inventory as a way to justify the costs of more rapid chip pile rotation (*17*).

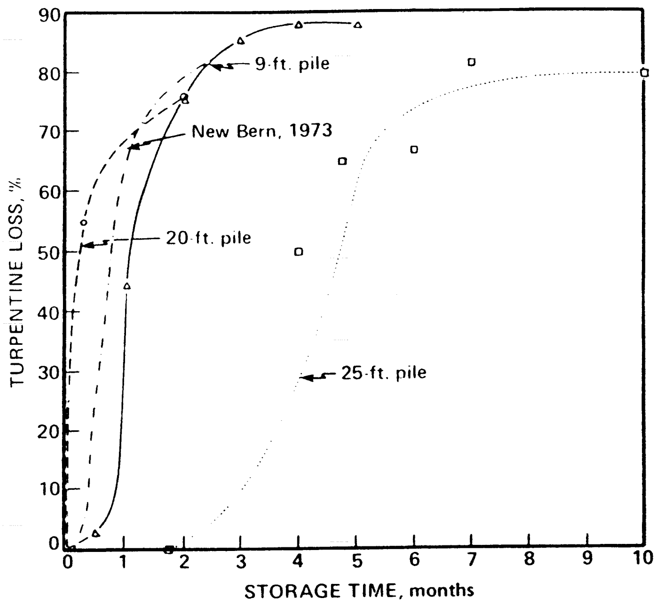
Chip pile treatment

Numerous chemical and mechanical methods for treating chip piles to prevent deterioration have been proposed in the last 20 years, but none have been used in long-term commercial practice (*19, 20*). Economic evaluations and the increasing price of wood have made treatment of wood impractical. During the 1970s, it appeared that it might be practical to treat wood purchased at a low cost for use at a later date when supplies were less abundant or the price had risen sharply. As wood costs and interest rates have risen sharply over the last decade, this concept has been abandoned.

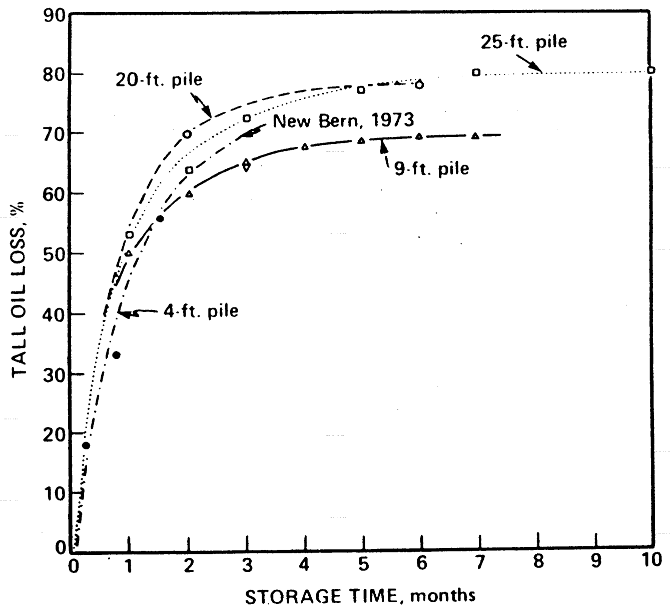
Inventory strategy and economics

As the cost of chips and interest rates have increased, it has become more attractive to maintain less and less material in storage. Determining the optimum inventory has brought into use simulation models of various types (*21-23*). The basic approach is to weigh the total costs of inventory (wood, physical losses, mill losses, and interest on investment) against the risk of running out of chips. Analytical techniques used in other industries for parts and products have recently been applied. Finke used the beta-type probability analysis to derive a risk and cost analysis as shown in Fig. 5. The advantage of this method is that it draws together the wood supply organization and the pulp mill staffs to develop the probabilities of wood supply for each source and chip use for each product jointly and then to agree on the level of risk of running out of chips the company as a whole is willing to incur. In cases where it has been applied, it is not unusual for inventories to be reduced by a factor of from 3 to 6. Mills that have gone to the lowest levels on the risk curve (point A) have yet to run out of chips.

3. Loss of turpentine by-products.



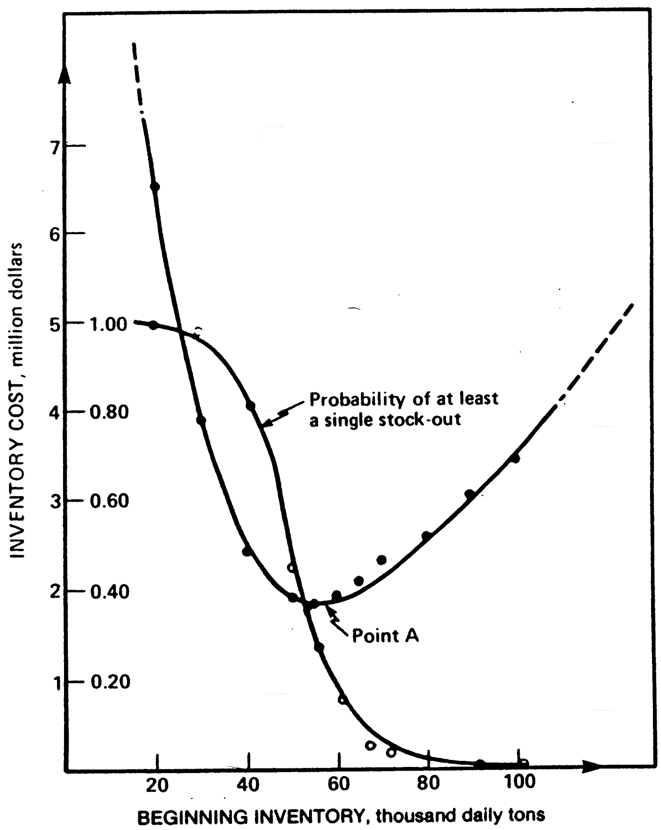
4. Loss of tall oil by-products.



