"All timber licensees who have no processing plant and who have no plan to establish the same shall, jointly with wood processors, adopt a scheme or schemes for the processing of the log production in accordance with Section 30 hereof."

SEC. 3. Sections 33, 34, 35, 36, 53, 55, 61, 62, 63, 68, 69, 71 and 76 of the same Decree are amended to read as follows:

"SEC. 33. Lands to be reforested and/or afforested. - Lands to be reforested and/or afforested are as follows:

"1. Public forest lands. -

"a) Bare or grass-covered tracts of forest lands;

"b) Brushlands or tracts of forest lands generally covered with brush, which need to be developed to increase their productivity;

"c) Open tracts of forest lands interspersed with patches of forest;

"d) Denuded or inadequately timbered areas proclaimed by the President as forest reserves and reservations as critical watersheds, national parks, game refuge, bird sanctuaries, national shrines, national historic sites;

"e) Inadequately-stock forest lands within forest concessions;

"f) Portions of areas covered by pasture leases or permits needing immediate reforestation;

"g) River banks, easements, road right-of-ways, deltas, swamps, former river beds, and beaches.

"2. Private Lands -

"a) Portions of private lands required to be reforested or planted to trees pursuant to Presidential Decree Nos. 953 and 1153 and other existing laws."

"SEC. 34. Industrial tree plantations, tree farms and and Agro-forestry farms. - A lease for a period of fifty (50) years for the establishment of an industrial tree plantations, tree farms or agro-forestry farm, may be granted by the Department Head, upon recommendation of the Director to any person qualified to develop and exploit natural resources, over timber or forest lands of the public domain categorized in Section 33 (1) hereof except those under paragraphs (d) and (g) with a minimum area of one hundred (100) hectares for industrial tree plantations and agro-forestry farms and ten (10) hectares for tree farms: *Provided*, That the size of the area that may be granted under each category shall, in each case depend upon the capability of the lessee to develop or convert the area into productive condition within the term of the lease.

"The lease may be granted under such terms and conditions as the Department Head may prescribe, taking into account, among others, the raw materials needs of forest based and other industries and the maintenance of a wholesome ecological balance.

"Trees and other products raised within the industrial tree plantation, tree farm or agro-forestry farm belong to the lessee who shall have the right to sell, contract, convey, or dispose of said planted trees and other products in any manner he sees fit, in accordance with existing laws, rules and regulations.

"Reforestation projects of the Government, or portion thereof, which, upon field evaluation, are found to be more suitable for, or can better be developed as industrial tree plantations, tree farms or agro-forestry farms, in terms of benefits to the Government and the general surrounding area, may be the subject of a lease under this section."

"SEC. 35. Priority. - Over any suitable area covered by a timber license agreement or permit, the priority to establish industrial tree plantation, tree farms or agro-forestry farm shall be given to the holder thereof after the Bureau had determined the suitability of such area and has set aside the same for the purpose.

"The priority herein granted must, however, be availed of within a reasonable period otherwise the area shall be declared open to any qualified person and consequently segregated from the licensee's or permittee's area.

Priority shall also given to the establishment of communal industrial tree plantations by barangays, municipalities or cities and provinces.

SEC. 36. Incentives. - To encourage qualified persons to engage in industrial tree plantation, tree farm and/or agro-forestry farm, the following incentives are granted:

"a) Payment of nominal filing fee of fifty centavos (P0.50) per hectare.

"b) No rental shall be collected during the first five (5) years from the date of the lease; from the sixth year to the tenth year, the annual rental shall be fifty centavos (P0.50) per hectare; and thereafter the annual rental shall be one peso (P1.00) per hectare: Provided, That lessees of areas long denuded, as certified by the Director and approved by the Department Head, shall be exempted from the payment of rental for the full term of the lease which shall not exceed twenty-five (25) years; for the first five (5) year following the renewal of the lease, the annual rental shall be fifty centavos (P0.50) per hectare; and thereafter, the annual rental shall be one peso (P1.00) per hectare: Provided, further, That notwithstanding the foregoing, no rental shall be collected from a lessee who upon verification by the Bureau, substantially meets the schedule of development of the industrial tree plantation, the tree farm, or agro-forestry farm, as the case may be, as prescribed in the development plan submitted to and approved by the Ministry Head, upon recommendation of the Director:

"c) The forest charges payable by a lessee on the timber and other forest products grown and cut or gathered in an industrial tree plantation, tree farm, or agro-forestry farm shall only be twenty-five percent (25%) of the regular forest charges prescribed in the National Internal Revenue Code:

"d) Exemption from the payment of the percentage tax levied in Title V of the National Internal Revenue Code when the timber and forest products are sold, bartered or exchanged by the lessee, whether in their original state or not, as well as exemption from all of sales tax, local and municipal taxes, and from the real property tax under the provisions of Presidential Decree No. 853;

"e) A lessee shall not be subject to any obligation prescribed in, or arising out of, the provisions of the National Internal Revenue Code on withholding of tax at source upon interest paid on borrowings incurred for development and operation of the industrial tree plantation, tree farm, or agro-forestry farm;

"f) Except when public interest demands, the boundaries of an area covered by an industrial tree plantation, tree farm, or agro-forestry farm lease, one established on the ground, shall not be altered or modified;

"g) Amounts expensed by a lessee in the development and operation of an industrial tree plantation, tree farm, or agro-forestry farm lease to the time when the production state is reached, may, at the option of the lessee, be regarded as ordinary and necessary business expenses or as capital expenditures;

"h) The Board of Investments shall, notwithstanding its nationality requirement on projects involving natural resources, classify industrial tree plantations, tree farms and agro-forestry farms as pioneer areas of investment under its annual priority plan, to be governed by the rules and regulations of said Board;

"i) Approved industrial tree plantations, tree farms, and agro-forestry farms shall be given priority in securing credit assistance from the government and government-supported financing institutions which shall set aside adequate funds for lending to the lessee and/or investor at reasonable interest rates;

"j) The lessee and its field employees and workers shall be exempted from the provisions of Presidential Decree No. 1153;

"k) Government institutions administering or financing programs and projects requiring wood materials shall specify the purchase of, or utilize, manufactured products derived from trees grown and harvested from industrial tree plantations, tree farms or agro-forestry farms, whenever possible;

"l) No wood, wood products or wood-derivated products including pulp, paper and paperboard shall be imported if the same are available in required quantities and reasonable prices, as may be certified by the Department Head, from artificial or man-made forests, or local processing plants manufacturing the same;

"m) No processing plant of whatever nature or type, made of, or utilizing, wood as primary materials shall be allowed to be established, expanded or integrated, and operated without a long-term assurance of raw materials source from forest concessions and/or from industrial tree plantations, tree farms or agro-forestry farms in accordance with Section 30 hereof;

"n) Timber grown and harvested from industrial tree plantations, tree farms and agro-forestry farms may be exported without restriction in quantity or volume, and if the exporter is the same person or firm qualified and allowed to export logs under the provisions of this Decree, such timber from plantations/farms may be exported exclusive of the quantity or volume authirized under Section 32 hereof: Provided, That the rentals on the forest land and the forest charges on the plantation timber shall have been paid: Provided, further, That the export of the plantation timber shall be covered by a certificate to export issued by the Department Head on a yearly basis; Provided, finally, That the Department Head may at any time review the exportation of timber harvested from the plantations/farms and either reduce or totally suspend the export of such plantation timber whenever public interest so required; and

"o) Free technical advice from government foresters and farm technicians.

"The Department Head may provide other incentives in addition to those hereinabove granted to promote industrial tree plantations, tree farms and agro-forestry farms in special areas such as, but not limited to, those where there are no roads or where roads are inadequate, or areas with rough topography and remote areas far from processing plants."

"SECTION. 53. Criminal prosecution. – Kaiñgineros, squatters, cultural minorities and other occupants who entered into forest lands and grazing lands before May 19, 1975, without permit or authority, shall not be prosecuted: Provided, That they do not increase their clearings: Provided, further, That they undertake, within two (2) months from notice thereof, the activities to be imposed upon them by the Bureau in accordance with management plan calculated to conserve and protect forest resources in the area: Provided, finally, That kaiñgineros, squatters, cultural minorities and other occupants shall whenever the best land use of the area so demands as determined by the Director, be ejected and relocated to the nearest accessible government resettlement area."

"SEC. 55. Wildlife. – All measures shall be adopted to conserve wildlife. The Director shall regulate the hunting of wildlife in forest lands in order to maintain an ecological balance of flora and fauna."

"SEC. 61. Transfers. – Unless authorized by the Department Head, no licensee, lessee, or permittee may transfer, exchange, sell or convey his license agreement, license, lease or permit, or any of his rights or interest therein, or any of his assets used in connection therewith.

MALACAÑANG PALACE
Manila

PRESIDENTIAL DECREE NO. 1775

AMENDING SECTION EIGHTY OF PRESIDENTIAL DECREE NUMBERED SEVEN HUNDRED FIVE AS AMENDED, OTHERWISE KNOWN AS THE "REVISED FORESTRY CODE OF THE PHILIPPINES"

WHEREAS, criminal administration of justice against forestry law violators should be speedily dispensed with the "Revised Forestry Code of the Philippines" further strengthened by making it more responsive to present realities;

WHEREAS, it is of common knowledge that only few criminal cases are being filed against violators of the forestry laws; rules and regulations because of the apparent lack of manpower which predicament could not be feasibly augmented due to the present economic situation of the country;

WHEREAS, Section 80 of the "Revised Forestry Code of the Philippines" or any other law, rule and regulation does not authorize members of the Philippine Constabulary/Integrated National Police to file complaints against forestry law violators except when they are lawfully deputized by the Minister of Agriculture and Natural Resources pursuant to said Code;

NOW, THEREFORE, I, FERDINAND E. MARCOS, President of the Philippines, by virtue of the powers vested in me by the Constitution, do hereby decree that:

SECTION 1. Section 80 of Presidential Decree No. 705 is amended to read as follows:

"SEC. 80. Arrest: institution of criminal actions. A forest officer or employee of the Bureau or any personnel of the Philippine Constabulary/Integrated National Police shall arrest even without warrant any person who has committed or is committing in the presence any of the offense defined in this Chapter. He shall also seize and confiscate, in favor of the Government, the tools and equipment used in committing the offense, and the forest products cut, gathered or taken by the offender in the process of committing the offense. The arresting forest officer or employee shall thereafter deliver within six (6) hours from the time of arrest or seizure, the offender and the confiscated forest products, tools and equipment and file the proper complaint with the appropriate official designated by law to conduct preliminary investigation and file information in Court.

If the arrest and seizure are made in the forest, far from the authorities designated by law to conduct preliminary investigations, the delivery to, and filing of the complaint with, the later shall be done within a reasonable time sufficient to the place of delivery. The seized products, materials and equipment shall emmediately disposed of in accordance with forestry administrative orders promulgated by the Department Head.

The Department Head may deputize any agency, barangay or barrio official or any qualified person to protect the forest and exercise the power or authority provided for in the preceding paragraph.

Reports and complaints regarding the commission of any of the offenses defined in this Chapter not committed in the presence of any forest officer or employee or any personnel of the Philippine Constabulary/Integrated National Police or any of the deputized officers or officials shall emmediately be investigated by the forest officer assigned in the area or any personnel of the Philippine Constabulary/Integrated National Police where the offense was allegedly committed who shall thereupon receive the evidence supporting the report or complaint.

If there is a prima facie evidence to support the complaint or report, the investigating officer and or/members of the Philippine Constabulary/Integrated National Police shall file necessary complaint with the appropriate official authorized by law to conduct a primary investigation of criminal cases and file information in court.

SECTION 2. This Decree shall take effect immediately.

Done in the City of Manila this 14th day of January in the year of Our Lord nineteen hundred and eighty-one.

(SGD.) FERDINAND E. MARCOS
President, Republic of the Philippines

Appendix 5A-1. CARBONIZATION AND ACTIVATION TESTS WITH SMALL-SCALE PLANT

In these tests, sawdust carbonization and activation tests were carried out on the basis of the Implementing Arrangement (I.A.) using various kinds of raw materials including the raw materials selected as the objects of testing in the I.A., Lauan belonging to Dipterocarp family confirmed to be promising through earlier researches conducted by the Government Industrial Research Institute. Hokkaido, as well as waste sawdust generated by sawmills in the raw material sites surveyed by the F/S team. The purpose of the tests was to obtain and confirm various kinds of manufacturing conditions and further to obtain all basic data relating to continuous operation as well as analysis and refining of the powdered activated carbon produced which are necessary for the commercial operation.

5.1 Raw Materials

Table 5A-1-1 shows the various kinds of raw materials put to test by the small-scale plant. Heartwood of timbers such as ipil-ipil, kakauate and white lauan were procured and used in these tests after crushing them by the method described in Paragraph 5-2-1. Other samples consisted of waste sawdust generated by sawmills.

Table 5A-1-1 RAW MATERIALS TESTED

Common Name	Botanical Name
Ipil-Ipil	Leucaena glauca (L) Benta
Coir dust	Cocus nucitera
Kakauate	Gliricidia Sepium (Jacq.) stued.
Apitong	Dipterocarpus grandiflorus Blanco
Falcata	Albizzia falcata Back, Albizzia falcataria (L) Fosberg
Davao Sawdust	C. Alcantara and Sons, Inc., Mixed lauan but more on white lauan
I.D.C. Sawdust	Industrial Development Corp., Mixed red and white lauan
E.A. Sawdust	East Asia Sawmill Corp., Mixed sawdust, Mainly Apitong
E.A. Red Lauan	S. negrosensis Foxw
Davao White Lauan	Pentacme contorta (Vid.) Merr. and Rolfel

5.2 Preparation of Raw Materials

5.2.1 Crushing

Timber heartwood was cut into segments having a thickness of less than 25 mm and width of less than 75 mm, and these segments were crushed into fragments of 0.2–2.5 mm by using a crusher (Model MC-10, product of Akita Lumbering Machine Seisakusho Co., Ltd.) Fig. 5A-1-1 shows the crusher, and Table 5A-1-2 its specifications. Since the crushing noise was as high as 120 dB, crushing was accomplished in a noise isolation chamber (2,000(L) x 2,000(W) x 2,000(H) mm) made of concrete blocks.

Fig. 5A-1-1 CRUSHER

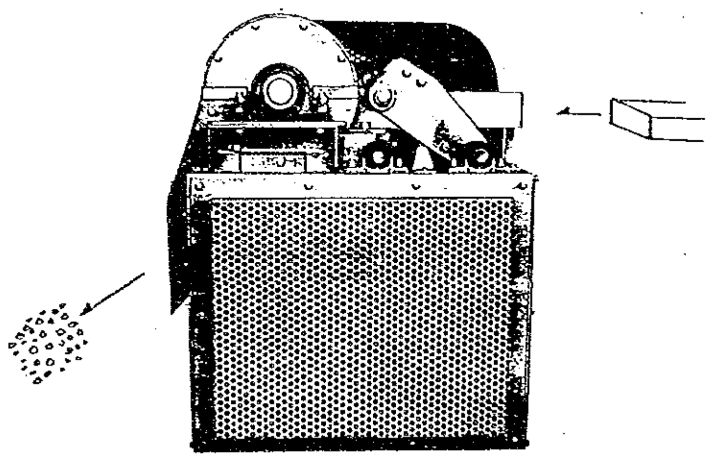


Table 5A-1-2 SPECIFICATION

Type	MC-10, Rotary cutter type
Size	500W x 750L x 950H
Weight	310 kg
Power	7.5 kW, 0.4 kW
Capacity	0.3–0.7 m^3/hr

5.2.2 Drying

1) Draft Drying

Since raw material sawdust has a moisture content as high as 20–40%, it was dried by utilizing the waste heat draft of flue gas generated in the carbonization furnace after introducing it into the burner. Fig. 5A-1-2 shows the flow sheet of the draft drying system, and Table 5A-1-3 the system's design conditions and design specifications.

Fig. 5A-1-2 FLOW SHEET OF DRAFT DRYING SYSTEM

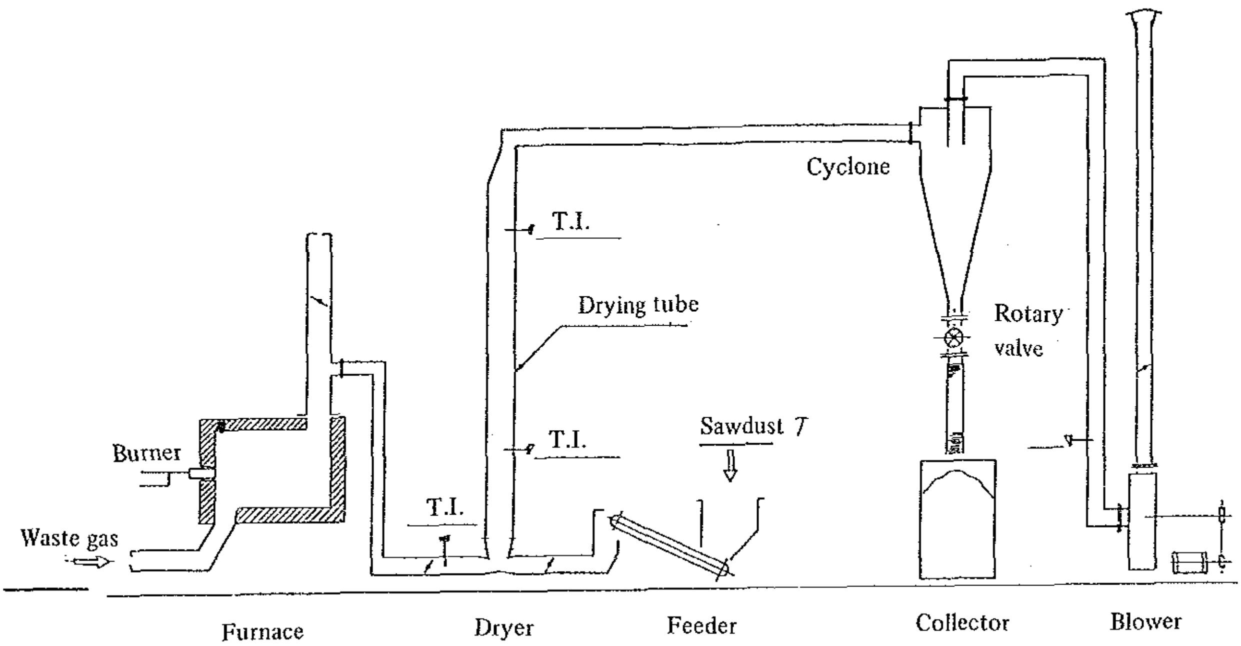


Table 5A-1-3 **DESIGN CONDITIONS AND DESIGN SPECIFICATIONS OF DRAFT DRYING SYSTEM**

System's Design Conditions:

Sawdust before drying (Mositure content 40%)	100 kg/hr
Sawdust after drying (Moisture content 30%)	75 kg/hr
Drying rate	25 kg/hr
Draft inlet temperature	350°C

Design Specifications:

Required heat energy for drying	$q\alpha$ = 16,725 kcal/hr
Required air flow	G = 297.3 kg/hr (250 m^3/hr)
Required energy	qt = 24,156 kcal/hr

Design of Drying Tube

Logarithmic mean temperature difference	$(\Delta t)_{lm}$ = 100.8°C
Coefficient of heat capacity	ha = 1,000 kcal/hr·°C·m^3
Required inner capacity	Vi = 0.167 m^3
Mean temperature in the tube	tg = 215°C
Mean humidity in the tube	Hav = 0.0495
Mean air flow rate in the tube	V = 443 m^3
Mean air velocity in the tube	LV = 7 m/s
Drying tube diameter	D = 150 mm
Drying tube length	L = 9.45 m

2) Solar Drying

A typical raw material, or Davao sawdust, was used for this test. Specifically, sawdust having a moisture content of 38.4% was put to solar drying test by placing it in partitioned compartment having a height of 70 mm and lateral faces of 500 mm, and while drying it by solar heat, the sawdust's drying time and residual moisture content were measured.

5.3 Testing Equipment

5.3.1 Open Hearth Type Carbonization Furnace

1) Carbonization Furnace

Raw material sawdust prepared by the method described in paragraph 5.2 was used and carbonized with an open hearth type carbonization furnace shown in Fig. 5A-1-3. Table 5A-1-4 shows the specifications of the furnace.

Fig. 5A-1-3 CARBONIZATION FURNACE

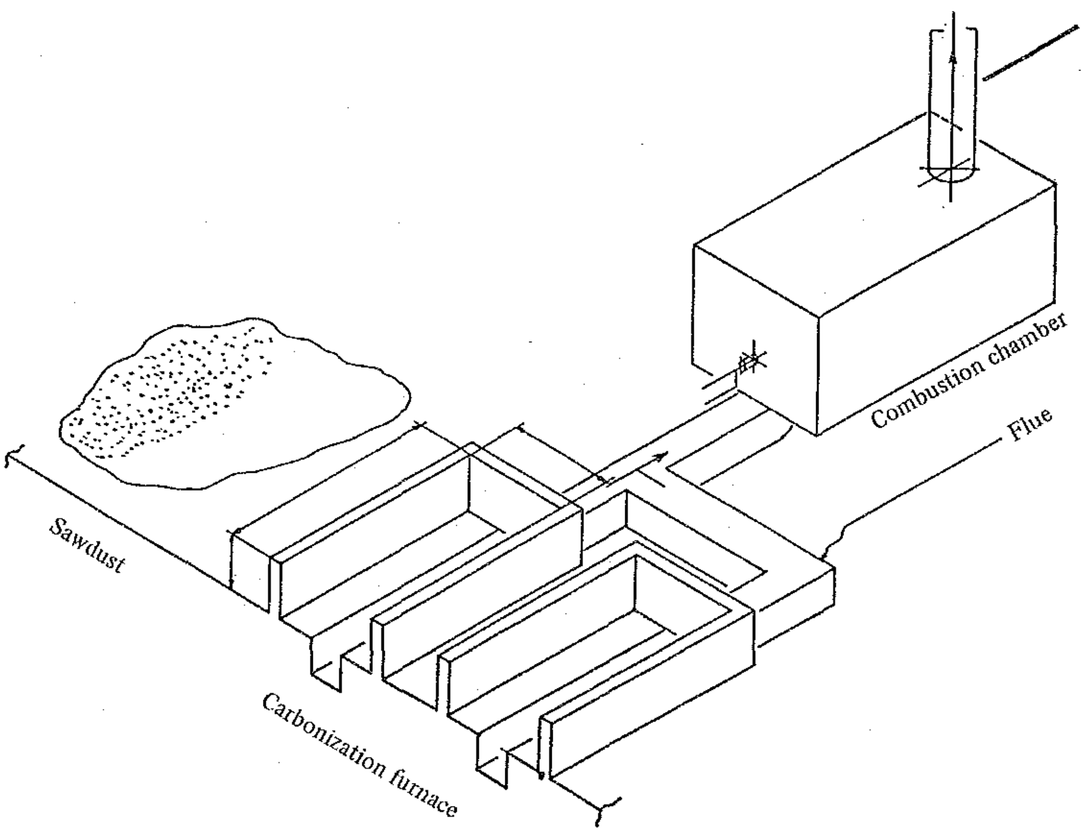


Table 5A-1-4 SPECIFICATION

Type	Open hearth carbonization furnace, Natural downward ventilation, Self-carbonization, Batch system
Capacity (by two furnaces)	Raw materials: Sawdust 400–500 kg/day Products: Sawdust char 100–125 kg/day
Carbonization time	3–6 days per cycle
Size	1,800W x 2,700L x 600H (x 2 sets)
Material	Ohya stone (TUFF)
Attachment	After burner and furance, Temperature recorder

2) Carbonization Furnace Operation Method

Coconut shell charcoal is leveled out to a height of 10 cm on a stainless steel screen (2 mesh) at the bottom of the carbonization furnace, then, sawdust in put on it to a height of 2–3 cm and ignited after kerosene is spread out on them. After the sawdust starts to burn, additional sawdust is spread out to a height of 5 to 10 cm and this operation in repeated, preventing partial combustion, until the carbonized layer attains a thickness of about 60 cm.

