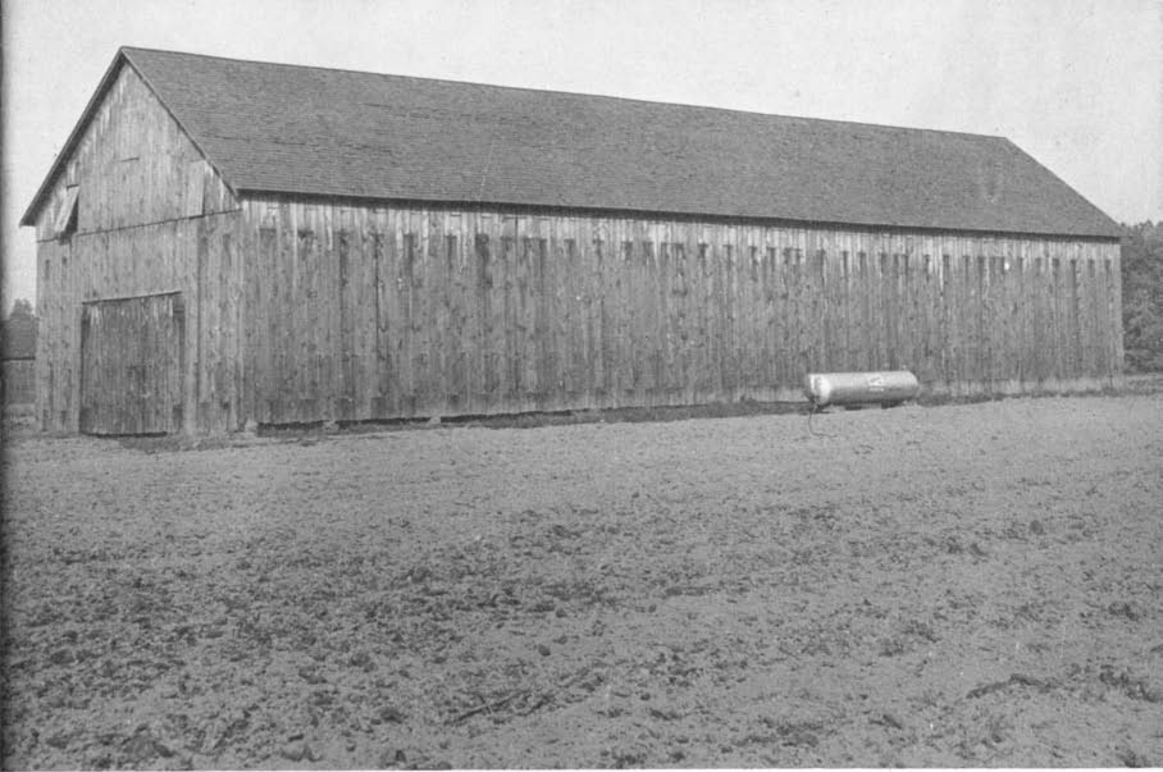

# PRINCIPLES OF CURING BROADLEAF AND HAVANA SEED TOBACCOS

## I. General Principles of Curing

## II. The Principles of Curing with LP-Gas

by A. B. Pack and W. A. Junnila

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION, NEW HAVEN

Published Cooperatively with the Storrs Agricultural Experiment Station, and the Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture

Circular 183

July, 1952

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# THE PRINCIPLES OF CURING BROADLEAF AND HAVANA SEED TOBACCOS


A. B. Pack and W. A. Junnila[1]


This publication presents the principles of curing Broadleaf and Havana Seed tobacco which have been advanced through research at The Connecticut Agricultural Experiment Station and cooperating institutions and through the experiences of successful tobacco growers. These principles represent our present understanding of the air-curing process. As research and experience on the subject progress, there will undoubtedly be additions to and, possibly, modifications of the material reported here.

## I. General Principles of Curing

### THE FIRING OF SHEDS

The references to firing in the paragraphs to follow and throughout this publication infer *adequate* firing. Poor use of fires or insufficient firing can be as bad as no firing at all in many respects. The following discussion describes what is considered to be "adequate" firing and its importance to proper curing.

#### Reasons for Firing Sheds

Firing or the application of supplemental heat during the curing of stalk tobaccos is used for two important reasons. First, firing accelerates leaf wilting and chemical changes within the leaf, both processes being essential to a proper cure of Broadleaf and Havana Seed tobaccos. Secondly, firing is an effective means of controlling the spread of pole rot.

The process of curing involves a series of complicated chemical changes, which are required to convert the green, non-smokable leaf into a brown leaf possessing desirable aroma, taste, and other smoking qualities. The rate of these chemical changes is increased as the temperature rises. Therefore, artificial heating of the shed atmosphere tends to accelerate the curing and reduce the time the tobacco is exposed to various troubles in the shed. Numerous experiments have shown that proper firing can improve tobacco quality because of its effect upon chemical changes within the leaf.

Firing accelerates the wilting of the green leaf, because raising the air temperature increases the rate of water evaporation from the leaf tissues. It is highly desirable to cause the green tobacco to become wilted and limp early in the cure. When the leaves are in such a condition, they tend to hang apart from each other and many more channels are opened up for better air circulation in the shed. Firing not only helps open up

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more air passages but induces air circulation itself owing to rising warm currents over the fires. Moreover, a wilted leaf is less susceptible to an attack of pole rot than one turgid with water or having moisture condensed on its surface. Firing dries out injured or bruised areas which otherwise become excellent courts of pole rot infection.

The use of supplemental heat in tobacco sheds creates conditions that are unfavorable for the infection and spread of pole rot. This disease relies chiefly upon abundant moisture for its growth. Any means of reducing the moisture on and within the leaf, and decreasing the relative humidity of the atmosphere, will serve as a control measure. When the shed temperature is raised by firing, the relative humidity is lowered and the leaf moisture is reduced due to increased evaporation.

Recent experiments have shown that Broadleaf tobacco from a non-fired shed was worth 30 dollars per hundred pounds less than similar tobacco from a fired shed on the same farm. This very significant loss in value was due to widespread pole rot damage. The average cost of firing a hundred pounds of cured leaf is much less than the 30-dollar loss due to pole rot.

## When to Fire During Curing

The experiences of many tobacco growers have shown that firing is beneficial when applied very early in the curing process. In other words, fires are started just as soon as a shed is filled with green tobacco, regardless of the weather. This firing operation is referred to by several names, such as the initial firing, the green firing, or the firing to wilt, and it seems to be quite important to the success of the cure. Among the growers of shade tobacco, the initial firing is a universal practice. It causes the green leaves to wilt quickly and tends to hasten the curing process.

In addition to the initial firing, it has been demonstrated that firing of sheds is of value whenever humid, muggy, or rainy weather occurs for two or more successive days. During periods of high humidity and very light winds, water loss from tobacco leaves proceeds rather slowly and water may even condense upon the leaf surface. Pole rot infection is favored by such weather and if these conditions persist for a few days, spread of the disease is encouraged. Since the unfavorable curing weather cannot be altered, the best measure available to control the disease appears to be the use of supplemental heat in the sheds.

When poor drying weather has prevailed for two successive days, experience has indicated that firing should be initiated during the second day. If for various reasons, firing is not started on the second day and a third day of bad curing weather occurs, firing can still be of value in reducing pole rot damage. Delayed firing is better than none at all, but is not as beneficial as starting the operation before the tobacco has been exposed to about 48 hours of poor drying weather. One day of muggy or damp weather followed the next day by good drying weather does not appear to cause a serious development of pole rot, and firing is therefore not necessary. Fortunately, in this climate, poor drying conditions do not often persist more than two or three successive days, but this is still long enough to obtain benefits from firing, when such conditions arise.



Daily weather forecasts may prove helpful as they indicate approaching bad curing weather and its expected duration, or how long a current bad spell will last. With a knowledge of the principles of proper curing as discussed herein, supplemented by weather forecasts and observations of the cure, it should be possible for a grower to decide whether or not firing is needed at any given time.

