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# Chapter 6:

# Fire Effects on Materials of the Historic Period

In a literal sense "historical artifacts" and "historical sites" are all artifacts and sites dating after the introduction of written history in any region. For example, in New Mexico, these would be sites dating after AD 1540, the year of the first Spanish *entrada* into what would later become the State of New Mexico. In many instances, historical sites can also include those sites created by American Indians who possessed at least some Euro-American objects, and/or whose methods of construction were influenced to some degree by Euro-Americans. The National Historic Preservation Act defines antiquities as over 50 years old; therefore, even late 20th century historical sites may be considered eligible to the National Register of Historic Places. (It is important to note that **only** cultural resource specialists can make a determination regarding the eligibility of a cultural resource to the National Register of Historic Places; see chapter 1.) Given this time depth and regional/ethnic diversity there exists a wide variety of historic architectural designs made of materials such as adobe, sod, logs, planks, firebrick, formed concrete and, quite often, combinations thereof. Artifacts present at even the most humble of historical sites can number into the thousands; virtually anything listed in a nineteenth century mail-order catalog could be found on a frontier ranch.

There are countless historical sites that have been continuously occupied up to present-day, resulting in an even greater variety of building materials and artifacts of varying degrees of combustibility. For example, a cabin built in 1870 might have the original log walls exposed in the interior rooms, its exterior walls lined with turn-of-the-century clapboards, which in turn are overlaid by aluminum siding installed in 1955. The nearby trash dump might contain fragments of ca. 1870 whiskey bottles, parts from a ca. 1900 wood stove alongside 1930s automobile tires, all capped over by a 1968 "Avocado Green" refrigerator. A grass fire might not affect the house, but the 1930-vintage tires could catch fire, resulting in destruction of the historic dump.

A review of the literature regarding effects of fire on cultural resources indicates an explicit bias in favor of studying the effects of fire on prehistoric resources, as opposed to studying these effects on historic structures and artifacts. Consequently, the following information is based in part on unpublished, anecdotal observations, conjoined with empirical data obtained from experiments conducted by arson investigators. The latter data contain a wealth of information that should be consulted by cultural resource managers and fire managers when considering the effects of fire on the wide array of historic period materials.

## Types of Fire Damage

- *Distortion* happens when materials change shape, temporarily or permanently, during fires. Nearly all materials expand when heated, affecting the integrity of solid structures when they are made from several materials. If one material expands more than another material, the difference in expansion can cause the structure to fail.
- *Spalling* is a condition associated with masonry plaster and concrete building materials and some artifacts. The primary mechanism of spalling is the expansion or contraction of the surface while the rest of the mass expands or contracts at a different rate. Spalling of concrete, masonry, or brick usually occurs due to high temperatures from an accelerant, for example, creosote-soaked railroad ties used as building material (NFPA 1998). An example of spalling on artifacts occurs when the colorless glaze on historic ceramics separates from the underlying ceramic paste.
- C*harring* is the carbonization of a fuel during heating or burning. The rate of charring is nonlinear and varies with wood density, a property that varies with species and growing conditions, and with the duration of heating. An often-quoted simple "rule of thumb" for pine is that charring occurs approximately at the rate of 3.5 cm (1.4 in) per hour at 750 °C (1382 °F) (DeHaan 1991).
- *Calcination* refers to the various changes that occur in cement- and gypsum-based plasters during a fire. Calcination involves driving the chemically bound water out of the plaster, turning it into a crumbly solid (NFPA 1998). Charring of organic binder, if present, will also weaken the plaster.
- *Build-up* of hazardous, highly flammable vegetation within abandoned/collapsed structures is a common occurrence at historic sites. *Collapsed, rotted roof beams* can catch fire quickly, especially if dry vegetation, for example, tumbleweed, has piled up within or adjacent to the structure. Once ignited, the building materials become the primary fuels that will dictate severity of the fire and the resulting effects on its contents.
- *Fighting the fire* may cause some site damage. For instance, use of water to fight a fire on a historic trash dump could crack super-heated artifacts; use of a fire rake over a trash dump could damage the artifacts; and chemical fire retardants may alter the surface appearance of artifacts.
- *Removal of vegetation* by a fire may result in erosion of the site, and exposure of surface artifacts might lead to site vandalism.

## Historic Structures

### Native Materials Structures

American Indians traditionally used readily obtainable raw materials from the land around them, fashioning structures from wood, bark, leaves, grass, reeds, earth, snow, stone, skin, and bones. Their principal types of construction were (1) tensile or bent frame with covering for example, wigwam, wickiup; (2) compression shell, for example, hogan, tipi; and (3) post-and-beam wood frame with various walling materials, for example, earth lodge, plank house (Nabokov and Easton 1989). Such structures usually were not conceived as articles of permanent craftsmanship; once abandoned they quickly deteriorated. However, aboveground remnants of late prehistoric and historical periods combustible structures exist in the arid and/or high-elevation regions of the United States and Canada.