Charred sawdust is discharged from furnace by first transferring the surface sawdust layer to an adjacent furnace and extinguishing the fire by spraying water on the sawdust' surface. The surface layer is turned over with a shovel or other suitable implement, followed with fire extinguishing and cooling, after which the sawdust char is taken out of the furance. It is then scaled, filed into drum cans and sealed hermetically for storage.

In the commercial process, the sawdust char is transported to the packing section by pneumatic conveyor, then filled into 15 kg bags or 1 m^3 container bags.

5.3.2 Circular Fluidized Bed Activation Apparatus

Fig. 5A-1-4 shows the circular fluidized bed type activation apparatus used in the tests, and Table 5A-1-5 the specifications of the apparatus. The reaction furnace of the activation section has a diameter of 260 mm and length of 3,200 mm, and activation is terminated by the gaseous activation process with steam through the following chemical reactions:

$$C + H_2O \rightarrow CO + H_2 \quad -28{,}200 \text{ cal/mol.}$$
$$C + O_2 \rightarrow CO_2 \quad +97{,}000 \text{ cal/mol.}$$
$$C + CO_2 \rightarrow 2CO \quad -38{,}200 \text{ cal/mol.}$$

With the circular fluidizing bed type activation furnace employed in the tests, reaction gases are introduced through numerous nozzles provided tangentially in a cylindrical, lateral type reaction furnace. Meanwhile, the sawdust char fed continuously into the reaction furnace's inlet is fluidized and then circulated along the furnace wall by action of blown-in gas flow. The char is further circulated and undergoes activation reaction by action of the reaction gas blown in through the numerous nozzles during its transit toward the outlet of the furnace.

Since the short time reaction furnace is utilized effectively in this manner and the velocity is controlled with air and steam, and also since the period of time of char retension in the furnace can be regulated as desired, it is possible to produce activated carbon featuring various different properties through the same furnace. In addition to featuring a most compact construction, the furnace also lends itself to mass production and control with great ease.

Subsequent to the reaction, the formed gas and the produced activated carbon are subjected to heat exchange continuously in a boiler for cooling, and collected by means of a cyclone. Meanwhile, the steam generated in the boiler can be utilized in the activation process or can be used as the heat source for drying and other purposes.

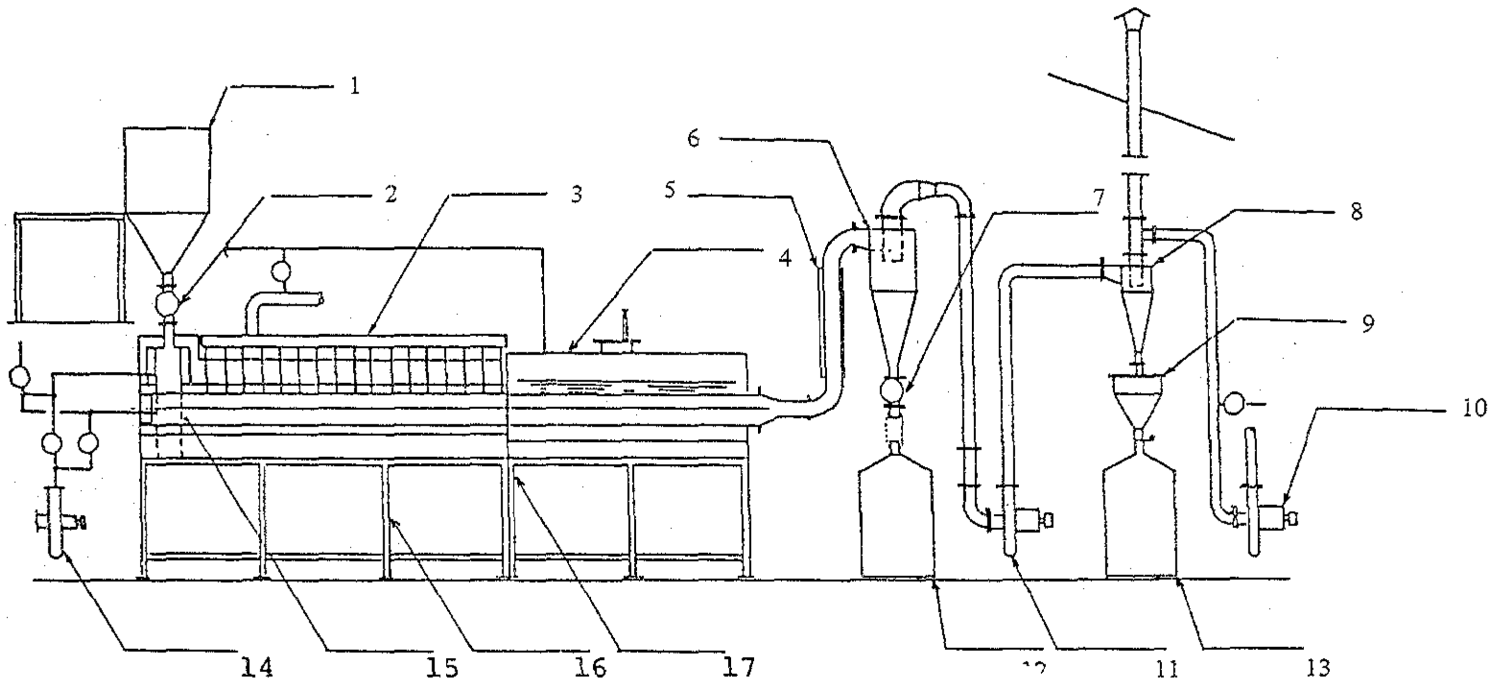
5.3.3 Crushing

A hammer type sample mill (Model KIII-I, product of Fuji Powdered Co., Ltd.) was used to crush various kinds of activated carbon into particle sizes of 200–300 mesh. Table 5A-1-6 shows the mill's specifications.

5.3.4 Refining

One volume of activated carbon crushed by the method described in paragraph 5.3.3 was added with 10 volume of 1N hydrochloric acid and stirred for 24 hrs, then placed in a centrifugal separator for dehydration and washing until its filtrate becomes neutral. The activated carbon was then discharged from the separator and dried. Table 5A-1-7 shows the specifications of the centrifugal separator and its accessories.

Fig. 5A-1-4 SCHEMATIC DIAGRAM OF CIRCULAR FLUIDIZING BED ACTIVATION FURNACE



1. Hopper
2. Screw feeder
3. Heder
4. Boiler
5. Condenser
6. Cyclone
7. Rotary valve
8. Cyclone
9. Storage tank
10. Blower (Air)
11. Blower
12. 13. Vessel

Table 5A-1-5 SPECIFICATIONS OF CIRCULAR FLUIDIZING BED ACTIVATION FURNACE (Pat. No. 1970-5646)

Type: Spontaneous combustion type steam activation furnace

Activation furnace dimensions:	3,600(L) x 800(W) x 800(H) mm
Quantity of sawdust char processed	15–20 kg/hr
Quantity of product	3–5 kg/hr
Quantity of activation gas	
Air	60 kg/hr
Steam	30 kg/hr
Circulation gas	100 kg/hr
Ancillary equipment:	
Boiler	Smoke tube type waste heat boiler 2,000(L) x 700 ϕmm Evaporation capacity 50 kg/hr
Cyclone	2 units: 250 ϕmm, 380 ϕmm
Blower	3 units: 3.7 kW, 0.4 kW, 0.4 kW
Supply of raw material	
Hopper	0.4 m^3
Variable screw feeder	0.75 kW

Table 5A-1-6 SPECIFICATIONS OF HAMMER TYPE SAMPLE MILL

Mill size:	400L x 400W x 600H
Weight:	40 kg
Type:	Rotary hammer mill
Power requirement:	0.75 kW
Accessories:	Material feed screw (manual) Bag filter for product recovery

Table 5A-1-7 SPECIFICATIONS OF CENTRIFUGAL SEPARATOR

Washing tank	Capacity 8 liters, made of PVC
Mixer	50 to 1,300 rpm (Variable)
	Max. torque 5 kg/cm
Centrifugal separator	Basket size 150ϕ x 80(H) mm
	3,000 rpm, with 0.8-liter cloth filter bag
Dryer	110°C±5°C

In addition to the washing conditions described above, effusion tests were conducted in conformance with various standard activated carbon testing methods in order to compare different washing conditions.

5.3.5 Analysis Method

Activated carbon was also analyzed by standard testing methods. Raw material timber and sawdust char were likewise tested in conformance with standard activated carbon testing methods.

Standard testing methods included the Powdered Activated Carbon Analysis Method (JIS K 1470), the Granular Activated Carbon Testing Method (JIS K 1474), the Official Statute on Medicinal Carbon and Food Additives (Tenth Revision) of Pharmacopoeia Japonica, and the Water Works Powdered Activated Carbon Testing Method (JWWA K 113) of the Japan Water Works Association. Other testing methods were also used in combination with these testing methods, such as the Government Industrial Research Institute, Hokkaido, Testing Method, and the Hokuetsu Carbon Industrial Co., Ltd. Testing Method.

A description of these testing methods is given below.

1) Adsorbability Test

The adsorbability was evaluated by measuring the quantities of adsorption of various kinds of specific substances in liquid phase and/or the surface areas under condition of adsorption of N_2 gas.

a)	Methylene blue decolorizing power	(ml/g)	JIS K 1470
b)	Methylene blue adsorbability	(specifications conformity)	Pharmacopoeia Japonica
c)	Iodine absorbability	(ml/g)	JIS K 1474
d)	ABS adsorption test	(ABS value)	JWWA K 113
e)	Surface area measurement test	(m^2/g)	Distribution Method, N_2-BET Method (By use of Model ADS-1B, manufactured by Shimadzu Seisakusho Co., Ltd.)

2) Properties Test

a)	Bulk density	(g/ml)	JIS K 1474
b)	Particle size	(%)	JIS K 1474
c)	Screen residue	(%)	JWWA K 113
d)	Technical analysis		JIS M 8812

3) Purification Test

a)	Weight reduction by drying (Moisture content)	(%)	JIS K 1470
b)	Intense heat residue (Ash content)	(%)	JIS K 1470
c)	Volatility	(%)	JIS M 8812, Hokuetsu Method
d)	Chlorides	(%)	JIS K 1470
e)	Iron	(%)	JIS K 1470

f)	pH value		JIS K 1470
g)	Water-soluble substances	(%)	Equivalent Electrically Conductive Salts Method
h)	Arsenic	(ppm)	JWWA K 113
i)	Heavy metals	(ppm)	

Quantitative analysis of effusion by JIS K 1470 and JWWA K 113 methods, as well as of incineration solutions by atomic optical adsorption intensity method. (Use of Model AA-630-12 Analyzer, manufactured by Shimadzu Seisakusho Co., Ltd.)

4) Thermal Mass Analysis

By thermal mass measuring apparatus.
(Model DT-30, manufactured by Shimadzu Seisakusho Co., Ltd.)

5) Gas Analysis

By TCD gas chromatograph method.
(Model GC 8APT, manufactured by Shimadzu Seisakusho Co., Ltd.)

Note:

JWWA:	Japan Water Works Association
JIS:	Japanese Industrial Standards
Pharmacopoeia Japonica:	Tenth Revision of Pharmacopoeia Japonica (Medicinal Charcol)

5.4 Test Results and Their Observation

5.4.1 Properties of Raw Materials

Table 5A-1-8 shows the results of analysis of the various kinds of raw materials employed in the test study, and Table 5A-1-9 the result of technical analysis and element analysis of Davao sawdust.

Table 5A-1-8 PROPERTIES OF RAW MATERIALS EMPLOYED IN THE TEST STUDY

Sample Name	% Moisture (as rec'd)	Dry Basis				
		% VCM	% Ash	% FC	Dp, mm	ρ_B (g/cc)
Davao sawdust	38.35	75.70	0.80	23.50	0.60	0.301
IDC sawdust	33.74	82.40	0.50	17.10	0.35	0.359
EA sawdust	18.95	85.74	1.46	12.80	0.65	0.262
Davao white lauan	10.34	86.97	0.76	12.25	1.05	0.240
EA red lauan	13.0	83.65	1.90	14.45	0.40	0.266
Apitong	43.56	85.10	2.60	12.30	1.20	0.336
Falcata	12.35	83.55	1.05	15.40	0.82	0.157
Kakauate	29.0	84.51	1.41	14.08	0.76	0.293
Ipil-ipil	8.40	87.90	1.20	10.90	2.35	0.253
Coir dust	86.0	85.71	3.57	10.71	–	–

Note: VCM: Volatile Combustible Matter
FC: Fixed Carbon
Dp: Average Particle Size
ρ_B: Bulk Density

Table 5A-1-9 ANALYSIS OF DAVAO SAWDUST

Technical Analysis:	
Moisture content (%)	3.83
Ash content (%)	0.3
Volatile matter (%)	80.07
Fixed carbon content (%)	15.80
Calorific value (kcal/kg)	4,650
Element Analysis:	
C (%)	51.57
H (%)	5.88
O (%)	35.90
S (%)	0.03

5.4.2 Crushing of Raw Materials

To conduct carbonization tests on various timbers which cannot be obtained as sawdust or on sawdust which do not mix with those obtained from other kinds of timber, crushing of these timber are crushed using the crusher described in Paragraph 5.2.1.

Due to the crusher's small size, raw timber was cut into pieces before crushing with thicknesses of less than 25 mm and width of less than 7.5 mm, and bark was also removed since it may clog the screen. The particle size distribution of these crushed fragments was controlled by selecting proper liner and adjusting clearance at the edge of crusher. In this crushing test, an edge clearance of 1 mm was found to be the most suitable.

Table 5A-1-10 shows an example of the conditions under which the crusher was employed, and the particle size distribution of the crushed fragments.

Table 5A-1-10 CRUSHING CONDITIONS

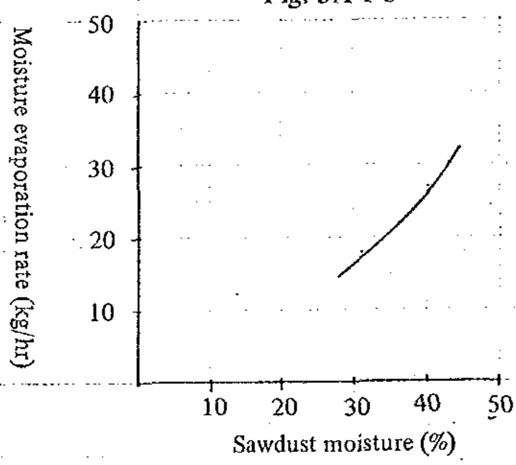
Kinds of Woods	White Lauan	Falcata
Load current (A)	29	25
Crushing capacity (m^3/hr)	0.6	0.8
Particle size distribution (%):		
under 10 mesh	5.7	23.0
10–20 mesh	50.3	47.7
20–42 mesh	40.0	27.3
over 42 mesh	4.0	2.0

5.4.3 Drying of Raw Materials

1) Draft Drying

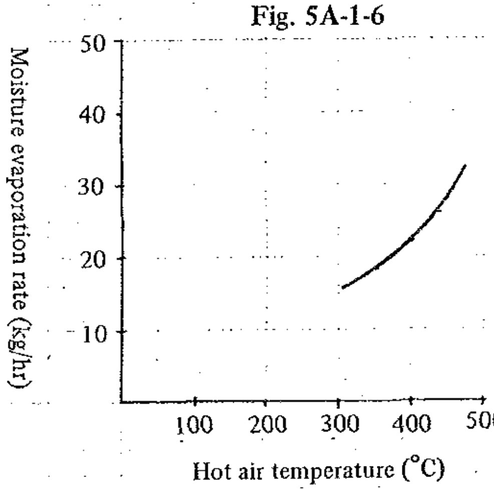
Draft drying tests were conducted on Davao sawdust and IDC sawdust by using the air dryer described in Paragraph 5.2.2, 1). Fig. 5A-1-5 shows the relationship between sawdust moisture and moisture evaporation rate, and Fig. 5A-1-6 the relationship between the dryer's inlet hot air temperature and moisture evaporation rate. An example of dryer operating conditions is shown in Table 5A-1-11.

Fig. 5A-1-5



Davao sawdust
Hot air temperature: 400°C
Sawdust supply rate: 70 kg/hr

Fig. 5A-1-6



Davao sawdust
Sawdist moisture: 36%
Sawdust supply rate: 80 kg/hr

Table 5A-1-11

Raw material sawdust moisture	%	36
Raw material sawdust supply rate	kg/hr	80
Dried sawdust moisture	%	10
Dried sawdust discharge rate	kg/hr	56.8
Moisture evaporation rate	kg/hr	22.2
Inlet hot air temperature	°C	400
Inlet hot air quantity	Nm^3/hr	250
Inlet hot air heat quantity	kcal/hr	22,500
Total air flow	Nm^3/hr	610
Air velocity inside drying tube	m/sec	5.4
Heat efficiency	%	44.8

2) Solar Drying

Solar (Natural) drying tests were conducted on Davao sawdust in conformance with Paragraph 5.2.2, 2).

Fig. 5A-1-7 shows the relationship between the drying time of sawdust at standstill and the residual moisture in the sawdust. With sawdust piled up to a height of 7 cm, there was hardly any drying in 1–6 hrs of drying. By contrast, with sawdust piled up to a height of 2 cm, drying proceeded linearly up to 3.5 hrs, after 6 hrs passed the drying rate remained almost constant indicating that the initial moisture was decreased by roughly 50%. Fig. 5A-1-8 shows the relationship between drying time and residual sawdust moisture with respect to sawdust having initial moistures of 40, 45, and 50%.

Next, the height of the sawdust pile was set at 4 cm and drying was continued while turning over the sawdust pile once an hour. Even in this case, the moisture reduction rate became constant beyond the sawdust drying time of 6 hrs.

Based on the results described above, the sawdust was piled up to a height of 4–5 cm, turned over about once every hour, when the sawdust was dried for 3–4 hrs by replacing it twice a day, it was found the most effective. In the case that the moisutre of sawdust is reduced from 40% to 30%, it is possible to dry sawdust of 6.7 b.d. kg/m^2.

An area of 87 m^2 will be required for drying sawdust equivalent to the two carbonization furnaces used in this tests. This method is highly effective especially for drying highly moist sawdust in order to improve the carbonization speed.

