Photograph of the Return-Stack orchard heater with cut-away drawings to show interior details.

Return-Stack Orcha

virtually smokeless heating service unde for 180 hours without cleaning demonst

The Return-Stack orchard heater is the only bowl-type heater available at the present time which has been proved by field tests to provide reliable operation over long periods of time without cleaning and without objectionable amounts of smoke, even in mass heating.

The extensive orchard heating required during the past two winters, particularly in southern California, brought forth renewed public demands for elimination of smoke nuisance. These two severe seasons also provided sufficient large-scale field experience with the Return-Stack heater to permit reliable evaluation of its characteristics.

The Return-Stack heater—developed at the University of California—has been available commercially for about 10 years. Most of the heaters from the first production lot, manufactured and offered for sale just before the war, were used to heat warehouses and shops and for other nonorchard space-heating applications. Although these heaters have given satisfactory service in such applications, this achievement by itself could not be taken as a demonstration of their suitability for orchard heating.

For several years following the war, the winters were so mild that those heaters which were in orchards during that period were not used enough to constitute an acceptable field test. Only during the past two winters have weather conditions been severe enough to cause the Return-Stack heater to be subjected to all the demands and abuses under which an orchard heater must be able to operate and give satisfactory service in the field.

The experience during these two heating seasons has demonstrated the ability of this heater to render reliable and virtually smokeless orchard heating service under the most severe conditions.

Although some bowl-type orchard heaters produce less smoke than others, all except the Return-Stack heater are basically unsatisfactory because of the high rate of soot formation by the pilot flame. This flame must be present within the bowl in order to provide heat for the vaporization of the fuel; its size, and thus the rate of vaporization of the fuel and the burning rate of the heater, is controlled by limiting its supply of oxygen. At all burning rates, therefore, the pilot flame is starved for oxygen.

In any ordinary bowl-type orchard heater the pilot flame thus burns in a highly concentrated mixture of fuel vapors. This leads to such a high rate of soot production within the bowl that any stack or combustion chamber—no matter how good it might be when clean—will soon become fouled with soot and its combustion will become smoky. Besides fouling the stack, some of the soot falls into the fuel in the bowl to form a sludge residue which gradually reduces the effective fuel capacity of the bowl and creates an expensive disposal problem.

The Return-Stack orchard heater was developed to correct this fundamental defect of all ordinary bowl-type heaters. A consideration of the various possible ways in which soot and smoke might be formed in a hydrocarbon flame led to the conclusion that by diluting the fuel vapors with some inert gas before they reach the combustion zone, a very substantial reduction in the smokiness of the combustion could be effected.

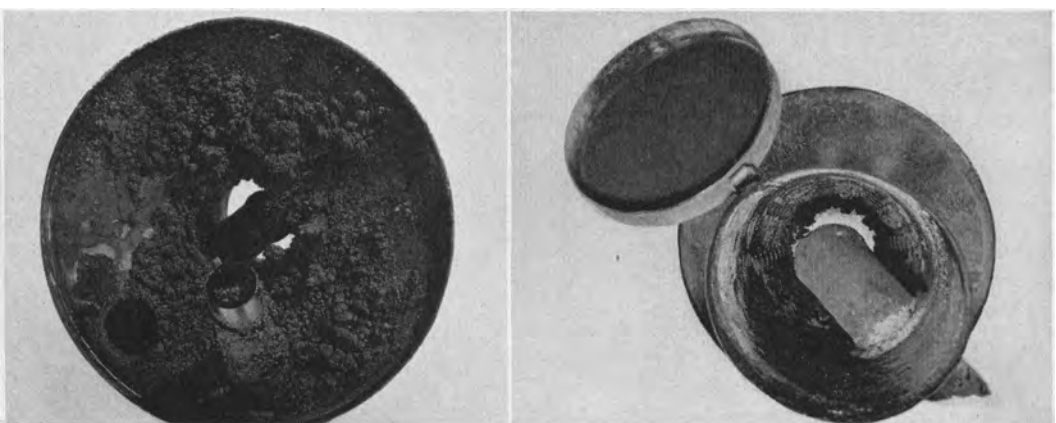
Later tests have substantiated this conclusion and demonstrated that, by dilution with sufficient amounts of carbon dioxide, water vapor, or nitrogen, any hydrocarbon fuel—including such smoky fuels as acetylene and benzene—can be made to burn with a soft transparent flame without smoke. Since the combustion products from the heaters themselves are composed almost entirely of these three inert gases, this gaseous mixture should be satisfactory for diluting the fuel vapors.

