The Role of Fire in Northern Circumpolar Ecosystems
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CHAPTER 14

Measures for Fire-Prevention on Peat Deposits

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ABSTRACT

Fire characteristics and fire suppression techniques are described for undisturbed peatlands, fields being harvested for peat, and peat stockpiles in northwestern USSR. In undisturbed peatland or peatfields, fires are most commonly caused by forest fires. In peat harvesting enterprises over one half of the fires are caused by spontaneous ignition of peat in stockpiles. Locating the perimeters and extinguishing slow-burning peat fires is time consuming. Stockpiles must be monitored for temperature increases and, when heating occurs, the heat must be dissipated or the heated zone must be removed and replaced with wet peat. Once dry, peat is very difficult to rewet because of the high bitumen content. Therefore it is essential to add wetting agents to water used for fire suppression. Machinery used in harvesting is normally used in fire suppression but specialized equipment has also been developed and effectively employed.

14.1 INTRODUCTION

Fire danger on peat deposits is related to the natural physiochemical properties of dry peat as a fuel. These properties include the low temperature of ignition (270–280°C), the ability of peat to catch fire from small ignition sources at moisture contents of 20–30%, the ability of a peat mass to burn independently at an absolute moisture content up to 235%, and the tendency to ignite spontaneously during storage in stockpiles.

14.2 PEAT FIRES ON UNDISTURBED PEAT DEPOSITS

14.2.1 Characteristics of Peat Fires

Peat fires on undisturbed peat deposits usually occur during the second half of the fire danger season (August to October) when peat is very dry and wetting by rainfall is ineffective. Frequently, peat fires are ignited by surface forest fires. However, peat can also easily catch fire, even at a relatively high soil moisture content, from other ignition sources such as bonfires, glowing cigarettes, or lightning.

Peat fires burn vertically downwards into the deeper layers and then burn laterally, so that tree roots can be partially or completely consumed. The trees, losing their support, usually fall with their tops pointing to the ignition site of the fire. Thus, fallen tree stems lying radially from a central point is a very characteristic feature of a peat fire.

During a peat fire, oxidation proceeds down through the peat profile to the mineral layer or to deeper peat layers, where a high moisture content prevents combustion. As a rule, burning takes place by glowing combustion at low oxygen levels because oxygen does not move readily to the zone of combustion. That is why the speed of a peat fire front is low and is usually measured in metres per day.

If we examine a cross-section of a beginning peat fire, we can observe that the burning process in a peat mass is considerably more intensive at the bottom than at the top. This occurs because dense fresh air saturated with oxygen diffuses to the bottom part of the combustion zone, where the oxygen promotes greater burning intensity. The low oxygen-content, heated air, enriched with products of combustion, rises up the sides of the combustion zone and inhibits combustion. This peculiar pattern of air currents has a tendency to deepen peat fires. After burning into the bottom peat layers, the fire can expand laterally for tens or even hundreds of metres from the ignition point. The fire may remain under the soil surface for much of this distance and appear at the surface in only a few places.

The caloric value of peat is as high as 6600 kcal/kg, which explains why peat is regarded as a good fuel. A peat layer of 50 cm depth can liberate about 165 000 kcal/m^2 during the combustion process. This is quite sufficient to prepare another similar layer, with a moisture content up to 500%, for combustion. Peat may contain up to 15–25% bitumens. At high temperatures during combustion, these gaseous paraffins are liberated and condense on the upper, cooler peat layers. This forms a water-repellent film which makes rewetting and thus peat fire suppression, difficult.

14.2.2 Fire Hazard

During the fire danger season the peat moisture, which was at its maximum in the spring, gradually drops to a minimum in August. This explains why peat fires occur at the end of the summer or at the beginning of autumn. For the northwest districts of the USSR, the probability of a peat fire beginning is determined, first of all, by the quantity of precipitation during the summer. With normal, seasonal precipitation (250–280 mm), only surface fires occur in forests with peaty soils. When precipitation is below normal, and there is no rainfall in July and August, the probability of peat fires increases sharply. This occurred, for example, at the end of the summer of 1972 in the central districts of European Russia, when the dry period lasted about 1½ months.

The draining of peaty forests also promotes peat fires. There is a distinct curvilinear relationship between the moisture content in the upper layers and depth to the water table. When examining this moisture relationship by depth in drained shrub-*Sphagnum* bogs, scientists came to the following conclusions:

(1) When the water table is lowered 10 cm from the surface the moisture content of the upper peat layer drops sharply from 2400% to 1600%.
(2) Lowering the water table to 30 cm results in an additional reduction of 400%.
(3) When the water table is lowered to between 30 cm and 50 cm, the moisture content of the surface layers is reduced by an additional 200%.
(4) Further lowering of the water table reduces surface moisture contents insignificantly (approximately 100%).