Fig. 5A-1-7

CORRELATION BETWEEN DRYING TIME AND SAWDUST MOISTURE

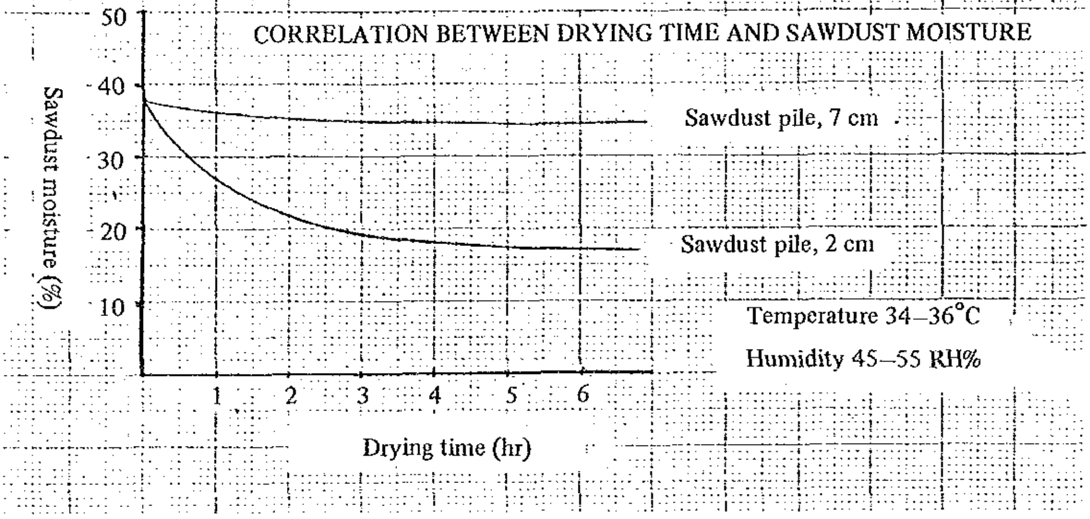


Fig. 5A-1-8

CORRELATION BETWEEN DRYING TIME AND SAWDUST MOISTURE

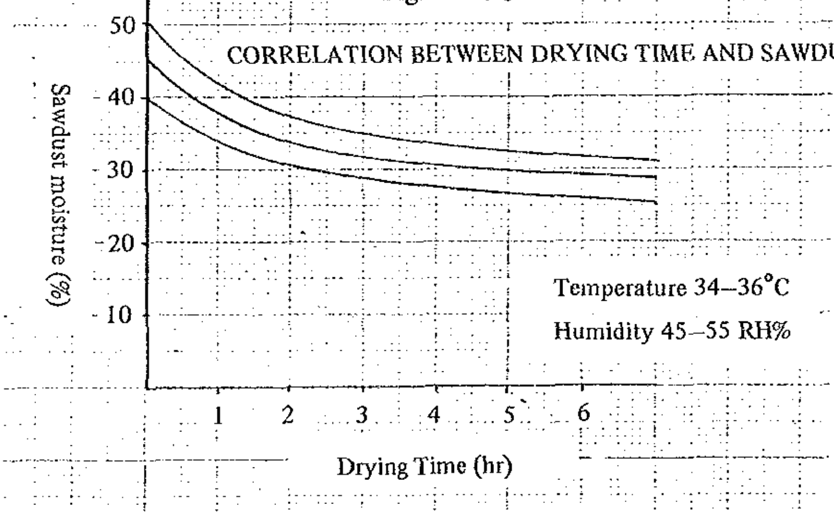


Table 5A-1-12 PROPERTIES OF CARBONIZED RAW MATERIALS

(Average Data)

Sample Name	% Moisture (as discharged)	Dry Basis % VCM	% Ash	% FC	Dp, mm	ρ_B (g/cc)
Davao sawdust	7.65	30.30	3.10	66.60	0.35	0.175
IDC sawdust	4.66	27.10	3.92	68.98	0.24	0.196
EA sawdust	6.66	31.60	5.10	63.30	0.46	0.199
EA red lauan	3.00	30.60	5.00	64.40	0.64	0.221
Ipil-ipil	1.37	21.85	5.8	72.3	0.60	0.228
Falcata	5.24	20.42	4.78	74.82	1.35	0.399
Japan sawdust	10.0	35.0	0.8–1	64.20		0.15

Table 5A-1-13 SUMMARIZED RESULTS AND DATA ON THE CARBONIZATION OF RAW MATERIALS

Raw Material	M_F (%)	F $(kg)_{DB}$	θ (days)	P (kg)	Yield $(\%)_{DB}$	Rate $(kg/day)_{DB}$
Davao sawdust:						
I (Ave. of 4 runs)	38.2	590	3.2	270	42	84.4
II (Ave. of 2 runs)	39.0	1,223	5.75	270	18	38.3
IDC sawdust:						
I (Ave. of 2 runs)	39.0	782	4.3	222	27	51.6
II (Ave. of 4 runs)	36.5	1,246	6.75	186	15	27.6
EA sawdust (Ave. of 4 runs)	22.0	870	2.5	320	35.4	128
Davao white lauan	12.0	1,227.3	3.0	380	29.0	127
Red lauan (Ave. of 2 runs)	40	601	2.8	234	36.7	83.6
Ipil-ipil	8.45	424	3.0	88.3	20	29.4
Falcata	12.2	78	2.83	31	32	11

Note: M_F – Moisture of raw material
F – Raw material charged
θ – Carbonization cycle
P – Charcoal product as obtained
DB – Dry Basis

5.4.4 Manufacture and Properties of Sawdust Char

1) Properties of Sawdust Char

Carbonization tests were conducted on various kinds of raw materials prepared in accordance with 5.2 and by employing the open hearth type carbonization furnace described in Paragraph 5.3.1. Table 5A-1-12 shows the technical analysis and element analysis obtained through the tests on Davao sawdust char and Japanese sawdust (cedar and cypress mixture) char.

Table 5A-1-14

	Davao sawdust char	Japanese sawdust char
Technical analysis:		
Moisture (%)	13.03	19.35
Ash content (%)	1.91	0.67
Volatile matter (%)	20.70	35.72
Fixed carbon (%)	64.16	44.86
Calorific value (kcal/kg)	6,680	5,600
Element analysis:		
C (%)	78.01	74.37
H (%)	2.97	3.29
O (%)	13.95	16.93
S (%)	0.05	0.02

Table 5A-1-13 shows the analysis values of various kinds of sawdust char and Table 5A-1-14 an example of the operational data of carbonization furnace.

2) Carbonization Reaction, Temperature Difference and Temperature with Lapse of Time

Carbonization reaction of sawdust starts when adhering moisture is evaporated at about 100°C, followed with decomposition of cellulose and lignin as the temperature rises gradually, then the generation of hydrocarbon components having low boiling points such as CO, CO_2 and H_2O generated and followed with the generation of hydrocarbon components of ever higher boiling points. Through these complicated polymerization, carbonized materials are being formed.

With the open hearth furnace used in this test, carbonization occurs at a temperature of more or less 300°C. Low molecular compounds of sawdust generated in nitrogen draft is reacted heavily with oxygen in the atmosphere. Heat of oxidation thus generated maintains the temperature at a constant level.

Fig. 5A-1-9 shows the temperature distribution at the bottom of the carbonization furnace as well as at the planes laying 13 cm and 28 cm, respectively, above the bottom surface.

The temperatures in these two elevated planes are distributed within the range of 290–330°C. These differences in combustion temperatures were due to the differences in air flow quantity, caused by the difference of ventilation resistances at these parts in the crarbonization layer.

Fig. 5A-1-10 shows the changes in carbonization furnace temperature with lapse of time, indicating that the temperature remains at a constant level of roughly 300°C throughout the entire period of carbonization. The temperature rises sharply just before completion of carbonization since the non-charred sawdust remained on the surface of carbonization layer was mixed with the carbonized sawdust, by which the combustion occured on the surface.

Fig. 5A-1-9 TEMPERATURE DISTRIBUTION ON THE CARBONIZATION FURNACE

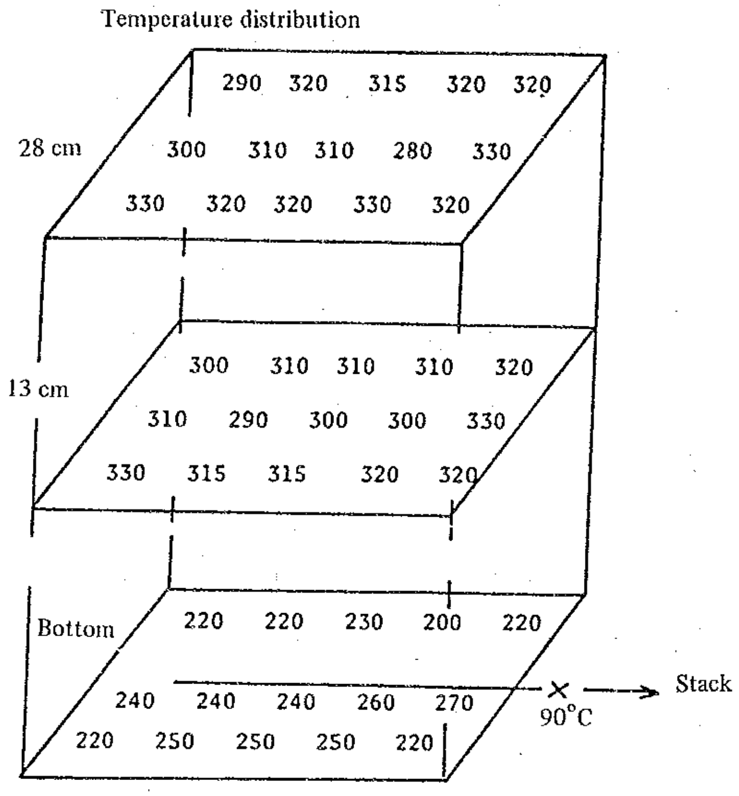
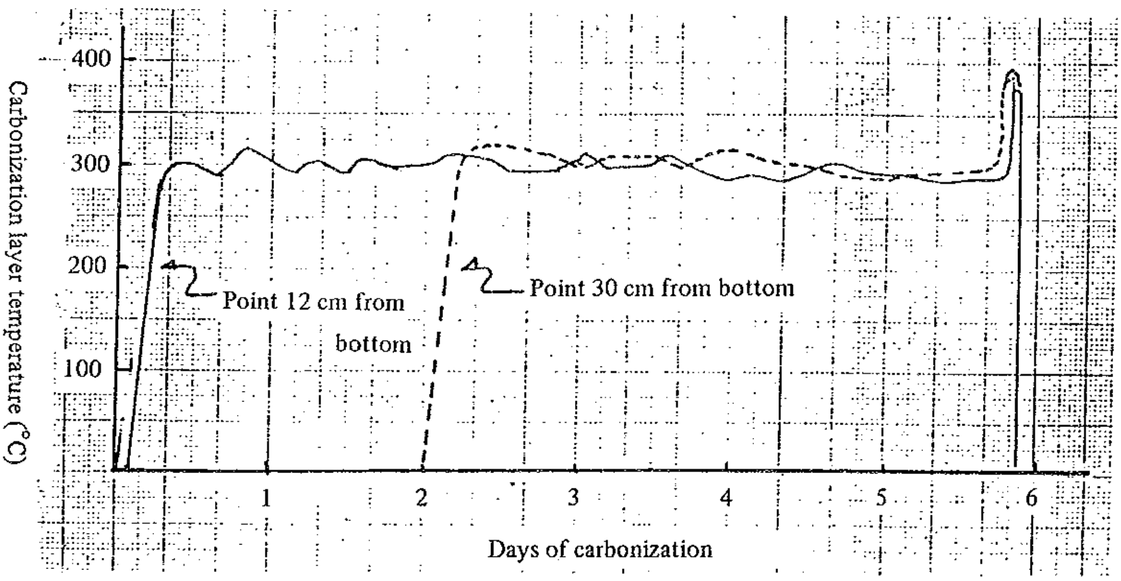


Fig. 5A-1-10 CHANGES IN CARBONIZATION LAYER TEMPERATURE WITH LAPSE OF TIME



5.4.5 Carbonization Conditions and Carbonization Yield

1) Carbonization Speed and Yield

Carbonization speed of sawdust is influenced by the sawdust's moisture. This is because the quantity of heat generated by carbonization is partly deprived by evaporation of sawdust moisture. That is, assuming that the heat efficiency is 100%, a heat quantity equivalent to the combustion of 6.5 kg of char will be required for drying 166.6 kg (100 kg in bone dry equivalent) of sawdust having a moisture of 40%. Likewise, with a moisture of 30%, a heat quantity equivalent to the combustion of 4.2 kg of char will be necessary. This means that the yield of char will be decreased by 6.5% and 4.2%, respectively. Also, an increase in the time required for evaporation of sawdust moisture in the process of carbonization will have the effect of increasing the time required for carbonization.

Fig. 5A-1-11 shows the relationship between sawdust feed rate (kg/hr.m²) and carbonization speed (kg/hr.m²) with respect to various sawdust moisture levels. Meanwhile, Fig. 5A-1-12 shows the relationship between moisture, and carbonization yield.

Fig. 5A-1-11

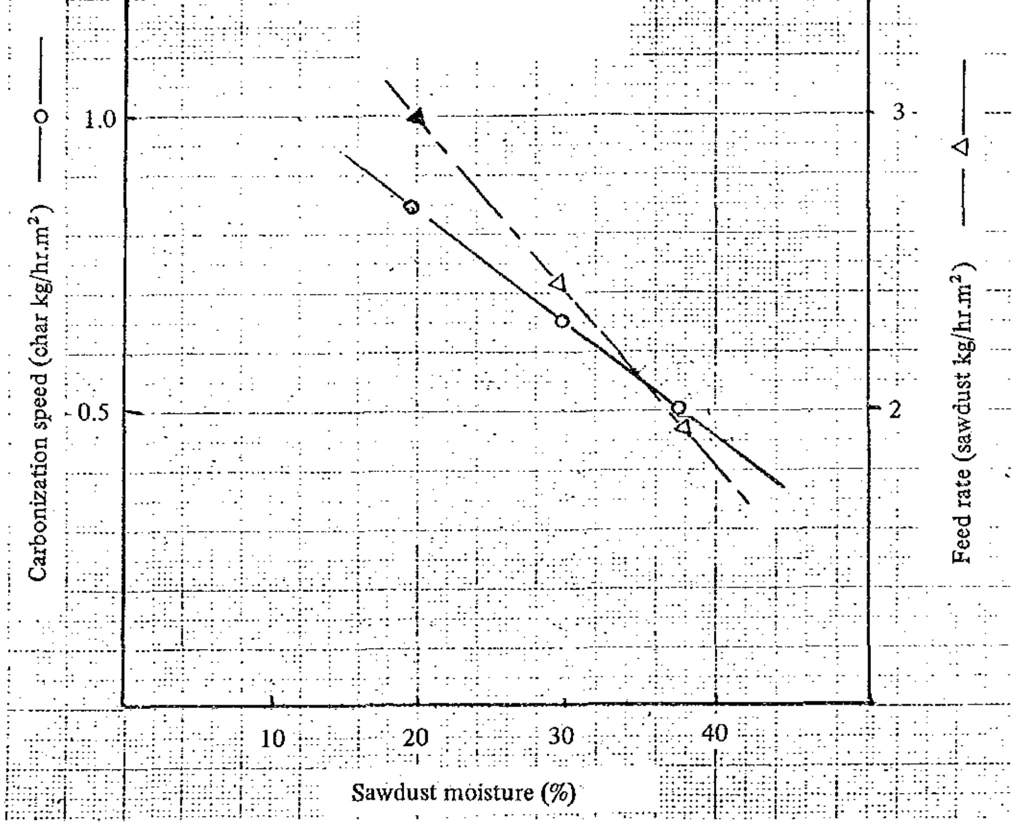


Fig. 5A-1-12

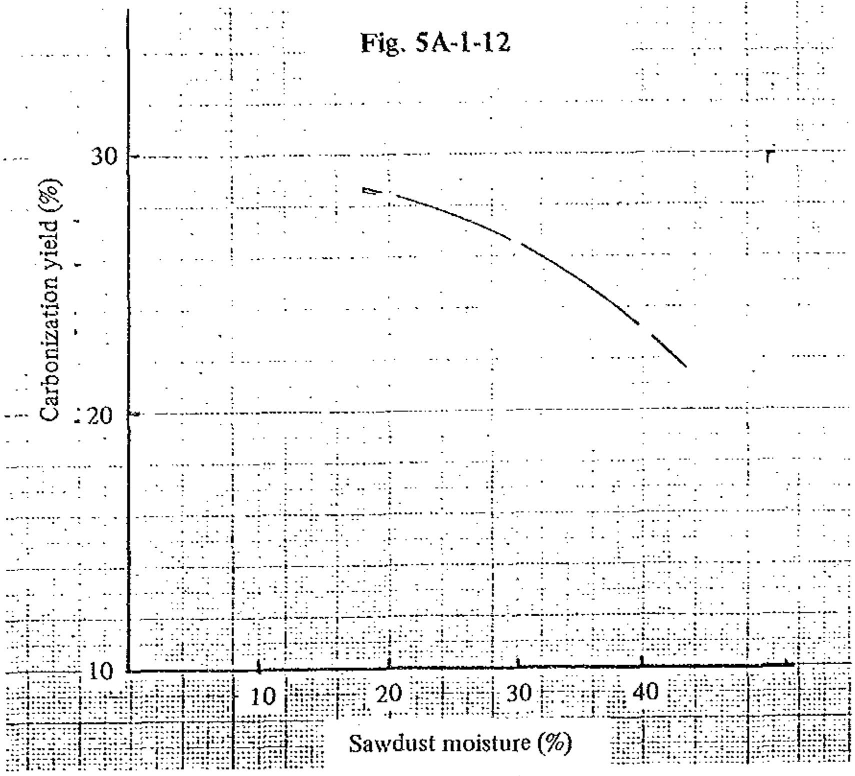
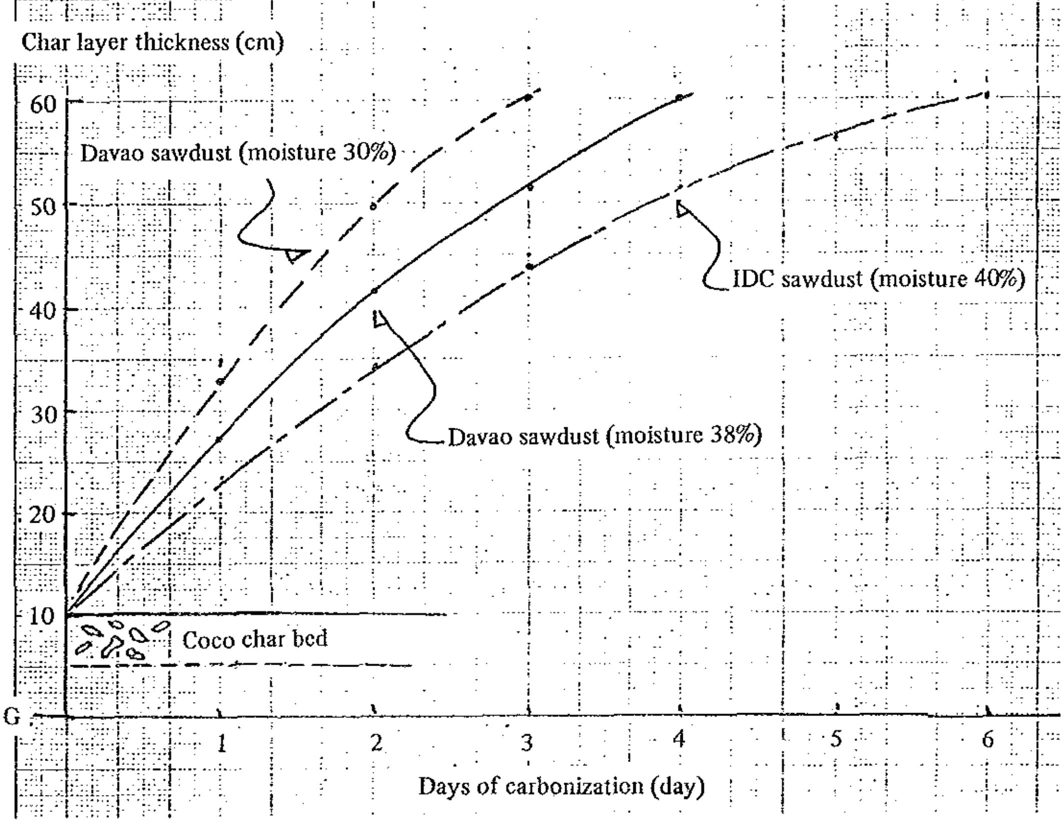


Fig. 5A-1-13



The moisture of sawdust collected from sawmills lies in the range of 41%, 35%, so in this case, the carbonization speed per square meter of carbonization furnace was 0.45–0.55 $kg/hr.m^2$, and the yield 24–25%.

Fig. 5A-1-13 shows the char generation quantity with lapse of time in terms of char layer thickness. That is, the char layer thickness increases and levels out with an increase in the number of days of carbonization. Accordingly, in order to improve the carbonization furnace's charring efficiency, it will be necessary to terminate carbonization within 3–4 days.

Another property of sawdust that influences the carbonization speed is the sawdust's particle size. The finer the particle size, the larger will be the char layer's resistance to air penetration, resulting in a slower carbonization speed. In order to decrease the char layer's air penetration resistance, IDC sawdust was added with 1/6th vol % and 1/15th wt % of wood shavings, which had the effect of increasing the carbonization speed by 1.5 times compared with non-mixed IDC sawdust.

The char layer's air penetration volume will be dependent on the chimney's height, diameter and the temperature difference between exhaust gas and outer air. When the afterburners which combust the exhaust gas at time of carbonization were stopped, cases have been confirmed in which carbonization normally terminated in 4 days required as long as 7 days. This is because that the carbonization furnace used in these tests was a small furnace having large heat radiation from the ducts and other places, however, no such large influence is likely with an commercial carbonization furnace.

2) Heat Balance and Carbonization Yield

The heat balance of the carbonization furnace was roughly estimated since an accurate analysis of the furnace's radiant heat or gas generation quantity will be very difficult.

This heat balance applies to a case of carbonization of 100 kg of sawdust (bone dry equivalent) having a moisture of 40%. The char yield is assumed to be 25%, while the sawdust's heat value of 4,650 kcal/kg and char's heat value of 6,600 kcal/kg were calculated on the basis of the technical analysis values shown in Tables 5A-1-9 and 5A-1-12. Data on thermal mass analysis in the temperature range of 300–350°C were also referred to for reference.

In order to increase the yield of char in the carbonization process, it will be necessary to decrease the volume of combustion of char shown in Table 5A-1-15. Therefore, the allocation of char combustion calorie was studied. Table 5A-1-15 shows that the char combustion heat quantity runs up to 118 x 10^3 kcal. This is equivalent to 17.8 kg of char.

Table 5A-1-15

Heat input			Heat output		
Item	10^3 kcal	%	Item	10^3 kcal	%
Combustion heat of 100 kg of char	465	100	Vaporized moisture	43	9.2
			Distilled gas	139	29.9
			Char combustion	118	25.4
			Ash	165	35.5

Heat input			Heat output		
Item	10^3 kcal	%	Item	10^3 kcal	%
Combustion heat of 17.8 kg of char	118	100	Vaporization of moisture	43	36.5
			Temperature rise of sawdust	13	11.0
			Sensible heat of exhaust gas	30	25.4
			Heat deprived by char	2	1.7
			Radiant heat of furnace	30	25.4

The accompanying table shows that the major factors influencing the char yield are the sawdust moisture and the furnace's radiant heat. The radiant heat of the furnace will be increased, the longer the period of carbonization, so shortening the period of carbonization and using sawdust of low moisture will result in better char yield.

5.4.6 Analysis on Thermogravimetry of Raw Materials

Table 5A-1-16 shows the names of trees which were put to analysis.