In the ordinary kerosene lantern the dilution principle has been employed for many years to reduce the smokiness of the lantern flame and provide clean combustion at a higher rate and with a larger flame than would otherwise be possible. In the lantern, inert products of combustion enter the return system at the top of the glass chimney, pass down through the tubular-frame at the sides, and are delivered to the base of the flame.

The application of this principle to the bowl-type orchard heater has led to the return-stack design shown. Dilution of the fuel vapors in the bowl, with stack gases, contributes to the very low initial smoke output of this heater. Even more significant is the reduction of smokiness of the pilot flame to the point where a smokeless stack can be operated for long periods of time without becoming smoky and without an excessive rate of sludge formation in the bowl.

Because it is necessary to use an appreciable percentage of excess air in the main combustion zone to obtain smokeless operation, the stack gases which are returned to the bowl for the purpose of dilution contain some free oxygen. This free oxygen contributes to the support of the pilot-flame combustion in the bowl. If for some reason, such as a lowering of the fuel level in the bowl, the burning rate of the heater decreases slightly, the amount of excess air and oxygen in the

Soot accumulation in Return-Stack heater operated the past two severe winters without cleaning. The 180-hour total operating time represents about five years of normal heating. Note the absence of soot in the stack—except for small amount at throat—and the relatively small amount on the cover.



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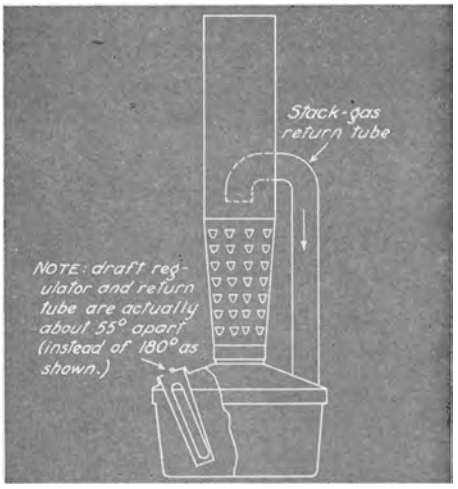
A. S. Leonard and Robert A. Kepner



The Return-Stack heater. The three-inch diameter return tube takes inert products of combustion from the center of the main stack and returns them to the bowl to dilute the fuel vapors and thus reduce the smokiness of the pilot flame and the main combustion flame.

stack gases will increase correspondingly. This increased amount of free oxygen in the returned stack gases will support a larger pilot flame which will tend to increase the rate of vaporization of the fuel in the bowl and thus tend to keep the heater burning at a constant rate. For this reason the burning rate of the heater, when operated with the draft regulator completely closed, decreases only slightly as the fuel level in the bowl falls. Also, this interaction between the main combustion zone and the pilot flame makes the burning rate of this heater less sensitive to changes in draft-regulator setting than that of other bowl-type heaters with stacks of comparable height.

The Return-Stack orchard heater is equipped with a standard down-draft tube and wick and is lighted in the usual manner. The bowl and cover are standard except for the addition of the return-stack connector to the cover. The combustion chamber and stack are made of galvanized iron and consist of a louvered combustion-chamber section tapering from six inches to 8¼ inches in diameter, and a cylindrical unlouvered upper section 8¼ inches in diameter. The return tube is three inches in diameter, and except for the scoop, is made of galvanized iron. The scoop is located inside of the 8¼-inch stack and is made of cast iron to insure a long life.