In general, the surface peat of a drained deposit in July has about one-half the moisture content of an undrained deposit.

It is well known that summer rainfall sharply reduces fire danger in forest stands on well-drained soils. However, in wet forest types, when the soil moisture is below the critical point, fire danger exists even after rainfall. This can be readily explained because concentration of bitumens per unit weight increases after the peat mass has dried and the particles of dry peat respond to water as if they have been 'treated with resin'. These soils are so water-repellent that, although heavy rainfall penetrates through the cracks in the peat, it is not absorbed. Thus the fire hazard is affected only indirectly through the rising of the subsurface water table.

14.2.3 Fire Suppression

The principal method of fighting peat fires is to dig a trench to mineral soil around the perimeter of the fire and then to extinguish the fire with water. Great quantities of water are required initially to suppress fires. However, fires may start again because the water may not penetrate to all of the burning fronts within the peat mass.

In 1963–1964, Soviet scientists worked out an effective method for extinguishing peat fires by increasing the wetting ability of water through the addition of small amounts of surface-active substances (up to 0.3% weight). Most frequently, sulphanole has been used as the wetting agent. In addition, water is not simply poured on the fire but is introduced to the burning peat layers with the help of a specially constructed peat shaft. The peat shaft TS-1 is a small brass tube 1.3 m long with a diametre of 16 mm and a detachable nozzle. The lower 40 cm of the tube has forty openings 3 mm in diameter. After the shaft has been inserted into the burning zone of the peat the water and wetting agent mixture is released through these openings. At the upper end of the peat shaft tube there is a fire hose coupling and a T-shaped handle, which is depressed to release water when desired.

The tactics for extinguishing peat fires are as follows. The surface fire must first be extinguished using pumps, fire hoses, and nozzles. Then the perimeters of the deep peat fires are determined. It is assumed that these peat fires will be only tens of square metres in size during the first 24 hours and the probable burning depths can be estimated as well. It should be noted that it is extremely difficult to determine the underground burning zone from surface characteristics, and thus caution should be exercised in approaching an open part of a peat fire. Extinguishing the fire should begin on the up-wind side not screened by smoke, because a peat fire, as a rule, has no front, flanks or rear; rather it develops more or less in all directions. The peat shaft is inserted into the peat with the valve closed and then water is released. The shaft is removed and inserted at 30- to 40-cm intervals along the perimeter of the fire. To fully extinguish the fire it is necessary to make a second row of holes 30–40 cm from the first row and to arrange the holes in a chessboard fashion. The duration of water supply, from a fire hose line with a recommended pressure of 3–6 atm, depends upon the depth of the burning peat and has been determined experimentally. For peat depths of 20–40, 40–70, 70–120, and 120–200 cm the time of supplying the liquid is 5–6, 10–12, 10–12, and 14–16 sec, respectively. Using the peat shaft TS-1 it is possible to extinguish fires up to 1.2 m in depth. When extinguishing fires in deeper peat layers, a 2-m long peat shaft called the TS-2 is used.

14.3 FIRE HAZARD DURING PEAT DEPOSIT EXPLOITATION

Fire hazard on peat deposits under development must be considered during the production process because a large amount of flammable material is handled. Since only a small quantity of harvested peat results per unit area, large areas are exploited at any one time. This raises the danger of fire spreading over large areas once a fire begins. Also, the production activities with many different machines increases the probability of ignition sources. The fire hazard of the peat is high because the moisture content must be lowered substantially to make the peat useful. Even after harvesting and stockpiling the peat successfully, there is a danger of spontaneous combustion in peat piles.

The fire statistics on peat enterprises in the central zone of the USSR in

1972–1973 show that causes of fire in the peat production fields were as follows: the spontaneous ignition of peat in piles (58%), failure of spark arrestors on internal combustion engines (5.25%), the careless handling of fire (5.25%), and the spreading of forest fires into peat production fields (31.5%).

14.3.1 Spontaneous Ignition in Peat Stockpiles

The most widespread method of peat harvesting for thermoelectric generation in the USSR is the milling method. The harvested peat is stored in piles of triangular cross-section for an average of about six months. The height of such piles is 8 m and the length about 80 m or more.