Table 5A-1-16

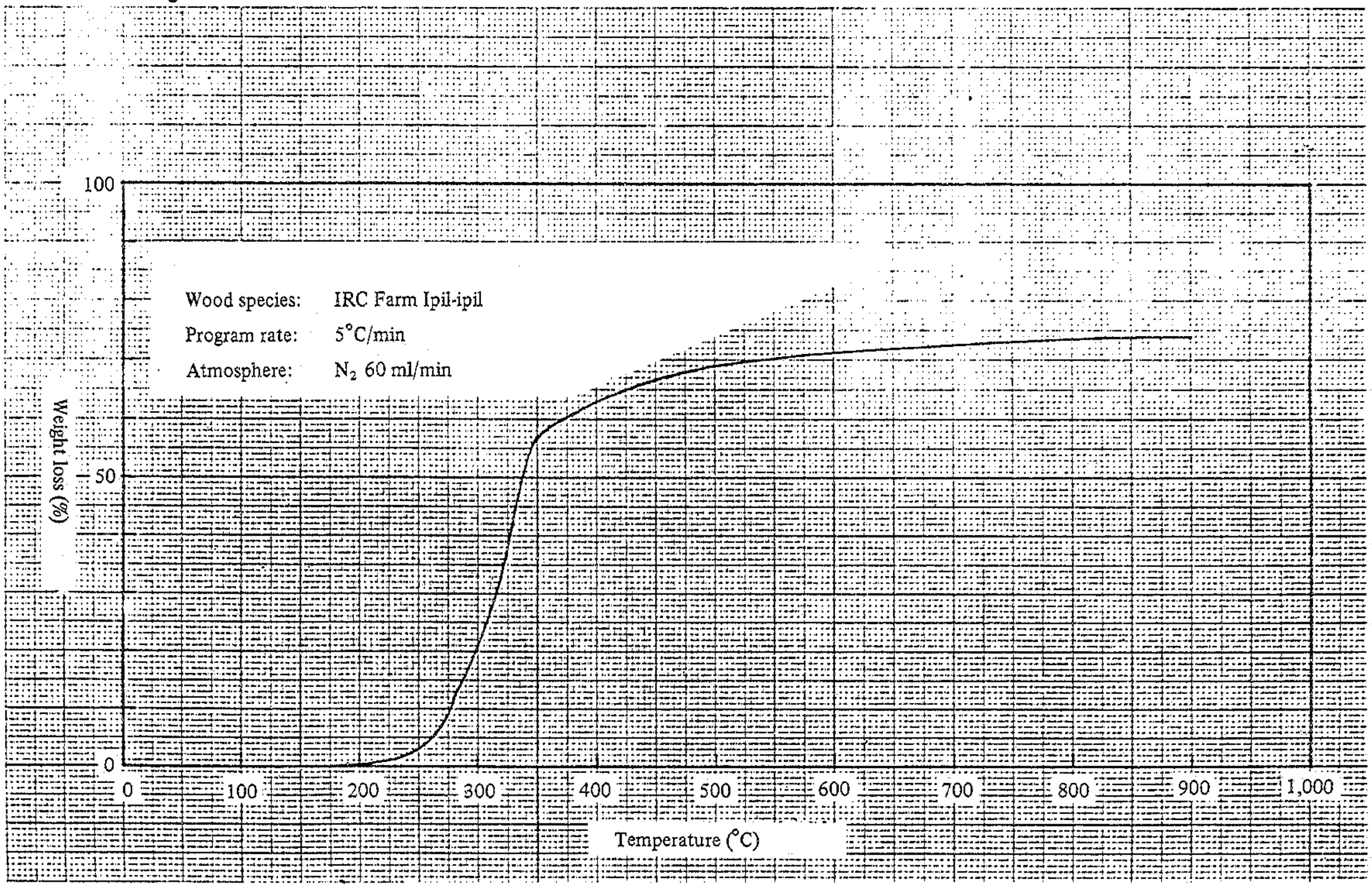
Ipil-ipil
Apitong
Falcata
Davao sawdust
IDC sawdust
EA sawdust
Kakauate
EA red lauan
Davao white lauan
Japanese cedar
Japanese cypress

Thermogravimetry is a method for continuously measuring the changes occurring in the weight of a sample through thermal reaction, and provides the starting-out and ultimate temperatures and weight change quantities attending weight changes. By utilizing this method, it is possible to make inference of the carbonization temperature and char yield from the wood's thermal decomposition characteristics and thermal stability, and to establish criteria for setting optimum carbonization furnace operating conditions for the manufacture of char.

Fig. 5A-1-14 shows an example of thermal decomposition of ipil-ipil in a nitrogenous environment. The abscissa represents the temperature and the ordinate the weight reduction ratio (%) with respect to various temperatures.

Wood consists almost entirely (95%) of cellulose, hemicellulose and lignin. Among these three substances, hemicellulose is known to be decomposed first of all at a temperature of about 180°C in the process of thermal decomposition. Next, a part of lignin starts to decompose at temperature of about 300°C, cellulose decomposes intensely at 275°C, and finally the non-reacted part of lignin starts decomposing at a temperature of about 350°C.

Fig. 5A-1-14 THERMAL DECOMPOSITION REACTION OF IRC FARM IPIL-IPIL IN NITROGEN



The Philippine timber handled in this project also underwent the same thermal decomposition reaction and were ultimately converted into char. That is, the first thermal decomposition reaction occurred at from 180°C to 300°C, while the second and third thermal decomposition reactions occurred at from 300°C to about 500°C. Table 5A-1-17 and 5A-1-18 compile the thermal pyrolysis decomposition characteristic curves of various kinds of timbers.

The activation energy involved in thermal decomposition reaction serves as a criterion for evaluating thermal stability, and can be obtained by measuring the thermal decomposition reaction. In this method, the quantity of weight change occurring at various temperatures or the quantity of weight change of timber constituent substances at various temperatures, temperature T_1 at temperature rise speed ϕ_1, T_2 at ϕ_2 ..... T_n at ϕ_n, are measured. When the ratios of weight changes occurring at various temperatures become equal, the following formula is established:

$$\log \phi_1 + 0.4567\, \Delta E/RT_1 = \log \phi_2 + 0.4567\, \Delta E/RT_2 \;\ldots\ldots\; \log \phi_n + 0.4567\, \Delta E/RT_n$$

Therefore, by representing the common logarithms of temperature rise speeds on the ordinate and the inverse values of absolute temperatures on the abscissa, a linear relationship will be obtained at a point where the ratios of weight changes become equal, in which case the linear inclination will be equal to $-0.4567\, \Delta E/R$, and from which the activation energy can be obtained.

Fig. 5A-1-15 shows an example in which the activation energy corresponding to the three stages of thermal decomposition of wood is obtained in connection with ipil-ipil. Fig. 5A-1-16 – 5A-1-35 show the same results in connection with other tree species, while Table 5A-1-19 compiles the activation energy values of various kinds of woods.

Also, ordinary considerations on these results are summarized in the following items of from (a) to (e):

(a) Wood essentially consists of moisture, volatile combustible matter, fixed carbon and ash.

Table 5A-1-17 SUMMARIZED RESULTS AND DATA ON THE THERMOGRAVIMETRIC ANALYSIS

Wood species	Chars yield (%) of wood species at various temperature														
	Temperature (°C)														
	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900
Davao mixed sawdust	98.7	96.7	83.2	45.8	37.6	33.4	31.3	30.2	28.4	27.5	26.9	26.4	25.8	25.6	25.6
Davao white lauan	98.8	96.9	85.7	52.5	37.0	33.0	30.4	28.9	27.8	26.9	26.1	25.6	25.3	25.0	24.9
Quezon City red lauan	98.9	96.9	86.6	56.6	39.2	34.8	32.0	30.2	28.9	28.0	27.3	26.7	26.4	26.2	26.1
IDC mixed sawdust	98.3	96.3	87.5	60.2	39.3	34.7	31.9	30.1	28.0	27.6	27.0	26.0	25.6	25.6	25.6
East Asia	98.4	96.6	84.4	56.7	40.3	36.1	33.8	32.1	30.9	30.0	29.3	28.5	28.3	27.8	27.7
Davao Falcata	98.2	96.5	83.2	49.5	31.6	28.0	25.8	24.4	23.4	22.5	21.9	21.3	21.1	20.8	20.6
Laguna coir dust	93.8	88.2	72.9	56.0	49.9	45.5	42.2	40.1	38.6	27.5	26.6	36.0	35.9	35.4	35.1
IRC farm Ipil-ipil	97.0	94.5	76.7	40.9	34.7	31.0	28.6	27.3	26.2	25.6	25.1	24.6	24.2	24.1	24.0
Apitong	98.9	96.8	85.1	52.2	37.7	33.5	31.1	29.5	28.3	27.7	27.2	26.7	26.4	26.2	26.1
Molino farm kakaute	98.9	96.6	84.6	56.0	41.3	36.9	33.8	32.0	30.5	29.7	28.5	28.1	27.6	27.4	27.2
Japanese cedar	98.7	96.9	85.9	53.2	35.1	30.9	28.5	26.9	25.6	24.8	24.1	23.7	23.4	23.1	22.9
Japanese cypress	99.0	97.2	86.7	52.3	34.8	30.7	28.3	26.9	25.8	25.1	24.4	23.8	23.7	23.7	23.7

Program rate: 5°C/min

Atmosphere: N_2 60 ml/min

Dry and ash basis

Table 5A-1-18 SUMMARIZED RESULTS AND DATA ON THE THERMOGRAVIMETRIC ANALYSIS

Wood species	Moisture (%)	VCM* (I)		VCM* (II)		VCM* (III)		Total VCM* (%)**	Fixed carbon (%)**
		(%)**	Peak point temperature (°C)	(%)**	Peak point temperature (°C)	(%)**	Peak point*** temperature (°C)		
Davao mixed sawdust	35.7	20.2	286	36.5	340	13.1	357	69.8	29.4
Davao white lauan	9.9	20.3	290	37.9	345	12.3	367	70.5	28.8
IDC mixed sawdust	36.5	20.8	293	35.3	357	12.8	375	68.9	30.4
East Asia	25.7	24.6	296	29.6	352	12.0	368	66.2	32.6
Davao Falcata	10.0	25.4	295	37.3	351	10.5	367	73.2	25.7
Laguna coir dust	9.0	22.7	306	31.7	348	15.6	374	70.0	28.6
IRC farm Ipil-ipil	10.0	19.3	277	14.4	310	19.8	342	53.5	40.8
Apitong	9.2	26.0	285	30.7	335	13.4	364	70.1	27.5
Molino farm kakauate	8.5	21.1	291	36.0	347	12.9	367	70.0	29.1
Quezon City red lauan	32.0	24.7	302	35.2	358	12.7	372	72.6	26.5
Japanese cedar	34.5	26.4	303	34.1	352	11.9	368	72.4	26.7
Japanese cypress	16.0	19.2	293	35.8	352	13.6	368	68.6	30.7