Normal operation of the heater is with the draft regulator completely closed. This gives a burning rate of from one-half to two-thirds gallon per hour, depending on the amount of air leakage around the draft regulator and bowl cover. The rate may be increased by opening the draft regulator—preferably to not more than one 9/16-inch diameter hole.

The Return-Stack heater may be operated at burning rates up to nearly one gallon per hour without producing objectionable amounts of smoke, but stack deterioration will be accelerated at the higher rates.

The accompanying graph presents curves of smoke output vs. burning rate—clean heaters—for the Return-Stack heater compared with several other kinds which are representative of the better heaters now in use. At burning rates of from one-half to three-fourths gallons per hour, the smoke output of the Return-Stack heater is well below 0.2 grams per minute and is less than that from any other kind of bowl-type orchard heater, even when the latter is clean.

Information regarding field experience with the Return-Stack heater has been obtained from several growers in the Santa Paula area and from the Citrus Experiment Station at Riverside.

One large ranch, between Fillmore and Santa Paula, now has about 2,000 of these heaters, some of which have been in use for eight years, with a total estimated operating time of 300 to 400 hours each. Their usual draft adjustment has been with one hole open—9/16-inch diameter—which gives a burning rate of about three-fourths gallon per hour.

The Citrus Experiment Station now has over 4,000 Return-Stack heaters, some of which were operated for a total of about 180 hours during the past two winters. This amount of heating is equivalent to more than five years of average heating requirements. These heaters have been operated with the draft regulators closed, at an estimated burning rate of about two-thirds gallon per hour.

The eight-year old heaters at the ranch in the Fillmore–Santa Paula district have been emptied and cleaned only twice during the 300 to 400 hours of operation, while the two-year old heaters at the Experiment Station have not been cleaned at all during their 180 hours of operation.

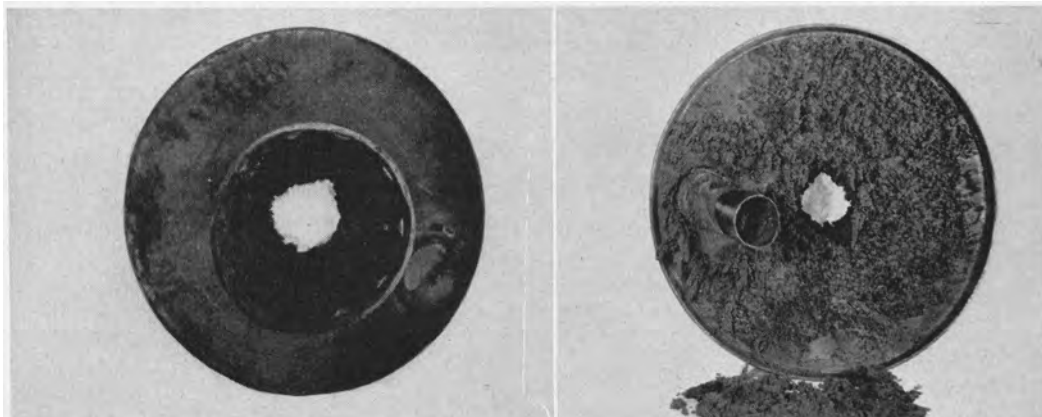
Both groups of heaters still operate at normal rates without visible smoke. The sludge accumulations have been small and can still be burned out without excessive burning rates or smoke and without damage to the heaters. Other growers in the Santa Paula area report similar results for heaters which are eight to 10 years old. The photograph on page 8 shows interior views of a representative two-year old Return-Stack heater from the Citrus Experiment Station. Note that even after two winters of heavy firing—180 hours total—there still is no appreciable amount of soot in the stack and only relatively a small amount on the cover.

