Development of Movable Charcoal-Making Kilns

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Introduction

The traditional method of making charcoal using kilns made of clay in Japan has been practiced by specialized skillful workmen. This method requires a lot of time for one cycle of charcoal-making operation[1,2], and kinds of woods which can be used as raw material were limited. The production and consumption of charcoal in Japan showed a peak in the 1950's, when the use of charcoal for fuel was the most, and then decreased as a result of energy revolution toward fossil fuels. Recently, however, the charcoal production tends to increase, though gradually, due to increasing demand for charcoal caused by newly developed scope of charcoal utilization, such as convenient 'carrying with' fuel for open-air recreation which is becoming popular, or materials for soil amendment, water quality improvement, humidity control in houses, etc. The utilization of charcoal other than for fuel is attracting people's keen interest.

On the other hand, in view of the efficient utilization of natural resources, attempts have been made to utilize forest residues, wastes of saw-mills and agricultural products. Reflecting such a situation, the development of simple charcoal making kilns (hereafter referred to as charcoal kilns) which can carbonize various kinds of wastes instead of good quality woods (so far used for charcoal-making) in relatively short time, without needing special skilled hands is urgently desired. Hence, we tried to construct two types of simple charcoal kilns which can carbonize diverse raw materials, and can be moved to places where raw materials are available.

The O-shaped charcoal kiln of the assembly type[3]

1) Construction

Three U-shaped, corrugated steel plates* (65 cm in height, width, and length with 0.2 cm of thickness), which are manufactured originally for the use in making drainage canals, were connected in series. Two sets of such connected plates were coupled vertically to construct the body of a kiln (Fig. 1). To the front of this body, a steel door (130 cm high and 65 cm wide), equipped with a fuel-feeding opening (ignition eye) and an air-inlet, was fitted. To the rear of the body a steel wall (130 cm high and 65 cm wide), equipped with a smoke exhaust was installed. A chimney (143 cm long with diameter of 11 cm) was installed on the top of the smoke exhaust, and a rectangular opening (4 cm high and 4.5 cm wide) was installed to the bottom of the smoke exhaust in order to facilitate the collection of wood vinegar and wood tar which flow down from the smoke exhaust. The front steel door has a pair of handles to facilitate removal and fitting of the door.

The lower half of the kiln body was buried in the ground with the purpose of keeping warmth. However, the front and rear of the kiln are left exposed for feeding raw materials and harvesting charcoal and others.

* Type A—650×650, for drainage canals (Nippon Steel Metal Products Co., Ltd.)