*: Volatile combustible matter

**: Dry basis

***: Unstable

Fig. 5A-1-15 OZAWA'S PLOT OF IRC FARM IPIL-IPIL DECOMPOSITION

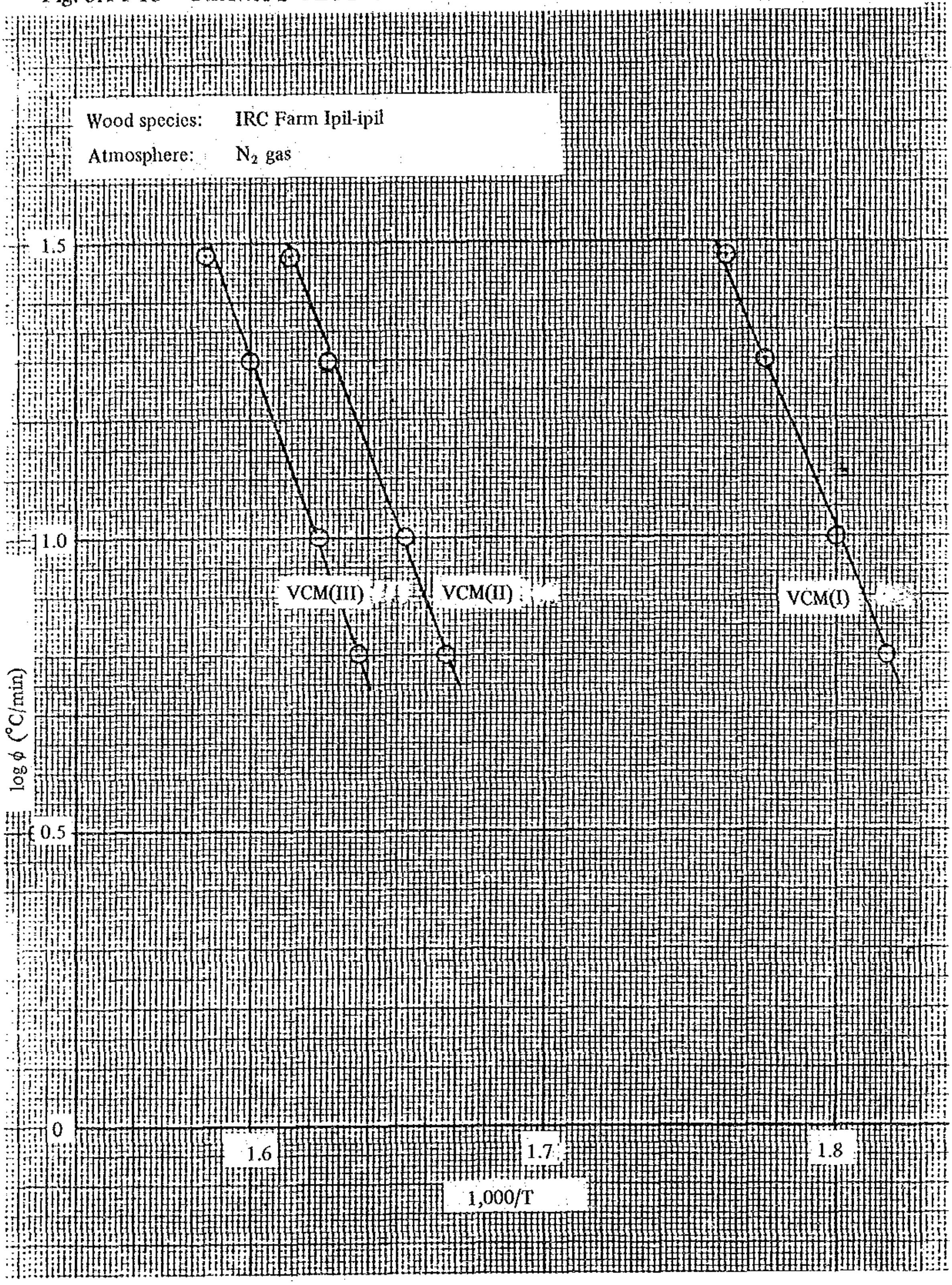


Fig. 5A-1-16 OZAWA'S PLOT OF DAVAO MIXED SAWDUST DECOMPOSITION

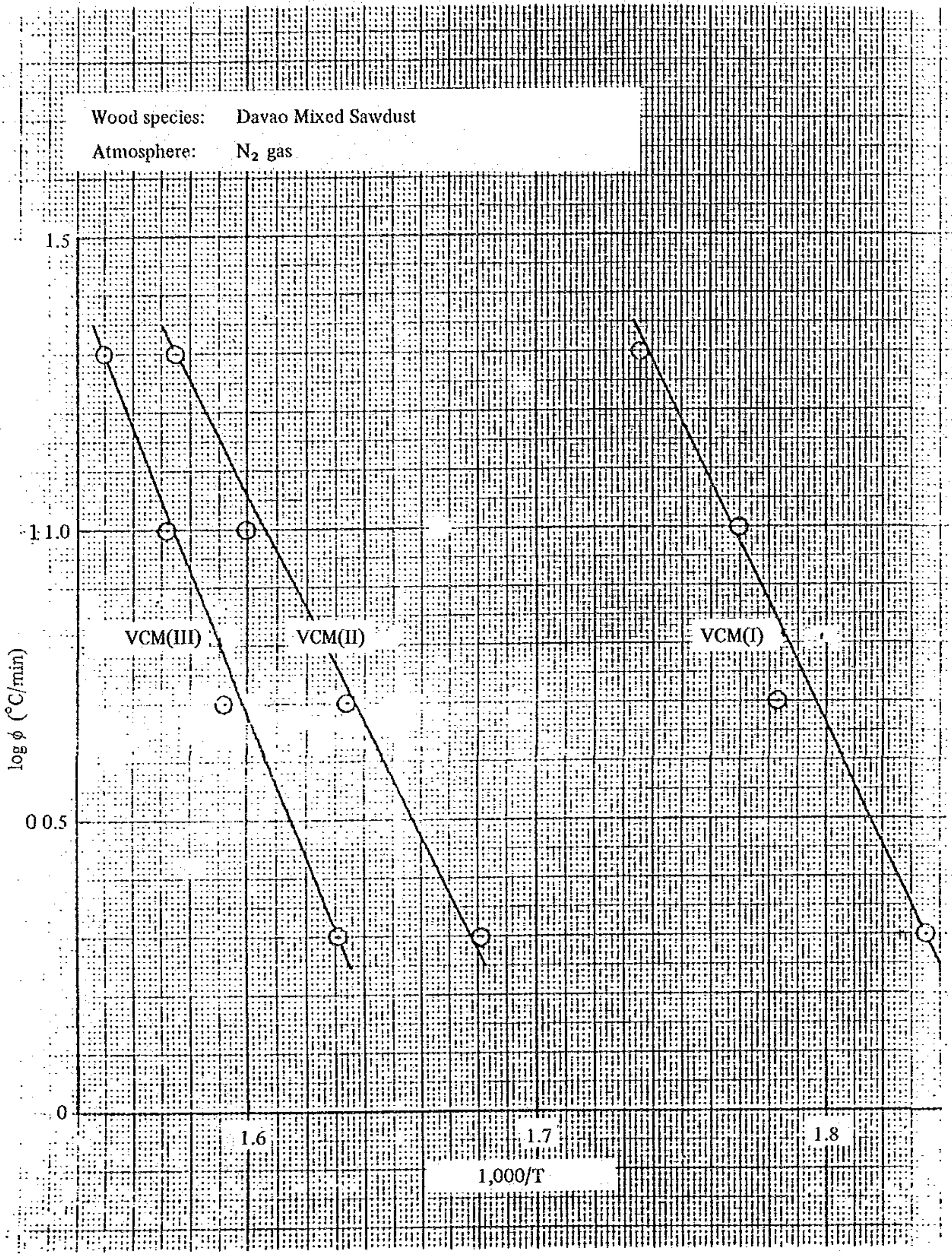


Fig. 5A-1-17 OZAWA'S PLOT OF QUEZON CITY RED LAUAN DECOMPOSITION

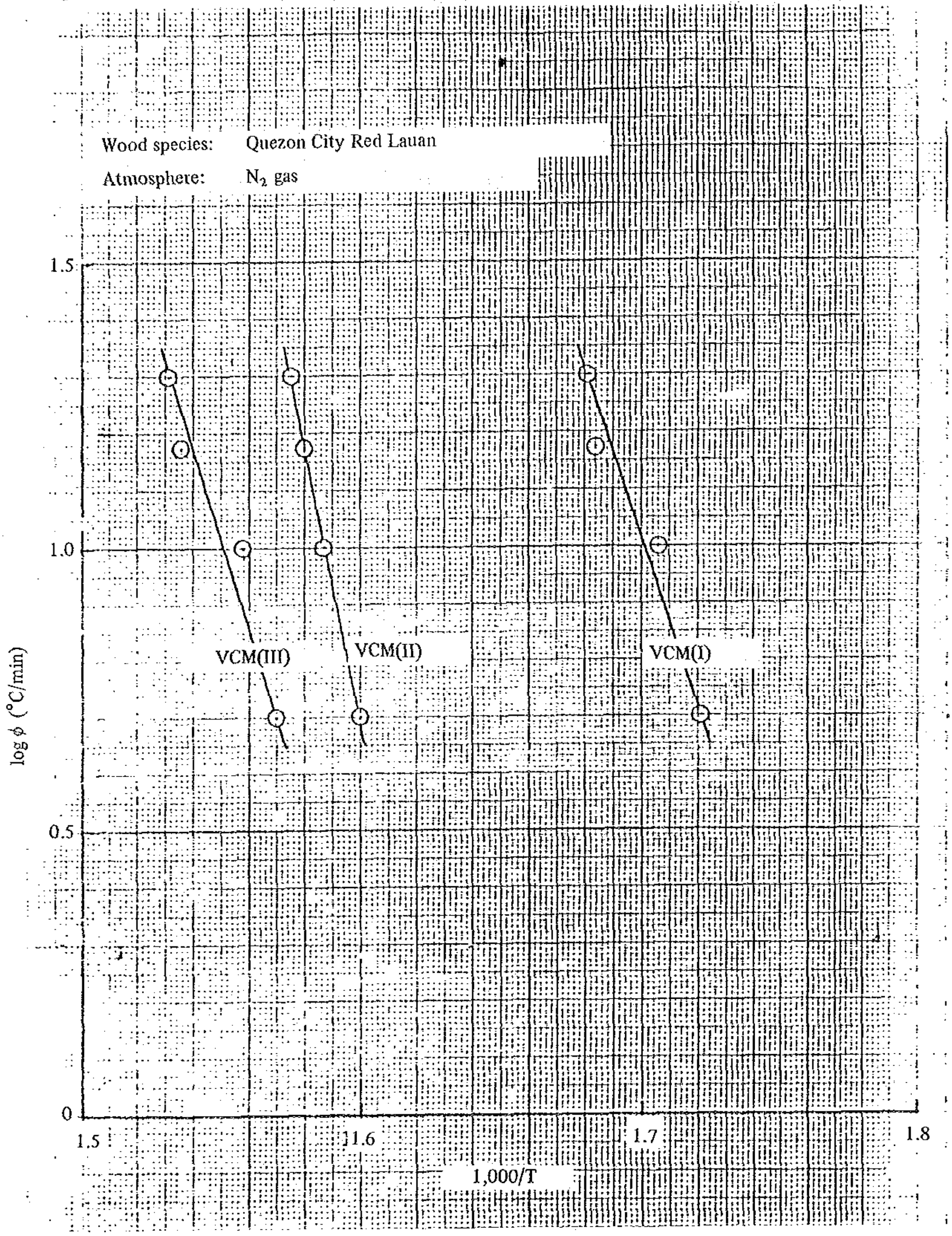


Fig. 5A-1-18 OZAWA'S PLOT OF DAVAO WHITE LAUAN DECOMPOSITION

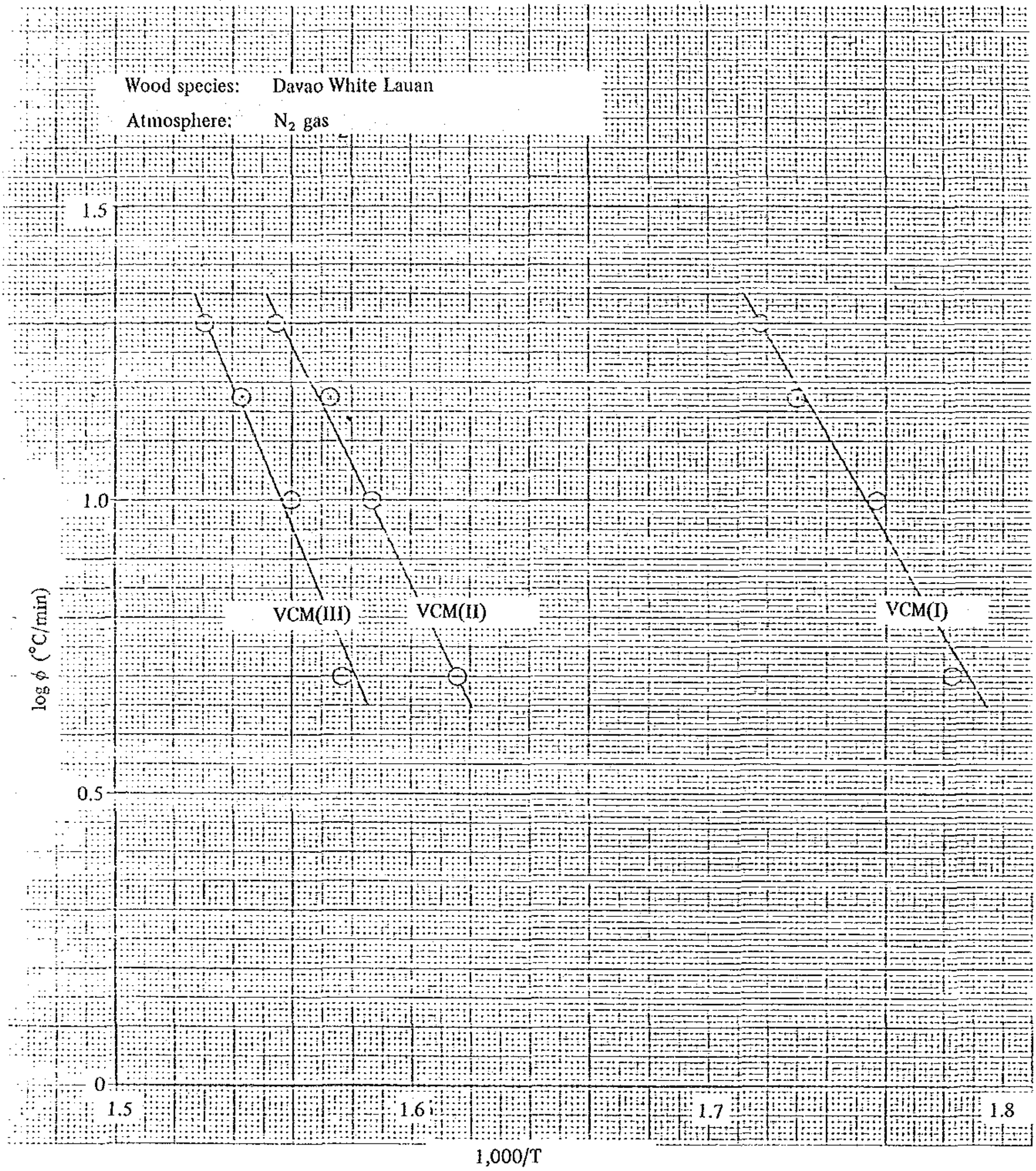


Fig. 5A-1-19 OZAWA'S PLOT OF JAPANESE CEDAR DECOMPOSITION

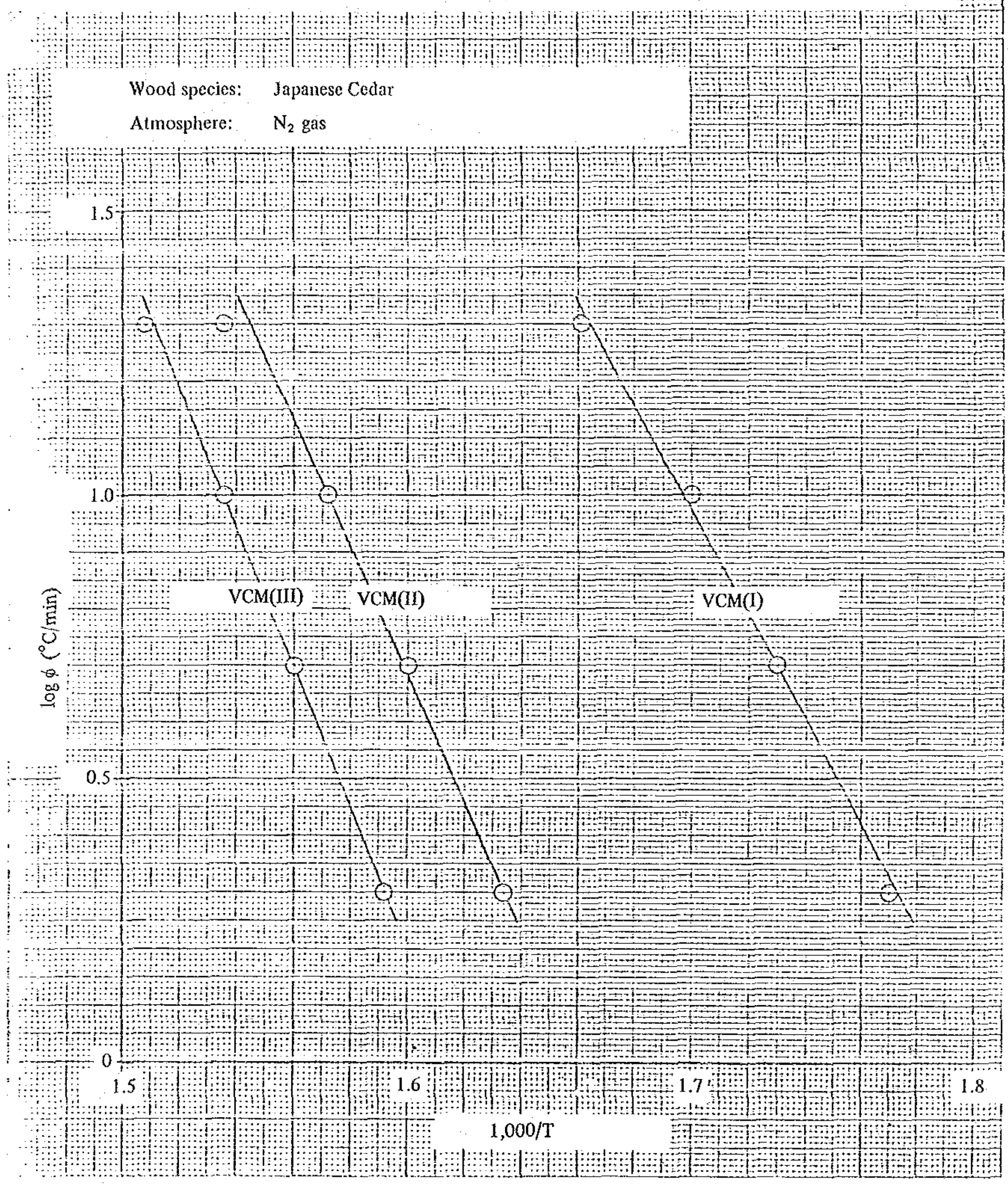


Fig. 5A-1-20 OZAWA'S PLOT OF JAPANESE CYPRESS DECOMPOSITION

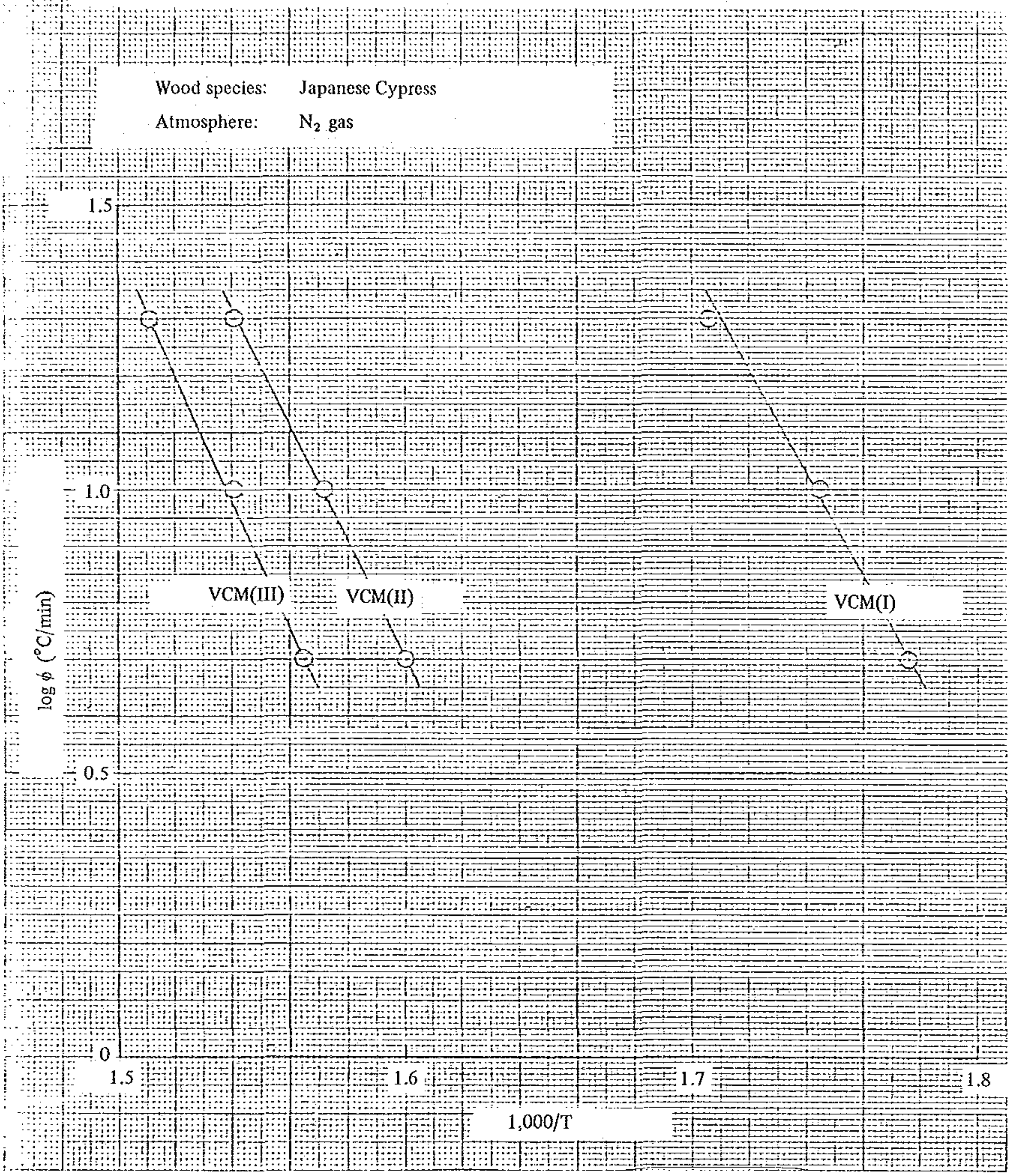


Fig. 5A-1-21 OZAWA'S PLOT OF DAVAO FALCATA DECOMPOSITION

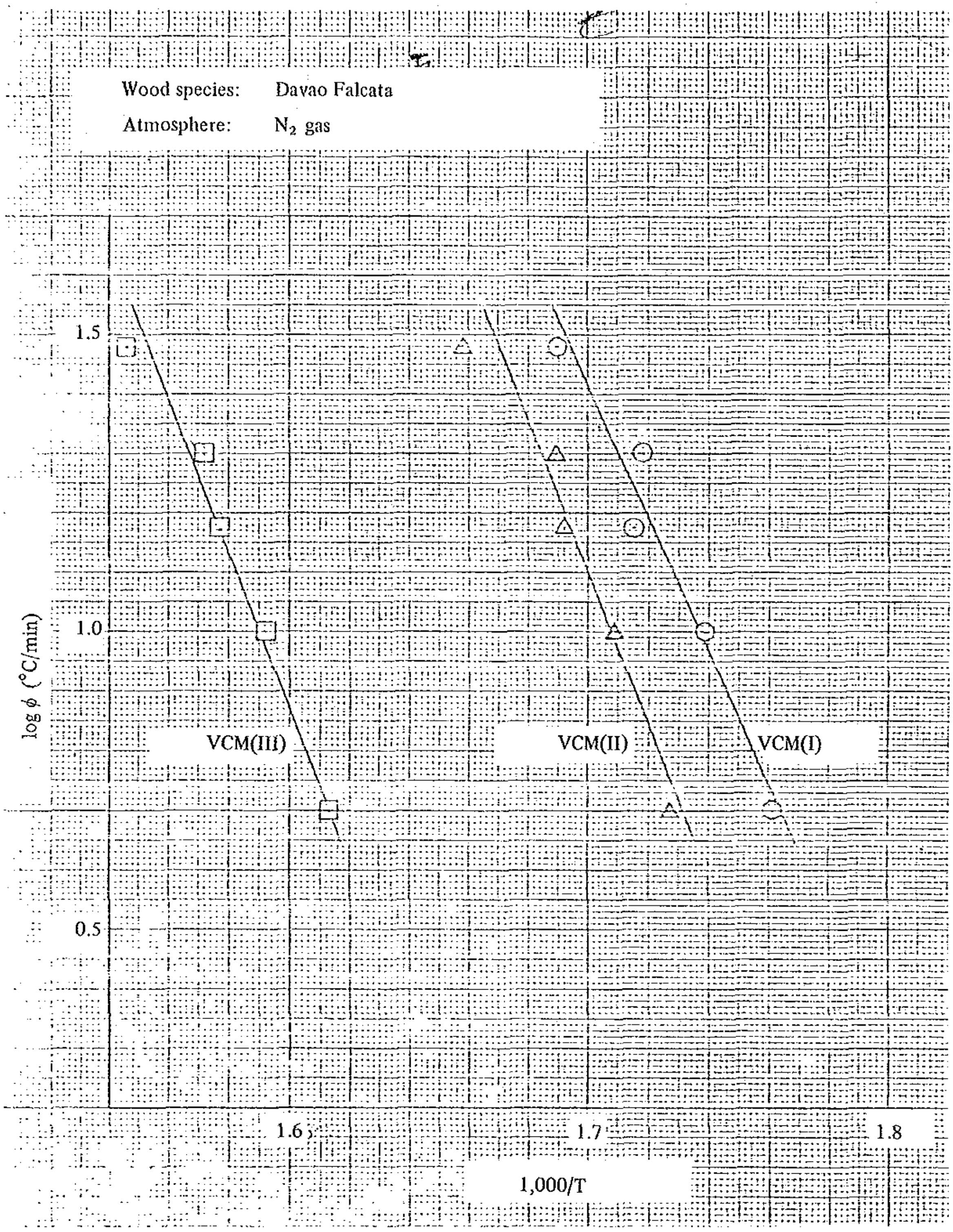


Fig. 5A-1-22 OZAWA'S PLOT OF MOLINO FARM KAKAUATE DECOMPOSITION

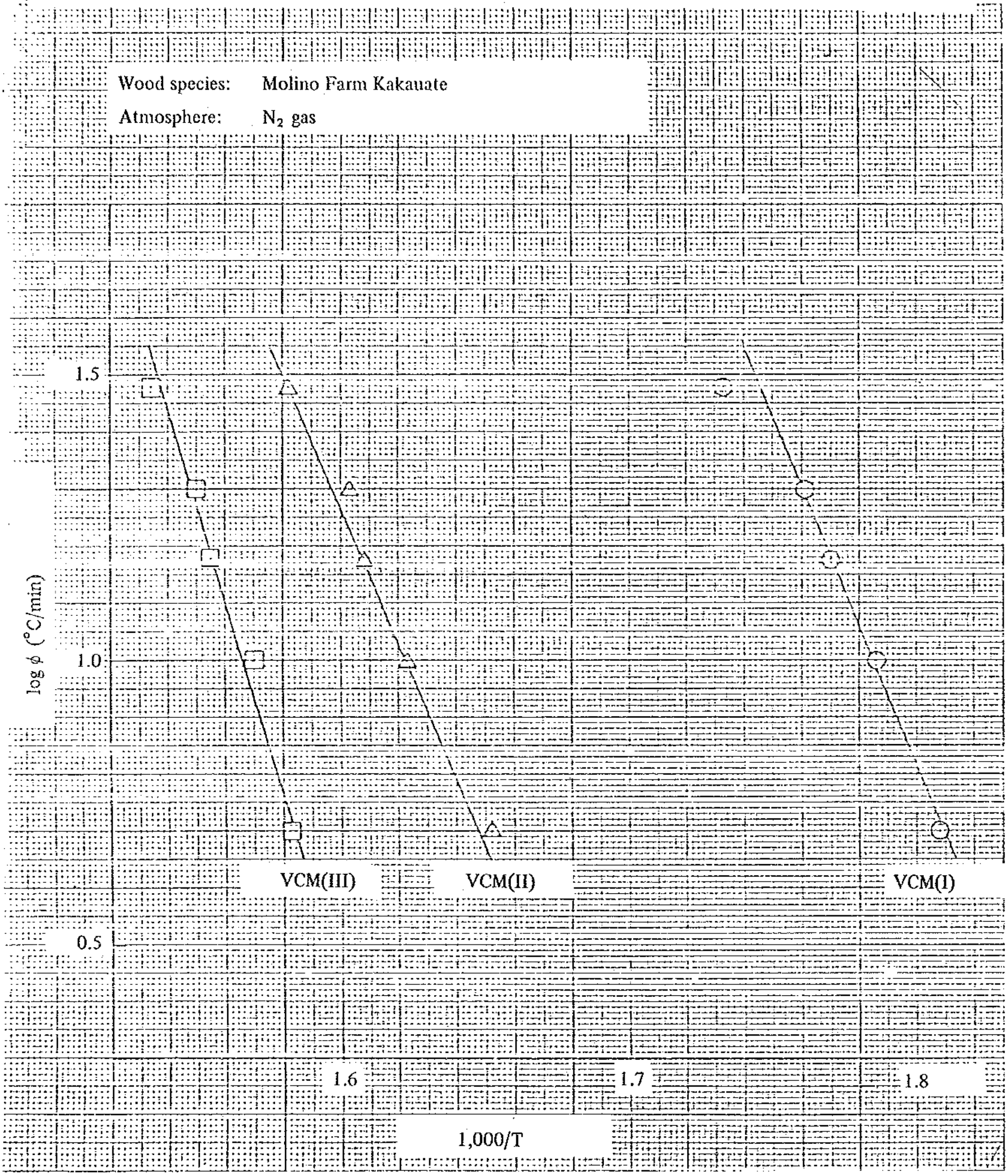


Fig. 5A-1-23 OZAWA'S PLOT OF LAGUNA COIR-DUST DECOMPOSITION

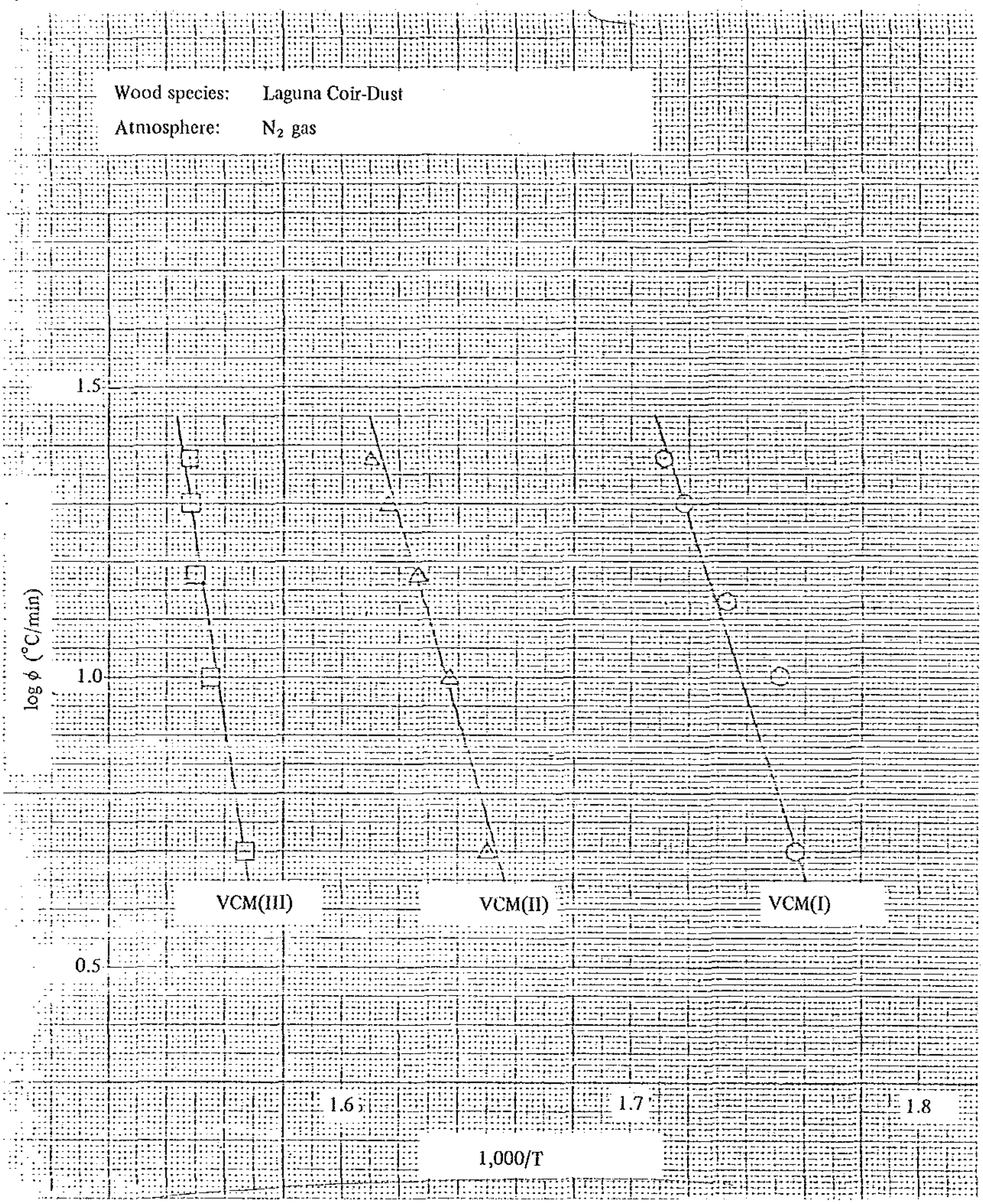


Fig. 5A-1-24 OZAWA'S PLOT OF APITONG DECOMPOSITION

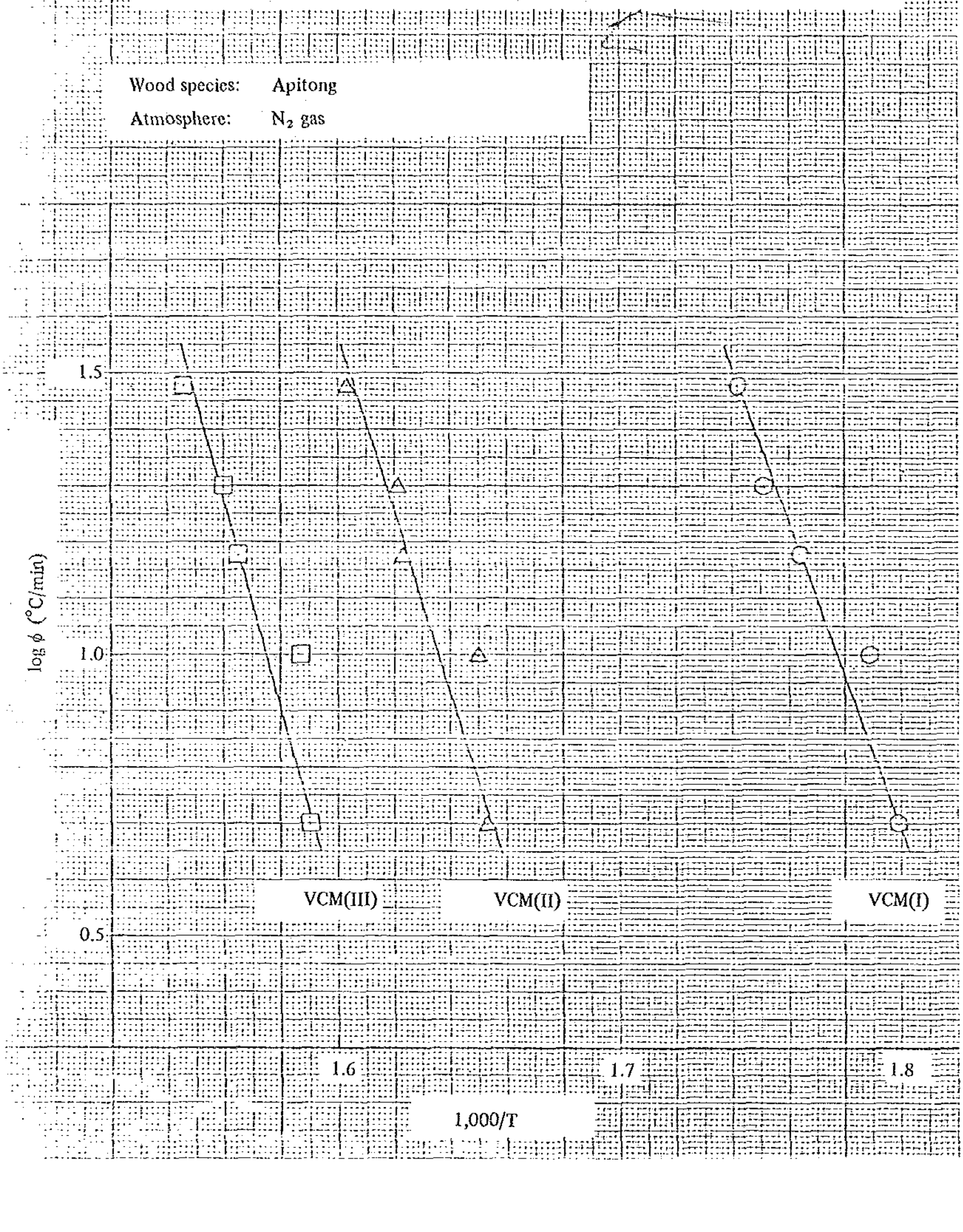


Fig. 5A-1-25 THERMAL DECOMPOSITION REACTION OF APITONG IN NITROGEN

