The curing of cigar tobacco with the use of kerosene as a source of heat, in comparison with the use of liquified petroleum gas for the purpose.

THE CURING OF CIGAR TOBACCO WITH THE USE OF KEROSENE AS A SOURCE OF HEAT IN COMPARISON WITH THE USE OF LIQUIFIED PETROLEUM GAS FOR THE PURPOSE

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THE CURING OF CIGAR TOBACCO

WITH THE USE OF KEROSENE AS A SOURCE OF HEAT,

IN COMPARISON WITH THE USE OF LIQUIFIED PETROLEUM GAS

FOR THE PURPOSE

By

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Thesis submitted in partial fulfillment

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INTRODUCTION

Nature of Curing Process

The curing of the tobacco is an important operation in the production of cigar tobacco. It is, however, only one of several important operations involved. In order to produce tobacco of high quality, it is necessary to grow the tobacco well, prepare it for harvest properly, harvest it at proper maturity, handle it carefully and cure it well. Failure to do one or more of those operations well, can cause the production of poor quality tobacco.

The purpose of curing cigar tobacco is to change the newly harvested tobacco to a condition in which it will be usable for making cigars. The changes that cigar tobacco undergoes in curing are both physical and chemical in nature. They consist of the gradual loss of water and transformations of carbohydrates, proteins, pigments, alkaloids and other compounds that are contained in newly harvested tobacco. These changes occur during the time the leaves are still alive. Thus, curing is not merely a drying process but rather one of gradual starvation under partial applied and natural conditions (6).

The end product of curing is tobacco having texture, color, flavor, burn and other properties which together comprise the quality of the cured tobacco. The quality of the cured tobacco may be desirable or undesirable depending on whether the tobacco being cured contains potentialities for high quality or not, and on the rate and extent of changes that are brought about in the curing process. Whether the tobacco to be cured contains these potentialities for high quality or not depends very largely on how well the tobacco was grown, prepared for harvest and harvested. The rate and extent of the changes that occur are determined largely by the temperature, humidity and circulation of air that are maintained in the curing barn (9).

Curing Conditions

The curing of cigar tobacco is done by what is known as the air-curing method, in specially constructed barns. The barns in the Connecticut Valley are practically all built according to the same general plan, but they often vary somewhat in some minor features. They all, however, permit the regulation of temperature, humidity and circulation of air within the barn in considerable degree.

The typical Connecticut Valley tobacco barn for curing stalk tobacco has a width of 32 feet; a length that is some multiple of 16 feet and a height of 16 to 18 feet to the eaves. The barn usually has a ridge roof. The sides of the barn and the portions of the ends above the doors are made of boards approximately one foot wide, fastened vertically, with every second or third board being hinged either on the side or at the upper end to permit opening. Sometimes the sides are battened to close the cracks between boards; other times they are not battened, leaving the cracks open. Whether the sides are battened or not is largely a matter of preference on the part of the operator. At either end of the barn there are large swinging doors which permit wagons and tractors to enter and to pass lengthwise of the barn for unloading tobacco.

The barns are divided into sections known as bents by supporting posts, which are spaced 16 feet apart lengthwise of the barn. There are crossbeams or girders which extend across the barn at plate level, and also every five feet below, making three sets of these beams between bents.

Four by four inch poles which are slightly more than 16 feet long are placed on these crossbeams at about four feet apart and lengthwise of the barn. The lathes of newly harvested tobacco are placed about eight to nine inches apart on these poles, making what are called tiers of tobacco. There is also room for a half tier above plate level which is usually spoken of as the peak tier. There are therefore three and a half tiers of tobacco in the average tobacco barn - three full tiers from the plate downwards and a half tier in the peak above the plate level. Beginning with the lowest tier, the tiers are usually designated as first, second, third and peak tier.

The elements of atmosphere in curing barns which have the greatest effect on the rate and extent of the curing process are temperature, moisture and circulation of air. Experience has shown that, air temperatures between 80 and 95°F. and relative humidities between 70 and 85 per cent in curing barns with a difference of about ten points being maintained always between the temperature and the relative humidity, give good curing results. Although these ranges of temperature and humidity are ordinarily most desirable for curing, it is very advisable never to heat the temperatures in the curing barn more than 10 to 15 degrees higher than the temperature outside the barn. A difference greater than 10 to 15 degrees between temperatures inside the barn and outside the barn may cause too rapid drying of the tobacco. It should be emphasized that drying is not the most important change to be brought about in the curing process, which should be gradual to facilitate the proper chemical transformation in the curing tobacco.

Some seasons natural atmospheric conditions closely approximate conditions that are most desirable for best curing results which are then obtained with little trouble. Often, however, the natural atmospheric conditions are less favorable for good curing and it becomes necessary to use artificial heat to regulate the temperature and relative humidity in the barn.

The use of artificial heat serves two purposes: (1) it creates atmospheric conditions unfavorable to the development of pole-sweat; (2) it promotes better chemical transformations of compounds in the tobacco and permits the curing process to proceed more nearly to completion (1,6,8,9).

Generally, the relative humidity in stalk tobacco barns varies between 50 and 75 per cent with 65 per cent on an average (13).

The two barns in which this experiment was conducted are located between Hatfield and Bradstreet on Main Street. To the northwest they are surrounded by the Great Pond and towards the east by the Connecticut River. The barns are set end to end, identical, with approximately 80 feet of space between them. They run east to west, are very open, measure 32 feet wide by 128 feet long and are known as 8 bent sheds.

Structurally they belong to the newer type barn classed as braced frame. The sidings are 10 inch boards of native hemlock or white pine applied vertically over girts. Every second board is hinged for ventilating purposes. The squared posts are set in concrete footings and set in such a manner that the length of the barn is a multiple of 16 feet. The height of the two barns used was 17 feet to the plate and from plate to peak 10 feet. They were provided with four tiers each. The first three tiers were five feet apart; the fourth tier between plate and peak represented about half the amount of tobacco hung on one of the lower tiers.

On the whole, these barns represent to a fair degree the average curing barn in operation in the Connecticut Valley.

Pole Rot and Off-Color

Two important troubles which are often encountered in curing cigar tobacco under natural atmospheric conditions in barns are the development of pole-rot and the development of poor color of cured tobacco.

Pole rot is a fungus disease. It is also known as pole sweat, pole burn, shed burn, stem rot, and stalk rot. The two fungi which occur most commonly and cause most of the pole rot in the Connecticut Valley are species of Botrytis and Sclerotinia. A species of Altermaria causes pole rot infrequently in the Connecticut Valley (3,9).

Spores of these fungi are on the tobacco in the field and are brought into the curing barn on the tobacco when it is harvested. Bruises and open wounds made during harvest or by other means make favorable infection centers for the development of pole rot after tobacco has been hung into curing barns. The spores contained on the curing tobacco will not germinate and develop pole rot, however, unless there is excessive moisture on the curing tobacco.

It is not always possible throughout curing under natural conditions to keep the surface of the curing tobacco free enough of moisture to avoid the development of pole rot. The alternative is firing to regulate the temperature and relative humidity, and by this means to prevent the occurrence of pole rot and the damage the disease ordinarily causes (1,2,3,4,5,6,7,8,9,11).

The poor color that sometimes develops on cured tobacco may result from several different reasons. One reason is farmers often harvest tobacco before it has matured sufficiently, and such tobacco never cures with desirable colors. Another reason is that very often temperatures in curing barns are not kept within the ranges that permit the curing processes to go to completion, causing poor colors in the cured tobacco. The correction for these difficulties is, firstly, to let tobacco mature better before it is harvested, and secondly, to regulate the temperature and relative humidity to proper ranges with artificial heat during curing.

Fuels for Supplemental Heat

It has been found that charcoal and propane are suitable sources of heat for curing tobacco. Charcoal has been the standard fuel for decades.

In 1949, a trial cure was run in the South with liquified petroleum gas as a fuel. Two trial cures were made with L.P. gas in Connecticut during the 1950 curing season. When it became known in March, 1951 that firing with L.P. gas produced higher quality tobacco than did firing with charcoal, and also provided many other advantages such as reduction in cost of labor and fuel, many growers decided to adapt gas as fuel for the 1951 curing season (13).

Liquified petroleum gases are hydrocarbons or mixtures of hydrocarbons that have been changed to the liquid phase under pressure in order to facilitate the transportation, storage, and use of the gas. The term "liquified petroleum gas" or L.P.-gas means any product which is composed predominantly of any of the following hydrocarbons or mixtures thereof: propane, propylene, butanes (normal and isobutanes) and butylenes. From the liquid phase these gases change all to the gaseous phase as long as the temperature remains over their boiling points. For propane and butane these boiling points are respectively - 44 degrees F. and +31 degrees F. at atmospheric pressure. Liquified petroleum gases, when released, expand rapidly from liquid into the gaseous phase in a ratio of approximately 270 to 1 (16).

The present investigation deals with the possibility of using kerosene as a satisfactory source of heat for the curing of cigar tobacco. It will reduce the cost of fuel needed for the purpose considerably below the cost of L.P. gas and much below the cost of charcoal. Kerosene and L.P. gas are both hydrocarbons and should yield the same combustion products, which are released directly under the tobacco in the barn by the burners.

Most burning installations are manufactured with special attention to the fuel which they are intended to burn at a maximum efficiency. Shell No. 1 kerosene was used in this experiment.

Because of the open-flame-type burners which release their combustion-products in the barn itself, oil with the lowest possible sulphur-content should be used. Too much sulphur in the oil used for curing might cause tobacco to become yellow, which is intolerable for cigar tobacco.

All No. 1 oil distributed by different companies will not necessarily burn satisfactorily in the "Model A" curer. If for some reason heavy and light oils are brought together the oil may still be No. 1 oil but the heavy oils which do not easily evaporate may be left behind on the bowls and wicks causing the burner to clog up. It is therefore necessary to obtain a clean kerosene that has not been contaminated with heavier oils.

The vaporizing portion of these burners (chimneys) operates around a temperature of 600-700 degrees F. (15). Oils not readily vaporizing under these temperatures would be left behind as residue, which would greatly disturb the ease of lighting the wicks for the second time.

It is recommended by the manufacturer that oil of the following properties be used in the "Model A" curers.

Flashpoint	- 115° F. Minimum (Pensky Martin closed cup test)	
Distillation Range	- (First drop	330 - 340° F.)
	(10% Receivers	350 - 370° F.)
	(90% in Receivers	490 - 500° F.)
	(End Point	under 350° F.)
Gravity	- 40 - 44 degrees Baume	
Carbon residue	- Minimum	
Sulphur	- Minimum	

The analysis of the oil provided by the distributor produced the following information:

Gravity° API	41.5
Color Graybolt	±21
Flash Tag. C.C.° F.	127.-
Sulphur °/o W.	.04
Corrosion C 122° F.	Neg.
Rams. Carbon Residue	.002
Kinematic Visc. C 100° F. f/s	1.80
Doctor Test	Neg.
Aniline Point °F.	149.5
ASTM Distillation °F.	

T.B.P.	33.8
10 °/o evaporated	384
25 °/o	411
50 °/o	445
90 °/o	506
95 °/o	528
F.B.P.	549

These tests are in accordance with latest ASTM or VV - L - 791 methods. The sulphur content indeed is negligible.

EQUIPMENT AND INSTALLATION

Oilfiring Installation

The main objective for the use of supplemental heat probably will be for reducing excessive humidity over relatively short periods of time. A system providing this capacity and to be practical must not be prohibitive in cost. It has to be efficient, reliable, safe and convenient.

The oilburning installation with 90 burners was obtained from Smith Heating, Inc., Kinston, North Carolina. This type of burner is known in the South as Smith's Model "A" Oil Burning Tobacco Curer. These burners were installed from June 16 to June 26 in barn No. 14 which is nearest to Main Street and on the westward side.

The installation is made up of four sections (see blueprint): A, B, C and D. Each section has four parallel main lines with burners. These lines can be broken down in shorter pipe-sections. Each section had to be connected to its own fuel tank and all fuel tanks were located on the south side of the barn. Although one central tank is desirable from a viewpoint of refilling and transportation, the rate at which the oil will reach all burners is considerably increased by having four separate smaller tanks, each supplying one individual part of the curing system.

The rated BTU output per burner (see blueprint) is approximately 12,250 BTU. With 90 burners this provides a barn total of 1,102,500 BTU per hour.

The original setup called for stakes in the ground to fasten the pipelines on with wire. As this was found too laborious during the trial-test without tobacco in the barn, the sections were placed upon bricks which suited the purpose. The instruction sheet calls for a far more rigid installing procedure (Appendix).

As all sections need to be levelled to insure an even oil flow to every burner, these too have to be level in order to prevent them from overflowing or drying up. It is clear from the blueprint as well as the instruction sheet that the installation is meant to be a permanent one, to be used during several years in the same barn. An absolutely level floor is a prerequisite to proper functioning of this installation.

On the basis of Professor E. Cox's experience and the heating value obtained from charcoal, including infiltration of air in fairly open barns, a heat-input of around one million BTU per hour for a 128 by 30 foot barn was thought adequate to maintain a temperature differential of ± 40° F. The total inside floor area for the 128 by 30 oil-fired barn equals 4,096 square feet, which amounts to 45.5 square feet per burner (90 burners). For the gas-fired barn this figure amounts to 65 square feet (64 burners).