The firings subsequent to the initial, green firing, and done primarily to combat pole rot, are to be applied while the tobacco is passing from the green-yellow to the brown stage. After the leaves have become completely brown and the midribs are approaching a dried state, they are no longer subject to pole rot infection. At this stage, firing is no longer essential and may for the most part be disregarded. However, there is a nondestructive but undesirable mold which, unlike pole rot, may sometimes grow on a moist cured leaf. Light firing may be needed to stop its growth.

## How Long to Fire During Curing

There is no fixed number of hours for the duration of either the initial firing to wilt or subsequent firings to control pole rot. Many factors, such as prevailing weather conditions, maturity and size of the tobacco, spacing on the poles, and the stage of the cure, will affect the number of hours to fire a shed adequately at any given time. A close watch of the tobacco and the feel of the leaves during firing is of greater importance than adhering to a fixed length of firing period. However, some general procedures may be cited.

The initial firing at the usual temperatures (to be discussed later) will require at least 48 to 60 hours to bring the leaves into a wilted, limp condition. If relatively dry weather prevails during the initial firing, this length of time may be sufficient. The occurrence of rather humid, damp weather during the initial firing will probably require extension of the firing period from 72 to 90 hours. A longer period is usually unnecessary.

Again it should be emphasized that the feel and appearance of the tobacco is most important. If the leaves are hanging very limp on the stalk and one can see up through the tobacco to the roof, firing may be regarded as sufficient for the present. Over-firing to the point that leaves become stiff and dry while still green is to be as much avoided as insufficient firing. Excessive firing or too high temperatures cause a "hayed" condition and ruin quality. While leaves remain relatively turgid and more or less hinder air movement, continued firing is indicated.

Frequently, good initial firing makes further firing unnecessary because it may accelerate the curing enough to permit completion of the process before poor drying weather occurs.

When fires are operated to control pole rot during a period of poor drying weather, it has been found that firing for about 24 to 48 hours is generally sufficient. If dry weather prevails after firing for approximately 24 hours, firing may cease. On the other hand, if poor drying weather still persists after fires have been in operation for about a day, the firing period may be extended another 24 hours. Usually at the end of 48 hours of firing the weather will have changed to relatively drier conditions. In any case the tobacco should be dried out enough after being fired for two days to withstand persistent damp weather for another few days. Over-

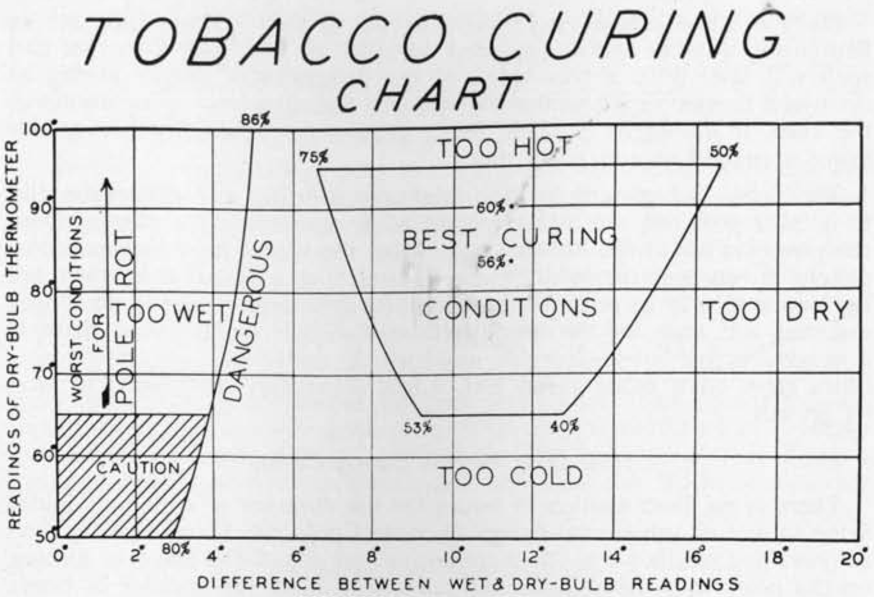



Figure 1. Tobacco curing chart. This chart shows the combinations of dry- and wet-bulb temperature readings which accompany various curing conditions. Note area designated as the best curing conditions.

firing to the point that the partially cured tobacco becomes very dry is considered detrimental to the final quality.

### Temperature and Relative Humidity Conditions During Firing

Experience has indicated that stalk tobaccos cure satisfactorily when the shed temperature is kept between 85° and 95° F. during both the green firing and later firing operations. Only during rare conditions of very warm and humid weather are temperatures of 95° to 100° F. desirable. In any case the temperature should be kept consistent with gradual but steady wilting, as in that way over-firing is avoided. Temperatures exceeding 100° F. for any appreciable length of time have been shown to injure leaf structure and elasticity as well as being uneconomical of fuel consumption.

A common practice among growers is to maintain the average shed temperature from 10° to 15° F. above the outside temperature during the initial and later firings. This differential will generally lower the relative humidity sufficiently to make conditions unfavorable for pole rot. Raising the temperature of the air by 20° F. will reduce the relative humidity to one-half its original value. Some experimental results indicate that shed temperatures of 75° to 80° F. are permissible at night. In many loose sheds it may be difficult to maintain a temperature of near 90° F. during abnormally cool nights.

A reliable thermometer hung centrally in the shed and midway between fires should prove useful. If a thermometer can be conveniently placed on an upper tier and reached without disturbing the tobacco too much, a more representative shed temperature may be obtained.



In the average tobacco shed it is not possible to exercise close control over relative humidity. It has been observed that, in general, relative humidities in sheds during firing are not as high as might be desirable for better curing. Limited experiments with shade-grown tobacco have suggested that the relative humidity (expressed as percentage) should be 10 to 20 points below the temperature (expressed as degrees F.). That is, at a temperature of 90° F., the best curing results were obtained when the relative humidity was maintained between 70 and 80 per cent. Measurements taken during the curing of Broadleaf and Havana Seed have shown the relative humidity to vary between 50 and 75 per cent, depending upon firing and outside weather conditions. The average was around 65 per cent. Good control of relative humidity in the sheds was not obtainable under the conditions of the cures investigated.

With the control of relative humidity in loose sheds seemingly difficult, it is still possible to observe and feel the tobacco frequently during firing to see if leaf drying is proceeding too slowly or too rapidly. It is to be remembered that when the air temperature is raised, the relative humidity is lowered and the rate of water evaporation increased.

If wet- and dry-bulb thermometers are used, a difference of 8-10 degrees should be maintained during firing.

### Fuels Suitable for Firing

Fuels suitable for the firing of Broadleaf and Havana Seed tobaccos include lump charcoal, processed charcoal (briquets), and liquefied petroleum (LP-) gas.

Figure 2. Curing tobacco with charcoal fires. This is shade tobacco, but the procedure for firing Broadleaf or Havana Seed is almost identical.

Lump charcoal has been used to heat tobacco sheds in the Connecticut Valley for about 40 years while charcoal briquets came into use about 25 years ago. The latter fuel has some advantages over lump charcoal, being easier to handle and ignite, less apt to spark, and subject to more complete combustion. On a pound basis the heat content of lump charcoal and briquets is quite similar. Both of the charcoal fuels have proved quite satisfactory to the many growers who have used them. About 50 bushels of charcoal are considered sufficient to fire an acre of stalk tobacco.

A new fuel, known commonly as LP-gas, has very recently entered the picture and shows promise for the firing of both shade and stalk tobaccos. Experiments begun in 1950 by the present authors and continued in 1951 on both tobacco types have shown gas to be very satisfactory. Much interest in firing with gas has since been shown by growers in this area. In 1951 an estimated 20 to 25 per cent of the shade tobacco was fired with gas, while in 1952 it is expected that firing with LP-gas will increase to include about 75 per cent or more of the shade and a sizeable percentage of the stalk tobaccos.

