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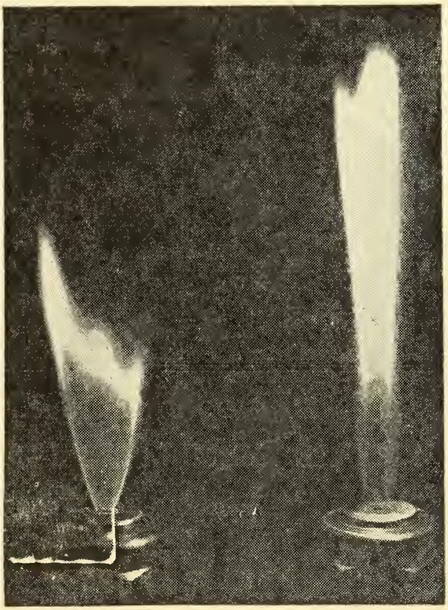

MISSISSIPPI STATE COLLEGE
AGRICULTURAL EXPERIMENT STATION
CLAY LYLE, Director
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ON THE COVER:

Figure 2. Flame produced by regular spray nozzle (left) and round orifice (right). The shorter flame pattern on the left indicates more efficient combustion than the long yellow flame on the right.

FLAME CULTIVATION

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The search for an effective and labor-saving method of controlling weeds in cotton and other row crops in recent years has resulted in the use of numerous mechanical and chemical weed-killing devices. One practice that has warranted a great deal of investigation is the process of applying a hot blast of flame to weed-infested crops. Although this relatively new method of weed control has met with varying degrees of success since its introduction in the late 1930's, it has to a limited extent, proved economical and useful in the development of mechanized cotton-production programs in some areas.

The first flame cultivator tested at the Delta Branch Experiment Station was a rather cumbersome, sulky-type rig, equipped with air compressor, gasoline engine, cone-shaped burners, and an assortment of valves, fuel lines, and other accessories. The flame was produced from a mixture of fuel oil and air.

Improvements were made in 1944 by mounting the machine on a tractor and utilizing the power take-off rather than a separate gasoline engine for operating the compressor. An ignition system, consisting of a distributor and automotive-type spark plugs placed in each burner, was also added to provide more uniform operation. Although these and other improvements by manufacturers and research workers greatly increased the efficiency of the early machines, more important developments were yet to come.

The Principle of Flame Weeding

Eradication of weeds in cultivated crops by flaming is a selective process. Different kinds of plants are able to withstand differing amounts of heat, depending upon their stem structure, age, size, and shape. Control of unwanted plants by this method of cultivation is therefore accomplished by moving an intense blast of flame along the base of the weed-infested crop. Growth is impeded or terminated in those plants having the least resistance to the high temperatures induced by the flame burners. When sufficient heat has been introduced to cause dehydration and rupture of cell walls, the plant dries and the process of destruction is completed.

The intensity and volume of the flame and duration of exposure are important factors in attaining effective results with flame. Desired exposures are obtained by varying the speed of the tractor, while the size and velocity of the flame pattern may be varied by changing the burner orifice and fuel pressure. The position of the burner in relation to the weeds is also highly important, since the most effective kills are obtained by destroying the buds of the plants. When weeds are as tall as the cultivated crop, they cannot be destroyed with flame without causing excessive damage.

New Developments

Flame cultivation, as we know it today, began with the introduction of the L-P gases, butane and propane, as fuel in 1945. The round, Barr-type, L-P gas burner was also introduced at that time and was subsequently adopted by most manufacturers. A self-energizing burner, which utilized heat from the burner flame in vaporizing the liquid-petroleum fuel, was also developed and used in some machines.

Although additional modifications and improvements in machine design followed these developments, flame cultivation failed to gain in popularity in the Cotton

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[1]Agricultural Engineers, Delta Branch of the Mississippi Agricultural Experiment Station, and Farm Machinery Section, Agricultural Engineering Research Branch, ARS. USDA. Stoneville. Mississippi, cooperating.