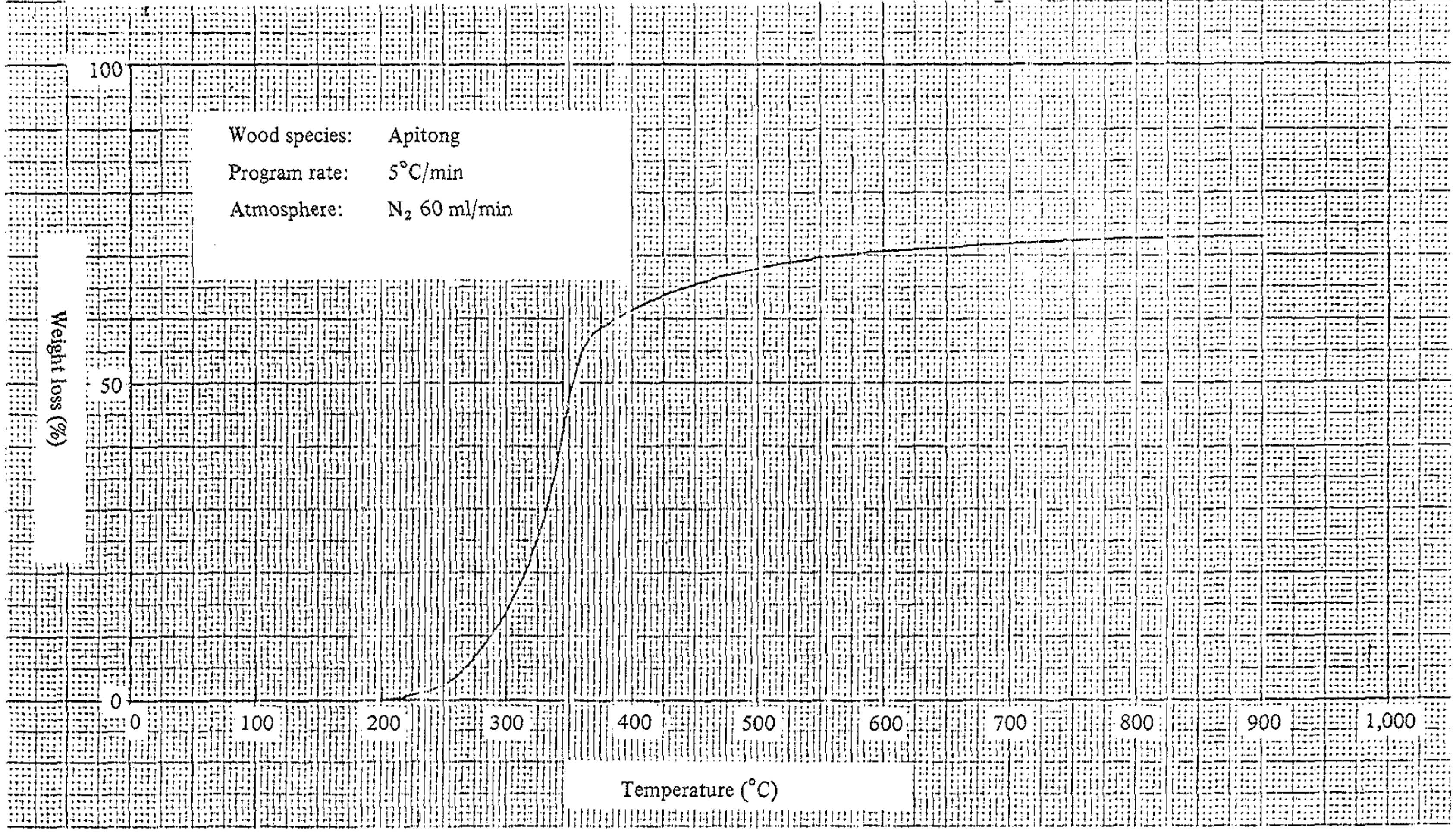


Fig. 5A-1-26 THERMAL DECOMPOSITION REACTION OF QUEZON CITY RED LAUAN IN NITROGEN

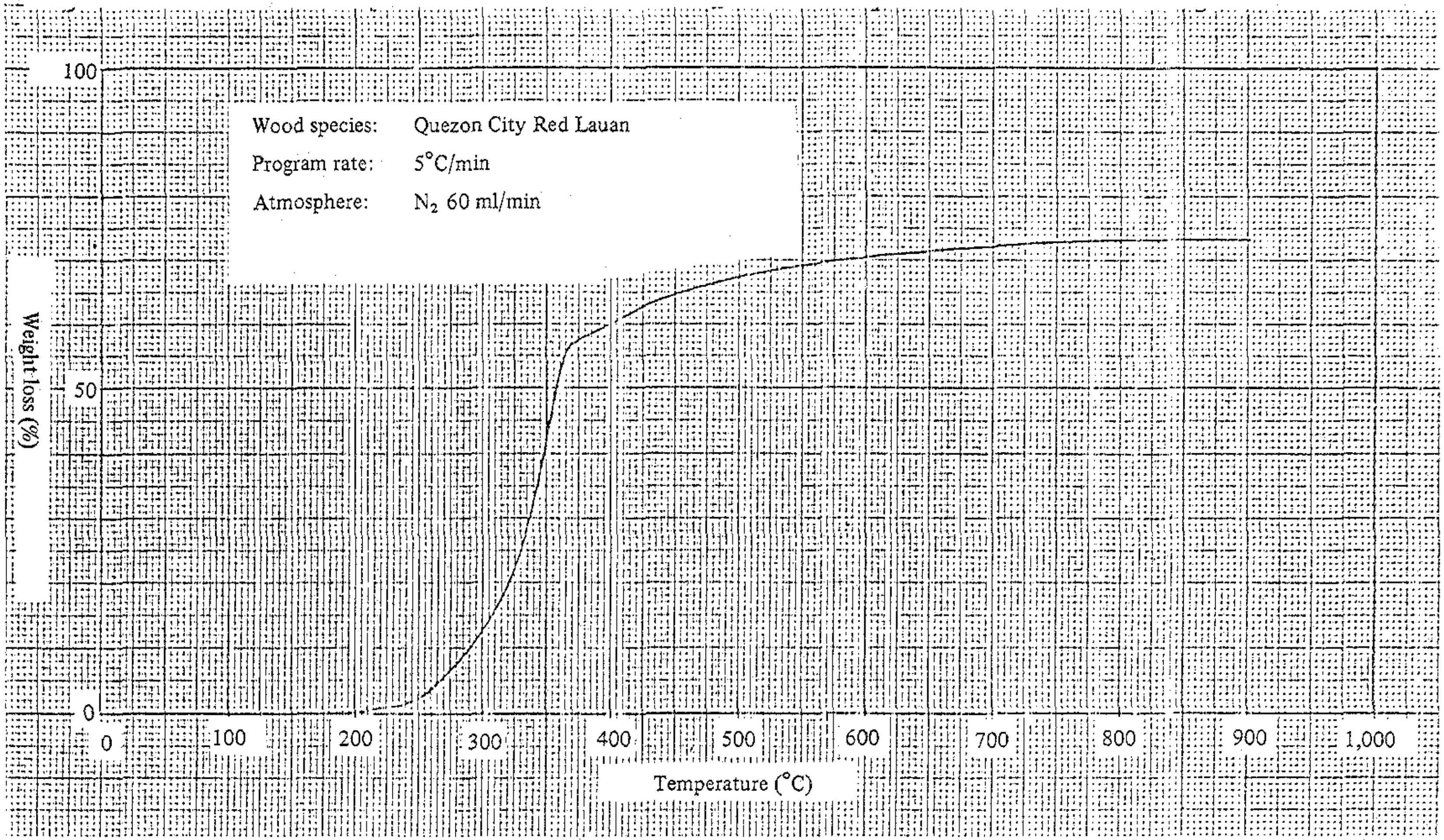


Fig. 5A-1-27 THERMAL DECOMPOSITION REACTION OF DAVAO MIXED SAWDUST IN NITROGEN

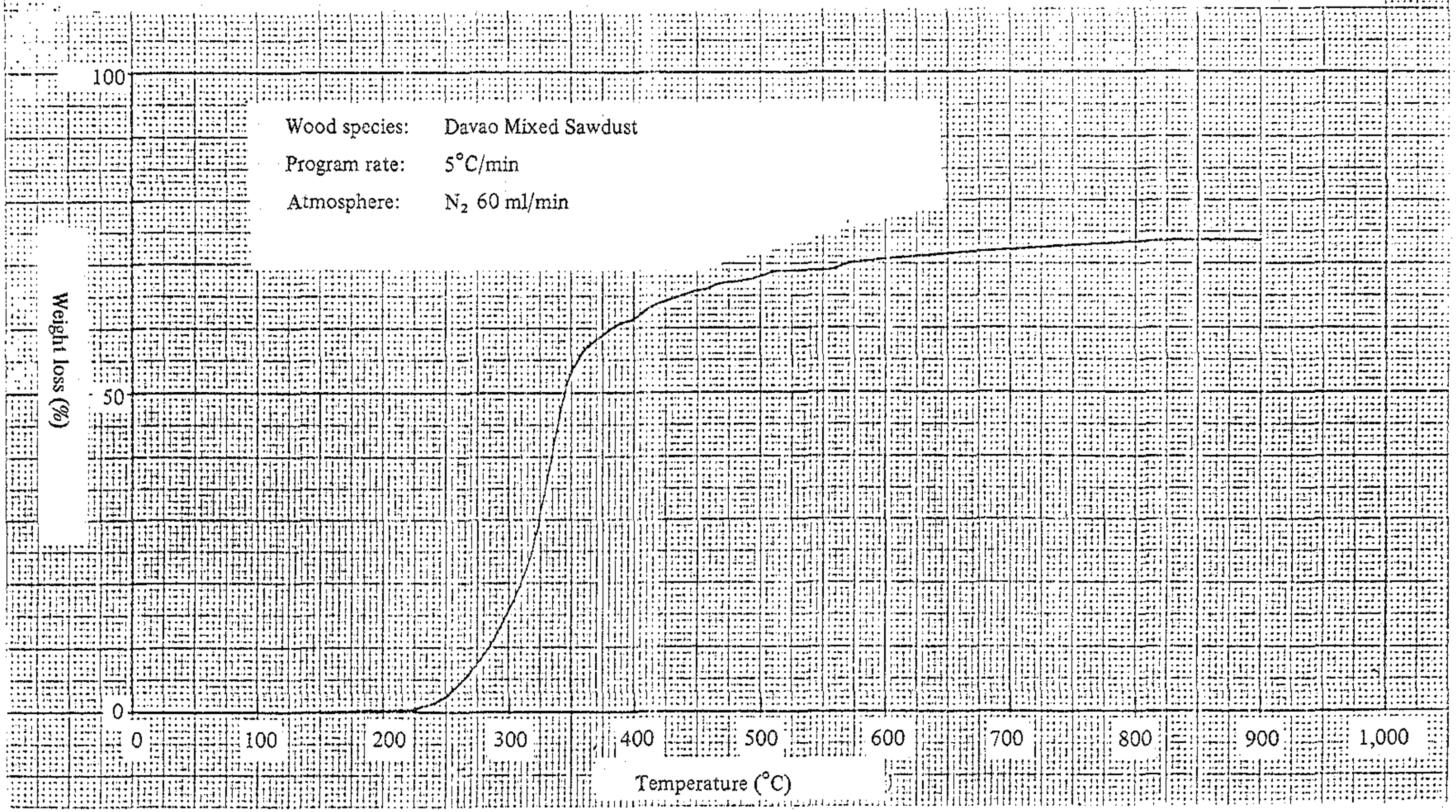


Fig. 5A-1-28 THERMAL DECOMPOSITION REACTION OF IDC MIXED SAWDUST IN NITROGEN

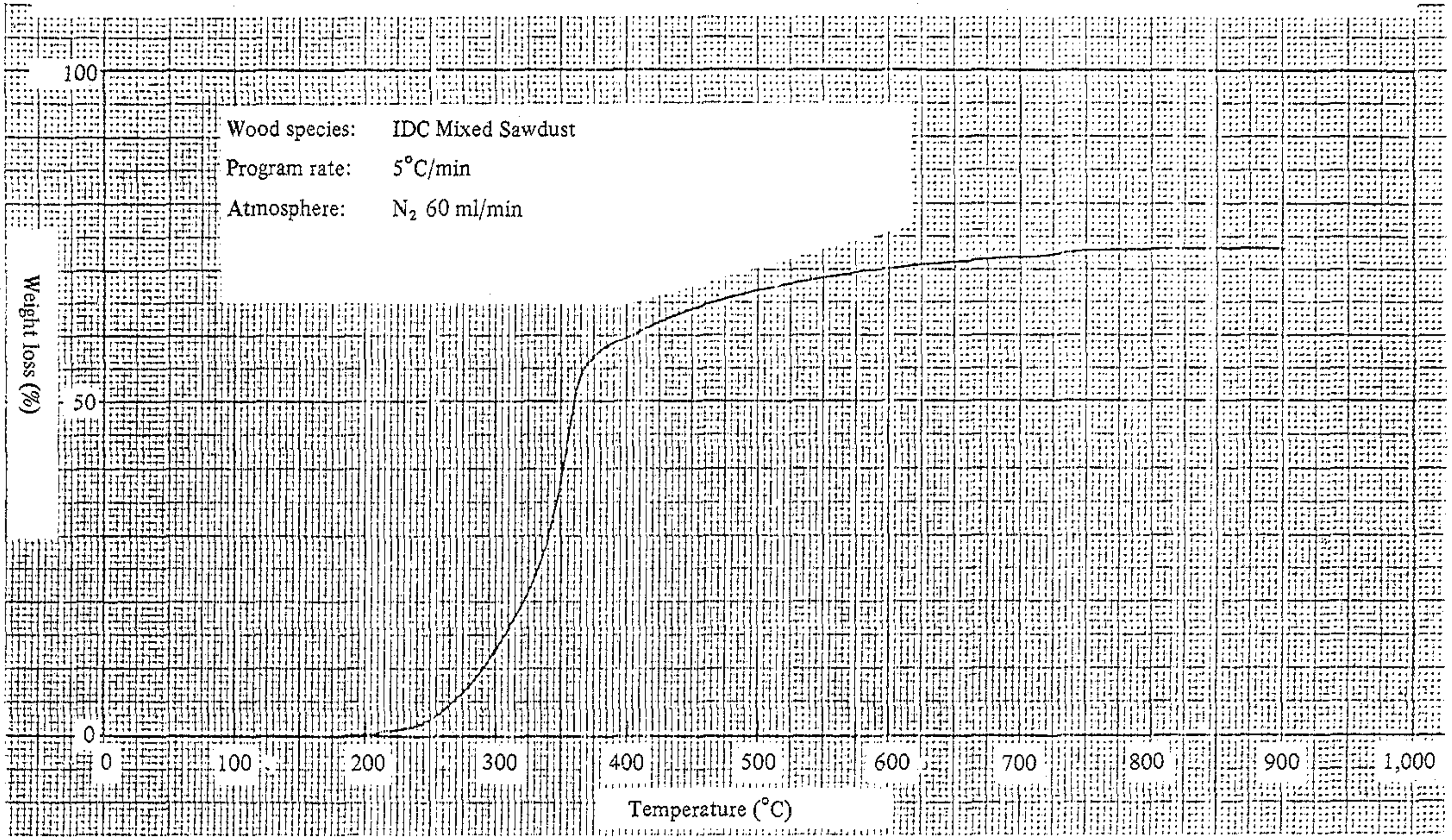


Fig. 5A-1-29 THERMAL DECOMPOSITION REACTION OF JAPANESE CYPRESS IN NITROGEN

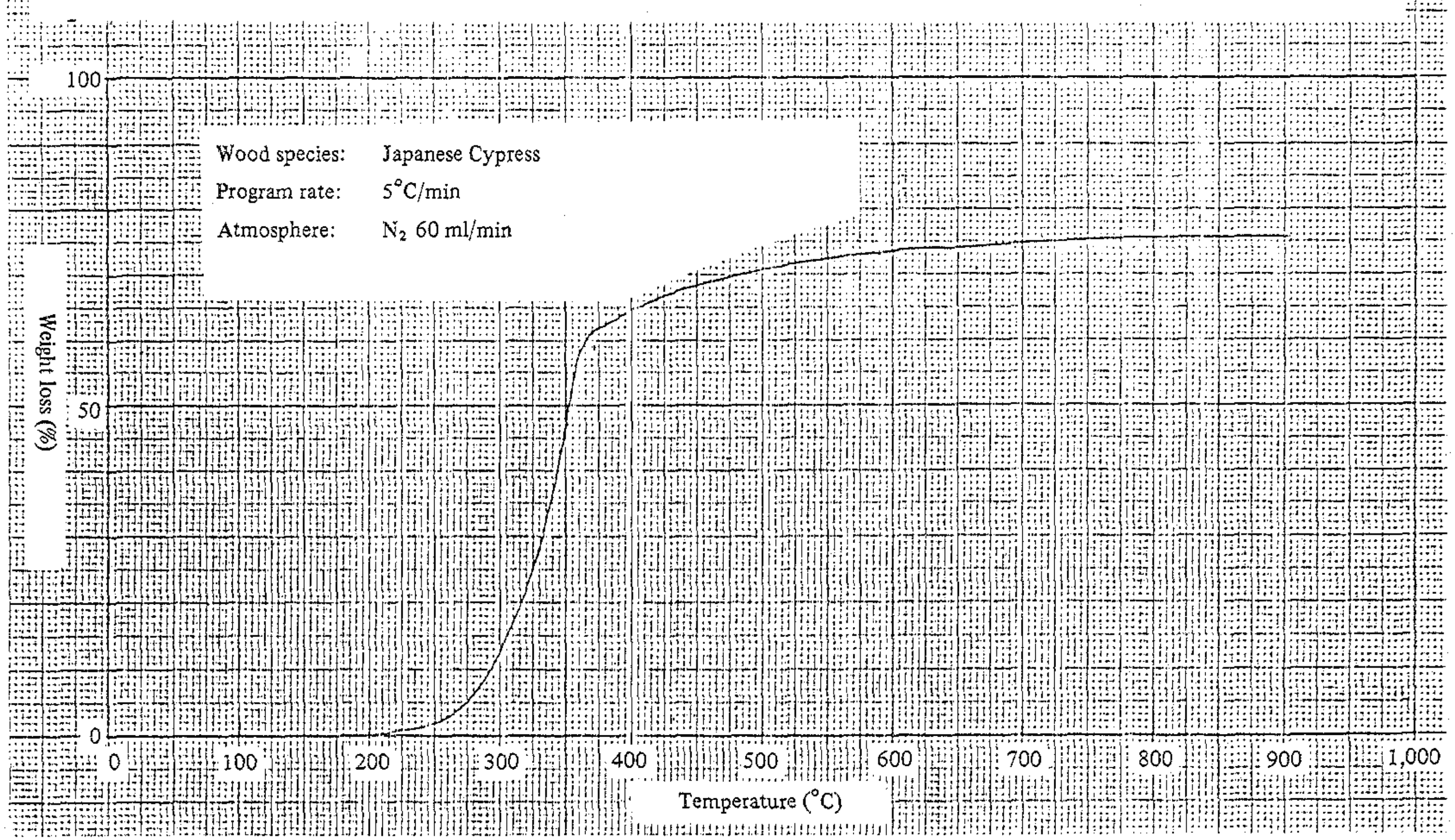


Fig. 5A-1-30 THERMAL DECOMPOSITION REACTION OF DAVAO WHITE LAUAN IN NITROGEN

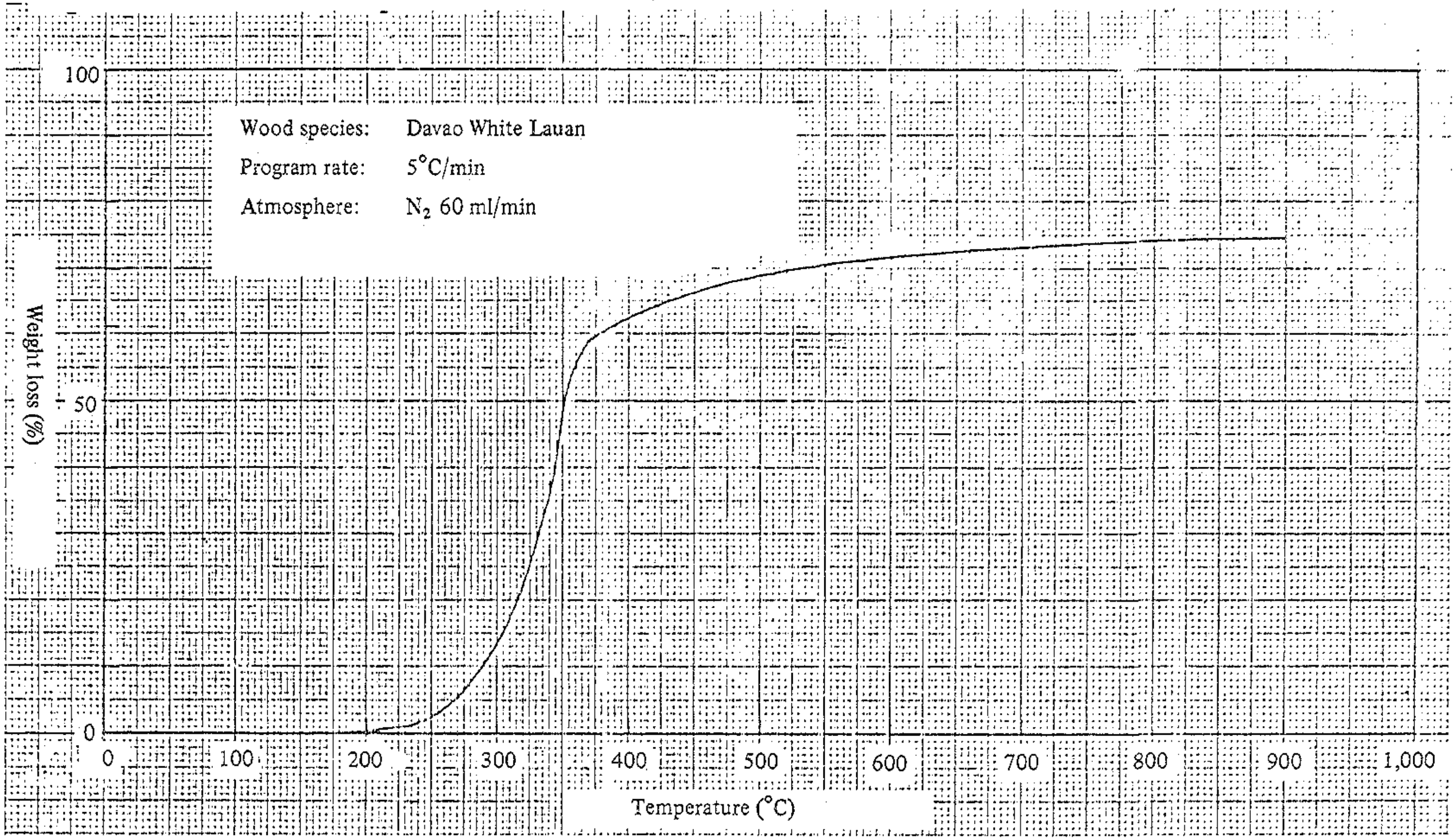


Fig. 5A-1-31 THERMAL DECOMPOSITION REACTION OF JAPANESE CEDAR IN NITROGEN

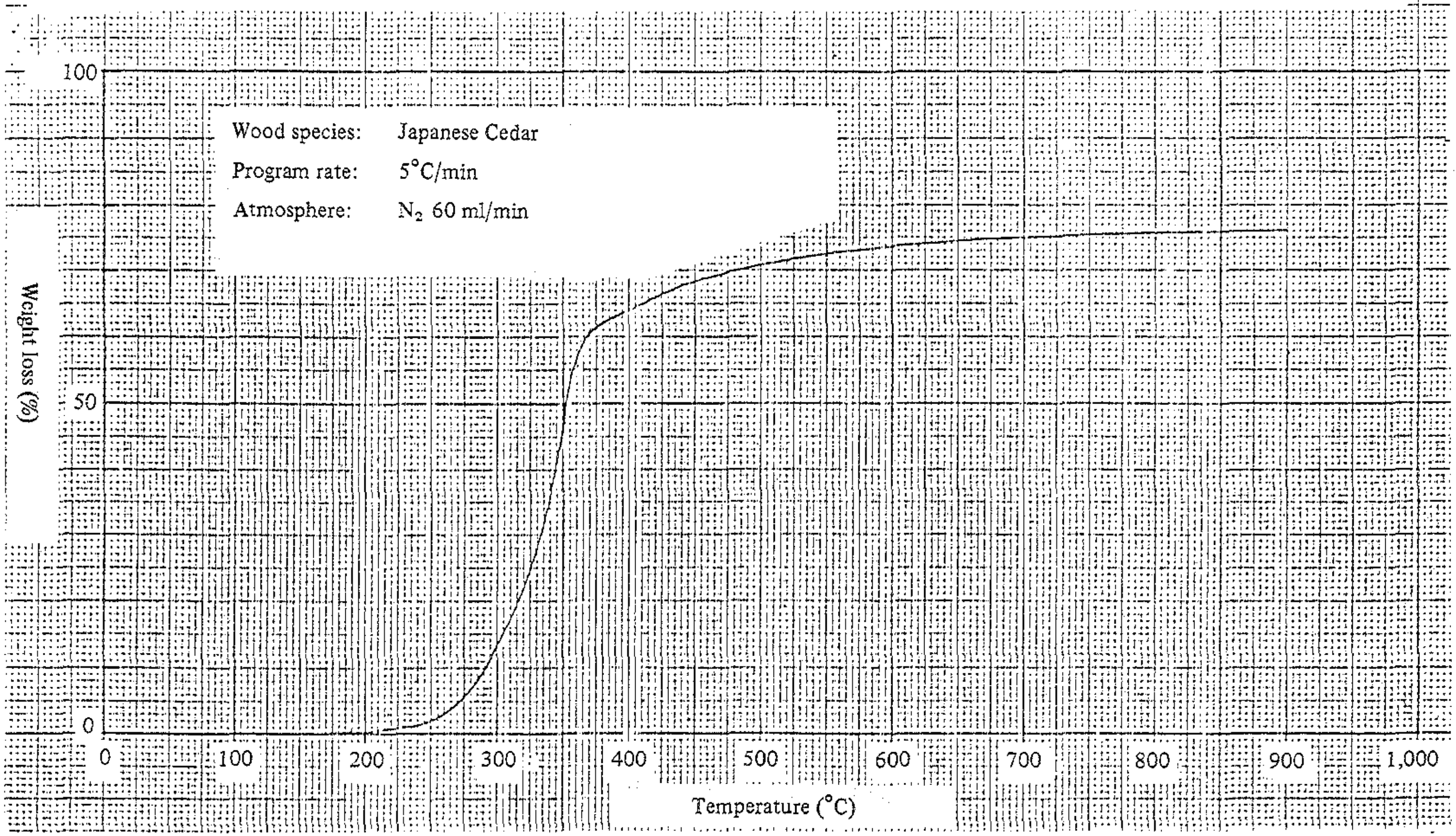


Fig. 5A-1-32 THERMAL DECOMPOSITION REACTION OF EAST ASIA MIXED SAWDUST IN NITROGEN

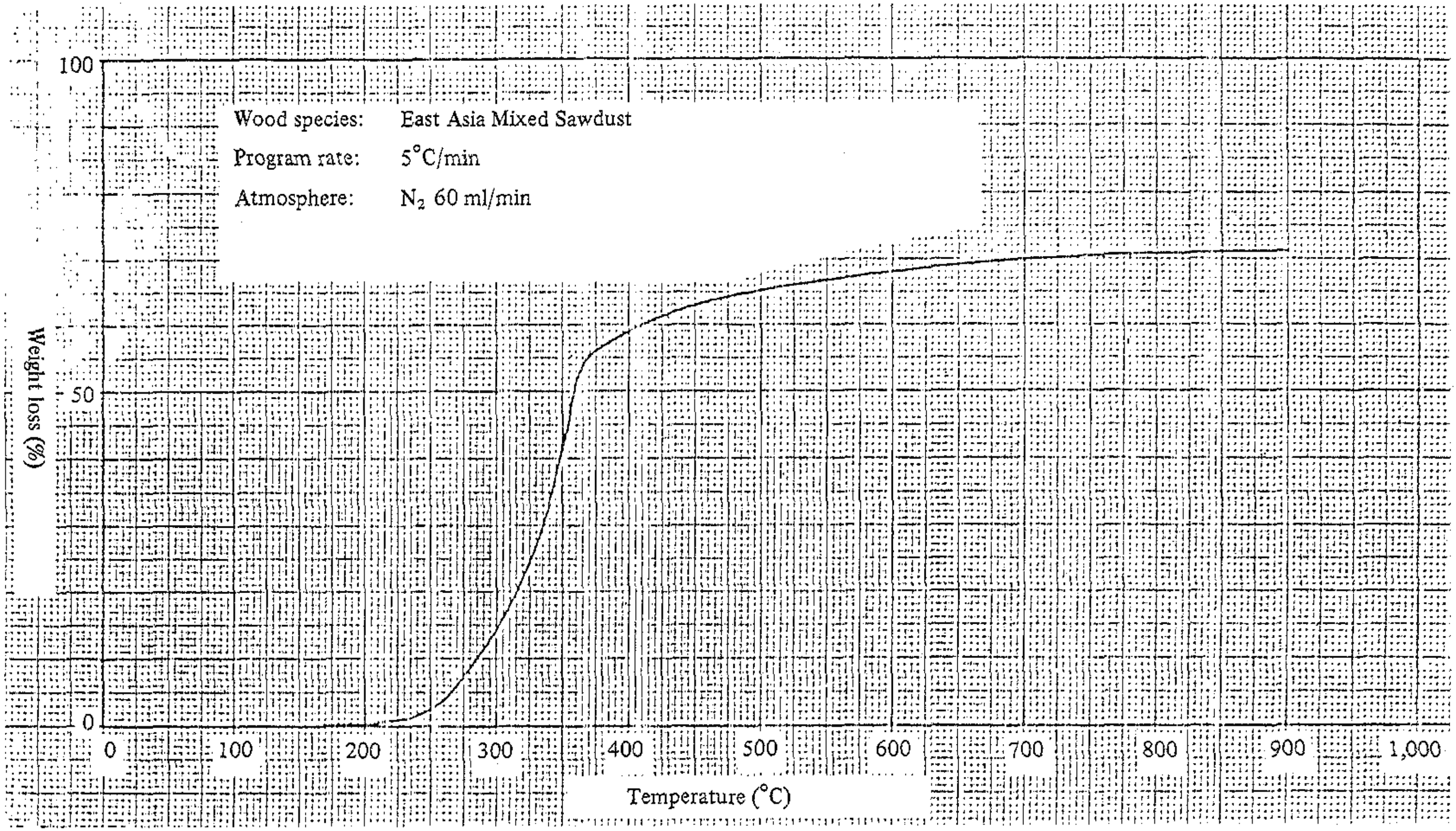


Fig. 5A-1-33 THERMAL DECOMPOSITION REACTION OF DAVAO FALCATA IN NITROGEN

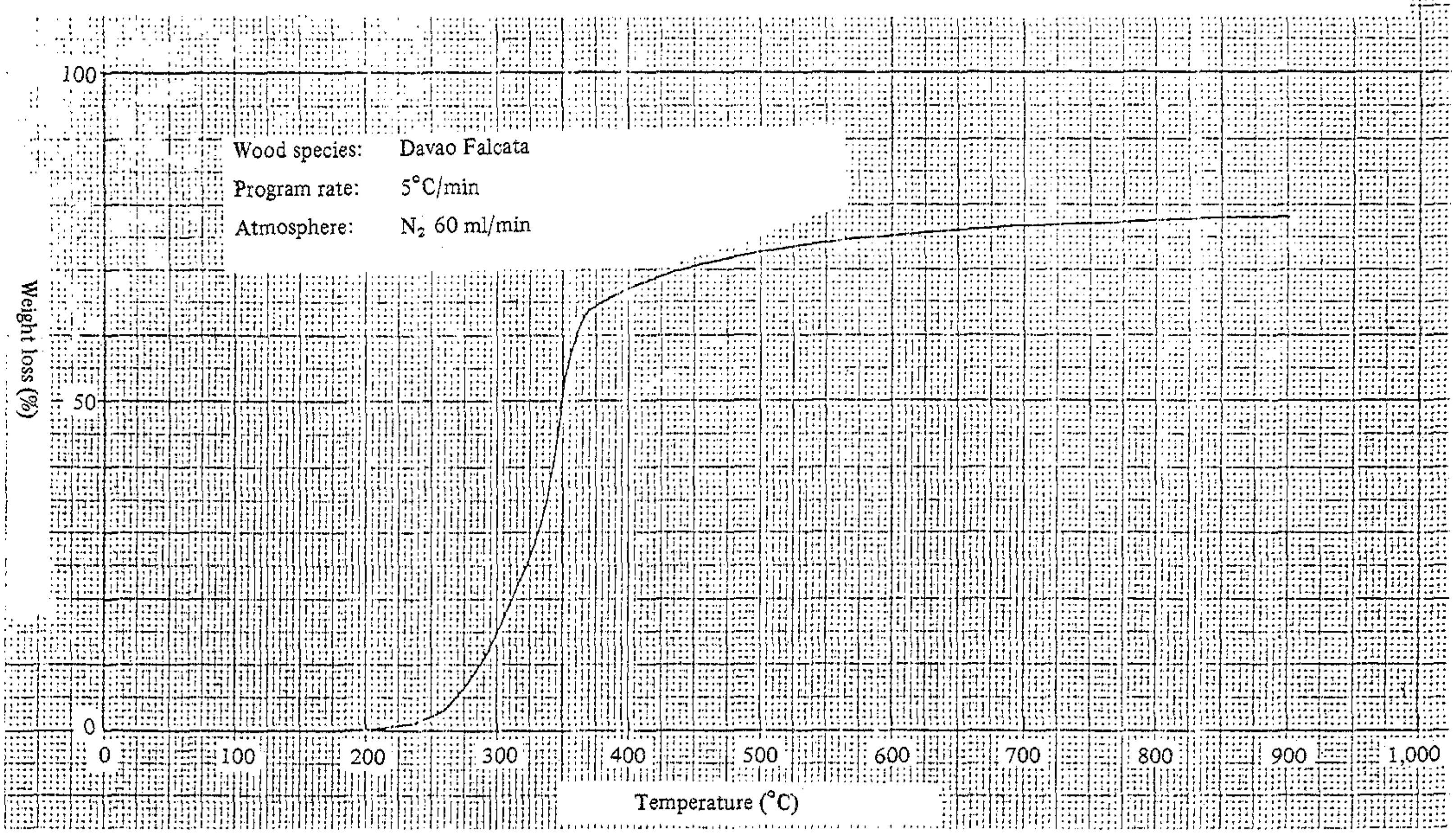


Fig. 5A-1-34 THERMAL DECOMPOSITION REACTION OF MOLINO FARM KAKAUATE IN NITROGEN

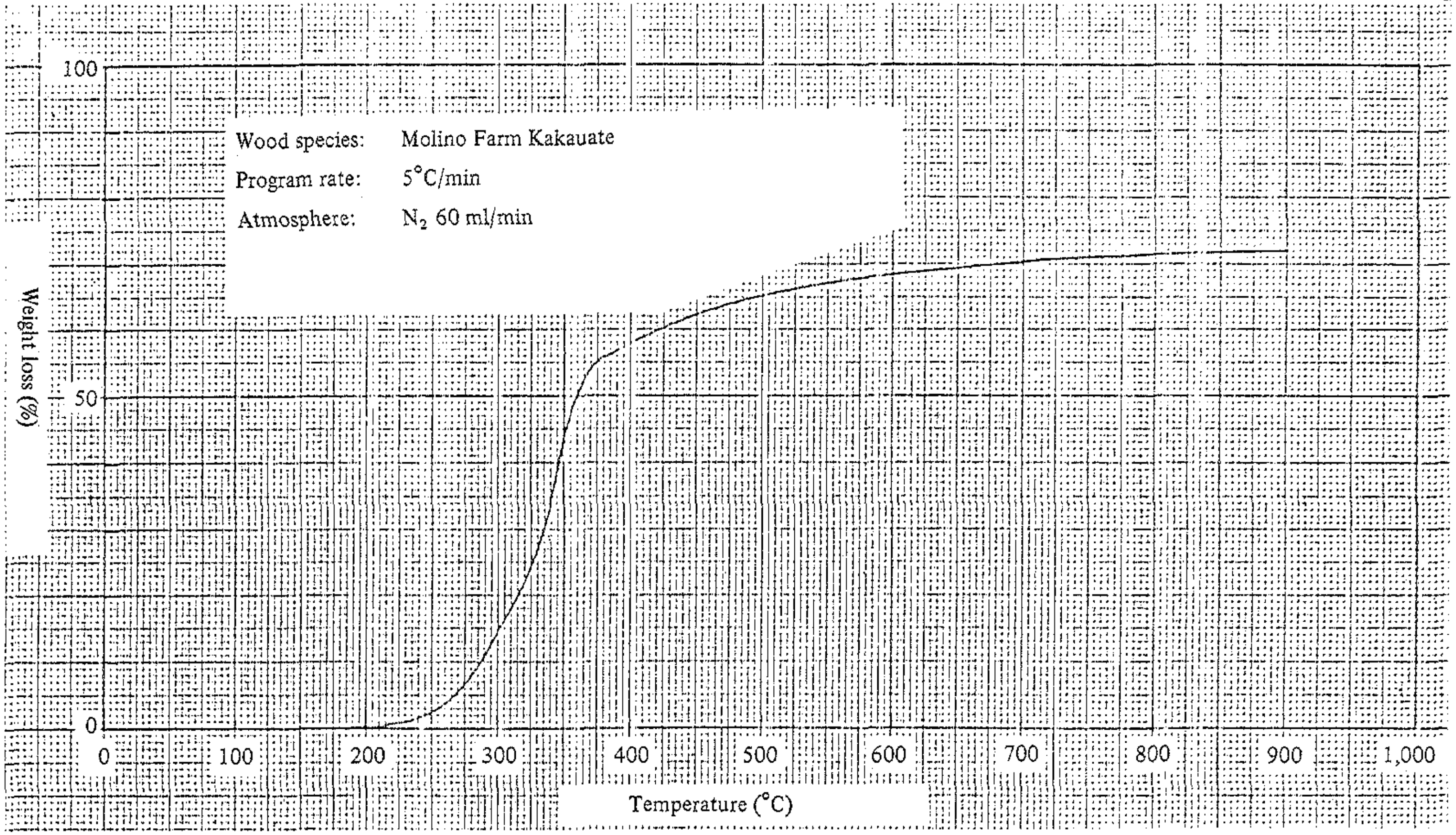