A discussion of gas firing principles is given in the second part of this publication. Detailed reports in the form of bulletins are expected to be issued in the near future on the subject of LP-gas as a fuel source for firing cigar-type tobaccos.

Coke, which is used extensively in the Burley tobacco areas, has not been found suitable for the firing of our cigar-type tobaccos. Tests have indicated that the combustion products from coke cause a bleaching of leaf veins and tissues, thereby reducing quality.

## Equipment for Firing

There are several satisfactory means of burning charcoal fuels in tobacco sheds. Small stoves of the salamander type or open pans similar to an old-fashioned wash basin are commonly used. In other cases small pits about 18 to 24 inches in diameter and a few inches deep are dug in the shed floor. These have worked successfully. All of these methods seem to be equally effective. The important considerations are the timing of the firing operation and the duration of the firing period.

Tobacco should not be hung very close to the fires, because in such cases it is dried too fast and hayed down, while at the same time tobacco on higher tiers dries more or less properly. Metal spreaders have been used to distribute the heat better and keep hot blasts from striking the tobacco in the near vicinity of the fires.

A large number of small fires is preferred over a few large ones, whether firing is done with charcoal or gas. A large number of small fires provides more even distribution of heat and possibly of air movement, which is important to the success of the curing. The number of burners used most commonly has been four for each floor area measuring 16 feet square. In most sheds this amounts to eight fires per bent. A greater number of fires per bent has been viewed as uneconomical of labor, fuel and equipment.

Good distribution of heat and air movement has been obtained by placing the stoves, burners or pits as evenly over the shed floor as conditions permit. Where tobacco must be hung close to the floor and limited space is available for fires, however, equal distribution in the bent is not always possible. If movable stoves are used, it is generally beneficial



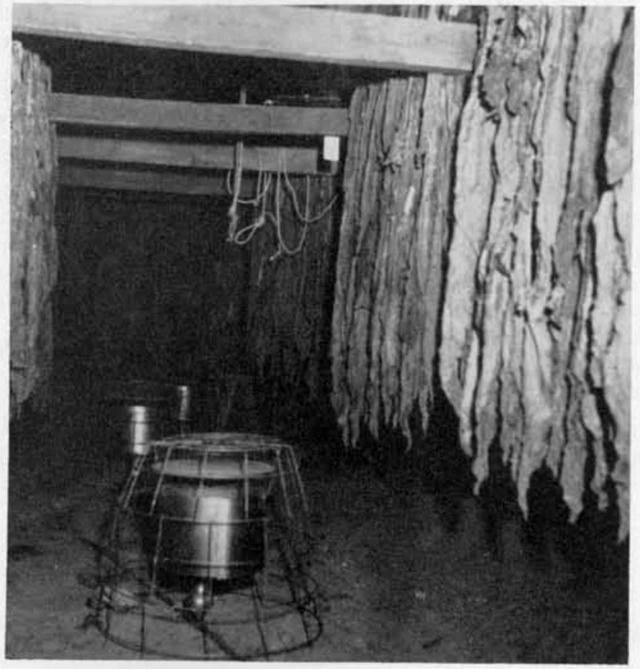


Figure 3. Curing Broadleaf tobacco with LP-gas as a source of fuel. Three stoves of the eight used per bent are visible in photograph.

to stagger them toward the windward side of the shed during damp, rainy weather. This helps to heat the cooler air more quickly as it is blown into the shed by the wind. Some growers have tightened sheds with building paper for about three or four feet from the ground. This has provided more heat for the windward side.

A discussion of the equipment necessary for gas firing is given in the second part of this publication.

## Weather Conditions and Forecasts During Curing

During dry, sunny weather the firing of stalk tobaccos does not appear to be necessary, except for the initial or green firing operation. As mentioned earlier, benefits are obtained by firing a shed of Broadleaf or Havana Seed just as soon as it is filled, regardless of the weather. Firing has also been cited as being effective for the control of pole rot, when two successive days of rather humid and poor drying weather occur. The length of firing period for both the green and subsequent firings is largely determined by the prevailing weather and the progress of the cure.

The occurrence of winds during curing is an important factor governing the use of fires. The stronger the wind, the higher the humidity which can be tolerated before firing becomes necessary. Air movement directly favors loss of water from leaves and keeps them from hanging close together. That is why during muggy, calm weather, firing has been found useful in accelerating wilting or in making conditions unfavorable for pole rot.

Fogs, which are common on August and September mornings, also affect the curing and the use of supplemental heat. It has been observed that after two or three consecutive days of heavy fog, pole rot often becomes serious in a shed, even though sunny, somewhat drier weather replaces the fog in the afternoon. Under such conditions, firing for 12 to 24 hours may prove effective in drying off the leaves and stopping the spread of the disease.

Since 1949, firing advisory broadcasts have been offered to the tobacco growers as a service during the curing season. In cooperation with the U. S. Weather Bureau, which furnishes 24- to 48-hour forecasts of temperature, relative humidity and wind, the Tobacco Laboratory prepares a daily advisory on whether or not the firing of sheds is suggested during that period. This advisory is then broadcast by local radio stations two or three times during the 24-hour period that follows.

Information as to the time and station of these broadcasts may be secured through your county agent or the Tobacco Laboratory in Windsor.

## SHED VENTILATION AND FANS

### Manipulation of Shed Ventilators During Curing

The proper handling of ventilators will do much toward reducing moisture and pole rot severity in a shed. The free movement of wind through the shed increases leaf wilting and removes excess moisture to the outdoors. A successful practice is to keep all ventilators open, except during firing or periods of high winds and blowing rain. This affords good air circulation while curing is taking place. When leaves are cured and become dry, they may be protected from wind damage by closing ventilators on the windward side, especially during intervals of high winds.

Ventilators, of course, are kept closed during firing in order to retain the heat in the shed as long as possible. Due to the looseness of construction, there is, however, an exchange of air with the outside even with ventilators closed. Moisture-laden air of the early curing usually diffuses out sufficiently to prevent a high concentration in the shed during firing. Some growers occasionally open ventilators on the leeward side of a shed for a few hours in the daytime. There is no apparent objection to this practice.

More tobacco is ruined by too little ventilation than by too much.

### The Use of Fans During Curing

Recent experiments have clearly indicated that fans used alone cannot be substituted successfully for firing, particularly during periods of damp humid weather and in the case of the so-called green firing. While air movement by fans has no apparent unfavorable effect on leaf quality, it will not check the spread of pole rot when conditions are suitable for the disease. Air movement, itself, will not alter the moisture content of the parcel of air in motion, unless it passes over a moist surface or a cooler surface onto which water may condense. Under very high humidity conditions, the evaporation of moisture from a tobacco leaf is retarded or even stopped whether air is in motion or not. Such a condition slows down



the curing process and makes it possible for the pole rot organisms to develop.

It seems possible that fans used in conjunction with fires would prove beneficial. Heating of the air supplemented by more vigorous air movement and better air distribution would promote wilting and consequently shorten the time required to complete the firing operation.

Fans may be useful during periods of moderately humid weather (average relative humidity 60 to 80 per cent) and very light winds. The use of fans may render firing unnecessary or reduce its duration during relatively short periods of high humidity.

## THE HARVEST AND HANGING OF TOBACCO

### Maturation and Harvest of the Plants

Experience has indicated that tobacco harvested in a fully "ripe" stage is in less danger of pole rot than immature tobacco. Ripe tobacco cures more quickly and therefore is exposed for a shorter time to pole rot and other troubles. How the stage of leaf maturity in the stalk tobaccos influences the curing process or quality of the cured leaf has not been fully investigated. At present, the best practice seems to be a delay of harvest for three weeks after topping time. This gives the tobacco more time to become fully ripened.

Allowing the cut plants to wilt as much as possible in the field before hanging in the shed is a common and wise practice. In doing so, the amount of water to be removed during curing is reduced and the curing process may get started sooner. If the hanging of wet tobacco cannot be avoided, drying of the leaf surfaces may be facilitated by opening the shed to drying winds or by firing the shed lightly for about 12 hours. This light firing, of course, does not replace the regular green firing. The firing of partially-filled sheds is sometimes done, when weather conditions or other factors greatly prolong the complete filling. This has been of much benefit, especially if very big and heavy plants are tightly hung in the shed or bad drying weather delays the filling operation.