<u>Gasfiring Installation</u>

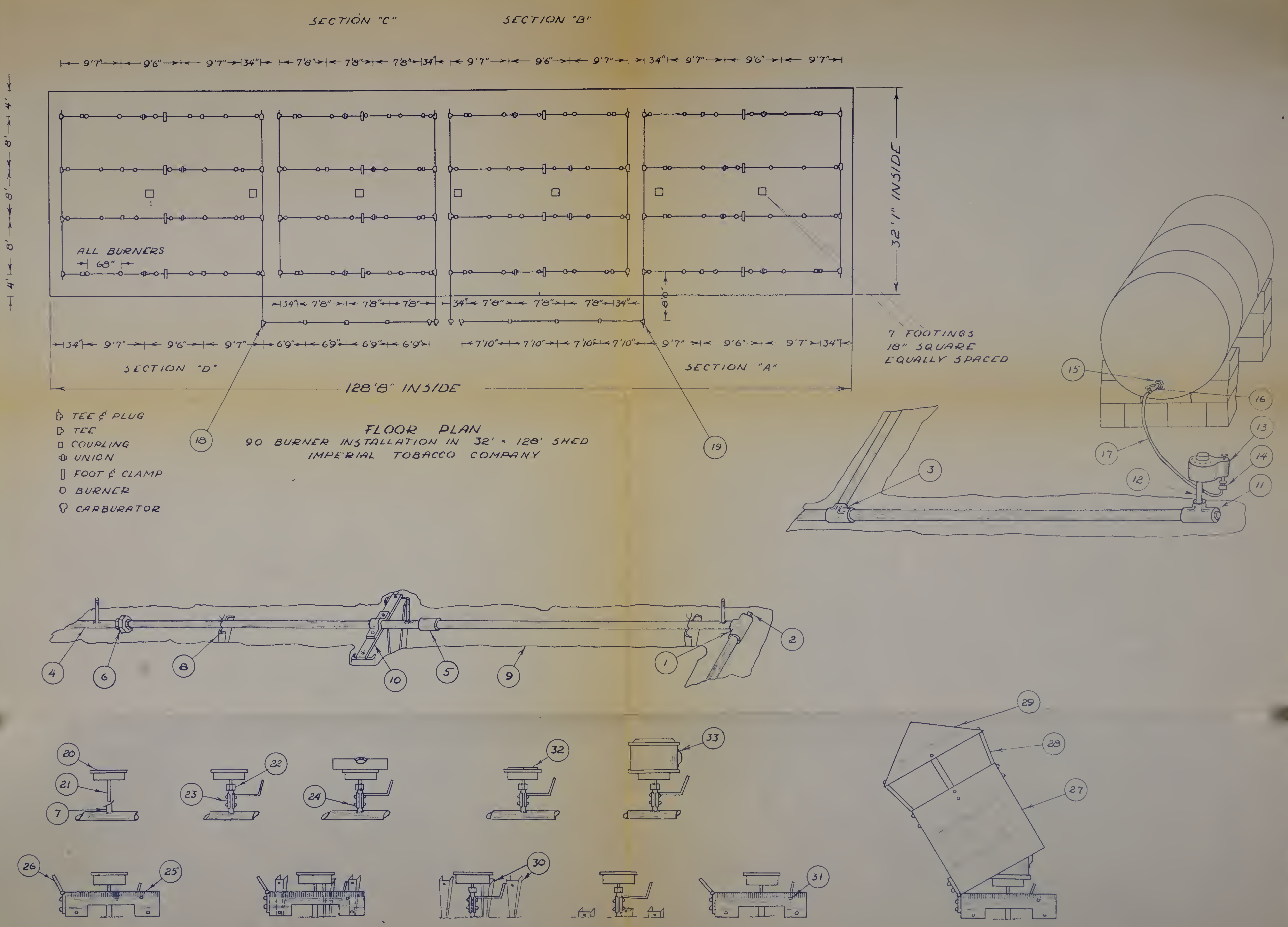
This equipment consisted of a portable outfit with one central 1 1/2 inch main pipe running lengthwise through the middle of the barn. Ten-foot long neoprene tubings connected to take-offs on the main pipe supplied two burners in series.

Each burner provided with a "manual control" valve which permits reducing the gas input to one stove and not to the other or both stoves, provides more flexibility as to temperature control in the vicinity of the units. In addition, each arrangement is provided with an on-and-off valve which is attached to the main gas supply line in the barn. The manual control valve when open permits the full amount of 10 cubic feet per hour to pass into the burner, and when closed through a by-pass in the valve, it permits a factor of safety when the stoves are operating under extremely drafty conditions.

This equipment is manufactured by the Buckeye Incubator Company, Springfield, Ohio. The stoves are designed to operate at a pressure of 11 inches of water. This is about the standard pressure required on this type of equipment. It is required to maintain as close as possible a pressure of 11 inches of water in the main line. If the pressure is too high (more than 11 inches water column), inefficient burning results and when it is too low, the burner cannot deliver its maximum capacity, which is 10 cubic feet per hour.

A portable installation is preferable over a permanent one as it fits better in the scheme of operation of tobacco-curing barns in the Connecticut Valley and reduces cost as the equipment can be used for several barns during one season. The burners are supplied by one 500 gallon central fuel tank, rented from the gas company, which is mounted on skids to ease transportation and prevent the tank from rolling (see picture). Although the tank has a capacity of 500 gallons (water volume), for sake of safety it is not to be filled over 80 per cent to allow liquid expansion and pressure in the tank to stay within a reasonable safety range. At 100° F. pure butane exerts a pressure of about 37 PSI and propane about 174 PSI. The total pressure depends upon the percentage and vapor pressure of the individual gases. It is essential for safe operation that a great enough vapor cushion exists above the level of the liquid within the tank. If the tank were filled nearly full and if much higher temperatures were encountered, the liquid would expand and indeed would fill the entire tank. A further slight increase in temperature would rupture either a safety plate, valve or the complete tank.

One single gas burner has a BTU output of approximately 21,000 BTU which provides for the gas-fired barn with 64 burners (one per 65 square feet) a total of 1,344,000 BTU. This is potentially higher than the 1,102,500 for 90 burners in the oil-fired barn. However, a greater number of burners, each with a smaller BTU output, provides a better temperature distribution than fewer burners, each with a higher BTU output. The two inside burner-rows in the oil-fired barn are identical as far as burner position on the lines is concerned. The wall-side burners (see blueprint) have the same distance between the lines and on the lines; however, the burner position is such that each burner is located halfway between the burners on the inside lines. This ensures a more uniform heat distribution throughout the barn and prevents formation of hot air pockets. Fewer burners often need to burn higher in order to provide enough heat. Frequently this results in too much heat around and above the burners and not enough between them.



FLOOR PLAN
90 BURNER INSTALLATION IN 32' × 128' SHED
IMPERIAL TOBACCO COMPANY

INSTRUMENTATION

The instrumentation for measuring ambient temperatures and dew point temperatures consisted of three Foxboro recording potentiometers for use with resistance temperature sensing elements and Dewcels. Two were multi-record Dynalog 6-point recorders situated on the south side of the gas-fired barn. The third instrument, a Segmental Chart Dynalog Recorder, provided records of 24 different measurements on one chart. Each measurement is recorded in an individually identified segment. A selector switch automatically connects one after another of the sensitive elements to the recorder. Automatic selection may be interrupted to permit normal control checking at any time. The switching sequence is a complete cycle of 24 points in 12 1/2 minutes for a 24-hour period. All three instruments may be used for either temperature or dew point measurements for all available points on the recorder. A continuous record is made up of small closely-spaced ink dots, red on the 24-point recorder for all points, and various colors on the 6-point recorders. Both 6-point recorders have the same colors which made it necessary to designate each instrument a code letter. This code letter is x for the recorder on the southwest and y for the one on the southeast end of the gas-fired barn. Both 6-point instruments complete one cycle in 36 seconds, recording a new measurement each six seconds. All three recorders make use of circular charts on which one single box pen on the pen arm, in case of the 24-point instrument, prints its measurement. In case of the 6-point instruments, the pen arm picks up one of six different pens and replaces the pen after the measurement is recorded. Each pen refers to one specific color on the ink-wheel. Each color is keyed; pen, color and measurement are positively synchronized, which permitted changing of the sequence without confusion (17).

Dewcel Operation

Dew point temperatures were measured by Foxboro Dynalog electronic type Dewcels. These Dewcels may be installed in any desired position as long as the sensitive element is immersed in the atmosphere being measured. Maximum permissible temperatures are not above 220° F., with a minimum of lower than -50° F. The system functions perfectly in still air and should not be exposed to air velocities above 50 feet per minute. To prevent the latter, the Dewcels were inserted in special draft shield boxes.

Moisture determination by the Dewcel is based on the fact that for every water vapor pressure in contact with a saturated salt solution there is an equilibrium temperature at which this solution neither absorbs nor gives up moisture to the surrounding atmosphere. Below this equilibrium temperature the salt solution absorbs moisture; above the equilibrium temperature, salt solution dries out until only dry crystals are left.

The Dewcel is a thin-walled metal socket covered with a woven glass tape impregnated with lithium chloride. A

25-volt alternating current power supply is connected to a pair of silver wires wound over the tape. If the temperature of the Dewcel is below the equilibrium temperature, the salt absorbs moisture from the atmosphere, the conductivity of the solution on the tape between the wires increases, and the current flow increases, raising the Dewcel to equilibrium temperature. This temperature is then determined and used on a measure of dew-point temperature as recorded on the circular charts (17).

The current for the Dewcel is furnished by a power unit which consists of a stepdown transformer (25 v. sec.) and a ballast resistor to limit the starting current. All power units were located on the shed wall near the recording instrument and grouped on boards. The ballast resistor is in effect a 30-volt 50-watt lamp bulb. The lamp will glow until the Dewcel connected to it is heated up properly. The bulb operates thereafter without glowing unless a sudden large change in the humidity conditions requires a large increase in current to restore the Dewcel to the equilibrium temperature.

Resistance Dry Bulb Operation

The Model 7086-MR-26 surface temperature bulb is supplied for the measurement of the temperature of stationary surfaces. Its operating range is -40° F. to +300° F. A set of padder coils must be used with the bulb which consists of a series resistor in the white lead, a shunt resistor between the white and black leads and an "A" resistor between the green and black leads. This padder coil assembly is contained within a junction box. This type of bulb has to be handled with extreme caution to avoid breaking the bulb or leads during installation as they do not have protective housing of conventional types of resistance bulbs.

Instrument Installation

The instruments were tested and calibrated during the month of June in the laboratory. On June 18, a beginning was made to install them in the barns. Preliminary wiring connections had been made up in the laboratory which have to be made before the bulbs can be installed. All connections were carefully soldered and wrapped with a suitable insulating tape to prevent short circuit or grounding. After wiring was completed, a check was made for short circuits. The 24 point instrument was installed during June to ensure proper functioning. The two 6 point instruments were installed during August. The final locations for dewcells and temperature measurements were selected after measurements with the 24 point recorder had been compared during the time the oil firing installation was tried out without tobacco in one barn.

Power Line

A temporary power line was run from the south edge of Bradstreet along the side of Main Street with the side road leading to the two barns. The cables had a total length of + 1500 feet. In the oil fired barn this main power supply of 220 volts was connected to a transformer which reduced the voltage to the standard use of 120 volts, on which all recorders operated. Western Massachusetts Electric Company erected for this purpose one extra pole to tap power from the main supply leading towards Bradstreet and installed a watt-meter to check the amount used. A furrow had to be plowed in the side road to eliminate possible danger of the wires being caught by implements, or hoofs of horses. This temporary system proved satisfactory in every respect.

During the first test of the oil installation without tobacco in the barn, the 24 point recorder was operated on the power supply of a transportable gasoline generator which provided also no difficulty.

TRIAL TEST WITHOUT TOBACCO

On June 26 the installation of oilburners and instruments (24 points) was completed. After every burner section had been levelled with a small surveying level and each burner individually with a plumbers level, the oil tanks were opened up and after about twenty minutes most wicks were ready to light. Leveling the sections was extremely difficult as the slightest movement on one of the pipe sections would set all the burners off level for one particular section. This became clear by accidentally stepping upon a pipe section. Bricks proved to be helpful in adjusting the burner height, but in parts of the sections considerable digging had to be accomplished to lower or raise the lines off level, in order to have the bowls filled with oil to about 3/8". If all burners are level this procedure is easy enough by lowering the carbureter outside which feeds all burners of one section. However, much raising or lowering with it cannot be done because either the bowls run over or dry up. The distance for adjustment is extremely small, often not more than a fraction of an inch.

The burners performed very satisfactorily, burning with even blue flames even during a brief thunderstorm with high wind velocity. The Amherst weather station recording: 84.5° F. mean temperature for the day, with a maximum of 90° F. and a minimum of 71° F., the relative humidity being 74 per cent. The number of hours bright sunshine for June 26 was 11.7, wind direction N.W., with a maximum velocity of 10 miles per hour.

The maximum <u>outside</u> temperature as recorded by the recorder was 104° F. with a minimum of 82° F. Inside mean temperature on the first tier was around 111° F., second tier 115° F., third tier 116° F., fourth tier approximately 119° F. Within one inch under the peak the temperature went up to a high of 134° F. It became clear that the temperatures did not fluctuate much in the barn and final location of instrumentation became primarily one of the right distribution over all tiers according to the number available for each barn.