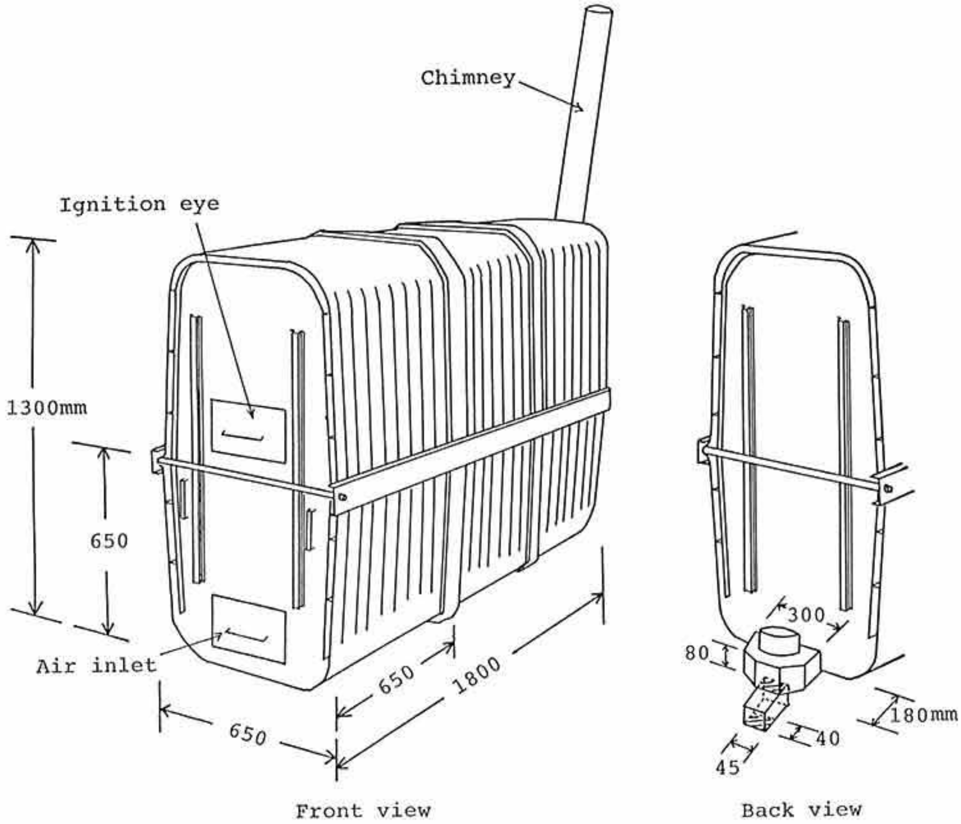


Fig. 1. The O-shaped charcoal kiln of the assembly type

Furthermore, the upper half of the kiln body was lagged with two layers of mat-like heat insulator* (100 cm long, 210 cm wide and 4.5 cm thick) composed mainly of SiO_2 and Al_2O_3.

2) Charcoal-making experiment

Three kinds of bamboo: *Sasa kurilensis* Makino et Shibata, *Phyllostachys pubescens* Mazel, and *Phyllostachys bambusoides* Sieb. et Zucc. were used as raw materials in the experiment. Packing of the raw materials was done as follows: (1) on the bottom of the kiln, four to six pieces of brick were placed in two rows, and iron-made hurdles were spread on them to cover the bottom of the kiln, (2) cut-pieces (about 1 m long) of raw material were packed (standing on the hurdles) into kiln, (3) to fill the space left on the mass of standing materials, more materials were packed (lying horizontally) into the space.

An example showing the change of temperature with time, in and outside the kiln packed with *P. pubescens*, is given in Fig. 2. The same trend of temperature was observed with other raw materials. The raw material caught fire about 3.5 hr after setting fire to the fuel wood, and then after about 1.5 hr the temperature at the ceiling portion and the central portion apparently increased, indicating the carbonization in progress. In this experiment, the temperature at the ceiling portion and that at the central portion were almost the same, showing the same trend of rising temperature. After 9 hr, the bottom temperature began to rise. After about 13 hr,

* Seramic fiber blanket (ISOLITE Insulating Products Co., Ltd.)

air inlet was opened slowly to raise temperature. During the carbonization stage, even the chimney was half-closed to prevent rapid carbonization, but at the final stage, it was fully opened to supply enough quantity of air for the refining process. After refining, the fire was put out, and cooled for 9 hr.

In this experiment, two workmen took 30 min to feed 342.5 kg of raw material to the kiln, and required a total of 23.5 hr to complete one cycle of charcoal-making operation up to charcoal harvesting. The rate of charcoal yield to raw material used was 17.1% on a dry weight basis (oven-dried).

Temperature outside the heat insulator lagged on the kiln was higher than that below the insulator by about 40–50°C, showing the effectiveness of the insulator used.

The BA-1 type movable charcoal kiln[4)]

1) *Construction*

The O-shaped kiln described above is movable, but it must be knocked down into parts and re-assembled whenever it moves. Therefore, we developed the BA-1 type on four wheels (Fig. 3). This kiln is not only very movable, but also superior to the former one especially regarding heat insulation.