### Hanging of Tobacco in the Shed

The hanging and arrangement of Broadleaf or Havana Seed tobacco in the shed is another factor that will influence the success of the cure. Unfortunately, many growers raise more tobacco than they have adequate shed space for and are therefore forced to crowd the laths too much.

Air movement and circulation are increased if laths are hung on the poles as far apart as shed space will permit. Laths of heavy tobacco need to be spaced farther apart than laths of relatively small tobacco. On the other hand, laths may be hung somewhat closer together in the peak than on lower tiers. A spacing of six or seven inches on the poles seems to be the minimum distance, while eight to ten inch spacing is more nearly optimum and of course, preferable. If the grower plans to fire regularly, the laths may be hung a little closer than if no firing is contemplated. Usually, a lath holds six plants of Havana Seed or five of Broadleaf.

## POLE ROT

### A Brief Description of the Disease

Tobacco hanging in sheds and cured by the so-called "air-curing" process (as contrasted to flue-curing) is subject to a disease called pole sweat, house burn, or preferably, pole rot. In most years this disease is responsible for greater loss to Connecticut Valley tobacco than any other. In relatively dry curing years like 1949 the disease is not too serious, but in other years, such as 1947, 1950 and 1951, pole rot reaches disastrous proportions.

Pole rot is caused by certain species of fungi which grow in the moist leaf and produce a destructive rot of the tissues. Studies of this malady have clearly shown that high humidity, fairly warm temperatures, and little or no air movement favor its occurrence and spread. Abundant moisture in and on the leaf and in the atmosphere are the keys to its existence. Also, a tear, wound or bruise of the leaf surface makes an easy entrance point for the fungi. It has been found that only a brown, cured leaf is immune to infection.

It is important that the disease be recognized during curing so that control measures may be initiated without delay. Under favorable conditions pole rot advances rapidly in a shed, particularly if unwilted leaves hang closely together, allowing easy spread of the disease. When leaves show a freshly rotted condition or have moisture condensed on the surface and tissues tear apart easily, it is indicative that pole rot is becoming serious. Extensive damage will then result, if pure drying weather prevails and firing is not begun.

Pole rot has generally been found to be worse in the tobacco hanging close to the ground than in the higher tiers. This has been observed even in fired sheds, because heat from fires rises and cannot adequately reach the tobacco hanging on the lower tiers a few feet to the side of the fires. In non-fired sheds pole rot frequently causes great damage on the third tier and is more serious in the center of the shed compared to the outer poles. Temperature observations indicate that in fired sheds a relatively cool area forms between the second and third tier. This has been reflected by a greater incidence of pole rot on the third tier compared to the peak or second tiers.

The most practical means for the control of pole rot, as pointed out before in this publication, is the use of supplemental heat in the shed. As also described earlier, this involves *adequate* firing of the shed just as soon as filling is completed (the initial or green firing) and, later, whenever two successive days of damp, muggy weather occur. Spraying or dusting in the field before harvest with a fungicide is not practical. At present no fumigant with fungicidal properties has been found to provide control in the shed. There is no evidence that tobacco seed carries the disease over to the next crop or that pole rot is in any way directly related to land fertility or fertilizer practices.

It should also be pointed out that firing with the new fuel, LP-gas, is not necessarily a new control method for pole rot. The control of this disease is influenced by when and how much one fires and not by the source of fuel used.



## LIST OF PUBLICATIONS ON CURING

The following publications issued by the Tobacco Laboratory of The Connecticut Agricultural Experiment Station contain information wholly or in part on the subject of curing Connecticut Valley tobaccos.

ANDERSON, P. J. Tobacco culture in Connecticut. Conn. Agr. Exp. Sta. Bul. **364**: 755-760. 1934.

————. Diseases and decays of Connecticut tobacco. Conn. Agr. Exp. Sta. Bul. **432**: 146-152. 1940.

————. Pole rot of tobacco. Conn. Agr. Exp. Sta. Bul. **517**: 1-19. 1948.

————, T. R. SWANBACK, AND O. E. STREET. Curing experiments in 1931. Production of color as related to rate of curing. Conn. Agr. Exp. Sta. Bul. **335**: 268-274. 1932.

————. Comparative studies of fuel for curing. Shade curing experiments. Conn. Agr. Exp. Sta. Bul. **359**: 362-372. 1934.

CHAPMAN, G. H. Experiments in the curing and fermentation of Connecticut Shade tobacco. Conn. Agr. Exp. Sta., Tobacco Substation Bul. **3**. 1923.

SWANBACK, T. R., O. E. STREET, AND P. J. ANDERSON. Comparative studies of fuels for curing in 1932. Shade curing experiment in 1932. Conn. Agr. Exp. Sta. Bul. **350**: 499-507. 1933.

The following publications have been published or are to be published in the near future by the Storrs Agricultural Experiment Station in cooperation with The Connecticut Agricultural Experiment Station and the Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture.

JUNNILA, W. A., A. B. PACK, AND M. S. KLINCK. Liquefied petroleum gas as a source of fuel for the curing of shade-grown tobacco. Storrs Agr. Exp. Sta. Information Series **24**. 1951.

————. The firing of shade-grown tobacco with LP-gas. Storrs Agr. Exp. Sta. Bul....... (In press).

## II. The Principles of Firing with LP-Gas

In the search for better methods of curing Connecticut Valley tobaccos it was logical for research men to try new fuels for the firing of sheds. Reports from southern tobacco areas indicated that LP-gas showed considerable promise as a new source of fuel for curing. Therefore, it was of interest to try this new fuel for the firing of tobacco sheds in the Connecticut Valley. Considering the methods of burning gas, it was apparent that a saving in labor might be effected in comparison with the conventional use of charcoal.

Shade-grown tobacco was successfully cured with gas fires in 1950. The following year the firing of stalk tobaccos with gas was tried experimentally and the results from these experiments along with those of a few growers trying gas indicate it has been satisfactory. Due to the increasing interest among stalk tobacco growers in this new method of firing, the principles of gas firing are discussed in the following pages.

### WHAT IS BOTTLED OR LP-GAS?

Natural gas is a mixture of various gases known as hydrocarbons, which contain the elements, carbon and hydrogen, in different chemical combinations. Butane and propane are gaseous components of this mixture and in the refining process they are more conveniently stored and used in liquid form. Storage and transportation is facilitated by putting these gases into cylinders or tanks under nominal pressure. Various mixtures of butane and propane, handled in this manner, have been termed liquefied petroleum or LP-gas by the industry. The public has become accustomed to calling it bottled or tank gas.

### A BRIEF COMPARISON OF GAS AND CHARCOAL FIRING OF STALK TOBACCOS

Experiments in which LP-gas and charcoal are being compared as fuels for firing stalk tobaccos have been in progress for only one season and the comments given below should be viewed in this light. The experiments are to be continued for at least one more season after which time more conclusive results will be published.

In tests conducted in 1951 the quality of both Broadleaf and Havana Seed was improved by firing with gas in comparison with charcoal. When comparable lots of both types were graded, it was found in each case that the gas-fired leaf was worth an average of about 2.5 cents per pound more than the charcoal-fired tobacco. This represents an increase in quality of approximately 5 per cent in favor of firing with gas.

With Broadleaf and Havana Seed, the increase in quality resulting from gas firing has not been as impressive in the first test as occurred in experiments with shade tobacco. After one year's study it appears that firing with gas tends to improve stalk tobacco quality somewhat in comparison with charcoal but no spectacular improvement is to be expected. Results thus far indicate that gas-fired stalk tobacco may occasionally be worth as much as 5 or 6 cents a pound more than similar tobacco fired with charcoal.