Belt. Much of the reluctance in using flame in cotton stemmed from the realization that this practice would not completely solve all grass and weed problems. Some farmers considered flame too limited in its usefulness in controlling weeds in young cotton, the time when hand labor is usually in greatest demand. Failure to adopt production practices compatible with flame cultivation and rising fuel costs were other factors that retarded the use of this new weed-eradication device.

The Flame Cultivator

The components of a typical flame cultivator are shown in the schematic diagram in figure 1. They consist of a high-pressure tank, tank fittings, vaporizer, fuel lines, quick cut-off valve, pressure regulator, pressure gauge, rockshaft, attaching frame, skid assembly, burner supports, and burners.

The fuel tank should be equipped with brass fittings and both tank and fittings must meet certain code specifications of the A.S.M.E. for handling butane and profane fuels. Each tank must be stamped with the State Inspector's approval.

As illustrated in the diagram, the necessary tank fittings include a filler valve, safety relief valve, fuel level gauge, pressure gauge, 85-percent-full indicator, vapor return valve, and liquid withdrawal valve. The filler valve is equipped to open automatically when the filler hose is connected and to close instantly as the hose is removed. The cap covering this valve should always be screwed in place as soon as the filler hose is disconnected.

The safety valve, which functions to relieve excessively high pressures, should be in good operating condition at all times and should be repaired or replaced only by a competent serviceman.

Either a slip-stick or dial indicating type fuel-level gauge may be used for determining the amount of fuel in the

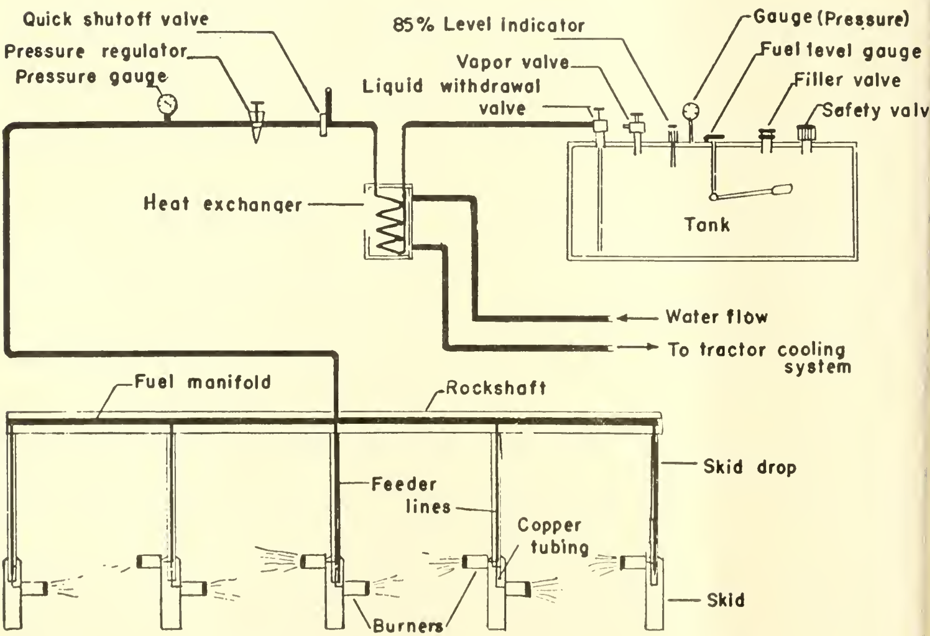


Figure 1. Schematic diagram of a flame cultivator.

tank. The dial type, which is actuated by a float, requires only a quick glance to read.

The high-pressure gauge, which indicates the tank pressure at all times, should be mounted in conjunction with a check value so that the flow of fuel from the tank will be stopped should the gauge be broken. The 85-percent liquid-level indicator prevents the tank from being filled beyond its maximum allowable capacity.