Fig. 3 shows a front view and a back view of this kiln. In the back view, the lid of the kiln is kept open. The kiln body with four walls looks like mounted on a chassis (80 cm wide and 150 cm long) of a carriage with four wheels, but the chassis itself constitutes the bottom of the kiln. The walls, bottom and lid are composed of double layers of stainless steel (0.2 cm thick)* and heat insulator** filling up the space between the stainless steel layers. They constitute the body of the kiln (75 cm wide, 128 cm long and 104.5 cm high). The lid can be opened at the right hand side of the front. The lid and walls are equipped with small ventilating nozzles (0.7 cm diameter) in order to protect the lid and walls against deformation forced by air expansion in them due to heat. This device is effective in releasing expanded air without causing

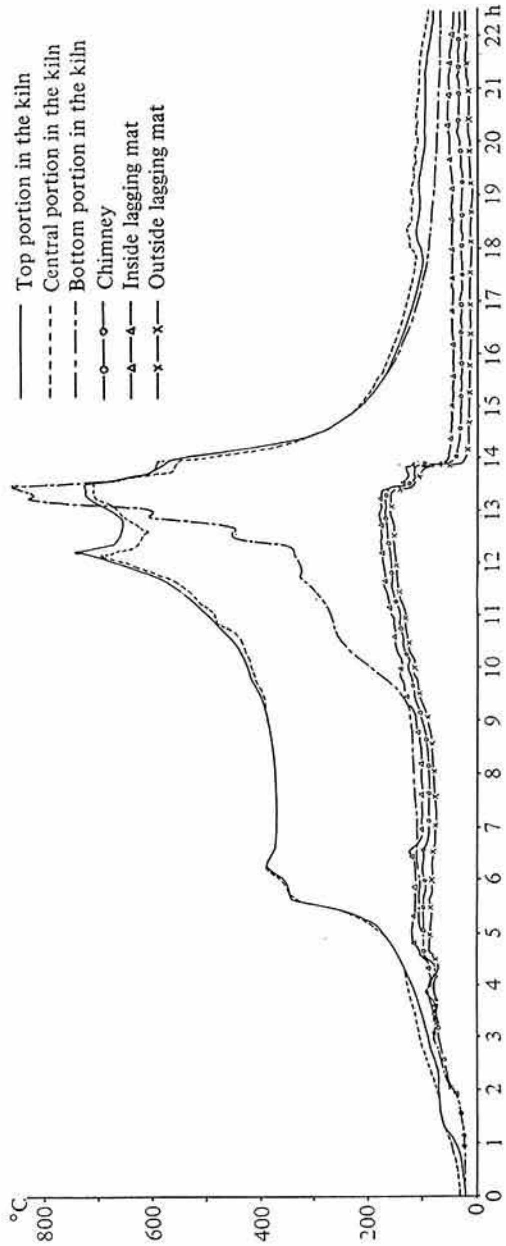
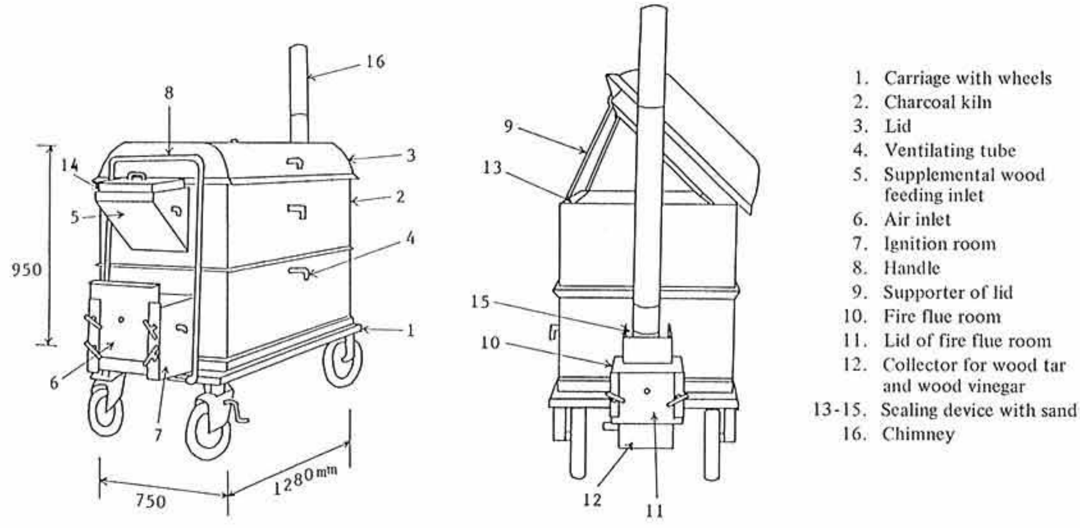