Where comparable sheds have been fired approximately the same number of hours, the cost of fuel has been cheaper in the case of LP-gas. On the basis of charcoal costing 90 dollars per ton, a saving of 10 to 20 dollars per acre has been effected from the use of gas. In carefully conducted experiments during the 1951 season, the cost of gas for firing an acre of Havana Seed or Broadleaf has ranged from 25 to 35 dollars as compared to about 40 to 50 dollars for charcoal. In either case such factors as length of firing periods, temperatures maintained and looseness of the shed will govern the cost of fuel for firing sheds of tobacco.

Probably, the most attractive feature of using gas to fire stalk tobacco sheds is the saving in labor and labor costs. While no exact figures have been obtained comparing the labor costs of gas and charcoal firing, it has been obvious that the former method is definitely cheaper and more adaptable to present conditions of farm labor shortage.

The use of charcoal requires the close attention of one or two firemen throughout firing in order to replenish fuel frequently, stir fires, and guard against the shed catching fire. On the other hand, only a short observation once an hour seems to be necessary with gas firing. An observation would comprise checking the shed temperature and condition of the tobacco, adjusting a few burners, if needed, and seeing that no burners are blown out. It appears possible that one or two firemen, normally needed for one charcoal-fired shed, could attend several nearby sheds, which are being fired simultaneously with gas. Of course, it must be remembered that with both gas and charcoal there is always the possibility of a shed catching fire and similar precautions should be observed in either case.

Reports from the few growers who used LP-gas initially in 1951 indicate that their fuel and labor costs and the quality of the cured leaf have been quite satisfactory. In their opinion the use of gas for firing sheds gave better results than were generally obtained from charcoal as a fuel.

### EQUIPMENT NEEDED TO FIRE WITH GAS

#### Storage Tanks

On the average it takes from 500 to 1000 gallons of gas to cure five acres of tobacco. The most widely accepted tank for storing LP-gas during firing is the large 500-gallon size. The tanks are mounted on skids and moved from shed to shed as needed. Larger tanks are too unwieldy and heavy to move around. In the initial gas firing tests, batteries of 100-pound cylinders were employed. This arrangement may be used where a grower has only one shed to fire. At present the gas companies are investing largely in the 500-gallon tanks.

As mentioned earlier, the storage tanks for gas firing contain the butane-propane mixture in liquified form and under high pressure. Some of the liquid is changed to gas while in the tank. When the pressure is released by opening the tank valve, the liquid changes more readily into gaseous form and the gas starts on its way to the gas burners at high pressure. This pressure is reduced by a regulator on the tank so that the much lower pressure required by the burners is attained. The rate of

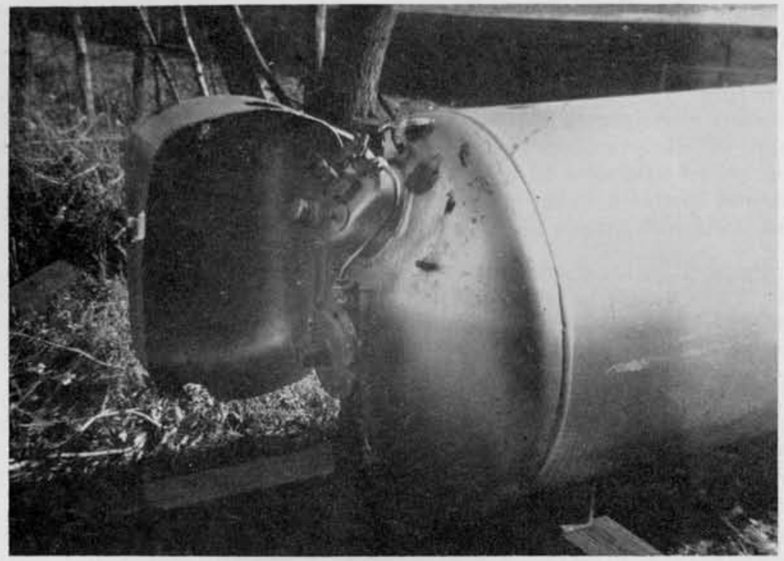


Figure 4. A view of a 500-gallon tank used for supplying gas to tobacco sheds. Photograph shows the pressure regulator, hose leading to shed and the skids on which tank is mounted for easy moving.

evaporation in the tanks is dependent upon the amount of gas (liquid form) in the tank, and the temperature and humidity of the atmosphere. One 500-gallon tank provides sufficient evaporation to supply the burners in a four-acre shed under normal conditions. Tanks should never be filled with liquid LP-gas to more than 80 to 85 per cent capacity because some space must be left for evaporation. Since liquids are not compressible, it is necessary to have some gas in the tank to insure proper pressure. All gas tanks are equipped with proper safety valves to relieve any condition of excessive pressure which may develop.

It has been found advantageous to time the refueling of a tank so as to have it nearly empty when moving to another shed. The moving of a full tank over wet places may be too heavy a load for an ordinary wheel tractor.

### Piping and Piping Installations

Both permanent and portable systems are in use. Some of the essential systems are listed below. See also Figure 5.

1. Permanent.
   a. Central Main.
      Underground main running lengthwise in the center of the shed.
      Copper tubing take-offs connect to bank of valves on center posts.
   b. Split Main.
      With two smaller pipes attached to sills on both sides of shed.



2. Portable
   a. Central Main
      Surface main running lengthwise with either short pipe fittings or long tubing for the take-offs.
   b. Multiple Main.
      Separate lines for each of four rows of stoves attached to a crosswise header in the middle of the shed. This system does not require flexible tubing.

The preference of stalk tobacco growers at the present time seems to be the portable system. Such a system keeps equipment costs at a minimum. Unions are used to break the pipe into lengths which are easily transported from one shed to another.

Black pipe is most commonly used for gas installations. Galvanized pipe has been used, but with this kind there is always the possibility of small metal flakes breaking loose and obstructing stove orifices. Shellac or a special joint compound is available for gas piping. White lead must not be used because it reacts with the gas.

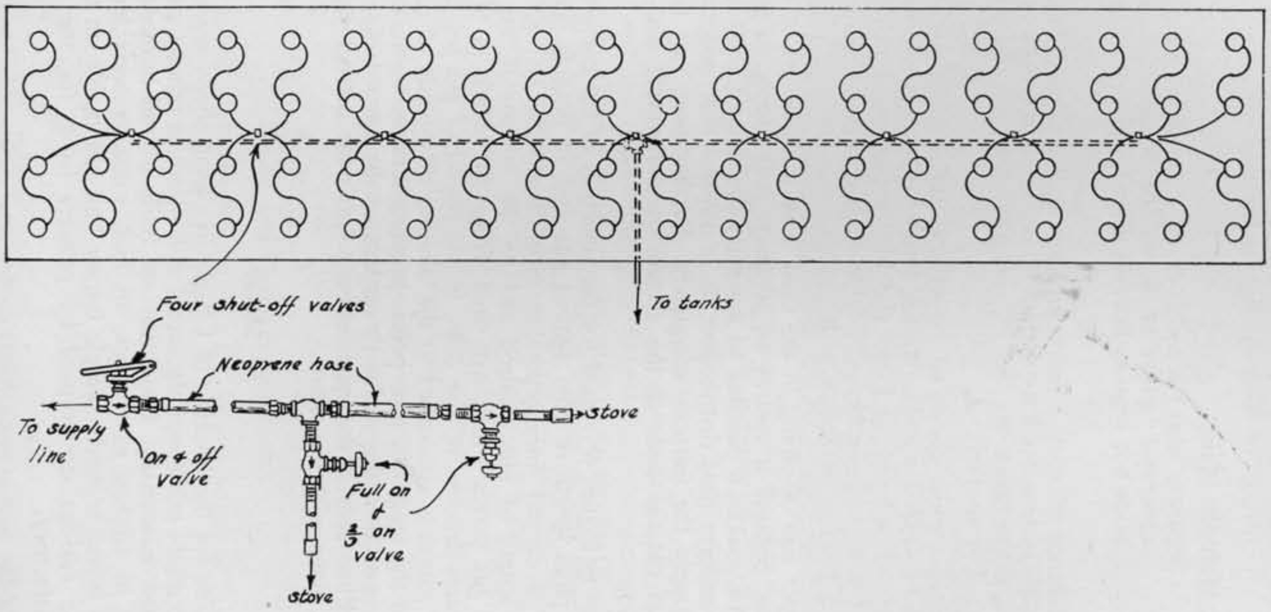
The proper size of piping in the shed is very important to the success of gas firing, because it insures an adequate fuel supply to each burner. This, in turn, makes it possible to maintain the desired shed temperature and more uniform heat distribution. It is obvious that undersized piping does not supply the burners adequately. Furthermore, any reduction in pipe size at the far ends of the system is undesirable and aggravates the problem.