American Indians sometimes incorporated building materials of Euro-American origin since at least the mid-19th century. Such a structure might follow the traditional building form yet be constructed of an amalgam of native and Euro-American building materials. Euro-American building materials are intended to last for many years even after structural abandonment and collapse; therefore, such objects as firebrick, milled lumber, and corrugated roofing may also be the surface indicators of an American Indian historical site.

**Adobe**—Soil for the making of adobe bricks or for use in rammed earth walls is available in virtually unlimited quantities almost everywhere. Proportions of sand, silt, and clay vary in the ground. If these proportions are unsuitable, the soil is tempered or balanced by the addition of another material, such as straw, hay, or other fibrous vegetal matter. Earth-wall structures can be found from high mountain passes to the humid lowlands of the eastern seaboard. Its basic form of construction consists of a solid, load-bearing wall built up of sun-dried bricks molded into flat layers, with adobe mud used as mortar (fig. 6-1). Surfaces are then smoothed with adobe plaster, which is a thin mixture of water and clay mixed with gypsum (calcium sulfate). For roof construction, closely spaced beams in the form of round logs are laid transversely on the tops of the walls. Thin branches, sticks, or reeds, laid in a dense mass over the logs, support a thick blanket of clay that makes a durable roof slightly pitched toward drain spouts outside the walls.

*Susceptibility to Fire*: Walls of an intact, well-built and maintained adobe structure will resist damage from an external fire source. Fire damage, however, can

**Figure 6-1**—19th century Hispanic structure, New Mexico; constructed of sandstone, adobe plaster, and log roof beams.

occur from even a low temperature fire if (1) vertical wooden support posts and lintels are in an advanced state of decay; (2) the wooden roof support posts have collapsed, exposing the vegetal roof material; or (3) the roofless structure contains an accumulation of dry and decayed material that is highly flammable. Gypsum plasters will calcinate when exposed to sufficient heat, resulting in spalling. Plaster spall, in turn, may expose otherwise protected vertical posts, which may also burn when exposed to fire. Adobe bricks, mud mortar, and plaster may be weakened by fire if the straw binder burns.

**Hogan, Tipi, Wickiup**—The *hogan*, a traditional Navajo dwelling, is susceptible to fire. Thousands have been recorded as historic archaeological features; 4,510 hogans have been recorded in New Mexico alone, with thousands more in Colorado, Arizona, and Utah. It was, and still is, a permanent single family house, built to retain heat in the winter and to keep cool in the summer (fig. 6-2). Earlier hogans began as a framework of five heavy poles set up in a cone shape, like the tipi (fig. 6-3), but with a small vestibule entrance. It had a smoke hole and was insulated with a heavy layer of sod. It was known as the "forked stick hogan" because of the shape of the poles that held up the structure. The surface remains of 389 forked-stick hogans have been recorded in New Mexico. Some of these remains date as early as A.D. 1550, up to the early 1800s. Eventually, stone-walled hogans and the present-day log wall hogan evolved because of the influence of Euro-Americans. By 1850 the Navajo had adopted, in part, the log technology of Euro-American pioneers to build the hogan walls. But furniture arrangement, roof construction, lighting, interior functioning, and the overall shape of the building remained the same.

**Figure 6-2**—Remains of a 17th century Navajo Hogan, New Mexico. These wood remains were later collected by fuel wood gatherers.

Other American Indian combustible structures include Shoshone semi-standing log structures in eastern Nevada (Simms 1989), *tipi*-like structural remains in eastern California (Bettinger 1975, 1982), and brush *wickiup* (fig. 6-4) remains in Death Valley National Monument (Deal and D'Ascenzo 1987; Wallace and

**Figure 6-3**—19th century tipi poles, Yellowstone National Park. These poles were later destroyed in a forest fire.

Wallace 1979). Other combustible features sometimes found on historical period American Indian sites are *ramadas*, which are sun shades constructed of vertical posts with a pole-and-brush roof; livestock pens constructed of brush and poles; and firewood piles.

*Susceptibility to Fire*: Hogans have been and are constructed of a variety of materials, including adobe and logs (see "Susceptibility to Fire" for adobe and log cabins). Sandstone is a common hogan building material. When exposed to sufficient temperatures, the surface of sandstone oxidizes, turns color, and spalls. The remains of forked stick hogans are especially susceptible to fire since the wood can be quite old—some have been dated to over 350 years old—and very dry. Many of these remains have the appearance of firewood piles and are in danger of being burned or hauled out by prescribed fire burn crews and firewood cutters. Given their construction materials and collapsed appearances, wickiups, tipi poles, forked-stick hogans, and ramadas are likewise in danger of being mistaken for hazardous fuel loads.