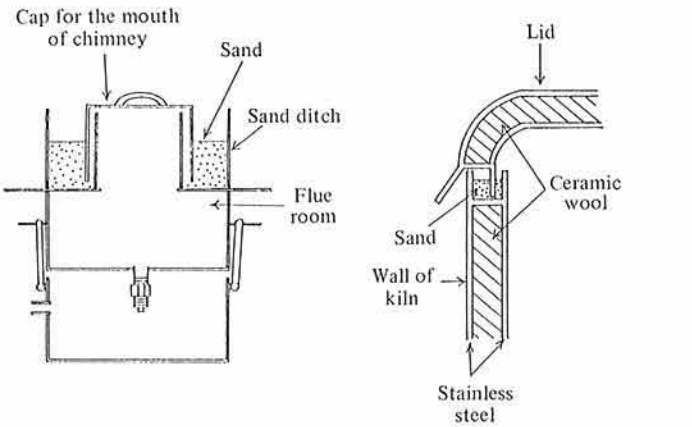
Fig. 2. Change of temperature with time in and outside the O-shaped kiln
Raw material used: *Phyllostachys pubescens* Mazel.

* Stainless steel plate, SUS 304.
** Seramic wool heat insulator.



(a) Front view (b) Back view

Fig. 3. The BA-1 type movable charcoal kiln



(1) Sealing the contact surface between the flue room and chimney (2) Sealing the contact surface between the kiln wall and the lid

Fig. 4. An air-tight sealing device using sand

great loss of heat from the kiln. The downward curvature of the nozzles prevents rain water entering.

A gate for feeding supplemental raw material is installed to the upper part of the front wall, and an ignition room which also functions as a ventilator is installed to the lower part of the front. The air flow through this room is regulated by sliding up and down the air flow control plate. A fire flue room with a chimney (153 cm long and 10.5 cm diameter) is fixed to the bottom of the rear wall. A handle which is pulled down and used to move the kiln is attached to the front wall.

When the traditional charcoal kiln was used, it is a custom to seal the air inlet, after closed to extinguish the fire, using the lump of soil moistened and puddled. This practice takes much time and labor, and has a defect that the soil lump cracks due to remaining heat, and allows air entrance. Therefore, we adopted the method of sealing with sand. This method was applied to the contact surface between the kiln body and its lid, and that between the fire flue room and the chimney. Fig. 4 shows cross-sections of the device. In Fig. 4-(1), the cap covering the space left after removal of the chimney is shown instead of the chimney.

2) Charcoal-making experiment

Branches of *Quercus acutissima* Car. mixed with *Quercus serrata* Thunb., of *Phyllostachys pubescens* Mazel, and of *Morus bombycis* Koidz were used as raw materials. Packing of the raw materials was done as mentioned above. An example of temperature in the kiln is given in Fig. 5. Starting from the time of setting fire to fuel, the raw material caught fire after nearly 3 hr. The temperature at the upper portion inside the kiln began to rise after 3.5 hr, and that of the central portion began to rise after 7 hr, showing the progress of carbonization. After about 14 hr, temperature at the bottom portion began to rise, and after 22 hr, the temperatures at these different portions became close each other, indicating that the carbonization came to the final stage. Then refining was made for about 2 hr. After that, all openings which allow air to flow were closed to extinguish fire, and the kiln was left to be cooled for 20 hr. As shown in Table 1, two workmen required 1 hr to feed 274.6 kg of raw material into the kiln, and about 45 hr for all the operations from setting fire to fuel through the harvest of charcoal. The ratio of charcoal yield to raw material was 27.54% on a dry weight basis (oven-dried).