A serious drawback of the milling method is the tendency of stockpiled production to self-heat, which may lead to spontaneous ignition and to fires. The process of self-heating is both biochemical and chemical in nature. During the first period of storage, heat is formed due to the physical, physiochemical, and fermentation processes. In the first 1½ months of storage most of the liberated heat is from microorganism respiration, which begins shortly after the peat is stockpiled. As the peat temperature rises above 60–65°C chemical heat release processes predominate. The volume of these self-heating layers may be a comparatively small part of the stockpile but the zone of self-heating may show intensive heat release. Under the influence of microorganisms considerable changes occur in the chemical composition of peat. Hydrolysis products of carbohydrate and protein complexes, organic acids, and other easily oxidized chemical compounds are formed. Spontaneous ignition of peat results from the oxidization of these organic compounds formed in the self-heating process. Maximum temperatures are found in these heated zones and the so-called 'stockpiled semicoke' is evidence of this intensive heating.

14.3.2 Fires in Peat Harvest Fields

The peat fires in 1972–1973 started between 10 a.m. and 1 p.m., when the wind sometimes reached 20–25 m/sec. Wind becomes particularly important when the peat layers are ignited, and wind speeds greater than 3 m/sec cause burning peat particles to be scattered down-wind, forming new peat fires. Wind speeds in excess of 10 m/sec cause burning particles to rise into the air, forming a revolving spiral column which moves along through the field, setting new fires in dry peats and in stockpiles.

The following empirical relationships for fire spread in fields of milled peat have been developed:

Distance of spark spreading (m)

$$D = \left(\frac{V_w - 3}{2}\right)^2 \qquad (14.1)$$

Speed of fire motion (m/sec)

$$V_{fm} = \left(\frac{V_w - 2.5}{88.8}\right)^2 \qquad (14.2)$$

Linear speed of fire spreading (m/sec)

$$V_{fs} = \left(\frac{V_w - 4}{24.6}\right)^2 \qquad (14.3)$$

Area occupied by the fire (m^2)

$$A = \frac{V_{fs}\,(t_d + t_l)^2\,\alpha}{360} \qquad (14.4)$$

where V_w = wind speed at 2 m height (m/sec), t_d and t_l are the time of development and time of localization of the fire, and $\propto$ is the angle of fire development, $\alpha = 65 + 2.6 \times V_w$ (degrees). These empirical relationships include necessary assumptions, such as an even distribution of milled peat over the fields and an average moisture content of the peat of 31%.

Under field conditions peat fire development is much more diverse and complicated. Fire spread is affected by the uneven distribution of peat moisture and whether the peat is on the field or in a stockpile. The barriers caused by a diverse landscape, and even conditions such as the state of the field surface and relief of the surface, are important. For example, while burning a stockpile 3–4 metres high at a wind speed of 11–12 m/sec the distance of burning particle movement from the top of the pile is fifteen to twenty times greater than the movement at ground level. The theoretical values of peat fire spread are useful but the natural variation in the field is of the utmost importance when considering fire suppression. More precise data on fire spread are obtained only from special investigations.

During fires, the relative burning rate of different materials varies quite widely. In the peat fields, milled peat which has been spread out for drying and turned over once or twice will burn completely in 1–1.5 h. Harvested peat placed in small ridges may burn in 20–30 min. Stockpiled peat may burn only 5 cm/h on the windward side; after 3–6 h the burning depth may reach 10–15 cm and have a 3–4-cm ash layer. The dry, excavated material near the main and side ditches burns in about 3–4 h and stacks of tree stumps and wooden poles of power lines may burn in about 1–1.25 h.

After periods of low rainfall and under windy conditions, peat fires are a complicated and menacing phenomena. By increasing the wind speed from 5 to 20 m/sec, the transfer distance of burning peat particles increases seventy-two times, the velocity of flaming front increases fifty times, and the area burned increases about two hundred and fifty times.

14.3.3 Measures for Fire Prevention in Peat Stockpiles

The whole basis for fire prevention and suppression in peat production fields is a programme of complete fire exclusion. A programme has many fire prevention measures which are formulated in the design and installation-building phases and well prior to the period of peat production.

Several measures are used to prevent the spontaneous self-heating and ignition of peat. These can be divided into (1) those which delay self-heating during the summer season when stockpiles are being formed, and (2) those utilized following completion of the stockpiling process. In the first group, fire prevention procedures include the harvesting of peat at low air temperatures, stockpile formation by unloading peat on both slopes of a pile, piling of peat into separate stockpiles according to the early and late portion of the season, the insertion of moist peat into the middle layers where the zones of high temperature are expected, and the layer-by-layer compaction of peat in the stockpile. During the summer stockpiling season partial shifting of stockpiles may be undertaken if heating becomes serious.