**Monuments**—This category includes grave markers, shrines, and cairns, the latter defined as a pile of stones used to denote a specific location. Varieties

**Figure 6-4**—Remains of an early 20th century wickiup, Death Valley, California.

of materials are used to construct grave markers, ranging from commercially manufactured and inscribed marble or cement slabs, crossed pieces of wood, or simply upright boards and unmodified stones. Although typically grouped within a community cemetery, grave markers can be found in association with homesteads, and even alongside roads and trails (fig. 6-5). Shrines usually incorporate an icon or symbol that is typically, but not always, religious in nature. Like grave markers, shrines may be constructed from a variety of materials, and also can be found virtually anywhere. Cairns, which are of ancient origin in concept and are easily constructed, can demarcate boundary corners, a trail route, a place of significance in history or prehistory, a cache of trade goods, or a burial. Some cairns hold significance that is sacred to American Indians; therefore, cairns should be given consideration as cultural resources, unless identified otherwise.

**Figure 6-5**—19th century Russian grave, Nelson Island, Alaska. Note potential fuel load of cured grasses that surround the grave.

**Culturally Modified Trees**—Culturally modified trees in various regions of the western United States and Canada are important archaeological and ethnographic resources (White 1954). As examples, there are bow stave junipers in the Great Basin (Wilke 1988); bark peel ponderosa in Montana and New Mexico (fig. 6-6) (Swetnam 1984); and Northwest red cedars, from which bark was harvested for making containers (Schlick 1984), or planks extracted from still-living trees (Hicks 1985; Stewart 1984). These culturally scarred trees are part of the landscape and are important cultural resources and, as such, should be given the same regard as hogans, wickiups, monuments, etc.

**Log Cabin**—Swedes who settled along the Delaware River in 1638 introduced the log cabin in America. It was not until around 1700 that non-Swedes built log cabins (fig. 6-7). By the mid-1700s, the log cabin had become the standard frontier dwelling, inhabited by all nationalities, as well as by American Indians. The log cabin had many features desirable to the early settlers and later pioneers moving westward. It was quickly built from indigenous materials—trees and rocks cleared from land to be used for farming. It was easy to build because it did not require an extra framework to hold up the walls. The fireplace was made of large stones and the chimney of sticks lined with mud. The floor was tamped earth and the roof

**Figure 6-6**—Ponderosa bark peel tree on a Mescalero Apache camp site, Guadalupe Mountains National Park, Texas.

**Figure 6-7**—19th century log cabin, Colorado.

split cedar shingles. Early log cabins were sometimes erected close to each other inside a log palisade to make a protected community.

*Susceptibility to Fire*: It is safe to say there is a close correlation between the presence of historic log structures and the abundant availability of trees. There are numerous examples of forest fires that have destroyed such structures. The primary cause of fire damage to a log structure is the general fire regime of the region, not of the logs themselves. All cabins, when made of the same materials, essentially have the same flammability potential. Yet there are also some contributing factors to consider as well: condition of the logs, for example, dry rot; average relative humidity of the region (log cabins in the Northwest Coast region have a far less chance of burning than cabins found in the Southwest high desert); flammability of roofing material (wood shingles versus corrugated steel roofing); and accumulation of flammable materials such as moss, pine litter, vegetative growth, and any chemical accelerants that may be within and around the cabin.

**Baled Hay and Sod**—The High Plains prairie lacks trees, stone, or fuels for firing bricks. Euro-American settlers may first have lived in quickly-built dugouts carved from small ravines or south-facing hills. Like the American Indians who constructed lodges from earth, the pioneers also used wild grasses and domestic hays baled into large building blocks to construct substantial, well-insulated homes. The front of the dugout was usually walled with sod bricks into which a door and window were cut. Baling machines were introduced in the 1850s and, by 1890, settlers were using hay bales as a construction material for houses and barns. Fire was a particular hazard to the baled hay house and extreme care had to be taken with cooking and heating. Plastering is a necessity for a hay bale structure, perhaps less so with a sod structure. A cement-based plaster was commonly used to protect the hay from moisture and as a fire retardant.

Sod bricks were made from ground plowed into 30.5 to 35.6 cm-thick (12 to 14 in) strips. These strips were cut into two-foot lengths and then placed lengthwise with the green grass facing down, making a wall two feet thick. When the desired height was reached, huge cedar ridge pole and cedar rafters were placed on the top of the walls to support a willow brush matting and sod roof. More affluent settlers built their sod houses with a wood frame roof covered with sheeting boards and tarpaper to support the sod.

