FOREST PRODUCTS LABORATORY (Madison 5, Wis.)
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
Approved Technical Article

Charcoal Production in Kilns[1]

EDWARD BEGLINGER

Chemist, Forest Products Laboratory[2], Forest Service
U. S. Department of Agriculture

A substantial portion of today's charcoal is produced in kilns. Recreational demand has greatly increased the market, but proflt margins are still not large. So far, research indicates that masonry-block kilns of 7-cord capacity are the most economical units, although the lower yield of portable sheet-metal kilns is at least partially offset by their utilization aspect.

Methods and Scope of Production

CHARCOAL HAS BEEN PRODUCED by American industry for many years. Although there has been gradual change from the primitive pit to kilns keyed for more uniform and efficient production, the method employed remains unchanged in principle.

Charcoal is formed in a kiln when wood is heated in the presence of regulated but limited amounts of air. The primary heat is furnished by igniting part of the charge. In addition, reaction heat becomes available as the wood undergoes conversion. After the surface zone of the wood has dried, and as controlled combustion heat increases, wood decomposition occurs and charcoal is formed. The heat required to maintain carbonization or coding conditions is supplied essentially by the wood as it decomposes and by combustion of the gases and vapors given off by the wood. A wood charge is considered to be "coaled out" when the smoke emerging from the stacks is maintained at a low level for some time. Cooling is accomplished by exclusion of air. Charcoal is recovered as the residue along with usually small amounts of ash produced during the coaling process. With the exception of the pit or earth kilns, the use of which has declined greatly, present facilities are still fairly representative of the types used throughout the industry for years (Fig. 1).

Roundwood from both merchantable and low-value stock and residues from primary manufacturing plants supply suitable raw material for kiln charcoal production. Wood from medium-dense species like birch, beech, ash, maple, hickory, and the oaks is preferred because of the greater charge weight that is possible as compared to the reduced volume weights of the lighter hardwoods and many of the softwoods. The greater yields of charcoal from the denser hardwoods provide not only a more favorable economic condition but also the firmer and heavier type of lump charcoal traditionally demanded. The less satisfactory condition of prevailing market reluctance for the bulkier charcoals from the lighter woods and the reduced weight yields per charge could be made more attractive perhaps by generally lower kiln site costs for this type of raw material. Briquetting affords a potentially good outlet for these lighter charcoals, since the bulkier product from the lighter species loses its identity after it is ground, and yields a material not unlike that of the heavier lump charcoals.

Charcoal production in the United States during 1956 amounted to 264,990 tons (1)[3]. About one-fifth of this amount was produced in approximately 234 kiln operations. Kilns are concentrated in greatest numbers in the Eastern, Great Lakes, and South Central regions. California is the only

[1] Presented at the Eleventh National Meeting of the FPRS, held in Buffalo, N. Y.. June 24–28. 1957.

[2] Maintained at Madison Wis. in cooperation with the University of Wisconsin.

[3] Numbers in parentheses refer to literature cited at end of this report.

The Author: Edward Beglinger has been associated with carbonization research at the Forest Products Lab. for many years. He directs fundamental and pilot-plant investigations as well as surveys of wood distillation and charcoal kiln installations. He is currently associated with the direction and coordination of Forest Service field studies, on the development and application of more suitable operating methods and facilities for kiln production.