By way of comparison, the photograph on page 9 shows similar views for one of the the better lazy-flame heaters, but after only 15 hours of operation. This soot accumulation, representing only one or two nights of operation without cleaning, is typical of all ordinary bowl-type heaters and is sufficient to cause a large increase in smokiness and a considerable reduction in burning rate.

In general, soot accumulations will cause the smoke output from ordinary bowl-type heaters—all except the Return-Stack—to increase by as much as from fifty to several hundred per cent during the first night of operation after cleaning. The greatly reduced rate of soot formation in the Return-Stack heater is a direct result of the dilution of the fuel vapors with the inert products of combustion from the stack.

The Return-Stack heater is easy to light by the usual methods. The filler cap

Soot accumulation in one of the better lazy-flame heaters after only 15 hours of operation at an average rate of 0.6 gallon per hour. Smoke output has increased to a value three to four times as great as for the same heater when clean.



should be closed and the draft regulated quite soon after lighting—one to three minutes—otherwise the high starting rate causes the stack to become extremely hot and results in excessive smoke during this period.

Extinguishing by the usual procedure of capping the stack and closing the draft regulator—or leaving it closed as the case may be—is not always successful because of the tendency of this heater to blow off the stack cap and go back into normal operation. Some of the other makes of bowl-type orchard heaters exhibit this tendency, but to a lesser degree.

A modified extinguishing procedure, which is being used by at least one of the Santa Paula growers, consists of opening the draft regulator to one hole when the stack cap is put on. This procedure seems to overcome the tendency to blow off the stack cap.

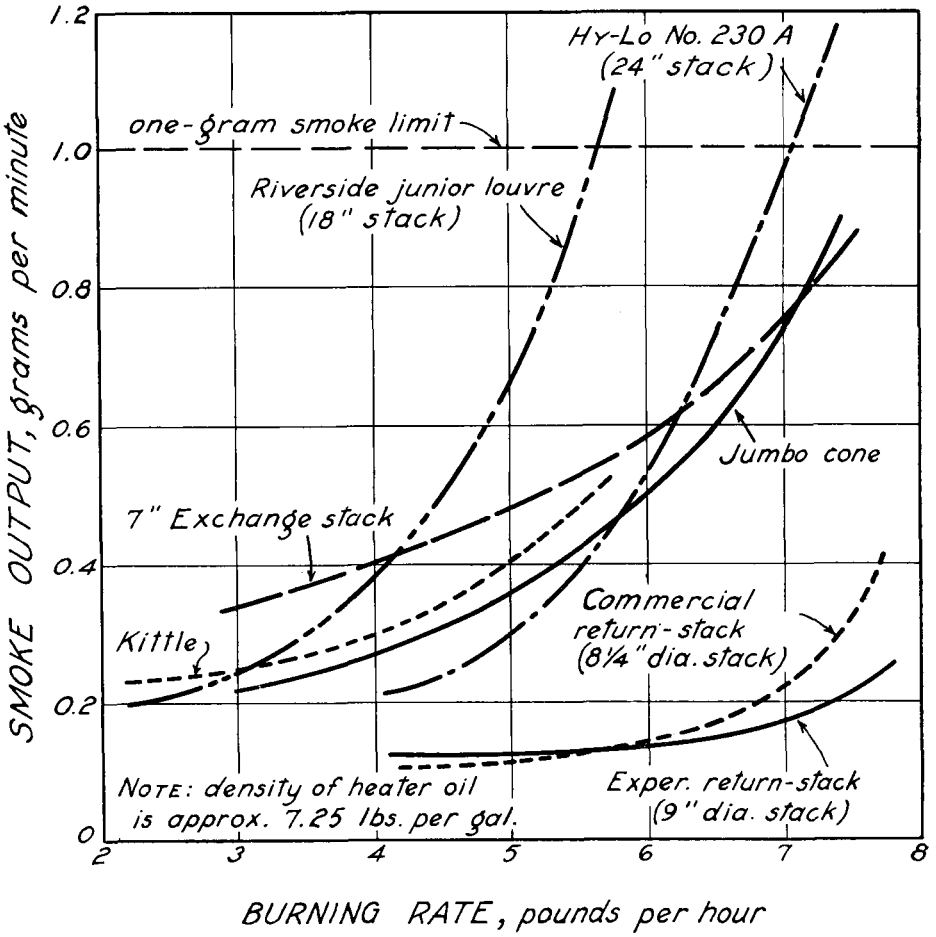
With the usual fuel oils burned in bowl-type heaters, the sludge residue which forms in the bowls amounts to as much as from 5% to 8% of the total quantity of oil burned. Most bowl-type heaters will not burn this residue unless excessive burning rates are used with resulting formation of large amounts of smoke and soot and possible damage to the heaters. Hence the accumulated residue decreases the effective bowl capacity of these heaters, represents an appreciable loss of oil, and creates a disposal problem.