The function of the vapor return valve is to provide connection of the vapor space at the top of the fuel tank with the vapor space at the top of the storage tank. This allows pressures in the two tanks to equalize during the filling operation. The liquid withdrawal valve permits the flow of liquid from the tank to the vaporizer and thence to the burners.

Although a vapor valve is used at the top of the fuel tank to supply gas to the burners in some two-row flame cultivators, the normal practice is to withdraw liquid from the bottom of the tank and vaporize it before it reaches the burners. In this process, water is circulated from the cooling jacket of the tractor engine around a coiled section of the fuel feeder line and returned to the tractor radiator. When the tractor is not equipped with a water pump, an auxiliary pump may be installed and driven either with a longer belt from the fan or from the power take-off.

After vaporization, the gas is conducted through a pressure regulator to a manifold where it is then channeled to the individual burners. A quick-opening valve, installed in the line ahead of the regulator and within easy reach of the tractor operator, should have a small hole drilled in the gate to allow a pilot light to burn while the burners are off for turning at the ends of the field.

The burners, which are normally mounted on skids, are connected to a rockshaft by means of a rigid arm, hinged at both ends. The skids operate in the center of each row middle and support either one or two burners, as shown in figure 1. The height of the burners above the ground is controlled by adjustments on the skid assemblies. Although a rubber hose is used to convey the fuel from the tank to the manifold, a short length of small copper tubing is used in the individual lines near each burner as protection against the burner flame.

An Experimental Machine

Significant developments in machine design in 1948 and 1949 were largely responsible for revival of interest in flame cultivation in the Mississippi Delta and other cotton producing areas. An experimental machine, encompassing several radical changes, was tested at the Delta Branch Experiment Station in 1948 in cooperation with The International Harvester Company.[2]

A special feature of this machine was a semi-elliptical, special alloy, cast iron burner, which employed a standard fan-type spray nozzle as an orifice. The burner produced a relatively short, flat flame and was designed to operate at a much greated angle than the conventional round-type burner. When setting the burner at an angle of approximately 45 degrees with the ground, the impact of the flame tended to displace the cool air near the soil so that no convection currents were created. As a result, the flame tended to flatten on the ground with little or no inclination to bounce.

Development of the Flat Type Burner

Further exploration of some of the principles contained in this new experimental flame cultivator, by Delta Branch Experiment Station agricultural enneers, led to other significant develop-

[2]Credit for development of this machine is due Mr. Stewart Pool and Mr. B. J. Shager, International Harvester Company Engineers.

ments.[3] These improvements were made after the machine was scrapped and released to the Delta Station by the implement company.

Laboratory tests were first conducted to determine the superiority of the spray nozzle over standard round-type burner orifices. With assistance from the Standard Oil Development Company, flames from the two types of orifices were produced and photographed (see cover). A study of results showed that flame from the regular spray nozzle used in the new burner was short, combustion was excellent, and a good flame pattern was produced. The standard round-type orifice, in comparison, emitted a long thin flame with poor combustion.

Intensive experimentation in burner design subsequently led to the development of a flat, rectangular, sheet metal burner which was equipped with a replacable, fan-type, spray-nozzle orifice (figures 3 and 4). Significant improvements in this burner included (1) low-cost construction, (2) improved flame pattern, (3) greater flame output, (4) accurate and fool-proof adjustment, and (5) adaptability to different machines. The short, flat flame produced by this burner reduced the danger of leaf damage in the cultivated crop, and the use of smaller nozzle orifices permitted earlier

[3]Acknowledgement is hereby accorded Mr. J. K. Jones, Product Development and Service Engineer, John Deere Plow Company, Memphis, Tennessee, for his improvements in flame cultivator equipment. Mr. Jones, formerly Agricultural Engineer at the Delta Branch Experiment Station, Stoneville, Mississippi, was responsible for development of the flat-type burner, which was subsequently adopted by most flame cultivator manufacturers.