Comparison of performance of different types of kilns

Table 2 shows results of charcoal-making experiment conducted with the O-shaped kiln, the BA-1 type kiln, the round-shaped movable kiln*, and the Japanese traditional black char-

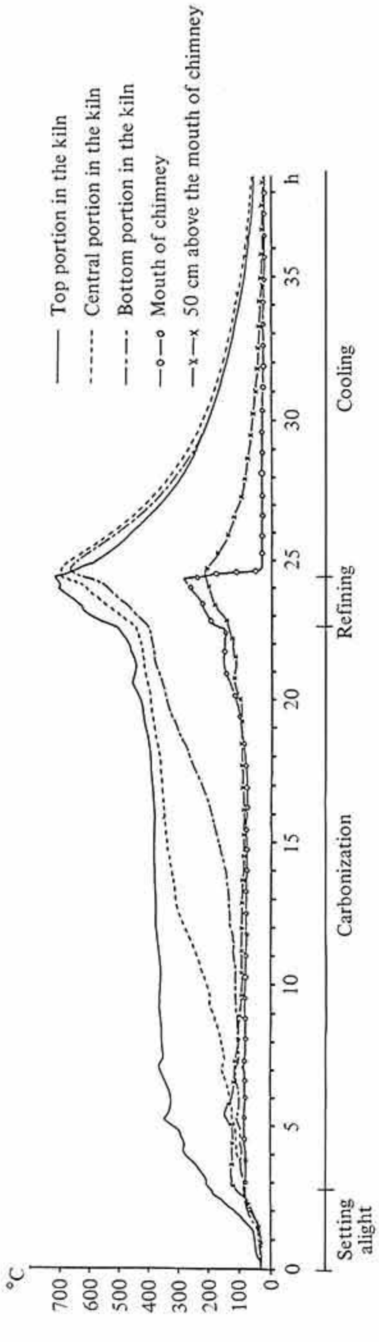


Fig. 5. Change of temperature with time in the BA-1 type kiln
Raw material used: A mixture of *Q. acutissima* and *Q. serrata*.

* The Meiller-type kiln which had been developed in Europe was improved in our laboratory and named the round-shaped movable kiln.

Table 1. Charcoal-making using different types of kiln

Kiln	Raw materials	Weight of materials[a] (kg)	Weight of charcoal obtained[a] (kg)	Water contents of raw materials (%)	Yeild oven-dried basis (%)	Time (hr) required for: Feeding raw materials[b]	Setting fire	Carbonization	Cooling	Harvest of charcoal from kiln[b]	Total process
O-shaped kiln	*Sasa kurilensis*	209.5	36.3	12.99	19.9	0.5(2)	2.5	12.0	9.0	0.5(2)	24.5
	Phyllostacys	342.5	50.1	14.44	17.1	0.5(2)	3.5	10.0	9.0	0.5(2)	23.5
BA-1 type kiln	*P. pubescens*	141.2	34.8	10.01	27.4	1.0(2)	1.5	18.0	18.5	1.0(2)	41.0
	Mix. of *Quercus serrata* & *Q. acutissima*	274.7	52.2	30.72	27.5	1.0(2)	2.7	18.0	21.5	1.0(2)	44.5
	Morus bombycis	72.6	14.0	12.0	21.8	1.0(2)	1.0	5.0	14.5	1.0(2)	22.5
Round-shaped movable kiln	*Pinus densiflora*	3992.0	460.0	41.60	19.7	3.0(5)	2.0	45.0	6.0	2.0(3)	58.0
Black charcoal kiln	〃	715.5	163.9	35.76	29.0	2.0(3)	3.5	30.5	13.0	1.5(3)	50.5

a) : Based on air-dried weight.
b) : Figures in parentheses show the number of workers.