The most widespread method of preventing self-heating and spontaneous ignition of peat once the stockpiles are formed is to prevent oxygen movement into the stockpiles. The most common way to accomplish this is to compress the surface peat, thereby decreasing the permeability to air. If cracks develop in the compacted layer, they must be filled with moist peat or snow, and compressed. To monitor self-heating in the stockpile special electric thermometers are inserted and examined every 15 days. If a zone of potential spontaneous ignition is identified, the zone and the surrounding 0.5-m layer is extracted from the pile. The resulting hole must be filled with moist peat and the surface compressed to the level of the stockpile.

Figure 14.2 Machine MTP-42, which is used for continuous deep milling to 0.4 m depth and which can be used to create a fire barrier of moist peat

Figure 14.3 A fire suppression unit (AK-5P) which has a 5 m^3 capacity for liquid fire retardant

Several specialized fire suppression machines such as the AK-5P (Figure 14.3) have been developed. This unit consists of a water-filled roller with a capacity of 5 m^3. It is pulled by a tracked tractor. Mounted on the frame of the roller is a pump and pipe with valves, a tank for wetting or foaming agents, and a cabinet for fire-fighting equipment. The unit is equipped with a flexible, 8-m suction hose and screen, with an ejection mixer mounted on the tank line. The amount of liquid in the tank is sufficient to extinguish about 1000 m^2 of peat fires and with the foam generator it is possible to obtain about 400 m^3 of foam.

To extinguish fires in peat production fields great quantities of water must be moved to the area that is burning. For this purpose a fire-fighting unit consists of a pumping station (which delivers 70–110 l/sec at a pressure of 6–8 $\times 10^5$ Pa.) and a quick-built fire pipeline of 180-mm diameter and 1000-m length. The pipeline is transported to the fire in a special sled-rack that holds 105 pipes. With this unit it is possible to extinguish a fire 25 ha in size from a single position.

14.4.2 Suppression of Large Peat Fires

During the hot and dry summer of 1972, forest and peat fires ignited in the vicinity of Moscow and quickly spread over hundreds of hectares. Surface fires burned through the forest with flame heights of 0.1 to 2 m and a speed of 3 m/min. These forest fires initiated peat fires, although sometimes the source of the peat fire was spontaneous ignition of peat stockpiles. To isolate deep peat fires, strips, trenches, and barriers were developed on natural or designated fire control borders. Bulldozers, digging machines, and, in some cases, even explosives were used to produce barriers.

Initially the survey of the burning area was undertaken with the assistance of helicopters and by separate groups on the ground. Helicopter units effectively discovered the burning zones and determined the fire size and direction of fire spread. With this information available it was decided how to approach the suppression and how many people were required to fight the fire.

The survey groups on foot consisted of two or three men equipped with probes and trenching tools, signal lanterns, and stakes. They moved in front of the bulldozers, choosing the approach and marking it with stakes during the day. Helicopters were sometimes used to show the direction to the bulldozers. During the night hours the surveyors used lanterns to direct bulldozers.

When a deep peat fire was detected, it was isolated by a 5–8-m fire break. Bulldozers were used to remove the trees and other vegetation cover. After this, the fire breaks in front of the fire were widened to 30–50 m and the fire was considered to be localized. If the peat fire was small, the extinguishing began immediately, but if the peat fire was large, it was divided with fire breaks at distances of 150–200 m. Burning peat was covered with mineral soil or water was applied if the burning peat was shallow. Deep-burning peat could not be extinguished with water, because even saturated areas would dry out during the night hours and would reignite.

Peat fire suppression was more successful when surface-active substances such as sulphanole were added to the water. The peat shafts TS-1 and TS-2 were used to supply water mixed with surface-active substances into the deep peat layers. Peat shafts were not effective where the peat depth was shallow (15–20 cm) or where the burning zones were large and the burning front extended for several kilometres. In shallow peats, not exceeding 30 cm in depth, fire breaks were cleared to mineral soil with bulldozers so that the extinguishing liquid could be poured onto the soil surface. In locations where the peat was up to 1.5 m in depth, digging machines were utilized. If the peat layer was thicker than 1.5 m, explosives were used.

Where fires were burning through peat stockpiles, the burning peat was first sprayed with water. This washed away the surface ash making it possible to reduce the consumption of the water-wetting agent mixture.

When dealing with the suppression of peat fires it is important to prevent surveyors and equipment from dispersing in an attempt to encircle as many burning areas as possible. Fire in peat can spread horizontally under the surface, and this burning can only be detected through the release of small jets of light gray smoke. In some cases it is possible to note that grass and leaves of trees and bushes become yellow as the fire burns through the peat beneath them. A concerted effort of the surveyors and machinery to identify this evidence of fire and to isolate these burning zones lead to greater success in fire suppression.

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