The chart in Figure 6 is used for the selection of the correct pipe size. The chart plots length of pipe against gas flow in pounds per hour and the series of curved lines represent pipe diameters. To use the chart, locate the length of pipe desired and on the horizontal line locate the number of gas stoves which will draw from the length of pipe desired. The maximum demand of one stove is one pound of gas per hour so the number of stoves is equivalent to the number of pounds of gas flow per hour. From the length of pipe point, proceed directly vertically and note where the two lines intersect with respect to the curved pipe size lines. The curved line nearest the intersection point is the correct pipe size. An example is given with the chart.

### Stoves

Two stoves for the burning of LP-gas in curing sheds are now on the market. No doubt other manufacturers will introduce other types of stoves in the future. Essentially, the stoves are built around burners similar to those used in kitchen gas ranges. In fact, some growers have already improvised stoves around a simple burner unit obtainable on the market. So far, the various stoves used by growers have, for the most part, proved satisfactory.

Photos of the two manufactured stoves now commonly used are shown in Figures 7 and 8. Various parts on each are labelled. These photos were supplied through the courtesy of the Buckeye Incubator Company, Springfield, Ohio, and the Bright Leaf Industries, Charlotte, North Carolina.





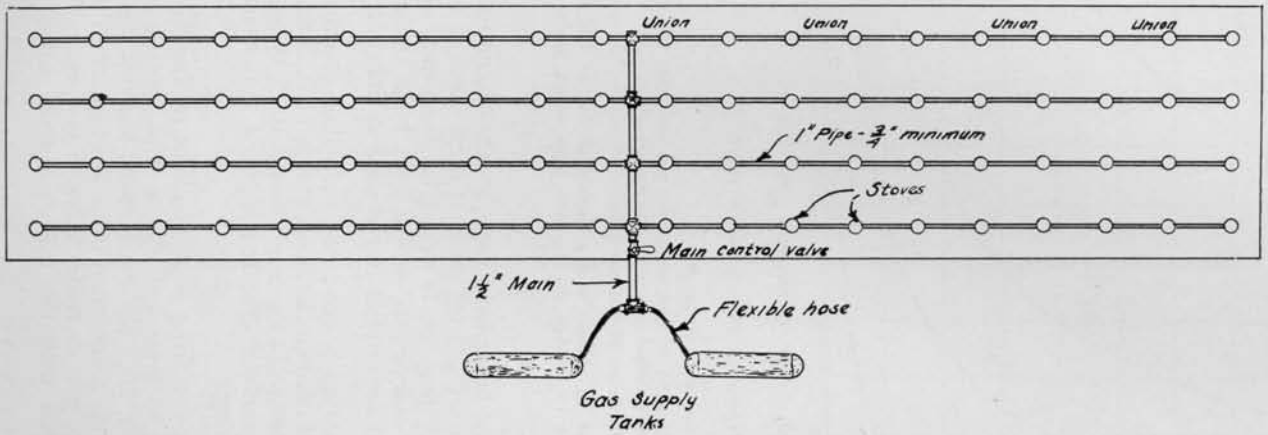




Figure 5. Upper diagram shows a central main piping system (portable or permanent). The main line is run underground or on the surface. At each center post a take-off feeds a bank of on-off valves (one valve per pair of stoves in this case). Underground installations have copper tubing take-offs to bring valves above ground. Surface installations use only pipe fittings connecting the main pipe and valves. At left is a drawing of a valve system which is placed at center posts of shed. Lower diagram shows a portable piping system using no hoses. Stoves attach directly to piping.

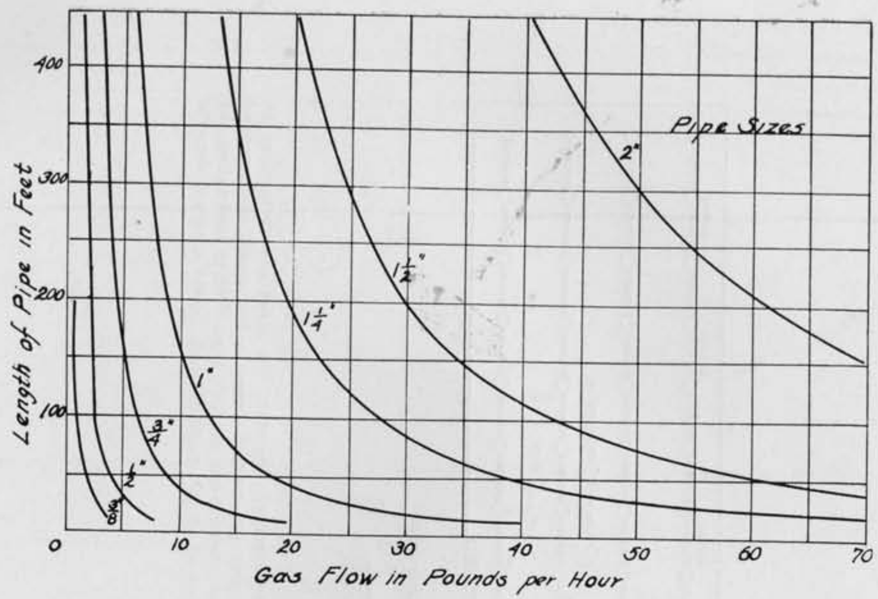



Figure 6. Pipe selection chart.

Example of how correct pipe size is determined:

Thirty stoves with maximum demand of one pound of gas per hour per stove are to be fed from a pipe 100 ft. in length. What size pipe is necessary?

30 x 1 pound/hour = 30 pounds/hour.

Intersection of vertical line at 30 pounds and a horizontal line at 100 feet indicates a pipe size in between 1¼ and 1½ inches. A 1¼ inch pipe would perform satisfactorily.

All installations for gas firing have some means of controlling the heat output of the stoves. An on and off valve at each stove or pair of stoves is essential when first lighting up. It would be dangerous to turn on all stoves at once with only one or two men to light them. Under such conditions sufficient gas would accumulate in the shed to cause an explosion.

In the first installations each stove had individual controls which permitted three settings: full on, two-thirds on and full off. Thus, any number of stoves could be adjusted to fit the conditions desired. When some stoves were turned off, the remainder were redistributed somewhat to continue to provide uniform heating.

Growers interested in gas firing were quick to realize the convenience of having a master valve to control all stoves. This valve is located at the head of the piping system. Such an arrangement requires the master valve system to be equipped with a minimum by-pass which at all times supplies the stoves with enough gas to resist being blown out. The minimum by-pass must be included with the master control valve to meet fire safety regulations.

With a normal control master valve, the heat output can be reduced uniformly throughout the shed as needed. Reduction beyond a minimum setting for safety must be obtained by turning out stoves.