<u>Observations</u>

During this initial setup it became obvious that the oil installation as such had certain distinct characteristics which do not fit in the scheme of operation of tobacco barns here in the Valley. It was clear also that their burning performance was satisfactory.

The installations' main drawback seemed to be that of not being portable and flexible, enabling the user to move it with a minimum of effort to operate the curer for the next barn.

Supplemental heat application is dependent upon the outside weather conditions; however, the initial firing period or green firing is on the average an operation of 72-100 hours after which period its application is dependent upon moisture conditions in the barn. A second firing period may or may not be necessary. Thus the more barns any curing installation will be able to serve, the cheaper the cost of operation and the more practical for the user. Only equipment like that which is provided in the L.P-gas installations is truly flexible and portable, and at the same time relatively safe, reliable and comparatively cheap in moving from one barn to another. The central tank is mounted on skids and moved easily in a lift wagon constructed for that purpose. The nature of barn operations while loading the tobacco makes it customary to drive with wagons, tractors and horses through the barn. This implies a path free of obstacles for the purpose. A permanent oil installation with rigid pipe suspended throughout the barn, with no means to brush it aside, is not feasible. Even if the pipe is buried underground, the above ground laterals and bulky and partially rigid burners provide great inconvenience. Heavy wagons could easily damage the not deeply buried pipes (3 inches) and break the laterals from them. Labor would have to be constantly on the lookout for not stepping upon vital parts which is not tolerable during such a fast operation as harvesting should be. In order to keep dismantling and assembling to a minimum and enable more convenient storage until the actual curing procedure, all four sections were cut and supplied with additional unions in such a manner that only four long main lines with the burner bowls still attached could be removed. The original setup made it possible only to disconnect all pipe sections. This enabled storage until September on long nails alongside the wall (see photo). The

Lay out of the modified oil burner section hoods or canopies stored along the sidewall with the chimneys. Although not ideal, this proved to be the only way to enable driving through the barn.

With the gas firing installation, driving through the barn is no problem as the burners are connected either to one central main pipe in the middle of the barn or to main pipes on each sidewall lengthwise. This enables putting the burners either in one row in the barn or in two rows along each side wall. Furthermore, as it is not usual to drive in the barn with the burners already installed, it would, however, be possible without much difficulty. The advantage of the gas installation, however, is that the main pipes are either already present in the barn or, in case of a complete portable installation, only one pipe has to be laid out. The burners can be brought to the barn a few minutes before firing as connecting to the main pipe is a matter of minutes.

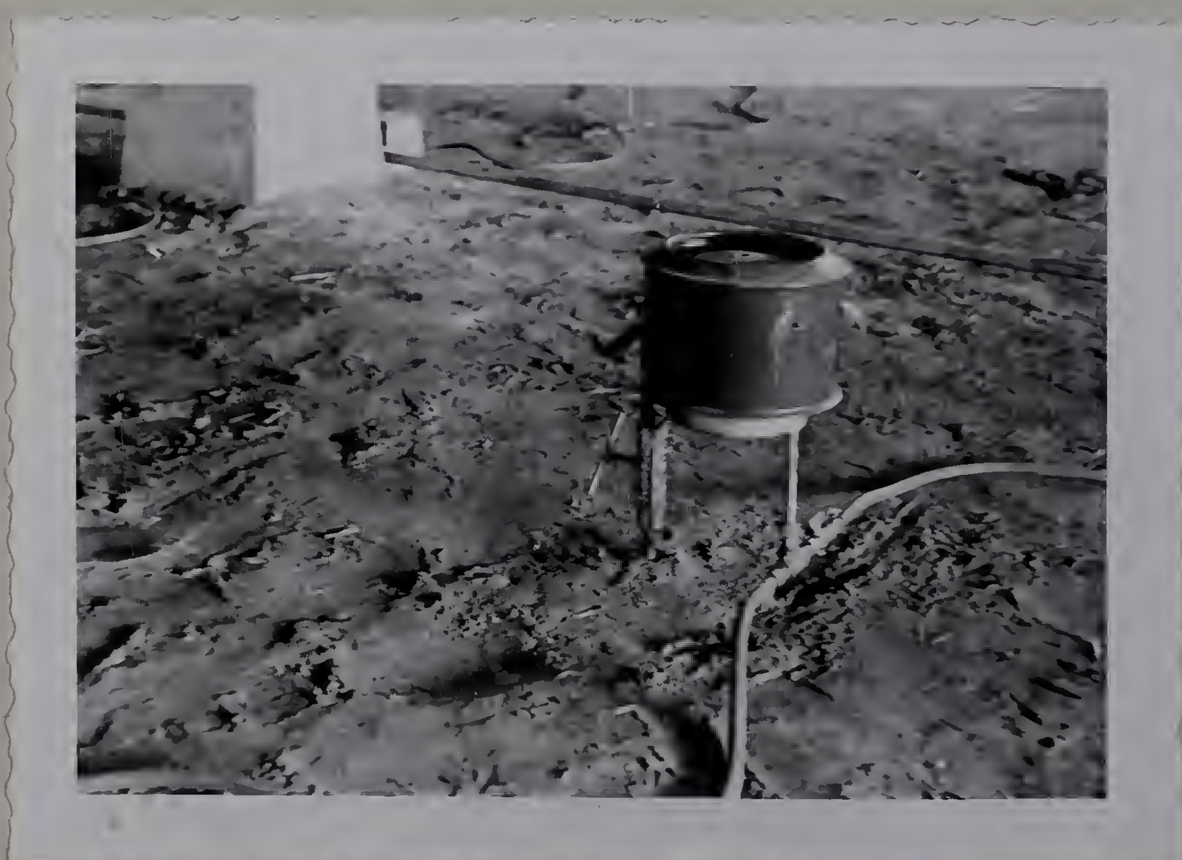
Modification of Equipment

Permission was obtained from the manufacturer to convert one section in what was thought to be a more flexible unit.

The general idea is very much the same as that for a portable gas installation. Carburetor and burners are mounted on vertical iron rods which are to be stuck in the dirt floor, and can be moved by releasing a setscrew toward the desired level.

These modified burners were stripped of their lever attachment and connections which had previously been fastened on one of the rigid pipes. This left only the bowl with its

Modified oil burner (without chimney)



Same with chimney in firing position

5/16" pipe section. On the opposite side of the 5/16" pipe a z-shaped iron bar (see photo) on which lower outside-end a 5/8" pipe section with a setscrew was welded to the bowl collar. This pipe section slides over the 1/2" vertical rod with the burner. Sufficient support is supplied by this construction to hold the relatively heavy vaporizer (chimney). The 5/16" pipe is accommodated with a T-coupling and small valve to permit one burner to be extinguished while the one on the inside nearest to the main line will continue to burn. Neoprene 5/16 inch tubings extended from the central pipe section and between the burners supply the oil. The carburetor is based on the same idea between the central main and the oil tank; however, this time inside the barn, which is more convenient in determining the desired level.

Still far from ideal, the system was easily installed and the burners could be placed in any direction desired. Leveling of the pipe sections was eliminated and only the burners themselves needed to be level. It was found, however, that some difficulty still existed with leveling two burners on the same line; when one was too high the other flowed over, and vice versa. Their performance was equal to the rigid burners. The need was felt for a self-leveling burner to eliminate leveling in order to make the system more convenient.

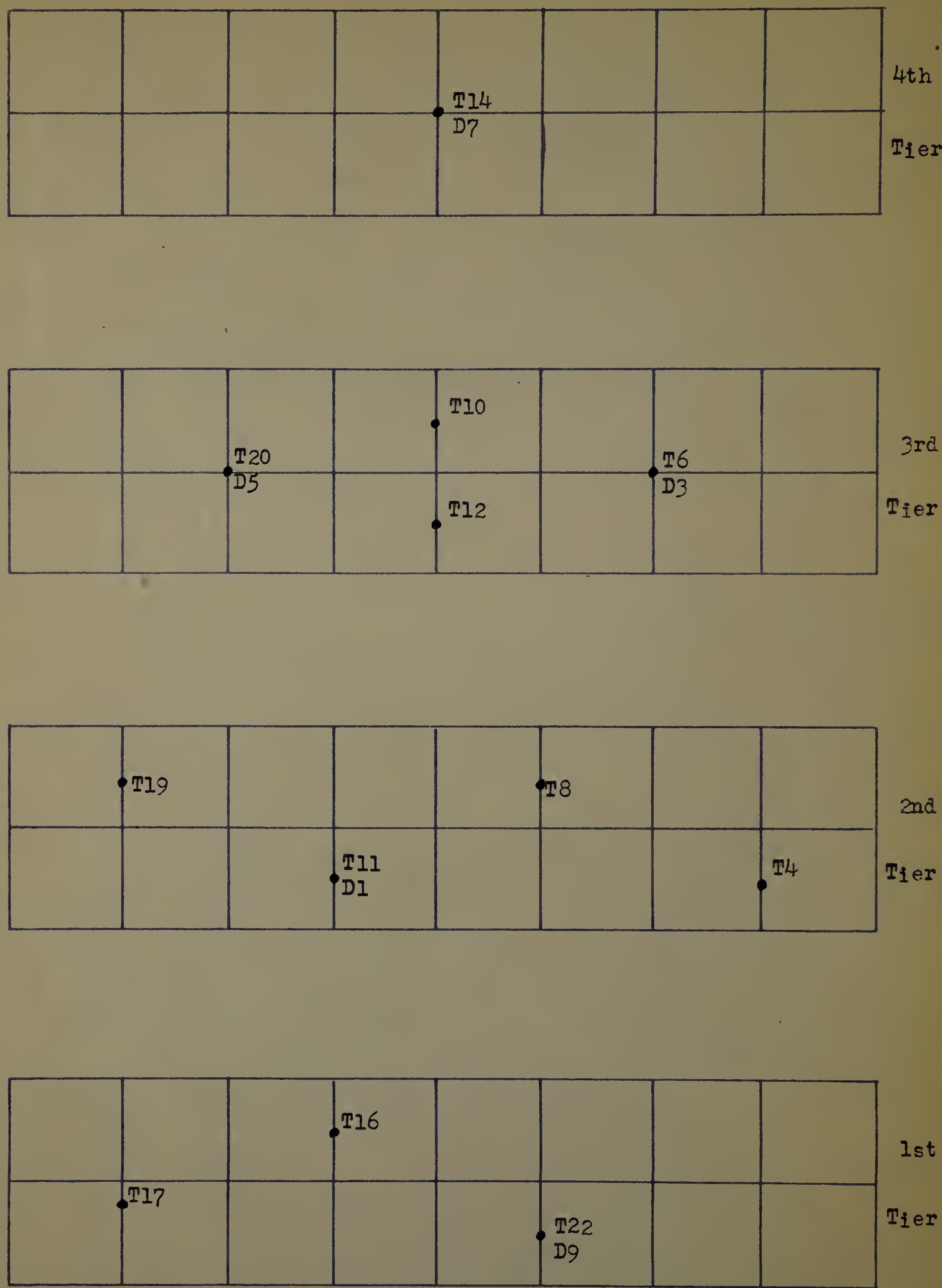
Location of Dry- and Dewcel Units

The following drawings show the positions on each tier in the two barns of the measuring devices. As noted, these are identical for both barns.