*Susceptibility to Fire*: Due to their high organic dust content, hay bales are far more susceptible to fire than the straw bales commonly used today. If the plaster of a historic hay bale structure is partly missing, then the fire hazard is much greater—even a minor grass fire or an ember could ignite the structure.

## Structures Using Manufactured Materials

As compared with structures of native materials, structures of this category include a much greater variety of construction materials. For example, a homestead might have fieldstone floor support columns, cement-mortared log walls, a stick-and-mud chimney, milled wood rafters, and corrugated steel roofing. Metal fasteners such as nails, bolts, and wood screws, are also present in relative abundance. Each of these building materials has its own rate of decomposition/oxidation, with a concomitant variation to its susceptibility to fire. As another example, a cement-plastered, adobe-walled structure could have creosote-soaked railroad ties employed as corner posts. If the plaster has spalled off from the railroad ties due to differing expansion rates, the structure is in much greater danger of burning from even a low-temperature grass fire. This is because creosote, used as a preservative on railroad ties, is an accelerant—and if the railroads tie has dry-rotted, the fire hazard would be even greater.

**Frame Structures**—Wood was the obvious choice for most early buildings and bridges. The introduction of the nail- and spike-cutting machines after 1790 and of the power-driven circular saw in 1814 greatly increased the production of boards and heavy timbers. Mass production of cut nails by the early nineteenth century permitted the development of light, or "balloon" frame building construction during the 1830s. Such inexpensive structures could be built where wood was not abundant, for example, the prairie and desert region of the American West. The advance of the railroad network throughout the West after the Civil War greatly increased the availability of milled lumber. This building material provided an alternative to native materials such as adobe, sod, and logs.

*Susceptibility to Fire*: A strong likelihood exists that a dilapidated, unoccupied historic frame structure eventually will be destroyed by fire. A dry-rotted frame structure, especially one in close proximity to an abundance of wildland fuels and other flammable materials (for example, Russian thistle, manure, accelerants such as rubber tires, and creosoted railroad ties), can quickly burn. Corrugated sheet metal, introduced as a fire retardant during the late 19th century, may still protect the historic structure when used as roofing and wall sheathing. However, if the structure is on piers, a grass fire could spread under it and ignite any dry-rotted floorboards.

**Shacks**—These structures are small, temporary, and crudely built, with walls perhaps made from tree limbs, recycled boards, doors, and railroad ties; the roof might be made of large pieces of bark, tar paper, corrugated metal, tarpaulin, rubberized cloth and, by the mid-twentieth century, sheet plastic (fig. 6-8).

*Susceptibility to Fire*: Being of an impermanent nature, shacks as archaeological features are usually totally or partially collapsed. Wood, when present, is in various stages of decomposition, with other building materials, for example, tarpaper, also deteriorated. Even low temperature grass fires can ignite and destroy these remains. The building material might be especially combustible due to accelerants, for example, creosote-soaked railroad ties, and glue used to make plywood.

**Cement-Mortared Fieldstone, Firebrick, Cinder Block, Cement Aggregate**—Structures utilizing these building materials are, in varying degrees, resistant to fire. Fieldstone, that is, unmodified native rock, is most resistant to fire damage. Firebrick is a common building material if good clay and fuel sources are locally available, or acquired from manufacturers. Cinder block has been a building material since around 1920. Cement—made of crushed and slaked limestone or crushed and slaked oyster shell, the latter used along the coastal regions of southeastern United States—has been a common building material mainstay for hundreds of years in the United States and Canada.

*Susceptibility to Fire:* Low-fired, relatively porous firebrick, which is typical of non-commercial, locally made brick used at many historical sites, can weaken and crumble if the fire is hot enough. Lime-based mortar can be affected by fire. It can calcinate and crumble under sufficient heat, thereby loosening the firebrick and, if not replaced, causing the brick wall to eventually collapse. Cinder block and masonry surfaces may spall, which appears as distinct lines of striation and loss of surface material resulting in cracking, breaking, chipping, and formation of craters on the surface.

**Figure 6-8**—Late 19th century homestead, South Dakota. Note heavy grass fuel load.

## Historic Artifacts

The great majority of historic artifacts can be assigned to three materials categories: glass, metal, and ceramic. A fourth materials category of "Miscellaneous Materials" includes objects of leather, rubber, wood, plastics, bone and shell.