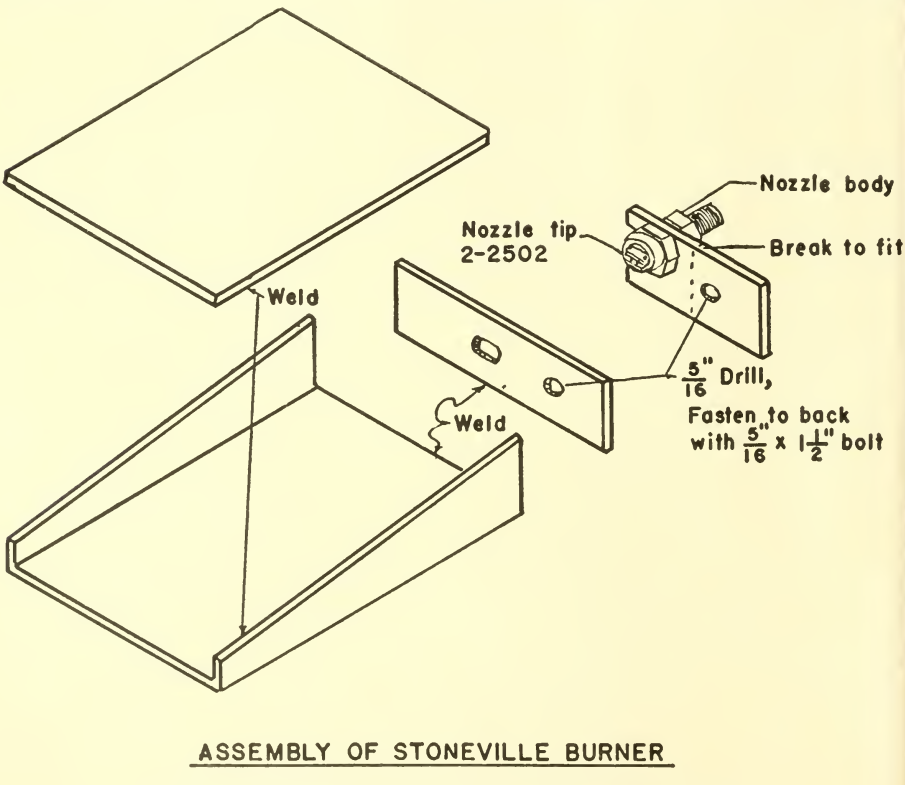
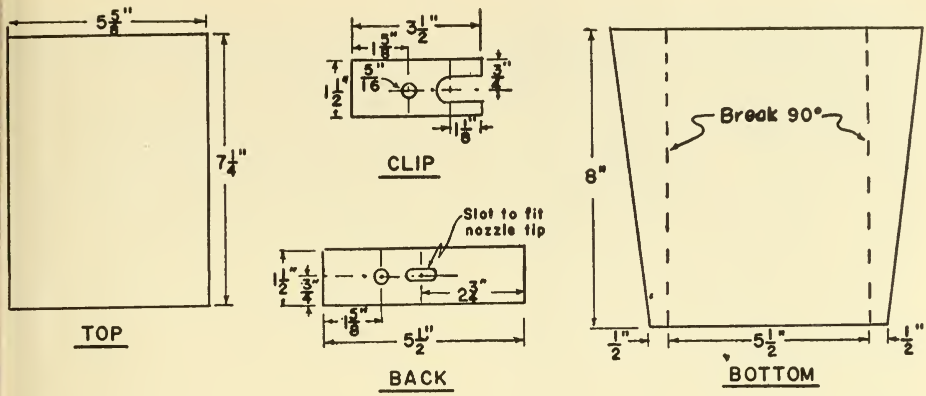


Figure 3. Exploded view of the flat-type flame cultivator burner.



NOTE: All parts fabricated from 10 gauge sheet metal

Figure 4. Sheet metal layout of the flat-type burner.

flame application. On the other hand, the wider flame pattern provided a longer exposure period, which allowed a faster rate of travel.