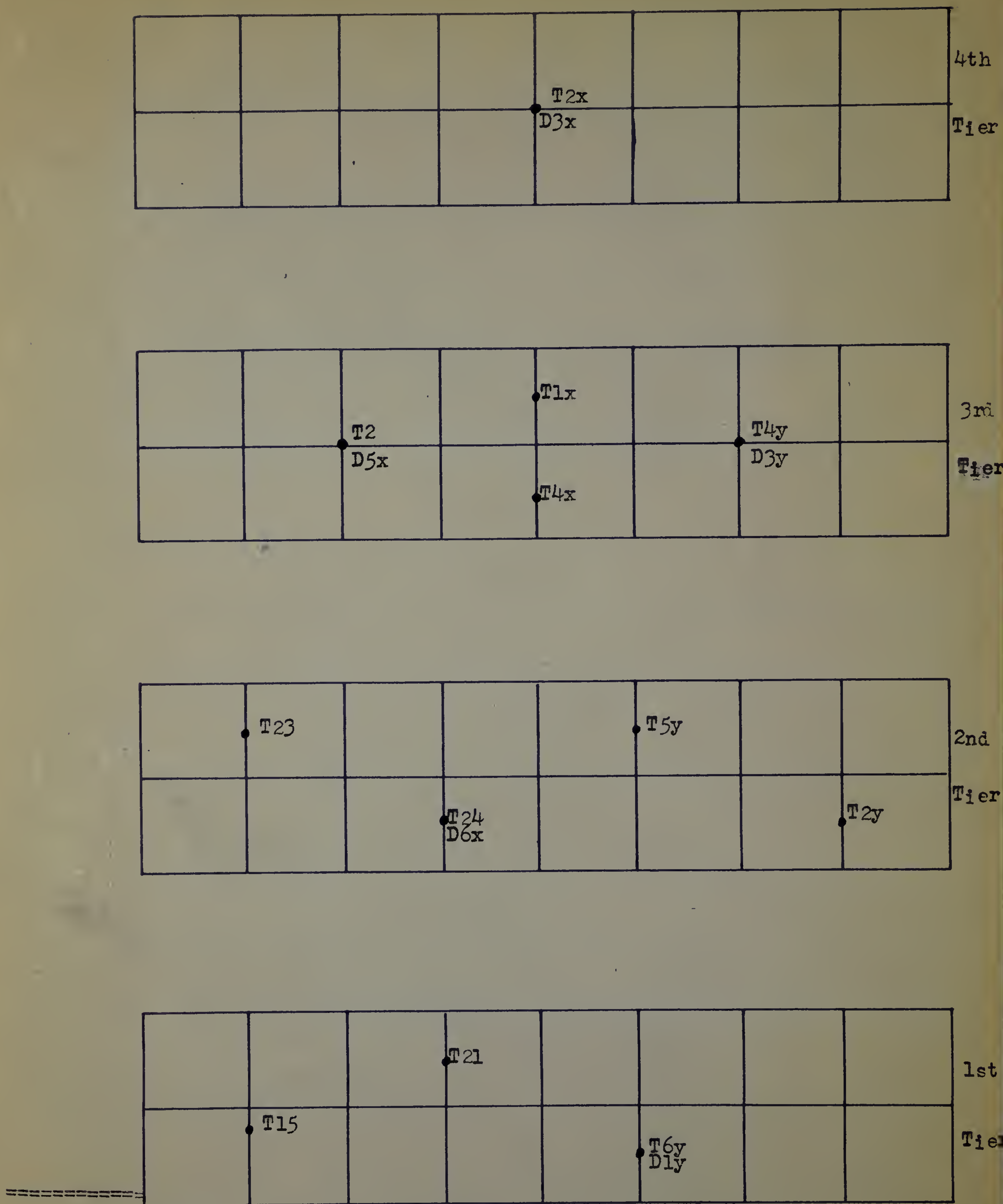
Since there were eleven Dewcels available, five were placed in each barn and one on the outside. With a total of 36 measuring units on all three recorders, this leaves 25 dry bulb measurements; twelve for each barn and one on the outside. Each barn thus had 17 points, making 12 stations. As the two six-point recorders provided 12 points together, five units had to be run to the 24-point recorder. The five points transferred to this 24-point recorder are designated on the drawing; the leads run under ground in a two-inch pipe, from the gas fired barn towards the recorder on the east side of the oil fired barn.

As x and y represent one of the six-point instruments and normal numbers all lead towards the 24-point recorder, each point and its location is readily identified (see drawings).

Location of Dewcels and Resistance Bulbs.(Oilfired Barn)



Location of Dewcels and Resistance Bulbs.(Gasfired Barn)



Harvest

The last tobacco to be hung in the oilfired barn.
Note the cardboard on top of each bowl to prevent dripping from the wet tobacco onto the burner wicks.

HARVEST

The leaves on the plant do not ripen all at one time and the plants are harvested at a time when most of the best leaves are ripe. This means a compromise between top and bottom leaves as those at the top are not quite ripe and the bottom leaves are overripe. At this stage the whole plant is cut and brought into the barn.

A beginning with harvest was made on August 30. Due to circumstances, the loads were not evenly divided over both barns. On August 30 only the whole fourth tier in the oil-fired barn was hung. Due to rain, hanging did not occur again until the 2nd of September and was completed for both barns on September 6th.

The variety of tobacco used in this experiment was Havana Kl. In the field it produced a general even stand, somewhat stunted by mosaic. Although by the method of topping the worst effect of the mosaic infected topleaves was taken away, it was possible that enough leaves infected with the disease remained on the plant to account for considerable quality reductions.

The short length of the tobacco due to mosaic proved to be more of an advantage from the viewpoint of curing, as much taller tobacco would undoubtedly have touched the canopies of the burners. The burner hood extended 30 inches above the floor which left approximately four feet for the tobacco, as the distance from floor to the first tier measured about 6 1/2 feet. Tobacco falling on or touching the canopy will not burn, but is scorched papery black, as has been intentionally experienced. Often less than a foot separated hood and tobacco.

In order to have all oil burners level it was decided to hang half of the first tier after leveling had been done. This was a strenuous procedure as the tobacco had to be partially brought in the barn through the sidewall ventilators. In comparison, the flexible and portable gas unit had a great advantage. In the gas-fired barn one could drive through and as soon as hanging was completed the gas burners were connected to the central main pipe. With the oil burners this was not possible. Another disadvantage was encountered during hanging which was that the dripping wet tobacco shed enough water on the burners to wet the burner wicks. To avoid this the bowls had to be covered with small pieces of cardboard. A wet wick is difficult to light and liable to sputter. The pieces of cardboard can be seen on the photo of the last tobacco being brought into the oil-fired barn. This was an additional operation to the already troublesome installation procedure.

To reduce overheating, tobacco poles were shifted in such a manner that side alleys were formed. These were approximately two feet wide. This did not prevent some tobacco from hanging directly over the burners as the burners were spaced intermittently, but the damage was reduced. Overheating causes too rapid dehydration and greenish colors. With burners of a higher capacity and same type this would have undoubtedly occurred.

Final installation of the oil sections did not offer much difficulty. However, attaining the desired levels was much more inconvenient.

PRESENTATION OF DATA

As all the data accumulated on the circular charts by the recording instruments do not fit in this paper, mean values for one day have been calculated by a planimeter.

However, as mean values over 24 hour periods do not show critical variation in temperature or humidity, an hour to hour record has been compiled from the charts for the firing periods and due to the fact that only one Dewcel and one dry bulb were located in the fourth tier, of which one Dewcel did not function properly, relative humidity measurements for the fourth tier were omitted for both barns. As it was found that the average of twelve dry bulb averages did not differ more than two degrees from that of the four dry bulb measurements in the same location as the four remaining Dewcels, Table I represents data from which the mean relative humidity can be directly derived.

All relative humidity readings are based on 29.29 m.m. Hg. In order to be able to have a picture of what actually happens to temperature and relative humidity in tobacco barns as they are built in the Connecticut Valley, the record was evaluated over the whole curing season (see Appendix).

The curing process of whatever importance cannot be viewed in respect to the firing periods alone. It therefore is interesting to note how much natural conditions fluctuate and are able to affect the cure of tobacco after the initial and artificially induced conditions have been applied.

First Firing Period (81 hours)

The initial firing, green firing or first firing period, started Sunday, September 7 at 9:05 A.M. in the oil fired barn and at 10:20 A.M. in the gas fired barn. The little more than one hour difference occurred because it was thought that lighting the oil burners, placing the chimneys on top of the bowls, and then placing the hoods over the burners with some burners not burning properly, would consume considerable time compared to the starting of the gas firing equipment which only had to be lighted by a burning stick. Only a few oil burners had to be leveled again and the time required for the whole operation was relatively short.

From the curves (See figs 1,2,3) it can be seen that the outside temperature at 9 A.M. was 62° F. with a relative humidity of 56 per cent. Inside the oil fired barn (Barn No. 14) the temperature at 9 A.M. was 52° F., relative humidity 83 per cent; and in Barn No. 15 (gas fired) 54° F. and 100 per cent, respectively. The oil burners were burning at maximum oil flow and performed with even blue flames.

The prevailing wind direction for September 7th was north with a maximum velocity of eleven miles per hour. The number of hours of bright sunshine was 5.9.

The outside temperature reached its maximum of 72° F. shortly after noon. Both barns were increasing in temperature and stayed well below 72° F. At 3 o'clock the oil-fired barn equaled the outside temperature which still was at 72° F., whereas the gas-fired barn read only 65° F., reaching the outside temperature of 68° F. at about 5:30 P.M., which was declining.

In six hours the oil-fired barn had increased its temperature by 20° F.; the gas-fired barn, during that period, increased only 11° F. It was recognized that the gas-fired barn maintained a lower temperature during all days except for the last day when it equaled that of the oil-fired barn for two hours. When the temperature is higher the relative humidity consequently will be lower, provided the ventilation is the same for both barns, and the dew-point temperature low. If the dew-point temperature is high and therefore the differential between it and the dry bulb is smaller, the relative humidity will be higher.

The curves show very clearly that there was a time lag between maximum and minimum temperatures in the barns and those of the outside. This time lag was about two hours. It is also obvious from these curves that the inside temperatures followed the outside temperatures according to the diurnal variation. The dew-point curves follow the temperature curves in a similar pattern.

The outside temperature may determine whether the inside temperature will be higher or lower during firing at a constant rate (= fuel flow); however, it will not directly affect heat distribution. In this discussion it is well to remember that the main effect of the sun was to increase the temperature in the upper part of the barn, which had a direct effect in increasing temperatures for the whole barn during the daytime. During the night, the lower the outside temperature falls the more the inside temperature will fall.

According to established practises which maintain 10-15 points between temperature and relative humidity and 10-20 points between temperatures inside and outside, it was noted that both barns had too high a temperature during both night and day. The gas-fired barn did not have so great a differential as the oil-fired barn, but was still on the high level. Over the entire 81 hour period the oil-fired barn maintained a temperature which was on the average 6° F. higher than the gas-fired barn, with the greatest differences between the two barns occurring shortly after noon and shortly before sunrise. Compared with the outside temperature, the oil-fired barn was, on the average, shortly after noon and shortly before sunrise, 25° F. higher; the gas-fired barn 24° F. This was for both barns not in accordance with desirable practises. However, during the total of 81 hours firing, the difference between outside and inside temperature for the oil-fired barn was 18° F.; for the gas-fired barn, 14° F. This brings the gas-fired barn into the desired range, but the oil-fired barn was too high.

The mean difference between the dew-point and dry bulb during the first, second, third and fourth days was: for the oil-fired barn 14, 16, 21, 16; for the gas-fired barn 8, 11, 12, 9. This was much too high for the oil-fired barn and slightly too high for the gas-fired barn, because for curing stalk tobacco 6 - 8 points are desired (13).

The greatest significance is seen in the mean relative humidity curves. The amount of moisture in the two barns during 81 hours firing was very divergent. Of course higher temperatures would have the effect of lowering relative humidities, and this would be one of the primary causes of a much lower mean dew-point in the oil-fired barn during firing. It was also noted that the curve for the gas-fired barn was more erratic than the one for the oil-fired barn. The outside relative humidity slopes into a short peak generally about two hours after noon. This was comparable with the rise in temperature during the morning which culminated in its highest value shortly after noon time, causing the relative humidity to be lowest for the day. The temperature outside dropped somewhat slower than the relative humidity increased. This was probably caused by the sudden fog spread from the area known as the "Great Pond" and the Connecticut River, which it is believed accounted for the sudden rise in relative humidity and consistency of the curve along 100 per cent during the night and early morning. This fog was observed and noted to vary in density during the early part of the evening, completely saturating the outside air around 10 P.M. This can easily be observed during the night with a flashlight whose beam shows not only density but also particle size.

The fact that the oil-fired barn was so much lower in relative humidity than the gas-fired barn was not readily explained on the basis of higher temperatures alone. It is believed that due to the very uniform heat distribution in the oil-fired barn this fog had not the same opportunity of diffusing into the oil-fired barn as in the gas-fired barn. Although higher temperatures would be the main reason, the very uniform heat distribution by the greater number of burners made it possible that an overall higher temperature resulted. The rapid increase in outside temperature during the morning until noon and rapid decrease at night until early morning affected the inside temperature of the oil-fired barn considerably towards undesirable higher levels.

Among the features of the L.P. gas installation is the fuel itself. During the night pressure from the gas tank seemed to become less the colder the temperature became. Apparently the liquified petroleum does not vaporize at a constant rate above its boiling point. This, however, was a desirable feature as it reduced the heat input in the barn in harmony with the outside temperature, with only slight manual adjustments needed. Kerosene, being a non-pressurized liquid, does not possess this ability and maintains equal amount of oil flow under any temperature change. Thermostatically controlled units would eliminate the danger of running the barn temperature over the desired range, and although not used in the experiment, are available with the oil firing units.

The curves show also that temperatures of 100° F. occurred for a short period of time. It is well known that tobacco which is cured too rapidly by too high a temperature becomes greenish in color and is "hayed-down" to a more or less extent. This will happen when tobacco brought into the barn is subjected for a number of hours to temperatures near and over 100° F. Although the greenish color did not seem to be present, it is likely that the tobacco received injurious effects from that particular treatment where drying proceeded too fast, killing leaf cells but not sufficiently to make the green color dominant.

The temperature curves show that efforts were made to lower the temperature in the oilfired barn shortly after noon on September 9, which brought both barns considerably closer in temperature. During the night the gasfired barn temperature went down much lower than the oilfired barn. The high outside air temperature of the following day, plus a minimum input of supplemental heat, caused a temperature over 100° F in the oilfired barn. Curing at temperatures over 100° F., even with sufficient humidity, is likely to result in an abnormal cure. Therefore it seems safer to cure at lower temperatures with lower relative humidities in order to avoid unbalanced air conditions during high temperatures, which undoubtedly resulted in the oilfired barn.