The Return-Stack heater will burn its own sludge—as well as sludge from other heaters—at reasonable burning rates, without excessive smokiness or soot accumulation, and without damage to the heater.

In regard to stack life, field experience with the Return-Stack heater is inadequate to allow more than an estimate. Some of the eight-year-old heaters at the ranch in the Fillmore-Santa Paula district have small visible holes through the stacks, due to heat and rust, but in general they are still serviceable and replacement should not be high for several years. Other heaters in the Santa Paula area are still in reasonably good condition after 10 years of use. The heaters at the Citrus Experiment Station are still in excellent condition after two winters of severe use.

It is estimated that the stacks should last for at least 10 to 15 years if operated at rates not exceeding three-fourths gallon per hour. The galvanized return elbows have a tendency to burn off where they join the cast iron scoops and will need to be replaced more often than the stacks. A recent change in design incorporates this elbow as part of the cast iron scoop.

Another difficulty encountered with the heaters now in the field is the tendency for the return tube to slip off of the connector at the cover. This is being corrected by a manufacturing change to incorporate a longer connector.



Relation of smoke output to burning rate for clean heaters. Ordinary bowl-type heaters, after being operated for only one or two nights without cleaning will have smoke outputs several times as great as those indicated by the above curves. Return-Stack heater still has low smoke output after several years of operation without cleaning.

At the present time, the initial cost of the Return-Stack heater is a little higher than that of other combustion-chamber heaters, and nearly twice as great as the cost of lazy-flame heaters. However, any heater having a round bowl and cover in good condition can be converted to Return-Stack at a cost considerably less than that of a complete new heater.

From an economic standpoint, the higher initial cost of the Return-Stack heater is partly offset by:

1. Elimination of cleaning requirements during the heating season. Other bowl-type heaters would require cleaning at intervals of eight to 10 hours or less in order to hold their smoke outputs down to a minimum—this frequent cleaning is not practical from a time and labor standpoint during prolonged periods of heating.

2. Elimination of the sludge-disposal problem, of the decrease in bowl capacity caused by the sludge, and of the oil loss represented by the sludge.

3. Added frost protection because of the greater heating capacity per heater without excessive smoke. This may be of considerable value in case of a severe freeze, and makes this heater ideal for use in conjunction with wind machines, where only a few heaters per acre are needed.

Although a number of the currently used bowl-type orchard heaters can—by frequent cleaning—be held within the present one-gram smoke limit, it must be realized that this limit was set rather arbitrarily many years ago and is much too high to be tolerated by the general public in the future. Also, during periods of prolonged and heavy heating, time and manpower limitations make it virtually impossible to clean heaters in addition to operating and filling them.

Growers must, therefore, be prepared to replace or convert most of their present heating equipment if they expect to be permitted to continue the large-scale use of orchard heaters.

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