### Glass

Glass is a combination of soda, lime, and silica, a composition that appears colorless. Glass color is the result of several factors, including both intentionally and unintentionally added chemicals in the glass formula. Glass articles and fragments constitute a significant portion of most historic artifact collections. These items represent common household foods, beverages, medicines, cosmetics, cleaners, windows, and lamps. Their evolution includes many manufacturing changes, some of which are useful dating aids. Period of use/disposal and function of a glass container can be determined by its shape, color, method of closure and, if present, its label, the latter made of paper, enamel paint, and/or raised lettering. If present, alpha/numeric codes on glass containers can also provide the year and place of manufacture, and the company that manufactured it, as opposed to the company that sold the contents of the container. Windowpane fragments are clues regarding the architectural layout of a structure, and the socioeconomic status of the original owners of the structure. In addition, the mean thickness of a window pane fragment can be used to derive a relatively accurate initial construction date for a dwelling (Moir 1987).

*Susceptibility to Fire*: Glass can be affected by heat buildup, smoke, and flame. Smoke staining and melting of glass items tend to occur in direct relation to the heat buildup, the intensity of the fire, the speed of fire spread, and nearness to the fire. Soda lime glass contains a mixture of alkali and alkaline earth to make it more durable and easier to produce. For hundreds of years this family of glass has been used for containers, window glass, pressed- and blown-ware, and lighting products where exceptional chemical durability and heat resistance is not required. Its melting temperature is 695 °C (1283 °F). Lead glass contains lead oxide (and, sometimes, lead silicate) and melts easily. Solder and glazes for decorating enamels on tableware are based on these low melting lead glazes. Their melting temperature is 380 °C (716 °F).

An increase in the temperature of a glass object causes a proportional increase in that object's molecular activity. The hotter the object the greater the molecular activity on its surface, which inhibits the amount of smoke staining that will form. A glass object heavily stained by smoke and soot was, therefore, cooler than one with a light buildup of soot. A heavy soot buildup on a glass surface suggests that the item was far from the fire's point of origin. However, a light soot buildup suggests that the item may be at or near the point of origin.

- *Checkering* of glass refers to the half-moon shapes that are sometimes seen on the surface of glass items. These half-moon shapes result after droplets of water (usually from fire fighting) land on a heated surface.
- *Crazing* refers to the cracking of glass into smaller segments or subdivisions in an irregular pattern. The extent to which a glass object (for example, window pane, soda bottle) will crack or craze is related to the type of glass involved, its thickness, the temperature range to which it was exposed, and its distance from the point of origin. Crazing into small segments or pieces suggests that the item was subject to a rapid and intense heat buildup. It also suggests that the items may be at or near the point of fire origin (NFPA 1998).

On historic archaeological sites, glass artifacts, usually in the form of fragments, are commonly concentrated within domestic trash dumps. Occasionally there is evidence indicating that the trash dump had been purposely burned during the period of site occupation. Where such trash burning occurred, there is sometimes evidence that glass artifacts melted or shattered. Fire temperatures can easily be reached that would craze and/or heavily soot glass. Enamel paint labels could oxidize, causing colors to change and the paint to flake off. It is less likely that a low temperature fire, such as a grass fire, would reach the melting point of glass, although whole objects, for example, bottles, might crack or even shatter from the heat. Fires having heavy fuel loads can reach temperatures that are hot enough to melt glass artifacts into unrecognizable lumps.

## Ceramics

Ceramic materials from the historic period have long been used by archaeologists for a variety of purposes, from dating the period of a site's occupation to understanding the role played by a site's occupants in a wider socioeconomic network. There is a vast body of information that deals with the various historic ceramics' pastes, glazes, decorations, and shapes (Majewski and O'Brien 1987); however, little quantifiable information exists regarding the effects of fire on historic ceramics, relative to the fire studies conducted on prehistoric ceramics.

Ceramics can be divided into four primary categories that are based on the character of the ceramic fabric, or body, of the object:

- **Unrefined Earthenware**—the body is made of coarse-grained clays; fired between 500-900 °C (932-1652 °F); body is easily scratched and broken, absorbs moisture; body is thick relative to refined earthenware. Unrefined earthenwares may also be glazed using powdered tin as a flux in the glazing process. These ceramics, called *majolica, faience*, or *delft*, are typically found on North American sites dating prior to circa 1780, and were quickly replaced in popularity by *white-bodied refined earthenwares*.
- **Refined Earthenware**—fine-grained clays; fired between 1100-1500 °C (2012-2732 °F); stronger, thinner body relative to unrefined earthenware; surface is sealed and protected with a translucent glaze. White-bodied refined earthenware is the ceramic most commonly found on nineteenth and twentieth century sites. These ceramics are durable, inexpensive, and come in a wide variety of shapes and decorations.
- **Stoneware**—coarse-to-medium grained clays; fired between 900-1100 °C (1652-2012 °F), becoming non-porous; body is strengthened by its thickness and (usually) vitreous glaze. Popular throughout the nineteenth and early twentieth centuries, stoneware was usually reserved for making utilitarian vessels such as crocks, jugs, and ale bottles.
- **Porcelain**—superfine-grained clays; fired between 1250-1450 °C (2282-2642 °F); vitreous, translucent, extremely hard body. This is a "high status" ceramic, thus rare on historic sites relative to the other ceramic types.