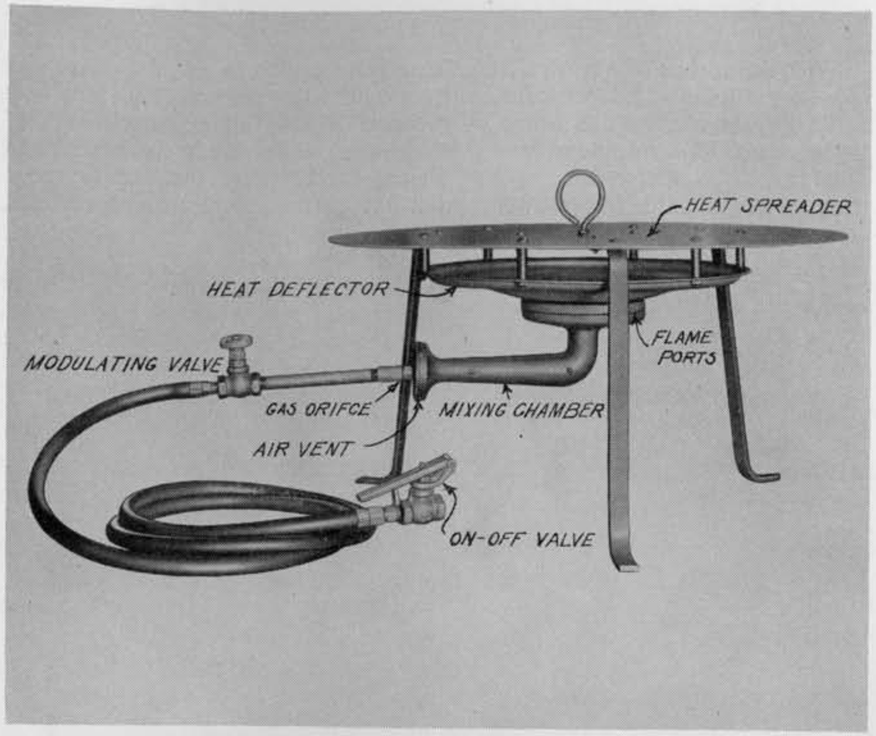



Figure 7. A type of manufactured stove used to burn LP-gas in curing sheds. Photograph through the courtesy of the Buckeye Incubator Co., Springfield, Ohio.

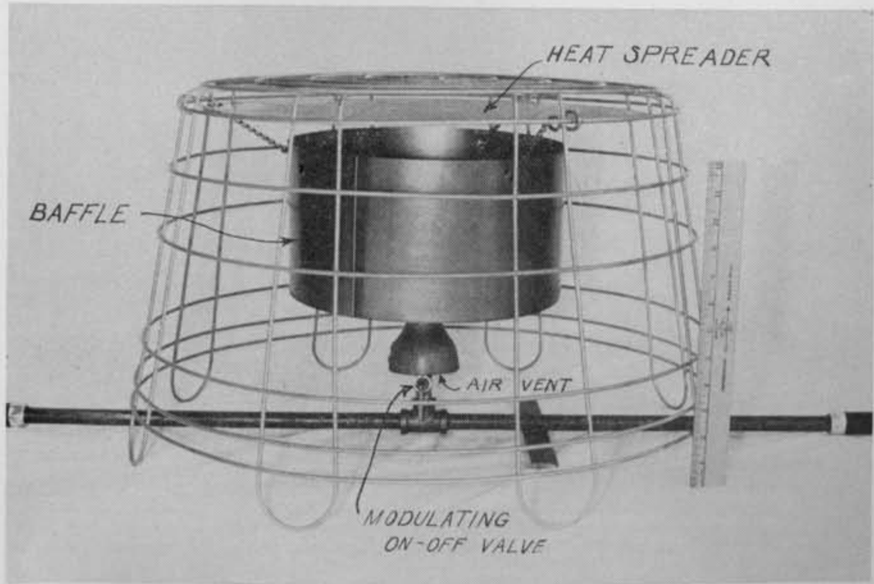



Figure 8. A second type of manufactured stove for the burning of LP-gas in tobacco sheds. Photograph through the courtesy of the Bright Leaf Industries, Charlotte, N. C.

## Automatic Temperature Control

With the advent of a controllable firing system such as gas, the possibility of using automatic temperature controls enters the picture. This is a new field of research in the firing of tobacco sheds. Some installations of thermostats have already been tested, but much study is needed to determine how many are required in the shed, where the one or more thermostats should be placed, and what setting is optimum for the various firings.

A labelled photograph of one type of automatic temperature control is shown in Figure 9.

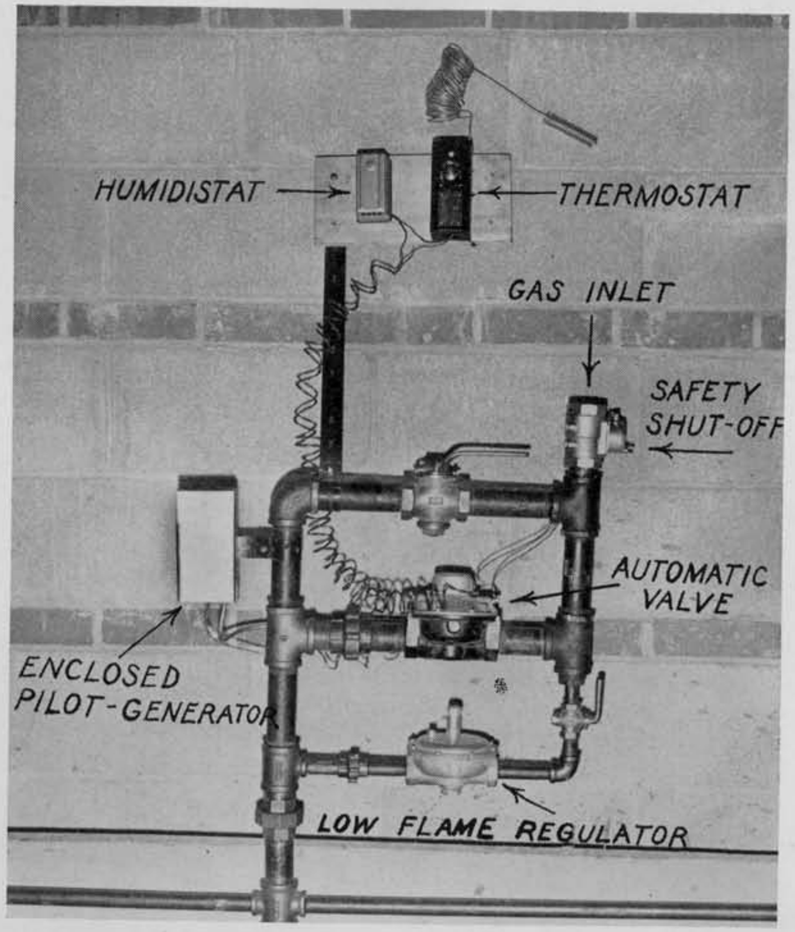



Figure 9. An automatic temperature and humidity control system to be used in firing tobacco sheds with LP-gas. Photograph through the courtesy of the Bright Leaf Industries, Charlotte, N. C.



## THE MANAGEMENT OF GAS FIRES

### Leaks in the Piping

All gas installations should be tested for leaks before lighting any fires. Testing is done in the following manner. Open the main valve momentarily to build up pressure in the line and then close. With a manometer or pressure gauge in the line, any drop in pressure in the otherwise closed line indicates the presence of a leak. The leak is then located safely by means of soap suds. *Never use an open flame*. If a leak is indicated, look for it in the order of unions, threaded fittings, and straight run of pipe. A suitable manometer can be obtained through the burner manufacturer or the gas dealer.

### Starting the Fires

There is always a quantity of air in the piping system. Until this air is largely forced out of the lines by the incoming gas, it may be necessary to relight the stoves a few times. Sliding the air port cover to decrease the opening will help maintain a flame until the air in the line is bled out. Some stoves now used have no provision for this adjustment. When the stove is successfully lighted, some adjustment of the air port may be necessary to obtain the proper flame.

A candle attached to the end of a wire facilitates the lighting of the stoves.

### Obtaining a Proper Flame

It is very important to obtain and keep a proper flame on each stove. Such a flame is characterized by being definitely blue in color and more or less stable. A yellow flame indicates incomplete combustion, while soot forms on the flame deflector and carbon monoxide gas is released. There are several causes of a yellow flame, which are listed below.