The final shape of this burner was determined by fabricating and testing various pre-production models. Among the critical points in construction was the size of the opening at the burner mouth. It was found that this opening should be exactly one-half inch wide and should be uniform across the burner. Tests showed that variations from this critical dimension adversely affected combustion, uniformity of the flame pattern, length of the cold-air cone in the center of the flame, and the action of the flame when striking the ground.

Further orifice investigations resulted in the development of multiple orifice jets. A twin orifice nozzle, which was developed in cooperation with The Spraying Systems Company, improved burner performance by reducing the length of the flame and smoothing out the flame tips.

Fuel Requirements

Tests were conducted at the Delta Station to compare the capacities of various types of standard burner orifices. As part of the flat-type burner efficiency studies, these tests were replicated and carefully performed under controlled laboratory conditions. Results of a series of fuel consumption determinations with both single- and double-orifice nozzle tips are shown in table 1.

The actual fuel consumption per acre for a specific burner orifice and line pressure may be determined by selecting the proper value under the "Gallons per hour per burner" column in the table. Consumption rates per acre, based on the rate of travel, are shown in the three right hand columns. For example, if orifice tip number 2-2502 was used with a line pressure of 50 p.s.i. and the rate of travel was 3 miles per hour, the amount of fuel consumed per acre would be 4.27 gallons. No allowance has been made for turning time, however. This will vary widely, depending upon the skill of the operator and length of the field.

Field Application Techniques

Careful adjustment of the burners is a primary requirement for maximum flame cultivation efficiency. As shown in figure 5, the flat type burner should be set at an angle of approximately 45 degrees with the ground. The mouth of the burner should be from eight to ten inches away from the drill and from eight to ten inches above the row middles. In this position, the flame should strike the ground two to three inches on the burner side of the drill. The outlet end of the burner should be kept parallel to the row to insure uniform application of the flame. The two burners on each row should be set in tandem so that the flames will not oppose each other. Pressures ranging from 40 to 55 p.s.i. are normally used in the flat-type burner. The higher pressure is used when weed growths are relatively dense.

A study of the actual shape of flame patterns may be made by observing the flame cultivator in the field at night. This should assist in setting the machine properly.

Although recent burner changes and improved application methods have indicated that flaming may be started in some instances when cotton plants are only a few inches tall, initial flame treatments are normally applied with standard size burners when the stalks are approximately 3/16 inch in diameter at the ground level. Since weeds that have reached the same height and toughness

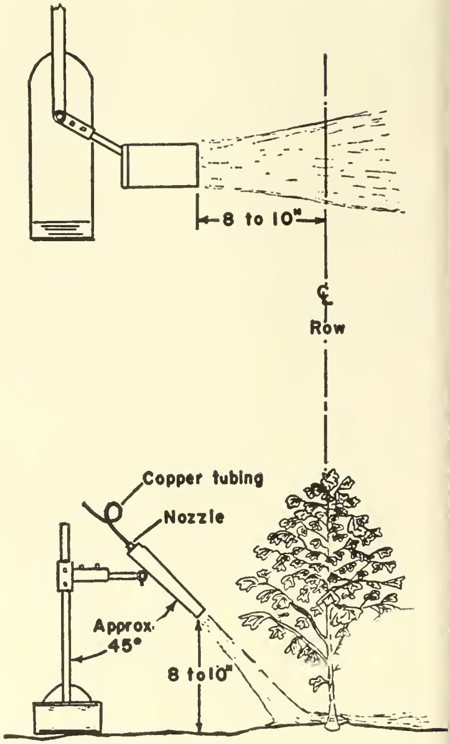


Figure 5. Proper setting for flat type burner

Table 1. Propane capacties of five standard orifice tips used in flat-type cultivator burners.