We will make the assumption here that all unglazed, unrefined earthenware Euro-American ceramics, for example, a flowerpot, have essentially the same chemical and physical properties as prehistoric ceramics. All unglazed, unrefined Euro-American earthenware that are exposed to wildfire, therefore, should exhibit essentially the same physical and chemical transformations exhibited by unglazed prehistoric ceramics.

*Susceptibility to Fire*: All earthenwares are affected by fire to varying degrees, depending on the characteristics of the paste, glaze, painted decoration if present, and temperature of the fire. The alkaline glaze that is typically used on high-fired refined white earthenwares (also known as ironstone, "hotel ware," and semi-porcelain) can crackle even in a low temperature fire, and the underlying ceramic body of the

## Sidebar 6-1—Cultural Landscape Restoration

Prescribed burn experiment, Knife River Indian Villages National Historic Site, North Dakota
Oct. 15th, 1988 and Nov. 2nd, 1988
References: Picha and others 1991

### *General Information:*

- Elevation: 506-572 meters (1660-1878 feet)
- Vegetation: prairie grassland
- Topography: level plains
- Type of study: prescribed burn experiment

### *Fire Description:*

- Temperature range:
  - o Maximum temperature reached: 316 to 399 °C (600-750 °F)
  - o Soil temperature (recorded by Tempilstick crayons)
  - o Plot 1-3 soil temp: 6.1 °C (43 °F) pre-burn, 8.8 °C (48 °F) post-burn
  - o Plot 4 soil temp: 14.1 °C (57 °F) pre-burn, 18.0 °C (64 °F) post-burn
- Duration: Plot 1-3: 1 minute; Plot 4: 30 sec.
- Relative humidity: Plot 1-3: 54%; Plot 4: 78%
- Fuel:
  - o 2 plots = mixed grasses and buckbrush
  - o 1 plot = mixed grasses with much less buckbrush
  - o 1 plot = mixed grasses, buckbrush and added clippings
- Type of Fire: Prescribed burn

### Discussion

In 1991, researchers conducted a prescribed burn experiment at Knife River Indian Villages National Historic Site in North Dakota (Picha and others 1991). They recorded effects of prairie fire on a variety of artifact material types. Specimens included non-flint cobbles, chunks and cobbles of knife-river flint, flaked flint, potsherds, cow rib-bone fragments, mussel shell fragments, wood, charcoal, lead pieces, and glass beads.

Researchers placed specimens in four adjacent burn plots, each measuring 10 $m^2$ (12 $y^2$). Fire temperature was measured with heat-sensitive crayons, and soil temperature was recorded by use of a "temperature probe" before and after each burn (Picha and others 1991:16). Specimens were placed at the surface of two plots (one with light fuel and one with heavy fuel) and 2 cm (0.8 in) below the surface of the other two (one heavy and one light fuel) plots. No unburned control and no replication of burn plots were included in this study. The maximum fire temperature reached during the experiment was 399 °C (750 °F), and heating duration was estimated to be about 1 minute.

The specimens were collected after the first precipitation and examined for change in color, shape, and size. No effects to charcoal could be observed. Pottery and large natural cobbles were only minimally affected. Most fire effects occurred to items that had been at the surface. All material types besides charcoal exhibited some color change due to smoke blackening or scorching. Other effects, such as fracture and deformation, were most severe to small thin items. Organic materials were found specifically vulnerable to fire.

Several of the observed effects to surface artifacts represented potential loss of archeological information. Flaked stone and animal bone were altered to resemble intentionally heat-treated flint and bone exposed to cooking fire. Mussel shell disintegrated and the wooden objects partially combusted. Glass beads were partially melted and discolored by soot, and small pieces of lead had melted.

softer-paste white earthenwares can oxidize and turn yellowish brown. Majolica glaze is fragile; its body is soft and porous, and can absorb water. Thus, majolica glaze will crackle and spall even in a low temperature fire (Haecker 2001).

If the ceramic decoration is an overglaze paint, that is, lying on the surface of the glaze, the paint will be damaged to some degree. If the fire reaches temperatures higher than that used to manufacture the ceramic it is possible that the glaze will oxidize or burn, and the whole vessel or vessel fragment (sherd) might split laterally in places. Water droplets hitting the surface of a super-heated ceramic can crack and shatter it (Haecker 2001). Porcelain melts at around 1550 °C (2822 °F) (NFPA 1998). If its paint decoration lies on the surface of the vessel, the paint could become discolored and/or burn off at temperatures much lower than this.