As the relative humidity was considerably lower for the oilfired barn throughout the curing season, it seems probable that injurious effects of overheating prevented the tobacco from taking on moisture at the same rate as the gas-fired tobacco did, during the night. These injurious effects must have been established during the very first curing days which necessarily were the first firing period of 81 hours. This seems the more likely as the greater air movement from the heat of 90 evenly distributed burners prevented the formation of hot air pockets or at least reduced them to a minimum. In the gas-fired barn with 64 burners, possibilities for the formation of air pockets were much greater. In the oil-fired barn more burners provided a better heat distribution and a better air circulation. As is remembered, the first tier had many side alleys due to the effort of saving tobacco from hanging too close on the hood of the oil burners and those alleys provided a much better ventilation and greater air movement within the barn, with the possibility that moisture could be more rapidly diffused out of the barn through the very open sidewalls. In the gas-fired barn these alleys were made, too, although they were not necessary - as the gas burners were much lower - but in general seemed to be less pronounced than in the oil-fired barn. This naturally had a great influence upon ventilation, and the diffusion of moisture laden air out of the barn, which controls the rate of moisture evaporating from the leaf area and in general constitutes an evaporation gradient which becomes greater further away from the leaf mass, depending upon wind direction and velocity.

Table I

FIRST FIRING

Outside	T	DP	RH	TDP	TRH		Oil T	DP	RH	TDP	TRH		Gas T	DP	RH	TDP	TRH
S7	60	48	65	12	5	:	68	60	75	8	+7	:	66	63	90	3	+24
		12			6	:	71	61	71	10	0	:	66	53	63	13	- 3
						:	74	55	51.5	19	-22.5	:	65	59	81	6	+16
						:	73	54	51.5	19	-21.5	:	67	59	75	8	+ 8
Averages						:	71.5	57.5	61	14	- 9	:	66	58.5	77	7.5	+10
S8	53	47	80	6	27	:	80	63	57.5	17	-22.5	:	75	81	100	6	+25
					22	:	80	66	63	14	-17	:	78	58	50	20	-28
			25			:	74	59	60	15	-14	:	72	66	82	6	+10
						:	78	59	52	19	-26	:	76	66	71.5	10	- 4.5
Average						:	78	61.7	58	16	-20	:	75	67.7	76	10.5	
S9	60	53	78	7	18	:	83	69	57	19	-26	:	82	72	72	10	-10
			24		19	:	89	66	55	18	-29	:	80	60	50	20	-30
						:	86	61	43	25	-43	:	77	69	77	8	0
						:	82	59	45.5	23	-36.3	:	77	68	74.5	9	- 2.5
Average						:	83.7	62.5	50	21	-33.5	:	78	67	68	11.7	- 10.5
S10	70	63	78.5	7	8.5	:	82	67	61	15	-21	:	80	77	91	3	+ 9
			11		8	:	83	70	65	13	- 8	:	79	64	61	15	- 18
						:	80	63	57	17	-23	:	77	74	91	3	+ 14
						:	79	62	57	17	-22	:	75	72	91	3	+ 16
Average						:	81	65.5	60	15.5	-18.5	:	77.7	71.7	83.5	8.5	+ 5

Second Firing (12 hours)

The second firing period which occurred for twelve hours on September 16 from 8 A.M. to 8 P.M. did not show much difference with regard to temperature between both barns. The main difference is seen from the curves for relative humidity, which again was much lower for the oil-fired barn, decreasing at a steady rate and reaching the outside relative humidity considerably earlier than the gas-fired barn did.

A lower relative humidity for the kerosene-fired barn might also be partially due to a lesser amount of moisture released by the combustion of the fuel. If one considers that 1.6 pounds of water was released for every pound of gas burned, then with a fuel consumption of 970 gallons of L.P. gas, 7015.04 pounds of water was released, which equals a quantity of 841.3 gallons during 93 hours. For kerosene, with 1.1 pounds of water released for every pound burned, 5181.1 pounds of water are released with a fuel consumption of 763 gallons of oil, or 621.3 gallons of water per 93 hours (1 gallon distilled water = 8.3389 pounds). This difference in amounts of moisture released by the fuel certain contributed to decrease the evaporating gradient within the gas-fired barn in which most moisture was released by the combustion of the fuel. (See Table 2)

TEMPERATURE

First Firingperiod 1952

81 Hours

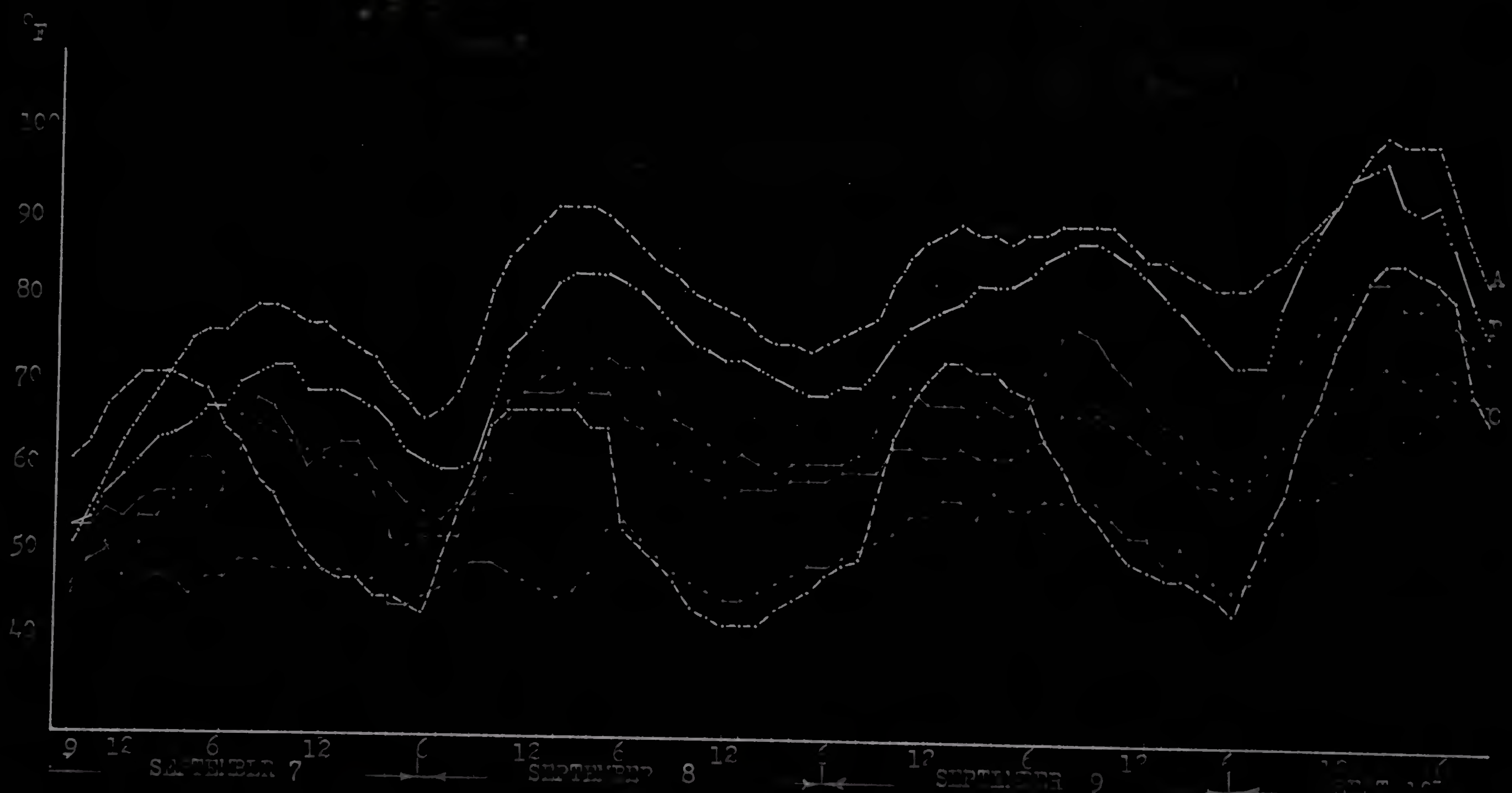


Fig. 1

[illegible] 5.9 [illegible] N 11 m/hr. 3.3 NW 4 [illegible] SE 5 [illegible] SE [illegible]

Outside (= C)

Gasfired (= [illegible] 15 = B)

Oilfired (= " " 14 = A)

Relative Humidity

FIRST FIRING PERIOD 1952

21 Hours

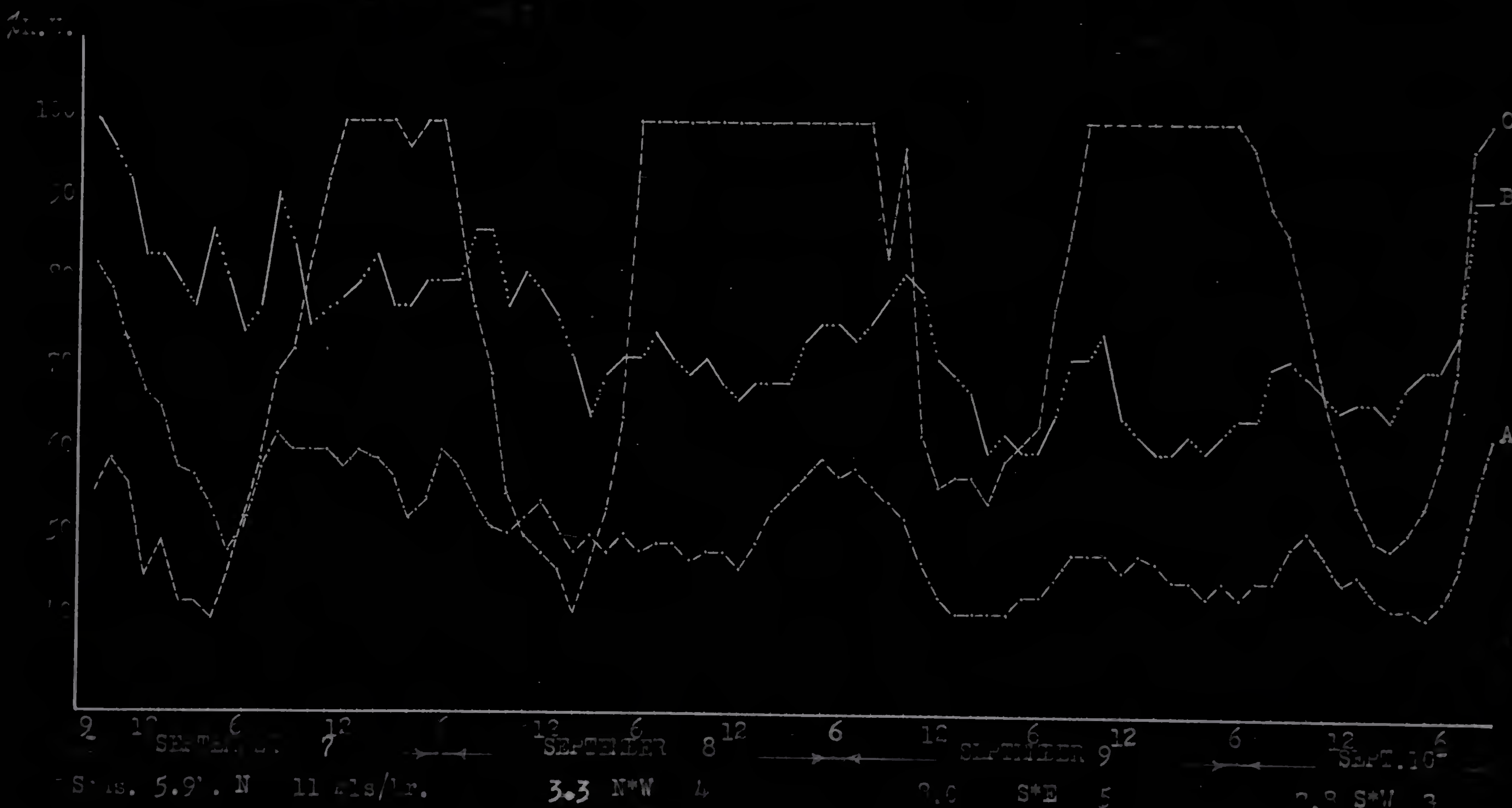


Fig. 2

------ Outside (=O)

-.-.-. Oilfired (Barn No.14 =A)

——.... Gasfired (" " 15 =B)

Mean Temperature and Relative Humidity. Season 1952.