Orifice tip No.	Line pressure (p.s.i.)	Fuel consumption: Gallons per hour per burner	Gallons per acre (2 burners per 40" row)[1]: 2 mph	3 mph	4 mph
2-2502[2]	30	1.86	4.60	3.07	2.30
	40	2.15	5.32	3.55	2.66
	50	2.59	6.41	4.27	3.20
2-2503[2]	30	2.68	6.63	4.42	3.31
	40	3.11	7.69	5.13	3.85
	50	3.65	9.03	6.02	4.52
4002	20	.75	1.83	1.22	.92
	30	1.20	2.97	1.98	1.48
	40	1.32	3.26	2.18	1.63
4004	20	1.52	3.76	2.51	1.88
	30	2.02	4.99	3.33	2.50
	40	2.25	5.57	3.71	2.78
4006	20	2.19	5.42	3.61	2.71
	30	2.86	7.08	4.72	3.54
	40	2.88	7.13	4.75	3.56

[1]No allowance was made for turning.

[2]Double-orifice nozzle tip.

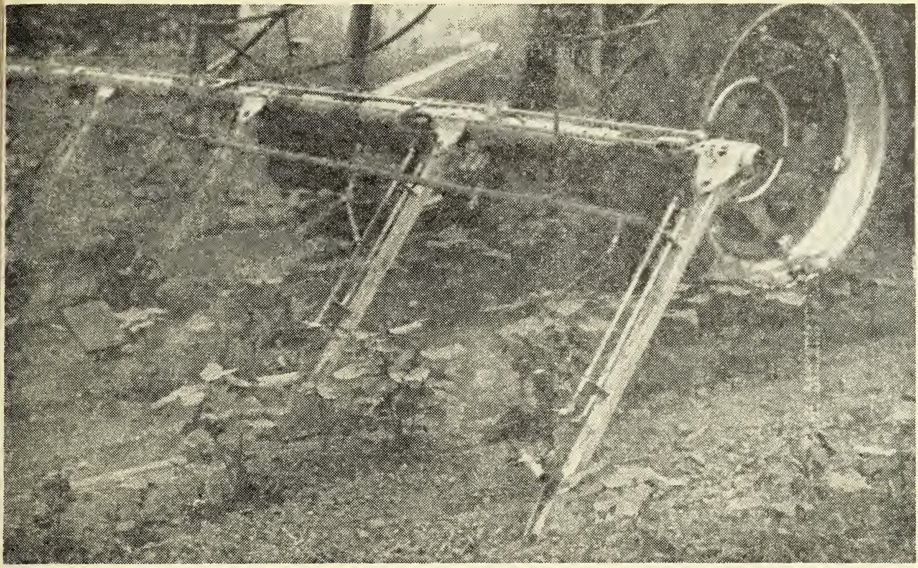


Figure 6. Low uniform beds and properly set burners are essential for maximum flame performance.

as the cultivated crop cannot be controlled satisfactority with flame, early season control measures are usually necessary before flame can be used safely. These may consist of the use of either pre- or post-emergence herbicides, mechanical cultivation, hoeing, or a combination of these treatments. Regardless of the method used, the row profile should be left as smooth as possible to permit maximum efficiency in subsequeent flame operations (figure 6).

Timing the flaming treatment is especially important, since the most effective kills are obtained when the weeds are tender and less than 3 inches tall. Frequent flame applications, especially in heavily infested areas, is essential for best results. When it is necessary to remove dense growths of weeds, however, the task should be accomplished through a series of burnings rather than by one or two extremely heavy applications. This will eliminate the danger of damaging grass fires during subsequent flame treatments.

The use of a flame cultivator in conjunction with conventional sweeps has proved to be a good production practice (figure 7). By cultivating the row middles and flaming the drill area simultaneously with one tractor unit, manpower requirements are cut in half, machine operating costs are materially reduced, and excessive machine traffic through the field is eliminated. Savings of this kind are essential in keeping machinery investments at a minimum and in reducing over-all production costs.

Flame cultivation has proved to be an effective tool for controlling most annual and some perennial weeds when properly used. It has not been effective in removing Johnson grass, pig weeds, cockleburs, and perennial vines from row crops, however, except when these plants were in the seedling stage. Best results have been obtained when flame cultivation was combined with other weed control measures, such as chemical weed control, crossplowing, and various other mechanical weed control practices.