## Metal

The melting of certain metals may not always be caused by reaching their melting points. Instead, it may be caused by alloying. During a fire, a metal having a relatively low melting point may drip onto or come into contact with other metals that do not often melt in fires. This phenomenon can also occur when component parts of a heated object are in contact with each other. That mixture (alloy) will melt at a temperature less than the melting temperature of the higher-melting-temperature metal and, in some cases, less than that of either metal. Examples of relatively low-melting-temperature metals are aluminum, zinc, and lead (table 6-1). Metals that can be affected by alloying include copper and iron (steel). Copper alloying is often found, but iron (steel) alloying might be found in only a few cases of sustained fire. Even if the metal object does not melt it can warp out of shape (NFPA 1998).

*Cans* represent one of the more common types of metal artifact found on post-1850 sites. Like glass containers, cans have been intensively studied by historical archaeologists and, like glass containers, are most useful in dating sites and providing evidence about subsistence and life ways. Information regarding date and contents can be determined by the dimensions and shape of the can, the techniques used to manufacture the can, and by the enamel paint or paper labeling.

**Table 6-1**—Melting points of materials commonly found on historical sites (derived in part from NFPA 1998:28).

| Material | Temp.[a] (F) | Temp.[a] (C) | Artifacts |
|---|---|---|---|
| Plastics | 167-509 | 75-265 | Disposable containers, toys |
| Solder (tin-alloy) | 275-350 | 135-177 | Patch repair work on brass and iron objects |
| Tin | 449 | 232 | Kitchenwares, toys, can lining, building materials |
| Pot metal (copper-lead alloy) | 572-752 | 300-400 | Flatware, pots, faucets |
| White pot metal | 572-752 | 300-400 | Kitchenwares |
| Lead | 621 | 327 | Bullets |
| Zinc | 707 | 375 | Plating for iron objects, e.g., cans |
| Glass | 1100-2600 | 593-1427 | Bottles, window pane |
| Unrefined earthenware | 1112-1832 | 600-1000 | Flowerpots, some marbles, prehistoric ceramics |
| Aluminum | 1220 | 660 | Kitchenwares |
| Brass (yellow) | 1710 | 932 | Cartridge cases, military buttons and insignia |
| Silver | 1760 | 960 | Coins, jewelry |
| Stoneware | 1832-2192 | 1000-1200 | Crocks, jugs, ale bottles |
| Gold | 1945 | 1063 | Coins, jewelry |
| Copper | 1981 | 1082 | Kitchenwares, building materials, coins |
| Refined earthenware | 2192-2912 | 1200-1600 | Dinnerware ceramics |
| Cast iron | 1920-2550 | 1350-1400 | Kettles, Dutch ovens, wood stoves |
| Steel (stainless) | 2600 | 1427 | Eating utensils, kitchenwares |
| Nickel | 2651 | 1455 | Plating |
| Steel (carbon) | 2760 | 1516 | Heavy machinery parts |
| Iron | 2795 | 1535 | Tools, nails, horseshoes, cans, corrugated roofing |
| Porcelain | 2822 | 1550 | Dinnerware ceramics |

[a] Temperatures are approximate.

Since cans are made of rolled tinned steel, they will eventually deteriorate if deposited in a moist, humid environment. In the dry Southwest, however, cans found on historic sites over one hundred years old may lack labels but are often in relatively good condition, albeit rusted.

Occasionally, there is archaeological evidence indicating can/trash dumps were burned by the sites' historic occupants, as evidenced by layers of wood charcoal found within the dump. These wood fires would have been hot enough to destroy the labels; however, the shape of the can usually remains the same. An exception might exist regarding fire damage on 19th and early 20th century lead-soldered cans (fig. 6-9). Since solder melts at 135-177 °C (275-350.6 °F), it is likely that such cans would be damaged by low temperature fires. The resultant alloying of the solder with the tinned steel also could cause the latter to become fire damaged at lower-than-normal temperatures. The tinned surface of the can may also burn off, thereby increasing the rate of oxidation of the steel body and ultimately the loss of diagnostic information (for example, can diameter, stamped lettering).

*Kitchenware* includes an extensive array of objects that can be found on the surface of historic sites and can be affected by fire:

- Cast iron objects such as kettles, pans, Dutch ovens, and wood stoves can crack if exposed to temperatures above 1050 °C (1922 °F). Even at temperatures lower than this, if water is applied to these objects, such as during the fighting of a fire, cast iron can crack from the sudden cooling.
- Enameled ironware (also known as agate ironware) objects such as plates, coffeepots, and kettles, have been popular household items since the late 19$^{th}$ century. Such objects are susceptible to damage by low temperature fires: some of the enamel can craze and/or pop off, exposing the underlying rolled metal to oxidation. Partial loss or discoloration of the enamel, however, should not affect the ability to date the artifact.
- Steel utensils that are plated with tin, brass, or silver will have their surfaces discolored and possibly burned off in a fire (table 6-1).