81 Hours.

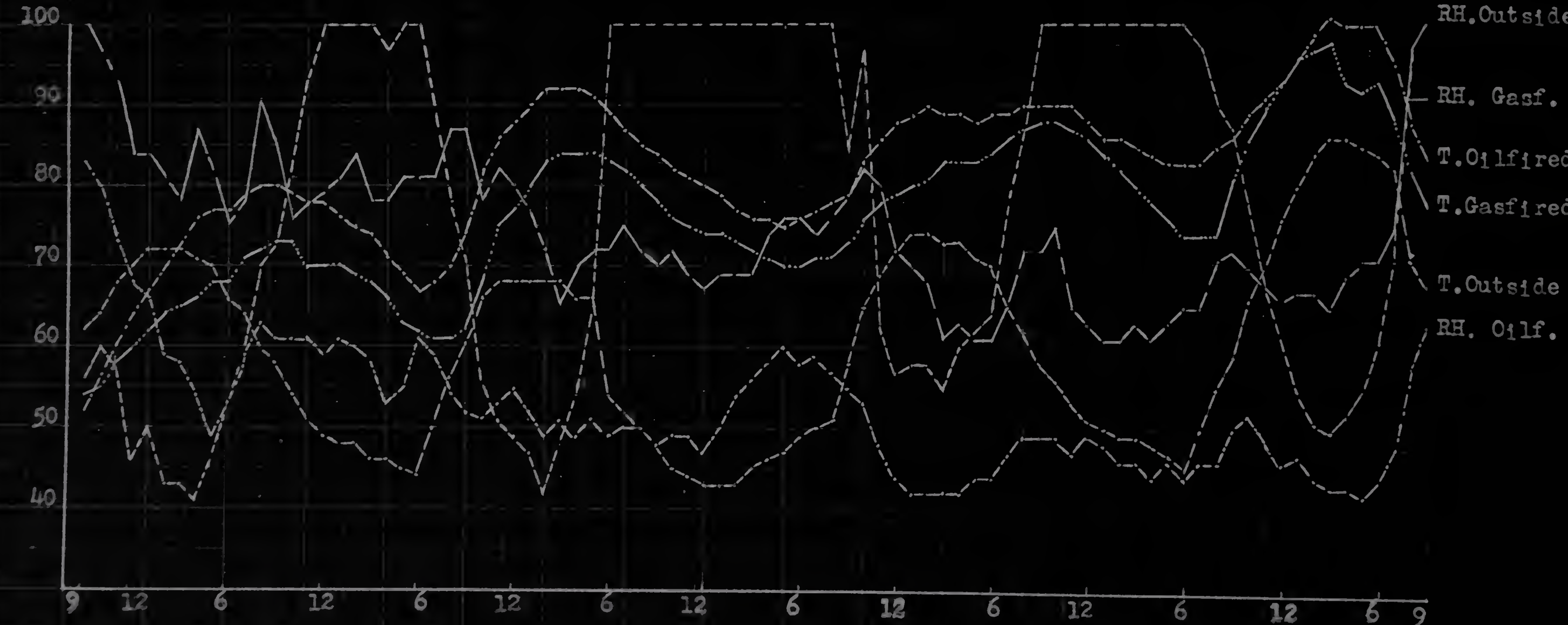


Fig. 3

36 D

SECOND FIRING

Outside

	T	DP	RH	TDP	TRH		T	DP	RH	TDP	TRH		T	DP	RH	TDP	TRH
516	61	55	81	6	20	:	71	59	66	12	- 5	:	74	68	82	6	+ 8
						:	74	63	69	11	- 5	:	74	58	58	16	-16
				11													
			12			:	72	59	64	13	-13	:	72	66	82	6	+10
						:	74	54	47	20	-27	:	69	63	81	6	+12
Average						:	72.4	58.7	61.5	11.5	-13	:	72.2	63.7	75.7	8.5	+ 4

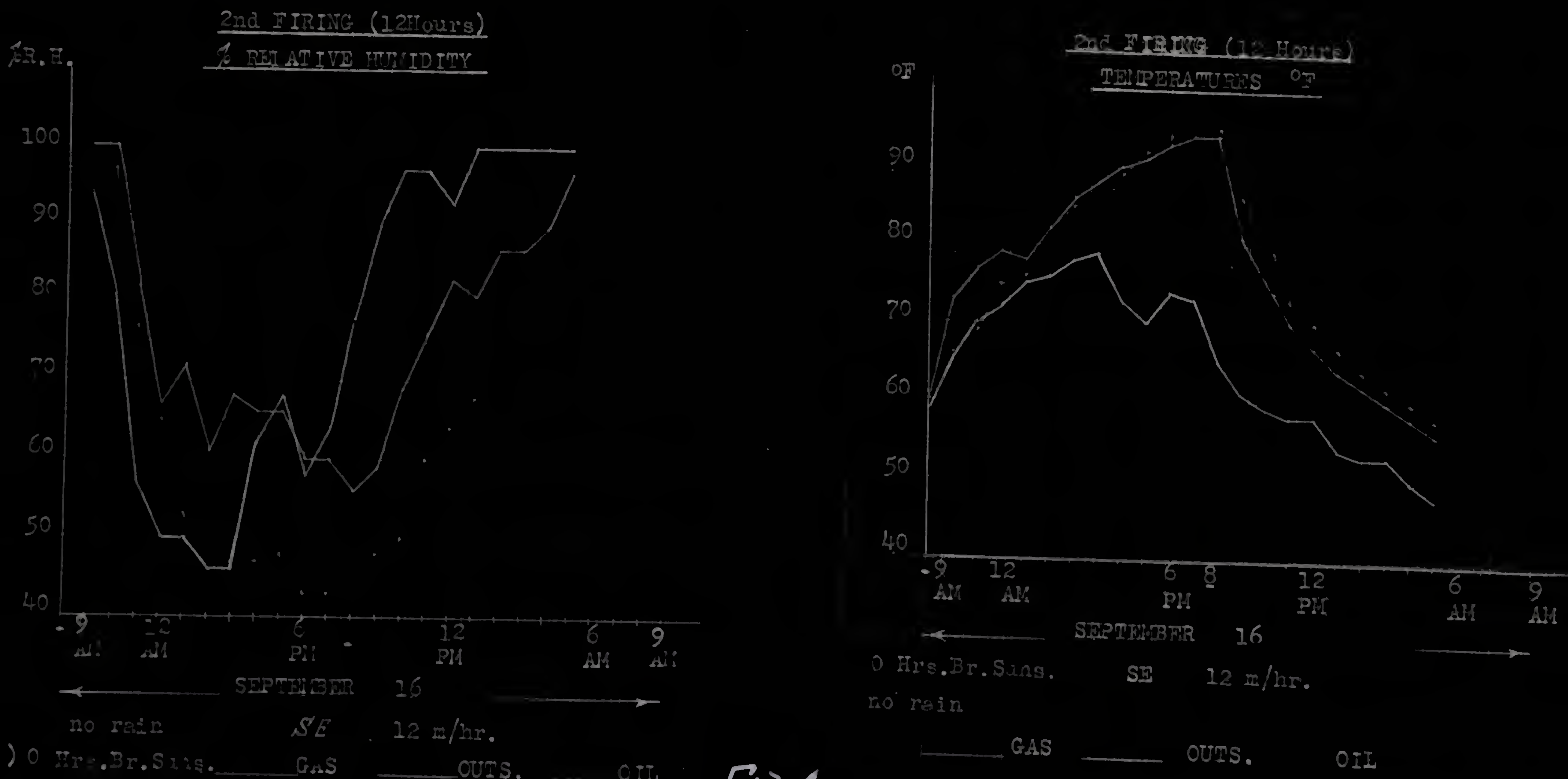

2nd FIRING (12Hours)
% RELATIVE HUMIDITY
%R.H.
100
90
80
70
60
50
40
9 AM
12 AM
6 PM
12 PM
6 AM
9 AM
SEPTEMBER 16
no rain
SE
12 m/hr.
0 Hrs.Br.Suns.
GAS
OUTS.
OIL
2nd FIRING (12 Hours)
TEMPERATURES °F
°F
90
80
70
60
50
40
9 AM
12 AM
6 PM
8
12 PM
6 AM
9 AM
SEPTEMBER 16
0 Hrs.Br.Suns.
SE
12 m/hr.
no rain
GAS
OUTS.
OIL

Fig.4

STRIPPING AND BUNDLING

When the leaves were thoroughly cured and no green mid-ribs existed, the plants were taken down although the stalks were still green. The plants were piled on the ground which was covered with paper to prevent dirt getting onto the leaves. Taking down tobacco is only advisable when the leaves are pliable. Usually a period of rainy or foggy weather will dampen tobacco due to the hygroscopic properties of mineral salts in the tobacco which enable it to absorb moisture (Anderson).

Before taking down the experimental tobacco, a natural damp occurred and for this reason the tobacco was steamed down, which was done on October 30 in the gas-fired barn. A steam generating unit operating around 90 pounds pressure blows steam through a flexible hose which is operated by one man in the barn. Steam clouds are blown horizontally under the tobacco, which, after a certain time depending upon the moisture conditions, becomes pliable and can be taken down. Both barns were steamed although the oil-fired tobacco was steamed to a lesser extent.

The tobacco was stripped and made into bundles of 50 to 70 pounds.

GRADING

Both barns were graded in the sorting rooms of the Imperial Agricultural Corporation in Hatfield. This company graded their tobacco into the following grades: Long-Seconds; Long-Dark Wrapper; Short-Seconds No. 1; Short-Seconds No. 2; Short-Dark Wrapper and Stemming. For comparison, all tiers were graded separately and the weights of each grade obtained were kept separate.

Table 3 represents pounds of tobacco obtained in each grade with percentage figures on the basis of tier, grade and barn. The oil-fired tobacco is designated with the letter "A" and the gas-fired with "B". The lowest section on the table represents total pounds per grade, and also expresses these values as percentages for the barn total. In the column "Total Lbs." the figures represent totals for each tier in pounds and also express the percentage on the basis of total pounds graded for each barn.

The differences between tiers on a total basis were not very impressive. The fourth tiers had nearly the same amounts of cured tobacco. The small total amount more in the oil-fired barn (456 lbs.) which represented only 4 per cent of the two barn-totals together (11.316 lbs.) might be partially due to moisture absorption during the days the bundles were kept in the barn and after this period in the sorting room itself. These figures represent only graded tobacco, whereas those for weighing in before grading differ slightly. These can be disregarded for the purpose of comparison.

In order to establish any significant differences between the amounts obtained on each tier and per grade for the oil-fired and the gas-fired barns, an analysis of variance was made.

Although in general no great differences can be detected from the grading figures, this difference cannot be judged on the basis of pounds alone. For this reason index-figures are shown in Table 3 which were derived by multiplying the percentage-figure from tier-total with the price for each grade. The prices as obtained from the Imperial Agricultural Office in Hartford were the following:

Long-Seconds	$1.00 per lb.
Long-Darks	.80
Short-Seconds 1	1.00
Short-Seconds 2	.80
Short-Dark together with Stemming	.13

As the grade "Short-Darks" yields only a very small number of pounds, this company combines Short-Darks with Stemming. The prices are generally somewhat high but for comparative purposes they are satisfactory.

LONG-SECONDS		LONG-DARKS		SHORT-SECONDS No: 1		SHORT-SECONDS No: 2		SHORT-DARKS		STEMMING		TOTAL LBS		A = Oilfired B = Gasfired
A	B	A	B	A	B	A	B	A	B	A	B	A	B	
382	381	325	293	5	14	25	16	17	10	21	25	775	739	LBS/TIER 4
49.3	51.5	41.9	39.6	0.7	1.9	3.2	2.2	2.2	1.4	2.7	3.4	100.0	100.0	% From Tier Total
12.6	14.2	13.8	13.2	9.1	15.7	17.7	12.5	22.7	11.5	10.0	10.9	13.2	13.6	% " Grade "
6.5	7.0	5.5	5.4	0.1	0.3	0.4	0.3	0.3	0.2	0.4	0.5			% " Barn "
1011	794	742	704	11	34	44	48	22	34	56	69	1886	1683	LBS/TIER 3
53.6	47.2	39.3	41.8	0.6	2.0	2.3	2.9	1.2	2.0	3.0	4.1	100.0	100.0	% From Tier Total
33.3	29.6	31.3	31.8	20.0	38.2	31.2	37.5	29.3	39.1	26.5	30.0	32.0	31.0	% " Grade "
17.2	14.6	12.6	13.0	0.2	0.6	0.7	0.9	0.4	0.6	1.0	1.3			% " Barn "
870	910	697	724	26	28	44	42	22	30	63	75	1722	1809	LBS/TIER 2
50.5	50.3	40.5	40.0	1.5	1.6	2.5	2.3	1.3	1.7	3.7	4.1	100.0	100.0	% From Tier Total
28.7	34.0	29.4	32.7	47.3	31.5	31.2	32.8	29.3	34.5	29.9	32.6	29.3	33.3	% " Grade "
14.8	16.8	11.8	13.3	0.4	0.5	0.7	0.8	0.4	0.5	1.1	1.4			% " Barn "
772	596	605	494	13	13	28	22	14	13	71	61	1503	1199	LBS/TIER 1
51.4	49.7	40.3	41.2	0.8	1.1	1.9	1.8	0.9	1.1	4.7	5.1	100.0	100.0	% From Tier Total
25.4	22.2	25.5	22.3	23.6	14.6	19.9	17.2	18.7	14.9	33.6	26.5	25.5	22.1	% " Grade "
13.1	11.0	10.3	9.1	0.2	0.2	0.5	0.4	0.2	0.2	1.2	1.1			% " Barn "
3035	2681	2369	2215	55	89	141	128	75	87	211	230	5886	5430	Colum Total LBS
51.6	49.4	40.2	40.8	0.9	1.6	2.4	2.4	1.3	1.6	3.6	4.2	100.0	100.0	% From Barntotal
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0			
354	---	154	---	---	34	13	---	---	12	---	19			LBS.Diff.betw.Gr.

LONG-SECONDS		LONG-DARKS		SHORT-SECONDS No: 1		SHORT-SECONDS No: 2		SHORT-DARKS		STEMMING		TOTAL		Index Figures
A	B	A	B	A	B	A	B	A	B	A	B	A	B	
.493	.515	.335	.317	.007	.019	.026	.018	.	.	.006	.006	.867	.875	Tie IV
.536	.472	.314	.334	.006	.020	.018	.032	.	.	.005	.008	.879	.866	" III
.505	.503	.324	.320	.015	.016	.020	.018	.	.	.007	.008	.871	.865	" II
.514	.497	.322	.330	.008	.011	.015	.014	.	.	.007	.008	.866	.860	" I

AVERAGE VALUE OF THE TOBACCO

There was little difference in the value of the tobacco per pound in the oil fired and the gas fired barns. Using the same price for each grade of tobacco, and the percentage yields of grades per barn, it was found that the tobacco in the oil fired barn was worth 87 cents per pound and that in the gas fired barn 86 cents per pound.