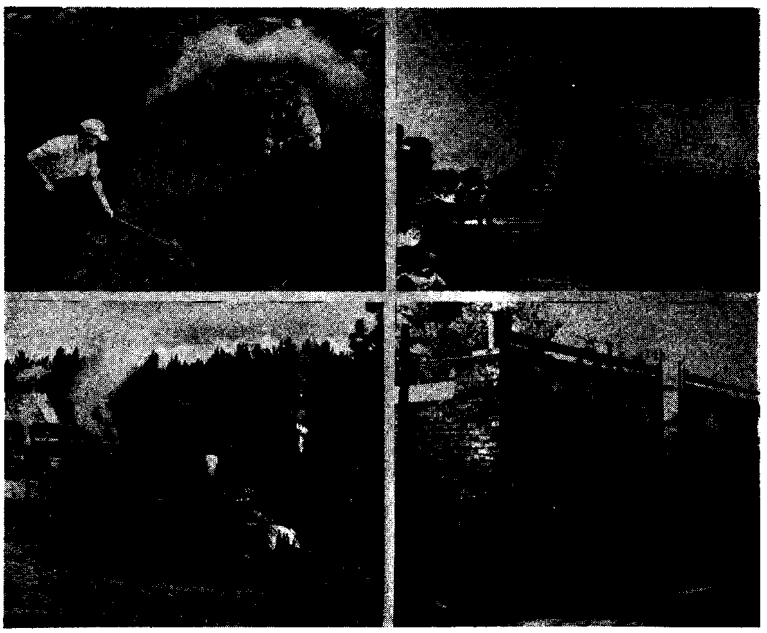

Fig. 1.—The evolution of commercial charcoal production methods. Upper Left: The primitive earth kiln; Upper Right: The beehive kiln, still in common use; Lower Left: The low-capacity, transportable, sheet-metal kiln; Lower Right: The higher yielding, masonry-block kiln with steel doors.

Reprinted from the November, 1957, Forest Products Journal (Vol. VII, No. 11). pages 399–403
Forest Products Research Society, P. O. Box 2010, University Station, Madison 5, Wisconsin

western state with a significant number. The majority of kilns in 1756, numbering 604, were of the masonry block type,(4, 6, 7) with wood capacities of 1 to about 25 cords (Fig. 2). There were 207 sheet-metal (2, 3, 5, 9) and 200 brick kilns. There is little uniformity in kiln type or operational capacity,since charcoal is manufactured in portable sheet-metal units that hold as little as 1/2 cord and in brick or ceramic-tile beehive kilns with much larger capacities. The pattern of production among these many units is quite as varied, and provides no common yardstick by which individual operations might be compared and evaluated on the basis of production effort and adequate return.

With a steadily increasing recreational demand for charcoal, interest in kiln production has likewise grown. This accelerated interest has led to misguided efforts and monetary losses, but for the most part a satisfactory profit has been realized. Should it be possible, however, to establish more suitable methods, greater benefits might well result. Research can, with the wealth of experience industrially available, accompish much in the development of more efficient methods for wood procurement, kiln operation, and mechanized facilities at the kiln. Operators face serious problems pertaining to charcoal yields, quality and uniformity of product, the kiln itself, and markets. Equally important are the problems of raw material, labor, kiln maintenance, and depreciation costs, all of which affect charcoal production costs. Prior knowledge associated with the solution of such problems is considered most essential in determining either an expected profit or insufficient return. Additional basic information is needed in all these fields, and would assist materially in the improvement of operational procedures and be of particular interest to others contemplating production in this field.

Research

To provide needed information, the Forest Service has extensive research underway involving kiln design, construction materials, structural performance, kiln operation, and process development. Much of this work, conducted primarily in both single- and double-wall, 7-cord, masonry block kilns, is an extension of the original investigations of H. W. Hicock and associates and their development of the single-wall, 1- and 2-cord units (Figs. 3 and 4) (4, 6, 7). Field work was started about 2 years ago. The initial investigations were conducted in 7-cord capacity, single-wall, masonry block kilns at St. John's University, St. Cloud, Minn., and the Argonne Forest in Wisconsin; in a 10-cord unit on the Dukes forest in Michigan; in a 7-cord kiln on the Whitehall Forest in Georgia; and in a 2-cord unit on the Bladen Lakes Forest in North Carolina. This work was done in association with the Lake States and Southeastern Forest Experiment Stations of the Forest Service and the North Carolina Department of Conservation and Development. All these kilns were operated conventionally with multiple side-wall air ports and single stack control.