*Construction, transportation, and agricultural/ranching hardware* items made of metal are often present on historic sites. Such items are typically made of cast iron, wrought iron, and steel, and, due to their sturdy construction, usually impervious to most fires. However, their surfaces might become pitted; paint surfaces, if present, can blister and/or burn off; and enhanced oxidation of the surface of the object may occur if water used to extinguish the fire also rapidly cools the artifact.

Copper and brass objects on historic sites are less common relative to steel and iron objects. Typical brass artifacts found on historic sites are ammunition cartridge cases that have been fired; sometimes unfired cartridges are also found. Cartridge cases are useful in dating a site, with data obtained from the object's dimensions and, if present, from its headstamp. Normally, cartridge cases are not seriously affected by fire, given the relatively high melting point of copper and brass; discoloration might occur but dating information is still present. However, there is one reported instance where fire has destroyed such artifacts. This occurred on the Little Bighorn Battlefield when, in 1983, a grass fire burned over this site. Several unfired cartridges

**Figure 6-9**—Lead soldered cans in a test fire using straw as a fuel load. Note beads of melted solder.

associated with the battlefield exploded. Also, several lead bullets found on the surface had partially melted as a result of this grass fire (Richard Harmon, personal communication, 1999).

The burn-off of vegetation on a historic battlefield is an atypical situation. One must keep in mind, however, that even a low-temperature grass fire could detonate unexploded cannon ordnance, perhaps injuring members of the fire crew.

### Miscellaneous Artifacts

- *Leather* is a material that is sometimes found on the surface of historic sites. Such objects as shoes, belts and horse tack become dry and brittle over time. Leather will char in a grass fire, and will be completely consumed at hotter temperatures.
- *Rubber* and *rubberized objects* are present on many historic sites, some dating to the Civil War period and even earlier. Rubber can be ignited and completely consumed at low temperatures such as those reached by grass fires (Haecker 2001).
- *Plastics* can appear on historic sites that date to the early 20$^{th}$ century, but is most common after circa 1950. Plastics have been used to manufacture a wide variety of objects such as toys, buttons, tool handles, and containers. Various plastics have varying melting points but most plastic objects would be affected to some degree by a low temperature fire.
- Of course, artifacts made of wood are quite common on historic sites, and can include everything from buckboards and Model T car seat frames, to ox yokes and axe handles. When present on a site and in the open they usually have some rot, increasing their susceptibility to destruction by fire.
- Bone, especially if dry and porous, will char in a grass fire, and will be completely consumed in a high temperature fire (Haecker 2001).
- Shell buttons will become discolored, flake and split laterally along the laminations, and eventually turn to powder if subjected to a high temperature fire (Haecker 2001). This will also occur at lower temperatures if the buttons are very small and thin.

## Summary

Historical sites that are eligible to be included in the National Register of Historic Places usually include a variety of materials not found on prehistoric sites. These materials vary widely in their susceptibility to fire effects. To date, there is little empirical data regarding the effects of fire on historic period materials. This dearth of information is offset somewhat by data derived from arson investigations, which should be consulted by cultural resource managers and fire managers.

Types of fire damage include *distortion*, *spalling*, *charring*, and *calcination*. Heat can be transferred within a structure by metal fittings such as nails and bolts. The chemicals used in manufacturing certain building materials (for example, plywood glues, creosote-soaked railroad ties) are accelerants, which increase the risk of fire damage even when the fire source is of relatively low temperature, such as a grass fire.

Artifacts are typically assigned to four material categories: glass, ceramics, metal, and miscellaneous. Glass can be affected by heat build-up, smoke, and flame. Examples of low-temperature fire damage to glass include the loss of paper and enamel paint labels, soot staining, and shattering of glass containers. All ceramics are affected by fire to varying degrees, depending on the physical characteristics of a given ceramic, and temperature of the fire. A fire may result in crazing of glazes and spalling of the ceramic body, burn-off of some types of designs and, if the fire is hot enough, cause calcination, even melting. Sufficiently high temperatures may not always cause the melting of certain metals. Instead, alloying may cause it. A low-temperature fire can completely destroy artifacts made of such miscellaneous materials as rubber, plastics, shell, and bone.

Exposure of a historic structure or object to fire, regardless of the temperature that is generated, does not necessarily equate with destroying its value as a cultural resource. For instance, a low-temperature prescribed fire that burns over a trash scatter may discolor fragments of ceramics and glass; however, the diagnostic aspects of these artifacts, such as decoration and vessel shape, may still be recorded with accuracy.