Price per Grade and Percentage Obtained

Grade	Price lb/cts	OIL % Grade	OIL lbs.	OIL $	GAS %	GAS lbs.	GAS $
Long-Seconds	100	51.6	3035	3035.00	49.4	2681	2681.00
Long-Darks	80	40.2	2369	1895.20	40.8	2215	1772.00
Short-Sec. 1	100	0.9	55	55.00	1.6	89	89.00
Short-Sec. 2	80	2.4	141	112.80	2.4	128	102.40
Short-Darks + Stemming	13	4.9	286	37.18	5.8	317	41.21
Total		100.	5886	5135.18	100.	5430	4685.61
Average value of tobacco				0.87			0.86

Although the average price per pound of tobacco, and also the percentage of grades of tobacco obtained from the oil fired barn were somewhat greater than those obtained from the gas fired barn, these values were not the only factors that should be considered in determining the value of kerosene for curing of tobacco. If the total cost of the installation is to be compared, certain differences reveal that the oil installation was considerably more expensive than the gas installation, and this is a very important factor.

FUEL CONSUMPTION

All four oil tanks had an individual capacity of 55 gallons. For practical reasons it was assumed that their maximum content was never over 53 gallons after filling. The gas tank maximum content was taken at 80 per cent.

	OIL	GAS
Sept. 7	193	227.3
Sept. 8	157	233.7
Sept. 9	182	245.1
Sept. 10	87	79.1
	619	785.2
Sept. 16	84	185.
Total gallons	703 @ 16 1/2 cts.	970. @ 21 cts.

The amount of oil used could have been considerably less as it was established that the oil-fired barn maintained too high a temperature with consequently higher fuel consumption.

Cost

The following summation presents both installations on a basis of comparative cost. However, it is to be noted that this comparison is with reference to fuel-cost only, which represents the greatest attraction for the use of oil as a source of supplemental heat.

COMPARATIVE COSTS

	Oilfired	Gasfired
Capacity Barns in Acres	4	4
Acres loaded in each barn	3.5	3.5
Total Lbs. cured Tobacco Graded	5886	5430

COMPARATIVE COSTS - Cont.

	Oilfired	Gasfired
Total Fuel Cost:		
703 Gal. Kerosene No. 1 16.5 cts per gallon	$115.995	
970 Gal. L-P Gas 21 cts per gallon		$203.70
Cost per Lb. cured Tobacco Graded	$0.0197	$0.0375
Cost per Lb. cured Tobacco before grading	$0.0203	$0.0370
Average Value of tobacco*	$0.87	$0.86
Average Value of tobacco minus fuel cost	$0.85	$0.82
Cost per Acre:	$33.43	$58.20
Difference in cost/acre	$24.77	

COSTS OF THE INSTALLATIONS

Burners 90 x 5.-	$ 450.-	Burners, Tubing 64 x 10.-	$640.-
Pipes, Drums, Valves, etc.	$ 300.-	Pipes 0.25 x 130 ft.	32.50
Labor 68 man hrs. x 1.-	$ 68.-	Manual Control Valve	50.00
		Labor 5 man hrs.	5.-
Attention 81 man hrs.	$ 81.-	Attention 10 man hrs.	10.-
+ 12 "	$ 12.-		
Fuel Kerosene No. 1	$ 116.-	Fuel cost	$203.70
	$1,027.-		$941.20
Difference			$ 85.80

The price per gallon of Kerosene No. 1 was 16 1/2 cents;

for L-P gas 21 cents.

*Based on the price for each grade and number of pounds for that grade.

CONCLUSIONS

From the preceding discussion it is established that the oil-burning equipment used in the experiment is not well adapted to use in the Connecticut Valley. It is complicated and too difficult to install to be practical.

It was felt that possibly a self-leveling type of burner might be more usable and might make the use of kerosene a practical matter. It would be more easily installed at least.

Indications are that no harmful effects will result from the use of kerosene as a source of heat in curing tobacco. It is apparently the adaptability of equipment that will determine the practability of kerosene for use in curing tobacco in the Connecticut Valley.

It was established through the records that the oil-fired barn did have too much heat to accomplish a satisfactory cure. This is partially due to the inability of the oil to exhibit diurnal variations in its fuel supply, which is a feature of the L-P gas and helps considerably in maintaining temperatures above the existing outside temperature in accordance with the desired range.

The 1952 curing season was one during which natural conditions were favorable for curing without supplemental heat. The experiment was performed late in the season (normally from August-September) and stripping had been ended on the 9th of November. The month of October was extremely dry for the time of the year. This certainly had its effect upon the tobacco in the oil-fired barn which had been slightly overheated during the initial firing period, and which had a fourth tier with tobacco already one week wilted when the first firing period started. This, of course, made a considerable difference in the release of moisture from the plants on this tier, and likely had its effect on the total moisture released into the barn.

The fact that during the entire curing period the oil-fired barn maintained lower relative humidity is thought to be due to injurious effects on the tobacco during the initial firing period. This prevented the tobacco from taking up moisture at the same rate as tobacco fired with gas under less forceful conditions.

As far as oil is concerned, as a fuel there are no indications which prohibit its use; odors and soot were not detected. Regarding burning qualities it is likely that tobacco of the oil-fired barn will have a less satisfactory burn. However, burning qualities are mainly a result of fertilizing practices and conditions which occurred during the growth of the plants.

Although the saving in fuel with kerosene as compared with L-P gas was impressive, the oil installation as such became more expensive on an overall basis. The enormous amount of labor involved, mainly due to the fact that a permanent installation was used and was operated in comparison with a portable gas-firing installation, made this oil-installation seem inconvenient, unreliable and expensive for use in normal

Connecticut Valley barn operations.

From the judgment of two experienced tobacco growers who were confronted with twelve samples of Long-Seconds and Long-Darks of each barn from the same locations: seven samples went in favor of tobacco cured with L-P gas; three in favor of tobacco cured with kerosene; two were equal. These experts were of the opinion that although no great color difference could be noted, the color of tobacco cured with kerosene was slightly poorer and that this tobacco gave a general impression of being poorer in pliability, body, elasticity and texture. Thus definite poorer quality for the oil-fired tobacco was established.

The reason why the oil-fired tobacco became overheated is not to be blamed entirely on the oil-firing installation but in part on the operator who lacked experience in operating the equipment. Also, since the burners were installed in the manner they were during this experiment, the heat could not be reduced sufficiently without extinguishing too many of the burners.

The need is felt for an individual, self-leveling burner which uses kerosene as a fuel and which is reliable and convenient to use and is not prohibitive in cost.

SUMMARY

Summary of findings in favor of and against the use of oil and the installation as used:

OIL

Favorable

1. Better heat distribution.
2. More uniform control of relative humidity.
3. Heating capacity not affected by outdoor temperature.
4. Fuel is cheaper.
5. Fuel supply facilities more adequate.
6. Fuel burned is less than that of gas.

Unfavorable

1. In mild weather, heating capacity can be too great and control is difficult.
2. Low sulphur content essential.
3. Equipment not developed commercially for this application.
4. Burners are tall (30 inches).
5. Fire hazard.

GAS

Summary of observations regarding L-P gas:

Favorable

1. Good heat distribution.
2. Best control of relative humidity in desired range.
3. Diurnal regulation of heat output which happened to be favorable.
4. Free working area in barn (no pipes).
5. Portable and flexible - same installation used in several barns during one season.

Unfavorable

1. Heat distribution could be improved.
2. Tank frosting reduces pressure at times heat might be needed.
3. Fuel is expensive.
4. Explosion hazard.
5. Sulphur content could be very low.

GAS - continued

Favorable	Unfavorable
6. Installation after tobacco is all in the barn.	
7. No liquid in lines.	
8. Equipment rugged.	
9. Lighting easy.	
10. Fire hazard less.	
11. Less storage space.	
12. Not affected by drippings from tobacco.	
13. Burner is low.	

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A P P E N D I X

MEANS FOR THE FIRST FIRING PERIOD (81 Hours)

	TEMPERATURE				RELATIVE HUMIDITY			
	*M	H	L	R	M	H	L	R
Oil	82	101	52	48	52	83	42	41
Gas	76	98	54	44	74	100	61	39
Outs.	59.8	86	43	43	77.5	100	42	58

MEANS FOR THE SECOND FIRING PERIOD (12 Hours)

	*M	H	L	R	M	H	L	R
Oil	83.5	95	66	29	58	97	40	57
Gas	85	94	73	21	71.5	100	56	44
Outs.	72.5	79	65	14	62.5	93.5	45.5	48

MEANS FOR THE SEASON (57 Days)

	*M	H	L	R	M	H	L	R
Oil	56.1	86	34	52	69.7	91	38	53
Gas	55.1	81	33	48	80	100	48	52
Outs.	53.9	76	34	42	72.2	100	34.5	65.5

*M = Mean   H = Highest   L = Lowest   R = Range

DAYLY MEAN TEMPERATURE SEASON 1952 (57 DAYS)

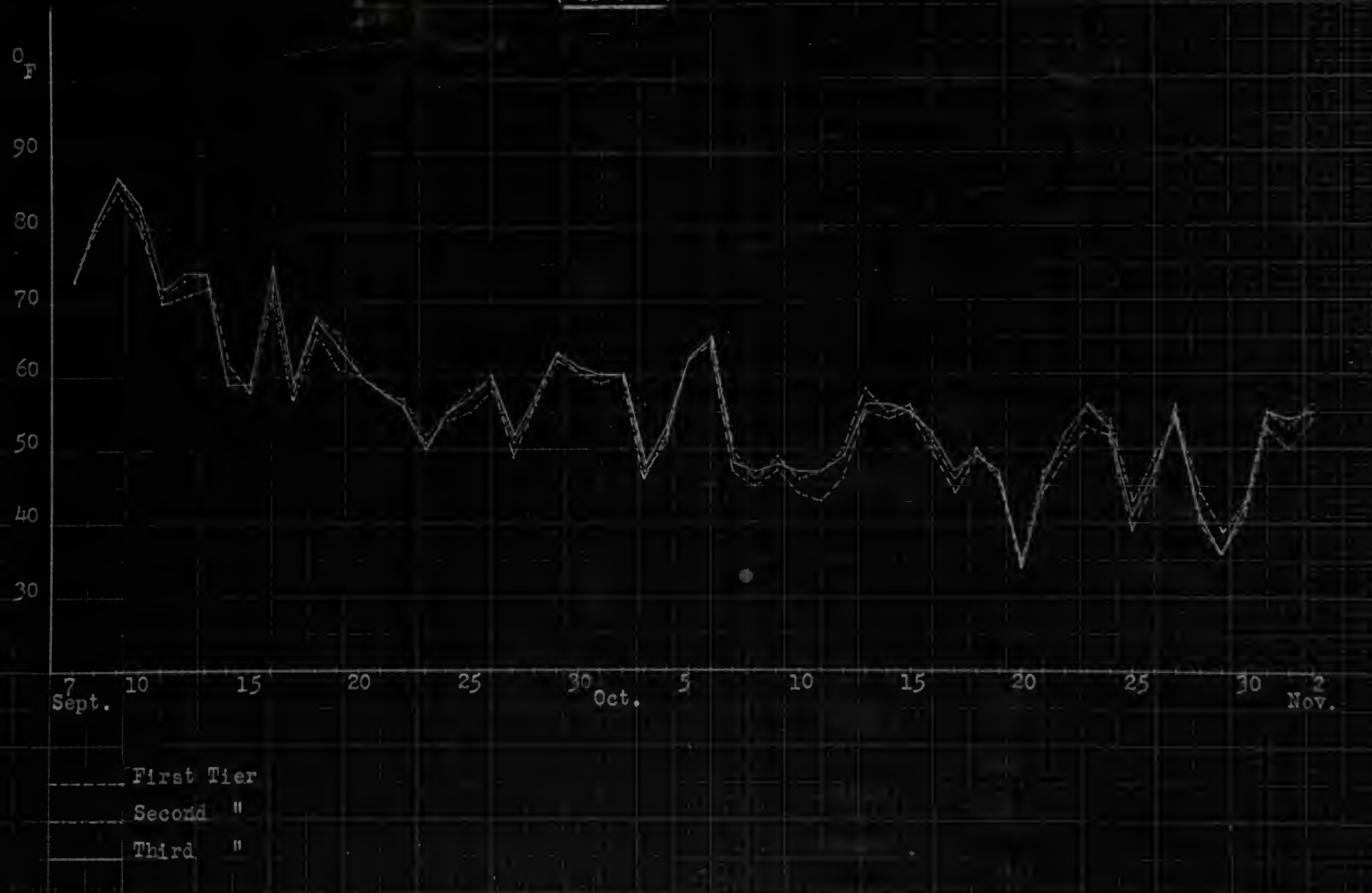
FOR BOTH BARNS


MEAN RELATIVE HUMIDITY SEASON 1952 (57 Days)
FOR BOTH BARNS
%.RH.
100
90
80
70
60
50
40
7 Sept.
10
15
20
25
30
Oct.
5
10
15
20
25
30
2 Nov.
B
A
O
OUTSIDE (O)
GASFIRED (B)
OILFIRED (A)