More recently, kilns of double-wall design and 7-, 3-, and 2-cord capacities have been developed and included in the program of field experiments. Important features of these kilns are a sand column between the walls that acts as a complete sealant during cooling of the charge, ports for air entry at a single location, and smoke stacks at the midpoints of the side and rear walls. Such air ports and stacks provided good dissemination and more efficient use of air at required input levels. Complete thermocouple gridding of the coaling chamber permitted establishment of controlled time-temperature coaling patterns for optimum operational procedure. Results indicate that kiln life can be expected to be substantially long with minimum maintenance, and that a uniformly high-quality product can be recovered at optimum time and temperature levels and inadequate conversion amounts.

On the average, about 50 per cent of the dry weight of the wood is available as carbon for charcoal production. At least as much is present in hardwood barks, but softwood barks contain somewhat less carbon on the average than does wood. Bark may therefore yield as much or probably more charcoal than does wood.

The charcoals made by controlled kiln burning and in externally heated recovery-plant ovens are alike in properties. The amounts of moisture (2 to 4 per cent), volatiles (18 to 23 per cent), ash (2 to 4 per cent), and fixed carbon (74 to 81 per cent) in charcoal largely determine its quality for general market acceptance. Production of charcoal with these component amounts assures not only good quality but a maximum yield per kiln charge. Charcoals with lower amounts of volatiles and correspondingly higher amounts of fixed carbon may be purposely produced by accelerated combustion or by uncontrolled overburning. Underburning through lack of proper kiln control, on the other hand, will produce charcoal that is definitely degraded because of high volatiles, and has a tendency to smoke when it is burned. Charcoals of low volatile content are desirable for specialized industrial use, but unless these markets are available at premium prices to overcome the reduced kiln yields, the producer's profit is likely to suffer. Degraded charcoals provide greater kiln yields and higher tonnage, but market confidence and security are very apt to be likewise degraded..

In general, the Forest Service study program has centered around these research objectives:

1. Development of designs for a commercial, medium capacity, low-cost kiln, with initial emphasis on masonry block construction.
2. Development of practical and reproducible operating methods to provide optimum charcoal yields and quality with minimum structural deterioration.
3. Determination of economics of kiln production with relation to forest and mill sources of low-value wood.
4. Development of kiln mechanization methods to minimize labor costs.

The scope of the study being conducted at the various field locations in-

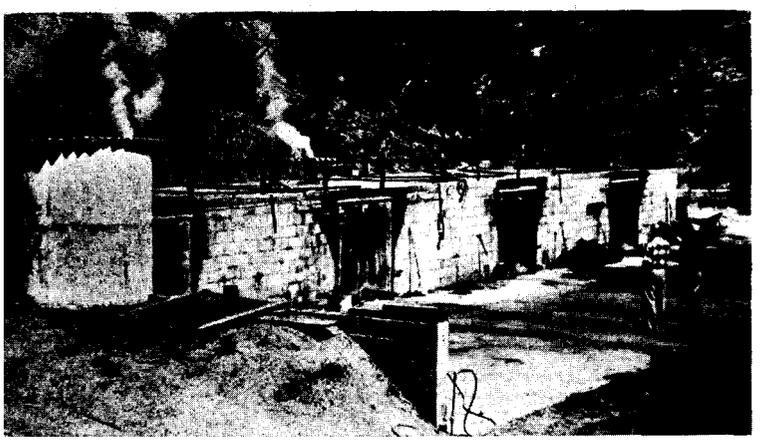

Fig. 2.—An up-to-date commercial charcoal operation in California, featuring the favored masonry block construction with steel doors.

Fig. 3. —Experimental 2-cord, sheet-metal kiln.