Various tests have been conducted to determine the relative efficiency of flame with other methods of weed control. An economic study comparing the efficiency of hand chopping with flame cultivation was conducted on four Delta plantations.

The results, which were published in Mississippi Agricultural Experiment Station Circular No. 143, showed that the average power and labor costs per acre for weed control in cotton were reduced approximately 15 percent by flaming.

A study designed to evaluate several methods of chemical and mechanical weed control was initiated by the Weed Control Project at the Delta Branch Experiment Station in 1950.[4] Under the conditions of this experiment, the most practical and economical method of controlling weeds in cotton with minimum hand labor was three applications of a post-emergence oil followed by five flamings with a pre-emergence herbicide either used or omitted. Tests conducted since 1950 have tended to confirm these results.

Flame cultivation has proved particularly adaptable to late season weed control in cotton, since heavy growths of weeds often occur following late-season rains (figure 8). Effective late-season weed control is an important factor in quality harvesting with mechanical pickers. By equipping the flame cultivator tractor with wheel shields (figure 9), weed control may be continued almost to harvest time.

[4]Results published in the 1951 Proceedings of the Southern Weed Conference.

Cost of Flaming

Fuel is the primary cost in operating a flame cultivator. Since the consumption of L-P gas normally ranges from 4 to 6 gallons per acre, the average cost of fuel is approximately 50 cents per acre. This will normally range from 40 to 70 cents per acre. Based on present machinery, labor and fuel prices, the overall cost of flaming per acre per cultivation ranges from 70 cents to $1.20 per acre. The size of the machine, speed of operation, and the additional operations performed are all factors that determine final costs. The number of flame cultivations required per season for efficient weed control will normally vary from four to six.

Although flame cultivation is not the sole answer in weed control, it has proved economical when wisely used as a part of regular cotton cultural practices.

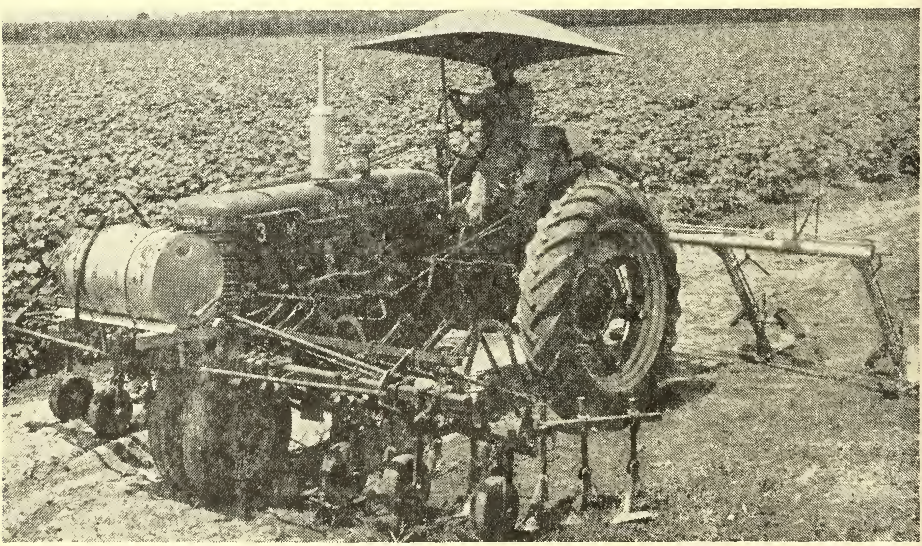


Figure 7. The use of flame cultivation equipment in combination with a standard cultivator reduces the cost of operation.

Figure 8. Flame cultivation has proved especially valuable as a late weed control practice in cotton.

Figure 9. Tractor wheel shields reduce stalk damage when farming late-season or rank cotton.