Fig. 5A-1-35 THERMAL DECOMPOSITION REACTION OF LAGUNA COIR DUST IN NITROGEN

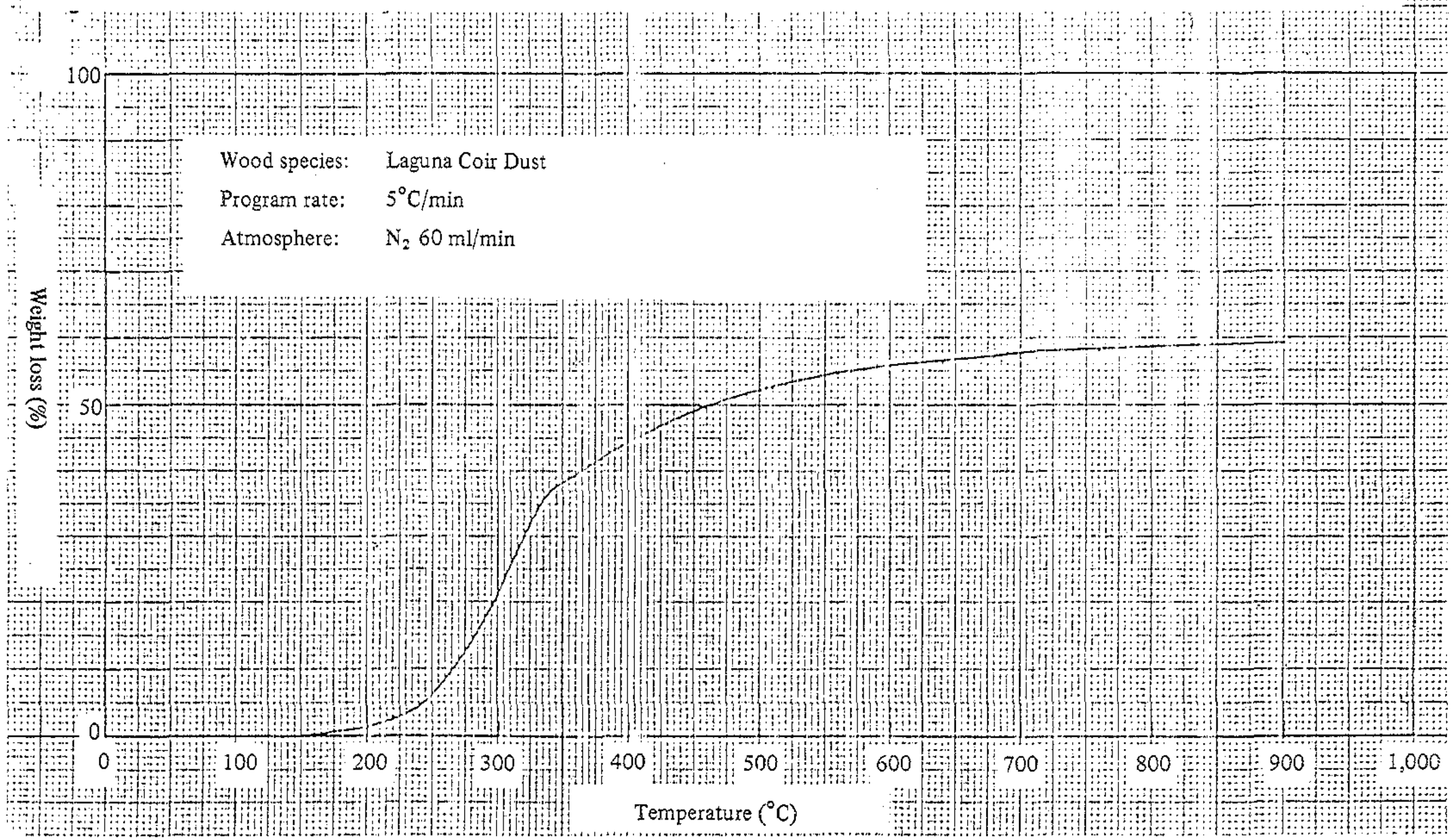


Table 5A-1-19 ACTIVATION ENERGY OF THREE COMPONENTS [VCM (I), VCM (II) AND VCM (III)] AT WOOD SPECIE'S DECOMPOSITION

Wood species	Activation energy		
	VCM* (I)	VCM* (II)	VCM* (III)
Davao white lauan	3.10×10^4 joule·mol^{-1}	3.64×10^4 joule·mol^{-1}	4.35×10^4 joule·mol^{-1}
Davao mixed sawdust	3.80×10^4	3.56×10^4	4.46×10^4
Quezon City red lauan	5.44×10^4	8.67×10^4	5.87×10^4
IRC farm Ipil-ipil	4.31×10^4	4.68×10^4	4.92×10^4
Davao Falcata	4.04×10^4	4.59×10^4	4.71×10^4
Laguna coir dust	5.58×10^4	6.04×10^4	11.44×10^4
Apitong	4.90×10^4	5.84×10^4	6.57×10^4
Molino farm kakauate	4.43×10^4	4.31×10^4	6.04×10^4
Japanese cedar	3.35×10^4	4.15×10^4	4.49×10^4
Japanese cypress	3.32×10^4	3.77×10^4	4.49×10^4

*: Volatile combustible matter

(b) Volatile combustible matter, broadly classified, may be divided into three compositions: VCM(I), low molecular weight component having a peak combustion point of 280–300°C, VCM(II) having a peak combustion point of 340–360°C, and VCM(III) having a peak combustion point of 340–375°C (unstable).