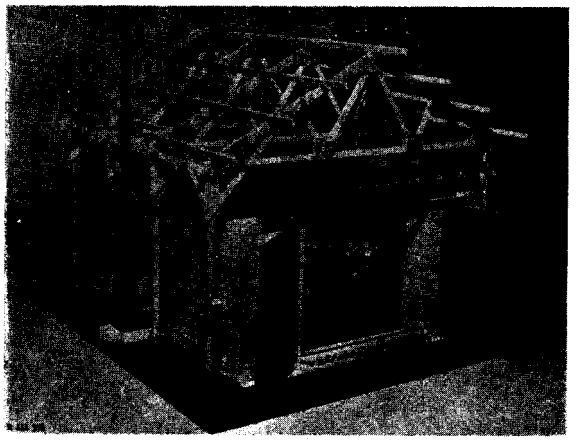

Fig. 4. - Model of the experimental 7-cord kiln favored by the Forest Service.

cludes such raw-material variables as species, moisture content, type form and size, density, and bark content. These variables affect the charcoal yield, quality, and production economies. As such, they have equal weight with such operation variables as location of ports for regulated air input, location of stacks, kiln ignition, and coaling temperatures and cooling methods. A suitable operational procedure has been worked out, and a structure that includes essential elements of design has been developed.

There are as yet too few data for final recommendations regarding either the method of operation or the structure itself. Resues attained thus far, however, give grounds for optimism about future investigations. A brief summary of results indicates:

1. Average conversion values of 28 per cent to 32 per cent charcoal from medium dense hardwoods with 50 per cent and 35 to 40 per cent moisture contents respectively.
2. Low-temperature coaling patterns for optimum yields of high-quality charcoal.
3. Coaling time may be reduced by one-half by using 3 stacks and single air-entry control.
4. Maximum coaling temperature need not exceed 950° F.
5. Operation can be improved with use of a low-cost temperature-indicating instrument (8).
6. A structure is possible that combines elements of comparatively low cost, operational flexibility, and long life expectancy.
7. Maintenance charges can be lowered.

These results, though useful for improved kiln operation, have extended value in conjunction with other and equally important factors for production at economic levels. At best, it is generally recognized that the profit opportunities are not large. Probably the most important single factor controlling profit or loss is the cost of raw material, since 2 to 3 cords of medium-dense wood are generally required to produce 1 ton of charcoal.

Thus the cost of the raw material may easily represent more than one-half the charcoal production cost per ton. Added to this are such costs as labor and kiln depreciation. If operating efficiency were improved, the relation of these costs to profitable production would be more readily evaluated. This is not meant to imply that the importance of these factors is not already well known, but rather to emphasize how critical each factor becomes when returns are somewhat marginal. Recent experimental results from a kiln comparison study (10) indicate what may be expected in ton production costs with wood at various assumed cord cost levels, labor charges at $1.00 per hour, and kiln depreciation at 5 per cent. These data, obtained from the experimental operation of two sizes of sheet-metal kilns and a small masonry-block unit, are shown in Fig. 5, together with similar data from the experimental operation of a 7-cord masonry-block kiln. The lower charcoal yield normally obtained from uninsulated sheet-metal kilns is a primary factor relating to the comparative influence of these costs in charcoal ton production costs.

Wood costs are of prime importance, as is shown by their marked effect on ton production costs at progressively higher levels. Assuming a break-even point of $50 a ton, which appears realistic marketwise, about $7.00 is the highest price that the smaller kilns

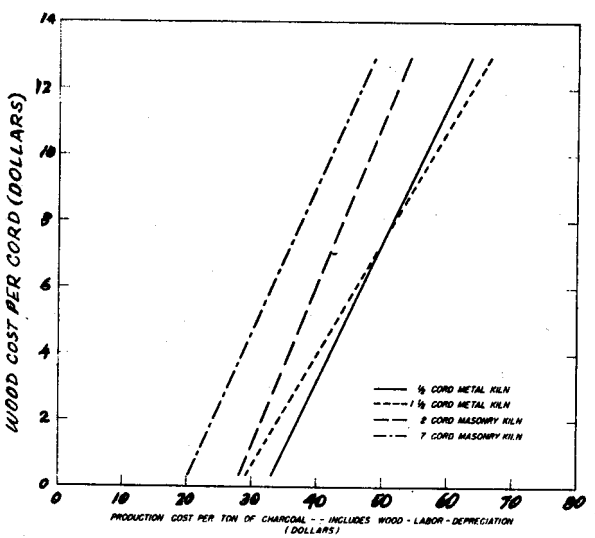

Fig. 5. - Experimental data-charcoal ton production costs at various wood cord costs.