1. Excessive draft in the shed causing the flame to flow to one side of the burner.
2. Dust stirred up by someone walking by the stove. In this instance, the yellow flame persists for only a short time.
3. Excessive gas pressure in the burner, causing the flame to float slightly away from its normal position.
4. The burner orifice being too large or turbulence of the gas in the venturi or small neck of the burner due to a restriction.
5. A restricted air shutter or port hole which reduces the amount of air necessary for complete combustion.
6. Excessive impurities in the gas.

### Placement of Stoves

One of the main problems of firing tobacco sheds is that of obtaining even distribution of heat throughout the shed. This tends to promote more uniform curing conditions. A system of flues, which could be adapted to the burning of cheaper fuels, was not successful because of relatively poor heat distribution.

Figure 10. Improvised gas stove using a manufactured burner part and a charcoal pan for heat deflection. This type was moderately successful in the shed of Broadleaf shown here. Note absence of rubber hoses. See Figure 5.

Theoretically, the more gas stoves used, the more uniform the distribution of heat in a shed. Eight stoves per bent (16 x 32 feet) have given satisfactory performance with a reasonable equipment cost. This number per bent is convenient also because it divides the ordinary 16 by 32-foot space into eight equal squares measuring eight feet on a side, each containing one burner or fire. It has been possible to cut this maximum number down to six in tighter sheds. When it is necessary to turn out a few stoves, a rearrangement of the other stoves is, of course, necessary to improve heat distribution.

The advantages of portable gas stoves cannot be as fully realized in most sheds of stalk tobacco as is the case with shade sheds, because the stalks are usually hung close to the floor and it is impossible to make any changes in stove placement without moving laths of tobacco.

### Opening of Clogged Orifice on the Stove

Where the gas enters the burner, a small brass fitting is provided. In one type, this is screwed into the burner; in another type, the burner slips over it. This brass fitting contains a very small hole which is called an "orifice." The gas going to the burner passes through this very small hole due to the pressure in the gas line. It is possible for the orifice to become clogged with dirt or other foreign matter. On some units the brass fitting must be taken out and the small hole cleaned by blowing



through it. Use of a sharp instrument to clear the orifice should be avoided because the size of the precisely drilled hole may be changed. Even a small increase in size will allow an excessive amount of gas to flow through. If a replacement is available, the hole may be peened shut and redrilled. The specification of orifice size is given by the burner manufacturer. One make of stove has the advantage of having a self-cleaning orifice. This is done by opening and closing the gas valve attached to the burner.

### Wind Protection During Firing

Due to the looseness of most tobacco sheds, some protection from wind is helpful in firing with gas. The gas flame is affected by relatively light drafts entering the shed. Some growers have solved this problem by temporarily covering the lower four feet of their sheds on the outside with building paper.

The use of tight sheds in curing tobacco is being studied but at present exact methods of management have not been worked out.

### Safety Measures with Gas Firing

Liquefied petroleum gas is a substance which must be treated with due respect. The main thing to remember is that under some conditions gas

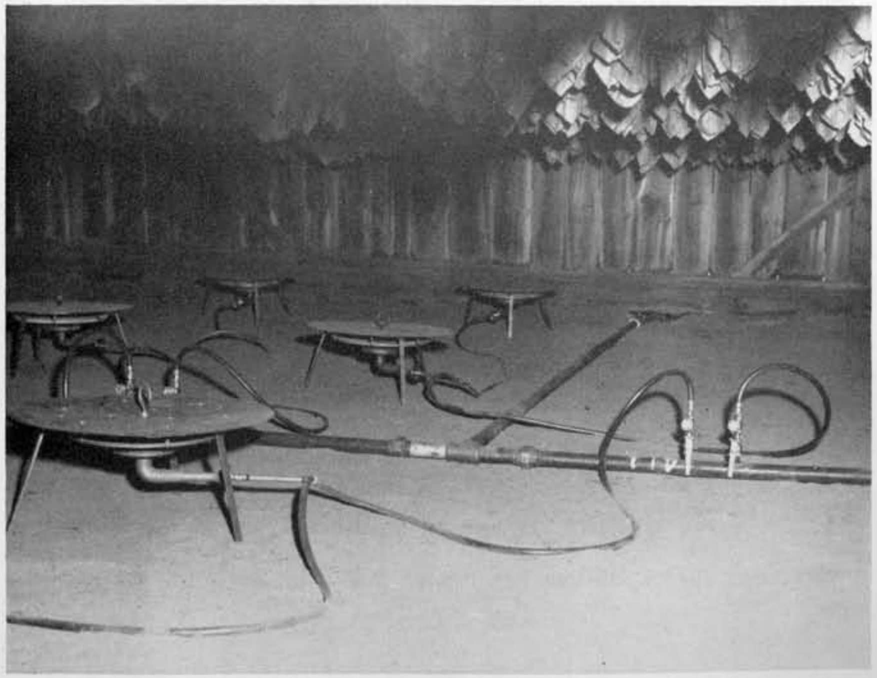


Figure 11. A completely portable piping system showing pipe entering shed from supply tank and the main pipe setting on shed floor. Note how gas stoves are hooked to supply line in the foreground.

can be violently explosive. In handling equipment, care must be exercised to avoid any rupture of pipe joints or other hazards leading to free escape of raw gas. It is essential to test for leaks by using soap suds and *never an open flame*. If a stove is blown out, the proper and best way to play safe is to turn off the gas coming to the stove and wait a few minutes before relighting. It appears that in our relatively loose sheds the gas, which is heavier than air, will drain along the floor and out of the shed quite readily. Dead grass and rubbish should not be allowed to accumulate near the supply tanks. Any external fire in this rubbish would cause the gas to blow open the relief valve and cause the spread of a disastrous fire.

After one season in which a considerable number of growers fired with gas, there was no reported instance of fire or explosion due to this fuel. However, one must never relax his respect for and proper treatment of this material.

### Storage

With good care it is reasonable to expect the gas burning stoves to last many years. The neoprene hoses, while probably not as durable as the stoves, should also give satisfactory service for a long period. When not in use, the neoprene hose should be laid out or hung straight in a relatively cool, dry room. At the same time, burner parts may be protected from rust by spraying with oil and storing in a dry shed.

## WHAT IS THE APPROXIMATE COST OF GAS FIRING EQUIPMENT?

For a ten-bent or five-acre shed the investment costs may be tabulated as follows:

| | | |
|---|---|---|
| Tanks: | furnished by the gas company | |
| Stoves: | 80 stoves @ $10 each | $ 800 |
| Piping: | | 150 |
| Manual control valve | | 50 |
| | Total cost for shed | $1000 |

The yearly cost of the five-acre curing system is figured in the following manner: Assuming the equipment listed above lasts 10 years, the yearly amortization rate will be 10 per cent of 1,000 dollars or 100 dollars. Interest for the 10-year period figured at 6 per cent would average 30 dollars per year. Therefore, the total yearly cost will be 130 dollars, including interest.

The cost per acre per year would vary according to the number of sheds in which the 1,000 dollars worth of equipment could be used during each curing season. The figures below illustrate this.

| *Condition* | *Cost per acre* |
|---|---|
| 1. Used in one 5-acre shed per year | $130 ÷ 5 = $26.00 |
| 2. Used in two 5-acre sheds per year | $130 ÷ 10 = 13.00 |
| 3. Used in three 5-acre sheds per year | $130 ÷ 15 = 8.67 |

It has been determined in experiments that a saving in fuel costs of about 15 dollars per acre can be made with gas over charcoal as a fuel.



With this saving applied to the cost per acre of the equipment, it can be seen that the equipment would pay for the yearly costs if used in two sheds. In other words, the saving in fuel costs per acre could amount to 15 dollars as compared to equipment costs of 13 dollars. In addition to the saving in fuel costs, it has also been shown that gas firing reduces labor costs substantially and improves leaf quality to some extent. These savings would also apply towards amortizing the yearly cost of the gas firing equipment.

It appears from the equipment cost figures given above that the use of gas firing in a single shed would not be profitable to a grower of stalk tobacco.