VCM(I)	10–25%
VCM(II)	30–38%
VCM(III)	10–20%
Total VCM	70% approx.

Qualitatively, Davao white lauan and Davao mixed sawdust possess properties which are very similar to those of Japanese cedar and Japanese cypress.
Among these woods, IRC Farm Ipil-ipil has a total VCM content of roughly 54%, which is about 20% less than that of other woods. Also, the peak combustion point temperatures of VCM(I), VCM(II) and VCM(III) are relatively low and lie around 20–30°C.

(c) Regarding fixed carbon content, IRC Farm Ipil-ipil has a high content of about 41%, while other woods have a low content of around 26–33%.

(d) Regarding activation energy, which represents the decomposition reaction and is usable for evaluating the thermal stability of substances, the energy level can be obtained by thermal analysis.
The activation energy ΔE (joule) was obtained in connection with Japanese cedar, Japanese cypress, Davao mixed sawdust, Davao white lauan, Quezon City red lauan and IRC Farm Ipil-ipil.
With woods other than Quezon City red lauan, the thermal stability was higher in the order of VCM(I) < VCM(II) < VCM(III). Specifically, these values were VCM(I): $3.3–4.3 \times 10^4$ joule, VCM(II): $3.6–4.7 \times 10^4$ joule, and VCM(III): $4.0–4.9 \times 10^4$ joule.
However, with Quezon City red lauan, the thermal stability was in the order of VCM(I) < VCM(III) $\ll$ VCM(II), indicating that the activation energy value of VCM(II) is very high compared with that of other kinds of woods. And the activation energy values were respectively VCM(I): 5.4×10^4 joule, VCM(II): 8.7×10^4 joule, and VCM(III): 5.9×10^4 joule.

5.4.7 Activation Test

1) Activation Conditions

Activation tests were conducted on the sawdust chars shown in Paragraph 5.1, Table 5A-1-1, by using the circular fluidized bed type activation furnace described in Item 5.3.2.

In order to obtain optimum reaction conditions for each of these sawdust chars, tests were conducted by changing the compositions and volumes of activation gas induced into the activation furnace and also by changing the feed quantity of sawdust char.

In the activation reaction, shortening the raw material retension time in the furnace, increasing the oxygen feed rate and raising the furnace temperature to over 1,050°C provided a high yield of activated carbon having numerous micro-pores. But activated carbon obtained by this method was characterized by poor adsorption for coloring matter having large molecular weights and was therefore found to be unsuitable for use in liquid state.

In order to produce activated carbon having numerous macro-pores, it will be necessary to use a comparatively large volume of steam and to control the circulating flow so as to prolong the period of retension of activated carbon in the furnace.

However, since these reactions are designed to further activate the capillary pores formed in sawdust char by means of the activation gas, the pore size of surface area of the activated carbon will be influenced largely by the kinds of tree of the raw material. This has been elucidated even by the results of basic tests conducted by ITIT (International Transfer of Industrial Technology).

The kinds of trees used in these activation tests were characterized by denser specific gravity and smaller capillary tube volumes compared with those of the pine, cedar and cypress being used in Japan. Accordingly, in order to obtain activated carbon having a quality level comparable to that of activated carbon produced from Japanese raw materials, a longer reaction time was necessary and the product yield was slightly lower. Table 5A-1-20 shows the activation conditions at near the product yield of 25% and the activated carbon's methylene blue decolourizing power.

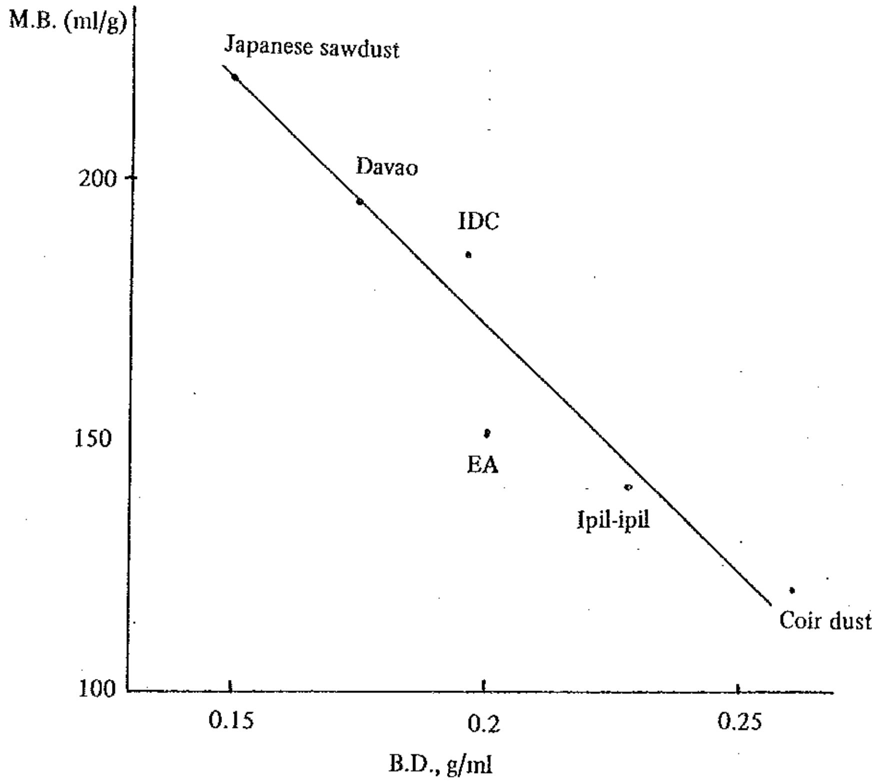
Fig. 5A-1-36 shows the relationship between methylene blue decolorizing power in the proximity of 25% product yield and bulk density of sawdust char. With the same yield, the methylene blue decolorizing power was less, the higher the bulk density of the sawdust char.

Table 5A-1-20 KINDS OF TREE AND TYPICAL ACTIVATION CONDITIONS AND RESULTS

Raw Material	Activation Condition			Yield, %	Methylene blue ml/g	Output, kg/hr
	Air, kg/hr	Steam, kg/hr	Temp. °C			
Davao sawdust	54	17	995	25	200	4.3
Davao white lauan	60	17	1,015	26	190	4.5
IDC sawdust	57	16	1,010	24	190	4.3
Falcata	48	14	995	25	160	3.5
EA sawdust	60	15	1,020	24	150	3.8
Ipil-ipil	60	17	1,015	25	140	3.5
Coir dust	62	23	980	18	140	3.0

Note: The furnace temperature is the temperature at a spot 2.5 m inward from the front part of the furance, measured when the temperature is stabilized.

Fig. 5A-1-36 RELATIONSHIP BETWEEN METHYLENE BLUE DECOLORIZING POWER AND BULK DENSITY AT 25% YIELD



With high density sawdust char, activation rate is slow. As a result, when manufacturing activated carbon having the same adsorbability the yield is decreased conspicuously.

2) Adjustment of Activation Conditions

Activation conditions are adjusted by regulating four variables --- steam quantity, air quantity, circulating gas quantity and raw material supply rate. For example, when working with a large quantities of activation gas flow rate, the raw material supply rate will have to be increased; otherwise, the entire volume of raw material will be reacted and vanished. Also, if only the air feed quantity was increased with respect to a fixed steam quantity, the furnace temperature will rise to accelerate the reaction, resulting in a large loss of raw material. Therefore, adjustment of activation conditions constitutes a vital economic factor.

In view of the situation, a test was conducted on activation conditions at 25% yield --- conditions which would be economical and also provide products fully acceptable on the market. Specifically, the test was conducted in connection with the interrelationship among raw material, steam volume and air feed rate, and the optimum activation temperature under these conditions. As a result, the relationship shown in Fig. 5A-1-37 was obtained through the data based on operational results by which the temperature range enabling stabilized operation of activation furnace (shaded part in Fig. 5A-1-37) was eludicated.

Table 5A-1-21 shows a typical example of circular fluidized bed activation furnace operating conditions and product methylene blue decolorizing power (mg/g) by the testing method of Government Industrial Research Institute, Hokkaido.

3) Relationship with Methylene Blue Decolorizing Power

Fig. 5A-1-38 shows the relationship between methylene blue (M.B.) decolorizing power and activated carbon yield in connection with activated carbon obtained from various kinds of sawdust char.

These results show that all activated carbons, with the exception of coir dust activated carbon, display excellent adsorbability and that their M.B. values lie in the range of 170–220 ml/l at yield of around 20%, indicating that powdered activated carbon better than those currently available on the market can be obtained. Also, regarding the M.B.-Yield relationship, the linear equations shown below (see Table 5A-1-22) were obtained which enable the performances of activated carbon products to be known with ease at time of plant operation.

Fig. 5A-1-37 INTERRELATIONSHIP AMONG ACTIVATION CONDITIONS, FURNACE TEMPERATURE AND OPTIMIZED RAW MATERIAL SUPPLY RATE (IDC SAWDUST)

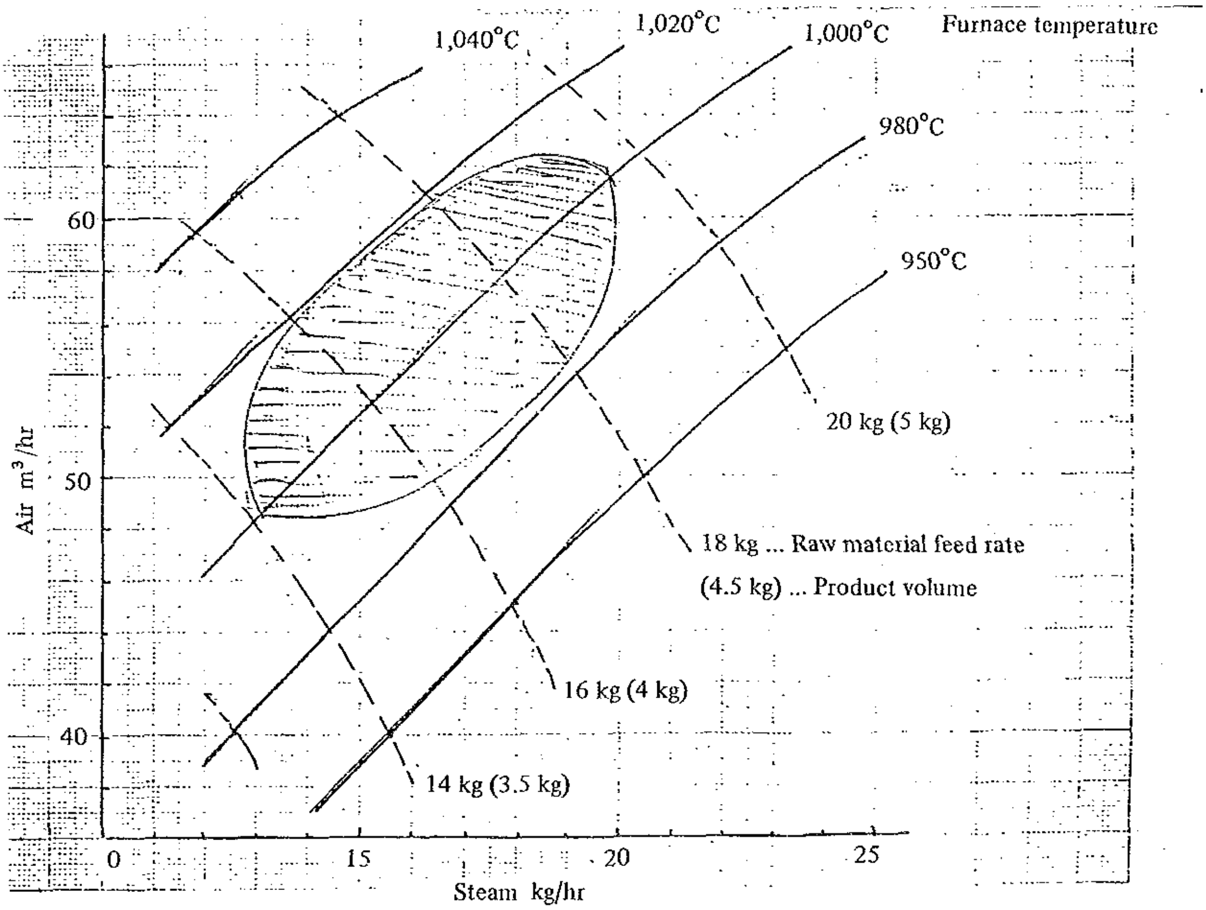
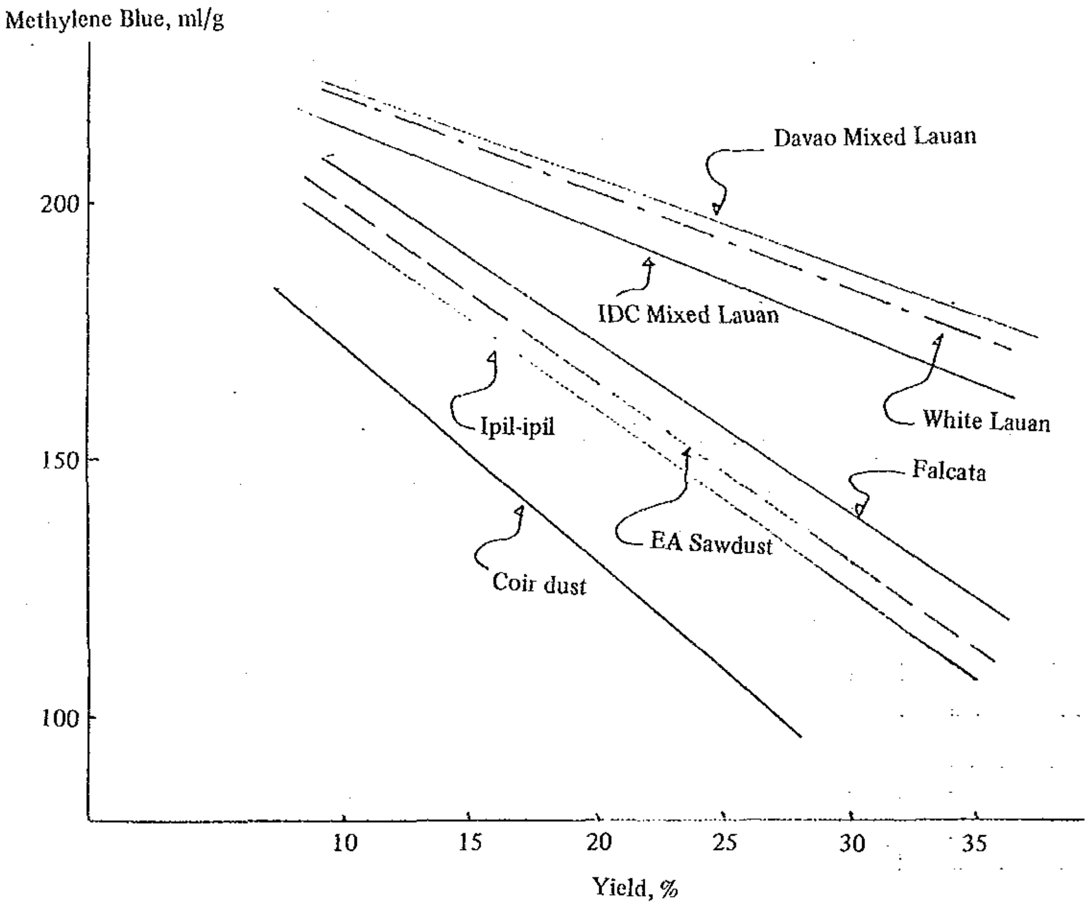


Table 5A-1-21 RESULTS AND DATA ON THE TIPICAL OPERATING CONDITIONS OF CIRCULAR FLUIDIZING BED ACTIVATOR APPARATUS

Name of char		White lauan	Sawdust (IDC)	Sawdust (Davao)	Ipil-ipil	Sawdust (EA)	Coir-dust
Feed rate (kg/hr)		16.79 (2.5)	27.24 (2.5)	15.00 (2.5)	14.64 (2.5)	20.00	8.23
Air (m^3/hr)	F-1	28	26	24	19	20	26
	F-2	48	41	27	38	30	36
Steam (kg/hr)	F-3	3	4	7.2	5.4	5.4	5.0
	F-4	14	10	18	13	22	18
Act temp.(°C)	T_1	1,147	1,166	1,063	1,074	1,130	1,142
	T_2	1,038	1,081	920	954	986	1,019
Activated carbon (kg/hr)		4.71	6.72	3.80	1.90	3.80	2.11
Yield (%)		28	25	25	13	19	25.6
M.B. (mg/g)		312	304	296	304	224	80

Act temp.: Activation temperature.
M.B.: Methylene blue decolorizing power (mg/g).

Fig. 5A-1-38 RELATIONSHIP BETWEEN YIELD AND METHYLENE BLUE DECOLORIZING POWER



The test results also revealed that the relationship between activated carbon yield and methylene blue decolorizing power can be classified broadly into three groups, as shown in Table 5A-1-22.

Activated carbon has many uses but its properties are not necessarily uniform.

Even with the same amino acid or industrial chemicals, its properties will vary widely and the same activated carbon may not always provide the best results. However, refined activated carbon washed by 1 N hydrochloric acid (HCl) displayed properties and quality conforming to rigid pharmacopoeia standards, or to medicinal carbon for pharmacopoiea japonica.

The methylene blue decolorizing power test is designated by JIS as the analysis method, and is a method that is adopted popularly.

Table 5A-1-22 RELATIONSHIP BETWEEN YIELD AND METHYLENE BLUE DECOLORIZING POWER OF ACTIVATED CARBON BY TREE SPECIES

The relationship between M.B. decolorizing power and yield with respect to activated carbon obtained from various wood species were arranged neatly into the three blocks as shown in the following table.

Wood species	M.B.
Coir dust	-4.3 Y + 210
Ipil-ipil	-3.5 Y + 230
EA sawdust	-3.5 Y + 235
Falcata	-3.33 Y + 240
IDC mix lauan	-1.83 Y + 235
White lauan	-1.89 Y + 240
Davao mix lauan	-1.76 Y + 240

Y: Yield

4) Adsorption Properties of Tested Activated Carbon

Table 5A-1-23 shows the results of analysis of M.B. decolorizing power, yield and purity of activated carbon products obtained from various kinds of tree.

As can be seen in the table, all the products excepting coir dust showed M.B. decolorizing power of over 150–200 ml/g. Meanwhile, the iodine adsorption performance is regarded as having a correlationship with specific surface area and the value of over 1,000 mg/g is specified in various standards.

As shown in Fig. 5A-1-38 and Table 5A-1-23, the activated carbon products produced from the kinds of tree used in this test fully conformed with the standards prescribed by JIS, Pharmacopoeia Japonica, Food Addition Law and JWWA, elucidating the possibility of manufacturing various kinds of powdered activated carbon products by using the raw materials described so far.

Table 5A-1-23 RESULTS OF ANALYSIS ON THE PROPERTIES OF ACTIVATED CARBON PRODUCTS

Sample	pH	M.B. (ml/g)	I_2 (mg/g)	ABS (Value)	Ash (%)	Yield (%)
Davao - SD - AC	10.80	225	1,079	22	7.1	19
	11.10	185	1,079	32	7.3	25
	11.10	175	1,066	42	8.9	28
IDC - SD - AC	10.5	195	1,072	28	7.1	20
		175	1,041		4.8	27
	10.9	170	1,022		4.7	30
		145	1,015		4.0	35
EA - SD - AC	11	140	920	48	8.5	19
		110	845		8.8	26
White lauan - AC	11.2	180	1,072	33	5.7	28
	11.3	195	1,051		6.4	25
Ipil-ipil - AC	11.7	190	770	45	18.6	13
	11.4	140	857		26.1	19
Coir dust - AC	11.1	90	795	52	16.5	18
Falcata - AC	11.30	155	964		10.31	19
Japanese - AC	9.8–10.8	180–230	1,020–1,150	40–30	3.5–5.0	25–30