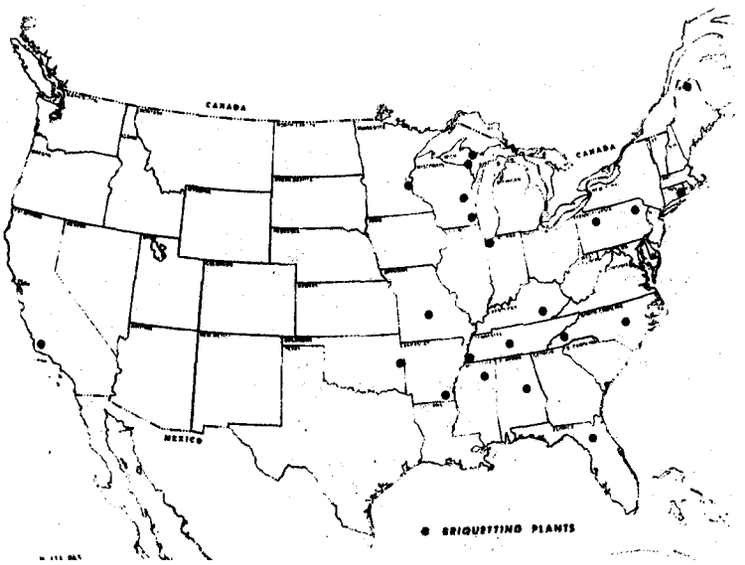

Fig. 6. —location of charcoal briquetting plants.

could economically absorb per cord. On this basis, the two larger kilns could operate profitably with wood that costs $11.00 to $12.00 a cord. Since labor costs are critically important, any reduction of them would be correspondingly reflected in the production cost. Substantial reductions in labor costs are most likely if more units arc run in staggered operations. The extent to which the curves of Fig. 5 may be shifted to the left, to lower production cost levels, will be determined in a series of further experiments. Additional data are required also for substantiation of the preliminary results shown by these curves.

General

Charcoal production in kilns is an obvious means of utilizing low-value wood profitably with comparatively little plant investment. Kiln costs are comparatively low, and generally run between $150 to $200 per cord of capacity. The smaller portable units, though somewhat higher in capital cost per cord of capacity, can be located easily or moved to near sources of wood supply and markets. Whether a given kiln operation is small or large, or is composed of units of various types and sizes, the numerous and long-established commercial producers have proven that a measure of profit is possible more often than not.

Table 1.—WEIGHTED AVERAGE COST PER CORD OF WOOD DELIVERED TO CHARCOAL PLANTS, BY FORM OF WOOD AND REGION, 1956

Region	Cost per cord, dollars	
	Roundwood	Residues
Northeast	12.00	7.50
Southeast	7.90	2.70
Lake	12.70	9.25
Central	6.90	5.90
Southern	12.65	11.70
California	12.10	----
Other West	7.80	6.50
Average	11.70	8.75

Additional profits might well result when kiln conversion is integrated with forest management. The heavy supplies of down and cull stock and thinnings potentially available from improved management practices are quite as suitable for raw material as high-value wood. The role of kiln production as a management tool should not be overlooked merely on the basis of an expected break-even return. While some margin of monetary profit is desirable and in most cases essential, the cost of removal of such material from forests and woodlots might be borne in large part by means of charcoal production.

The cost of forest or roundwood at the kiln site is not always attractive, and may run $12.00 or more per cord because of procurement charges and competition of other uses. The cost of mill residue is generally more favorable. Comparative kiln-site costs for both kinds of raw material by regions are shown in Table 1 (1). High wood costs make production distinctly marginal, if not unprofitable, for the majority of commercial operations. At higher levels of wood cost, it is increasingly important to get optimum charcoal yields and uniformity.