Mean Daily Temperature Season 1952 (57 Days)

First, Second, Third Tier Barn 14

(Oilfired)



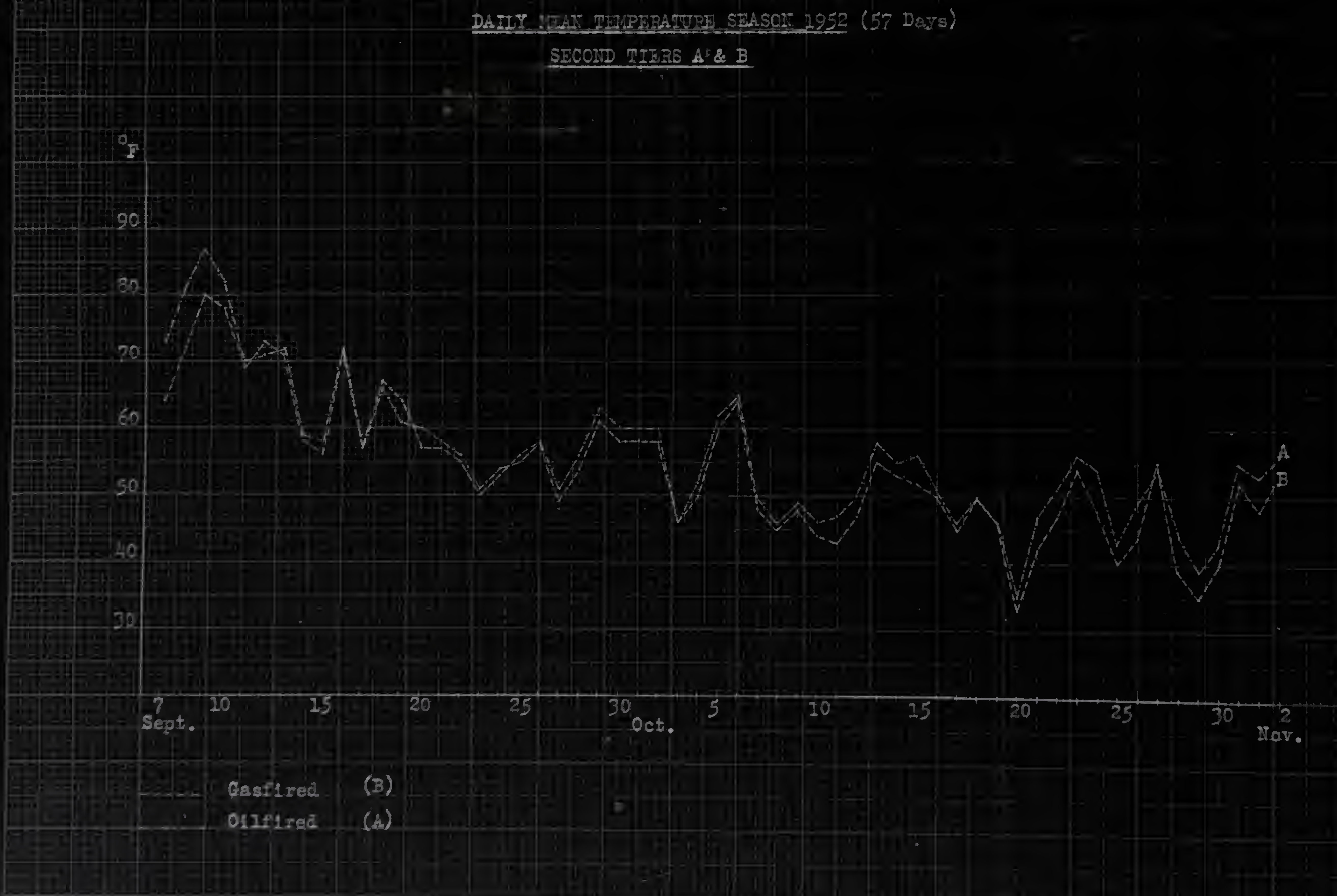
Mean Daily Temperatures Season 1952 (57 Days)

First, Second, Third Tier Barn 15

(Gasfired)

DAILY MEAN TEMPERATURE SEASON 1952 (57 DAYS)

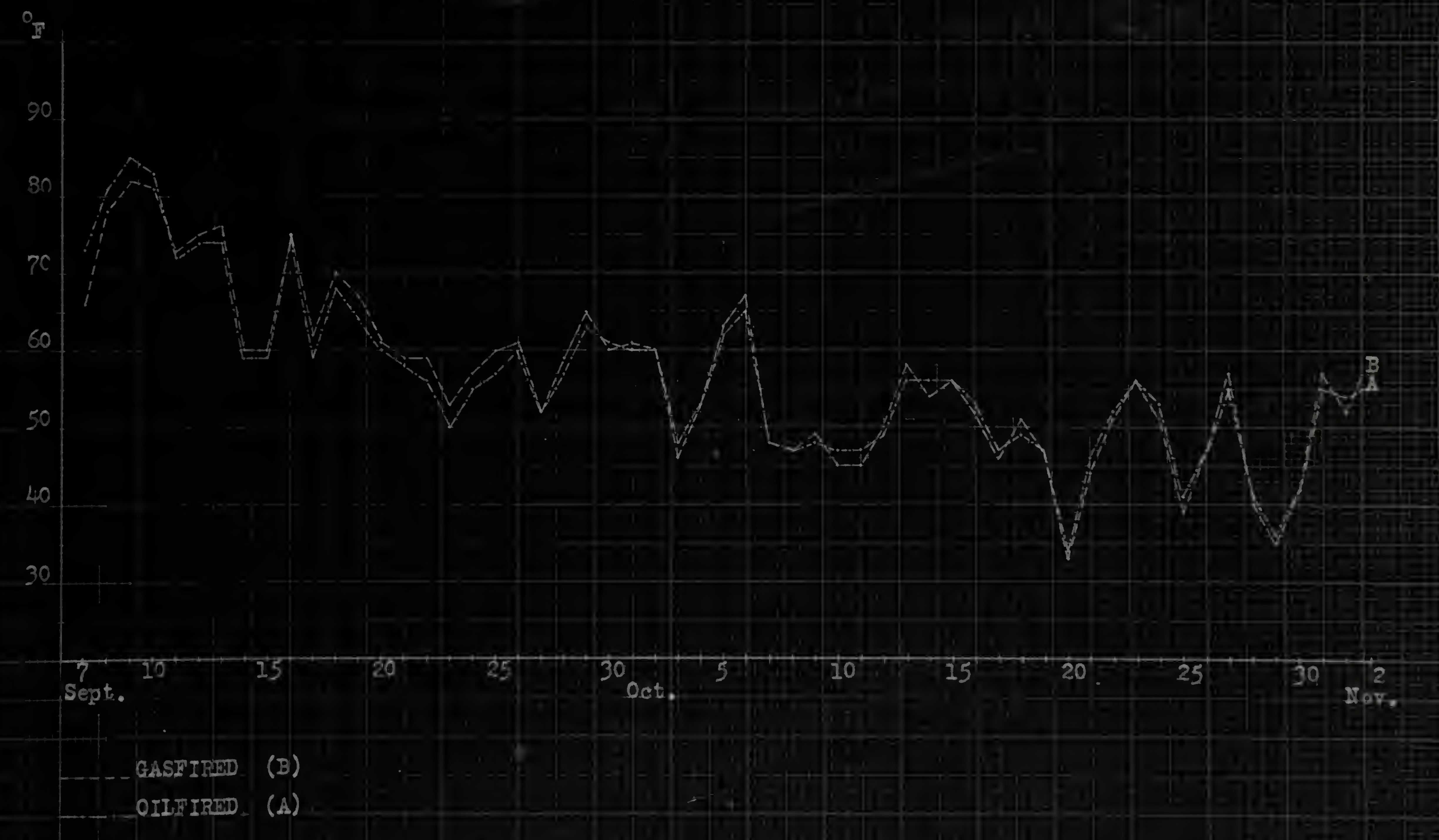
FIRST TIER A & B



DAILY MEAN TEMPERATURE SEASON 1952 (57 Days)
SECOND TIERS A & B
°F
90
80
70
60
50
40
30
A
B
7
Sept.
10
15
20
25
30
Oct.
5
10
15
20
25
30
2
Nov.
Gasfired (B)
Oilfired (A)

DAILY MEAN TEMPERATURE SEASON 1952 (57 Days)

THIRD TIERS A & B



Instruction sheet(Oil firing Installation)

This curer is in 4 sections. Each of the 4 pipe lines is complete with carburetor and packed in a separate case. Each case marked A, B, C and D corresponds to the same section above. The hoods are packed 30 to a case and the chimneys and bowls 24 to a case with one case containing 18 of each.

Assemble end pipe (8' pieces) using 4 3/8 x 3/8 tees. (1) Plug each outside tee (2) on one end of section. On other end plug one tee, leaving other open as at (3). Connect ½ of each burner line (4) using couplings (5) and ½ of union (6). After all burner lines are connected, lay in position in floor plan. Now screw ½ of burner lines into 3/8" tees at one end. Screw other ½ of burner lines into 3/8" tees; at other end have spindles (7) upright. Now connect line with unions (6), making sure line is in correct position; mark ground along pipe line with stick. Move pipe line. Drive pipe stakes (8) approximately 4 feet apart and half into ground, along mark, Starting at low corner, dig trench (9) about 2 or 3 inches in earth using mark as center and level. Drive stakes on down 1½" below ground level with a 4 ft. spirit level. Get tops of stakes <u>level</u> all around. Place pipe line in position on top of stakes. Put foot and clamp (10) about midway burner line. Drive stake under each end until foot is level with other stakes. Wire pipe line to stakes. Also foot. Tighten clamp to foot. Extend trench at corner (3) about 8½ ft. and under shed wall. Screw 8' feed pipe into 1/4" x 3/8" x 3/8" tee (11) and plug other 3/8" tee opening. Screw feed pipe into 3/8" tee opening. Screw feed pipe into 3/8" tee at pipe line corner (3). Drive stake under pipe near tee (11); wire to pipe. Screw 1/4" x 4" nipple (12) into tee (11). Screw carburetor (13) on nipple (12) using hole directly under large metering button. Screw compression connector (14) into carburetor using hole under small "of-on" button. Place drum in desired location and at least 6" above carburetor. Screw reducer (15) into drum bung hole. Screw "shut-off" (16) into reducer. Slip nut from "shut-off" onto copper feed line (17), then little sleeve from "shut-off" on end of (17). Stick copper line into "shut-off" and tighten it. This presses sleeve about copper line and makes an oil tight joint. On other end place nut from comp. conn. (14). Then sleeve and tighten on comp. conn. This is a completely assembled pipe line.

Note: 8' feedpipe may be cut off to place carburetor near wall. In section "A" and "D" extra pipe has been sent as shown in order that all carburetors may be placed together - <u>if ground is level</u>. If not fairly level, carburetors will have to be placed at (18) and (19). Take burner bowls (20) and push stems (21) into pipe spindles (7), as far down as possible. Tighten burner nut (22). Take small spirit level and level each bowl seperately both left-right and front-back. This can be done by grasping bowl firmly in both

Instr. sh. continued.

hands and bending stem (21) slightly at welded joint. Stem must be all the way into pipe spindle. Raise burner housing (23) a little and tighten nuts (24) clamping to pipe spindle. Now, using an extra long spirit level or transit, level each bowl top one with the other as you tighten the other housings. All bowls in each section must be level. Sections may be on different levels. Now fasten hood bottoms (25) and hinge (26) together with bolts and speed nuts. Fasten hood bodies together (27), but do not hinge to bottom yet. Bolt 4 top strips (28) to body and to top (29). Place bottom around burner with burner in center, and hinge toward wall. Drive 3 hood stakes (30) (small) inside bottom with stake hole in line with hood bottom hole. Remove hood and drive stakes within an inch of the ground. When all stakes are driven, place bottoms around stakes and bolt to same. Now bolt body (27) to hinge and bottom. There are 2 extra holes (31) in bottom. Put a bolt through each pointing outwards. Fasten with speed nut. This supports body on the side opposite hinge, when hood is upright. Open hoods. Take top off carburetor. Turn oil on at drum - after 15 minutes oil should fill each bowl 1/3 to 1/2 full, no more. If not enough oil, shut off carburetor. Unscrew a plug at one corner, drain line. Plug corner. Raise carburetor slightly and try again. Repeat until correct level is obtained. If too much oil, do likewise, only lower carburetor instead. Place asbestos wicks (32) into bowls with ends meeting over oil inlet. When wet, light and place chimney (33) over bowl, being sure that chimney is well seated. Lower hood body. Cover pipe line with earth. Burner should burn blue and well above top of chimney. If all burn too low, raise carburetor slightly. If one burns red bowl is probably not level or is not well seated. Replace carburetor top.

FUEL CONSUMPTION

		OIL	GAS
First Firing:			
90 Burners, 619 gal., 81 hours		7.6 gal./hr.	
	1 Burner	0.084 "	
64 Burners, 785 gal., 81 hours			9.69 gal./hr.
	1 Burner		0.151 "
Second Firing:			
90 Burners, 84 gal., 12 hours		7.0 gal./hr.	
	1 Burner	0.077 "	
64 Burners, 185 gal., 12 hours			15.4 gal./hr.
	1 Burner		0.241 "

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