The out-of-control chip pile

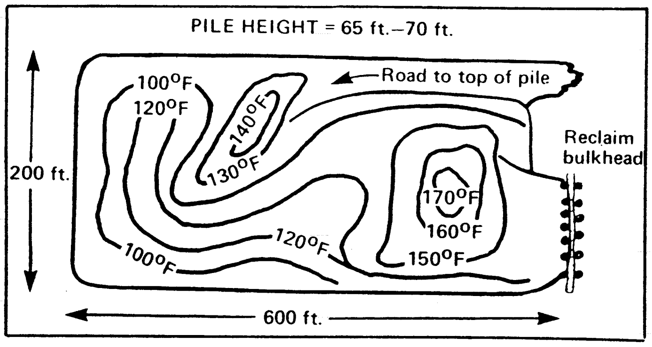
There may be an occasion when attention to chip pile management is not adequate and the pile does get out of control. The first signs of this are high temperatures and acetic acid odor observed by the chip pile operators. The first thing that must be done is to identify the extent and severity of deterioration. A long-probe soil thermometer is used to measure the temperature at the surface of the pile

5. Example results of inventory target analysis to determine optimum chip pile inventory size.



by setting out a grid as shown in Fig. 6, an example of a Douglas-fir pile that was out-of-control some years ago. Once the areas of high temperature were mapped, the decision to ventilate the pile by digging trenches in the areas of highest temperatures was made. The trenches reduced the temperatures from a high of 170–185°F to under 150°F. The pH of chips removed from the trenched area was 3.5–3.8, and the buffer capacity was 25–35 mL of 0.1-N NaOH per gram of wood. This is typical of a chip pile in this serious stage of deterioration. It has been found in observations of piles that the heat is highest at the surface in the general area of the highest internal temperatures. The internal temperatures are from 10–20°F higher than the surface temperatures. If high inventories are unavoidable, a program to monitor chip pile temperatures at least twice a week should be started when the pile height is over 50 ft tall or if it is known that compaction in the pile is high. The mill should also have some idea of chip pH and of the buffer capacity on fresh chips of their species mix for comparison to chips that are suspected to have deteriorated in the pile.

6. Chip pile temperature profile (Douglas fir, pile height of 65–70 ft).



Prescription for chip pile management

Based on the combined experiences of the industry, a prescription for maintaining chip pile inventories is proposed. Mills that have followed its guidelines have not only been able to avoid previous high-temperature catastrophic losses but have also increased by-product recovery and reduced the overall mill operations costs. As shown in the prescription in Table I, each guideline has a basis in the fundamental mechanisms of chip pile deterioration. This prescription is a summary of the state of the art in chip pile management that can be further augmented by installing chip pile handling equipment that will allow complete rotation of a pile at regular intervals. Such systems utilize mobile outstocking and reclaim conveyors and require no tractor activity to spread the chips. The pile height is limited to a fixed level, usually near the prescribed 50-ft target. The use of reclaim systems that recover chips from under the pile using a screw conveyor are also gaining popularity. Bottom reclaim systems have the capability of full reclaim on a first-in/first-out basis. The use of a model, as shown in Fig. 5, to design the size of the chip pile inventory system will allow a smaller system to be installed, thus allowing more automated equipment to be justified. Multiple outstocking and reclaim points allow pile rotation at shorter intervals. Chip costs require that more than ever, we regard chips as an investment to be handled carefully in storage, to maintain the value that has been created in precision chipping, extensive screening, species segregation, and chip quality-control programs. Following the elements of the chip inventory prescription presented here will help maintain that high value.

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I. Prescription for chip pile management (*24*)

Recommendation	*Deterioration mechanism involved*
1. Maintain pile height below 15 m (50 ft).	Avoids compaction and allows faster escape of heat generated by biological growth and chemical reactions.
2. Restrict tractor spreading of just-delivered chips to a minimum.	Avoids excessive compaction that slows the escape of heat, particularly in the reclaim pit or conveyor area. Reduces fines created by tractor movement.
3. Mix species of different deterioration rates only as needed, especially fast-deteriorating hardwoods (aspen, alder) and full-tree chips.	Avoids burying pockets of chips in the pile that have a high rate of heat generation and result in a larger zone of high-temperature deterioration.
4. Store full-tree chips, which contain bark, foliage and a high proportion of living parenchyma (ray cells), in piles less than 8 m (25 ft) high, and for less than 2-4 weeks.	Bacteria, mold and fungi can thrive on the fresh wood, bark and foliage, causing a very rapid buildup of heat.
5. Avoid mixing fine particles (sawdust, shavings, chip fines, and pulp mill knotter rejects) in chip piles, particularly where layering can occur.	Avoids creating a compacted zone that prevents heat escape.
6. Monitor pile temperature routinely.	Determines the heating pattern for the particular storage system of the mill. Allows early detection of heating problems

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Note: °C = (°F - 32) × 5/9.