Raw material costs less if the operation of the kilns can be integrated with that of nearby sawmills where slabs and other residues are available. The cost of this kind of raw material is substantially reduced where conditions that affect individual operations are favorable. A considerable rice advantage, on the average, undoubtedly exists for the mill waste as a kiln raw material.

The rapidly increasing and potentially unlimited markets for recreational charcoal should make possible much greater use of these waste raw materials and thereby encourage the practice of good forestry and the utilization of mill residues.

Several factors that have accompanied the expansion in the charcoal industry will no doubt continue to play an important part as time goes on. Chief among these has been the growing market preference for briquettes, and the upsurge it has stimulated in kiln facilities to provide more charcoal and the strategic placement of plants to convert and market it in the form of briquettes. Since about 1951, the number of briquetting plants has increased from 5 to 22 (Fig. 6). Three of these 22 plants have operated for some years in association with hardwood recovery practice, while 3 more have recently been constructed in conjunction with other by-product operations. A total of 16 briquetting plants are thus associated or closely integrated with kiln charcoalproduction.

Investmentwise, this extension of the briquetting industry to the use of kiln charcoal represents an estimated amount of more than $2,000,000 for the briquetting facilities alone. In addition, it is estimated that $200,000 has been invested in kilns that produce charcoal for briquettes and the lump market. These markets together provide good evidence of the continuing buildup of what may be appropriately termed a scavenger industry.

The heaviest Concentration of both briquetting and kiln operations is in the eastern half of the country. This is shown in Fig. 7, which includes charcoal plants with byproduct recovery facilities. All are closely associated with abundant and well-established sources of forest and mill raw material, and have markets within areas of high population density.

It cannot be ascertained dearly that kiln production on the one hand or briquetting operations on the other have been the dominating influence in creating the closely knit operational pattern that has developed. It is evident, however, that each must supplement the other in increasing degree, and thus provide industrial factors of benefit to both. One obvious and direct benefit is the wider market briquetting provides for kiln charcoal fines, which are produced normally at the rate of about 8 to 10 per cent of the total weight of a kiln charge of charcoal.

Another presumably is the more concentrated and widespread utilization of forest and mill wastes, which has the desirable end result of improving forestry practice and mill scrap utilization. This dual relationship might create conditions favorable to firm and long-time charcoal contracts at adequate price levels. These factors might also encourage development of large-scale cooperative kiln production with low individual investment, and favor the broadening of the charcoal selling base to include both briquette and lump forms.

If the market for charcoal continues to ex and, as might reasonably be predicted at the present level of national economy, the present investment in both briquetting plants and kiln production can be supplemented without critical danger of saturating the market for briquettes or general lowering of prices to the producer. Appraisal of a further factor of which brief mention has been made heretofore concerns especially the raw-material worth of the softwood and lighter hardwood species. The fact that kiln charge yields from these are lower than from the preferred species should not entirely eliminate their use, since there is indication in some areas that lower primary costs would tend to balance off the reduced yields of the lighter-weight woods. Greater expansion in the industry might then enlarge the possibilities for the economical conversion of additional low-value raw material.

Conclusions

Kiln production constitutes a substantial portion of the total charcoal tonnage now produced, and is in excellent position to expand as demands may multiply. It is not necessarily true that extension or duplication of the present pattern of the already established kiln industry will automatically assure continuation of production at generally satisfactory economic levels. Increased production of charcoal to meet the growing market demands will perhaps best be attained by progressive expansion of kiln facilities. Research results already obtained, together with those forthcoming, are needed to make such industrial expansion most effective and profitable.

Transition from the customary production pattern of widely scattered kiln operations to more compact and unified groups may be expected and is already underway. This will be accompanied by new problems of suitable kiln investment, raw material supplies, and market competition. The economic effed of the accelerated demand for briquettes on the producers who rely chiefly upon developed and fairly well established outlets for bagged lump charcoal cannot be predicted. Neither can it be foreseen, on the basis of expected increases in recreational markets to what extent more aggressive market competition with expanded production will affect favorably or otherwise the returns to the producer.