Table 2. Quality of charcoals produced in different types of kiln

Type of charcoal	Kiln	Refining degree[a]	Contents (%) of: Moisture[b]	Ash[b]	Volatiles[b]	Fixed carbon[b]	Hardness[c]	Calorie(cal/g)[d]: Air-dried basis	Oven-dried basis
Sasa kurilensis	Movable O-shaped kiln	5.5—7.5	3.36	5.65	14.51	76.48	1	7400	7600
Phyllostacys pubescens	〃	6.5—7.5	3.32	2.32	16.55	77.81	5	7600	7800
Phyllostacys bambusoides	〃	5.8—8	2.14	2.34	15.38	80.14	5	7800	8000
Phyllostacys pubescens	BA-1 type kiln	3.3	8.84	4.11	8.30	78.75	1	7000	7600
Mix. of *Quercus serrata* & *Q. acutissima*	〃	4	6.97	2.09	8.66	82.28	*Q. serrata* 6 *Q. acutissima* 11	7500	8100
Morus bombycis	〃	4	6.98	6.48	15.75	70.81	1>	6800	7400
Pinus densiflora	Round-shaped movable kiln	7—8	6.80	0.95	18.37	77.43	1>	7800	8200
Quercus serrata	Black charcoal kiln	7	5.53	1.63	15.47	77.57	5—6	7500	7900
Q. phyllyraeoides	White charcoal kiln	0	9.80	1.61	6.16	82.43	>20	7000	7700

a) : Determined with charcoal refining meter.
b) : Determined following JISM8812 (1963) method.
c) : Determined with MIURA charcoal hardness tester.
d) : Determined with Shimadzu bomb-type calorimeter (CA-3).

coal kiln. The rate (%) of charcoal yields on a dry weight basis (over-dried) of the BA-1 type and the traditional kiln was higher than 20% and nearly 30%, respectively, which were higher than the rate (17–20%) of other kilns tested. The O-shaped kiln required about 24 hr for charcoal-making, while other types of kiln needed 40–60 hr. Thus, the O-shaped kiln allows a higher rate of operational rotation than others. As mentioned above, the O-shaped kiln is movable, but it is not easy to knock down it into parts and reassembled whenever it is moved. To avoid this trouble, the type BA-1 on wheels was devised.

The type BA-1 on wheels is much superior to the O-shaped kiln in many aspects. Since the lower half of the latter is buried in the ground for heat insulation, it is difficult to get vertically uniform temperature distribution in the kiln. In contrast, the type BA-1 has the body and lid (ceiling) made of two layers of stainless steel holding heat insulator between them, and the special sealing system using sand layers. These improvements made it possible to produce good quality charcoal, due to more uniform distribution of temperature in the kiln, without heat loss. The quality (as expressed by refining degree, volatiles, and fixed carbon) of charcoal produced from *P. pubescens* wood in the O-shaped kiln and the BA-1 type kiln is given in Table 2. Apparently the BA-1 type gave better quality.

The high capacity of the BA-1 type in keeping heat facilitate raw material to catch fire in a short time with a less amount of fuel wood. In addition temperature in the kiln does not lower, even when the amount of air flowing in the kiln is less, i.e., the small amount of air supply is sufficient for carbonization progress. In contrast, the low capacity of keeping heat (insufficient heat insulation) causes carbonizing temperature to lower. Hence more amount of air has to be supplied. It causes a part of the raw material to burn to ash, resulting in reduced charcoal yields. It does not occur in the BA-1 type kiln. Moreover, as shown in Fig. 5, the temperature at the portion near the ceiling was kept almost constant (about 400°C) in the BA-1 type kiln, without fluctuation during the carbonization stage, until the temperature at the bottom portion increased to the level of the temperature at the top portion. It implies that wasteful heat loss did not occur. Thus, no big difference in the temperature among different portions occurred in the BA-1 type kiln. As a result, good quality charcoal is produced uniformly, irrespective of different positions of raw material packed in the kiln.

Another advantage of the BA-1 type kiln is that the feeding of raw material and the harvesting of cahrcoal can be done quite easily through the opening at the top of the kiln. In this respect, too, the BA-1 type is superior to the O-shaped kiln and the traditional black charcoal kiln.

Acknowledgement

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