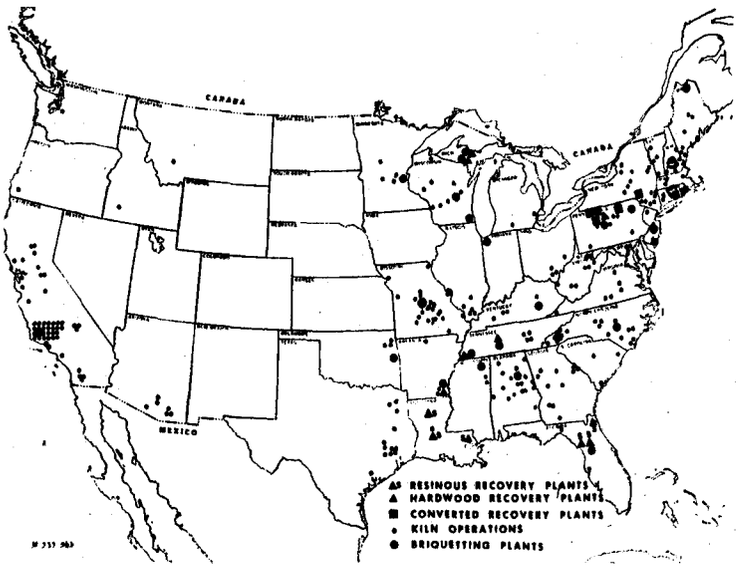

Fig. 7. —Distribution of briquetting plants with relation to charcoal production operations and by-product recovery plants.

That there are economic limitations, as well as favorable aspects of kiln production, is well recognized. In order that some of these limitations might be reduced, research is needed and the results can be gainfully applied. Organized and cooperative industrial efforts with a firm technical basis supplied by research could provide not only a very valuable but profitable management and utilization tool as well.

Literature Cited

1. Anonymous. 1957. Charcoal production in the United States. U. S. D. A., Forest Service, Div. of Forest Economics Research.
2. Baldwin, H. I. 1949. Yields and costs of charcoal making. Fox Forest Notes No. 43, Concord, N. H.
3. Baldwin, H. I., and E. A. Weld. 1941. Charcoal making in New Hampshire. Fox Forest Notes No. 31, Concord, N. H.
4. Hicock, H. W., A. R. Olsen, and F. M. Callward. 1951. The Connecticut Charcoal Kiln. Connecticut Agricultural Experiment Station Bull. 431, New Haven, Conn.
5. Hicock, H. W., and A. R. Olsen. 1941. A portable charcoal kiln. Conn. Ag. Expt. Sta. Bull. 448, New Haven, Conn.
6. Hicock, H. W., and A. R. Olsen. 1948. The Connecticut charcoal kiln. Conn. Ag. Expt. Sta. Bull. 519, New Haven, Conn.
7. Olson, A. R., and H. W. Hicock. 1946. A charcoal kiln made of cinder concrete blocks. Conn. Ag. Expt. Sta. Bull. 494, New Haven, Conn.
8. Peter, Ralph. 1956. An inexpensive method for measuring kiln temperatures. Southeastern Forest Expt. Sta. Paper No. 73, Asheville, N. C.
9. Tryon, H. H. 1933. A portable charcoal kiln. Black Rock Forest Bull. No. 4, Cornwall-on-the-Hudson, New York, N. Y.
10. Witherow, B. M., and W. R. Smith. 1957. Cost of operation for three types of charcoal kilns. Southeastern Forest Expt. Sta. Paper No. 79, Asheville, N. C.

Discussion

J. H. Knapp (Grenco, Inc.): What does your $50 per ton figure mean?

Mr. Beglinger: This represents a bulk charcoal price, that is, what an operator might expect in accordance with market quotations generally established. It is a price frequently quoted.

J. M. Sayward (Vermont Bureau of Industrial Research) : Your slide map indicated three or four kilns in Vermont. Are these commercially operating? How is the information on such kilns acquired?

Mr. Beglinger: We believe these kilns to be presently operating. Kiln operation information is obtained in a variety of ways-most generally by Forest Service field contact.