

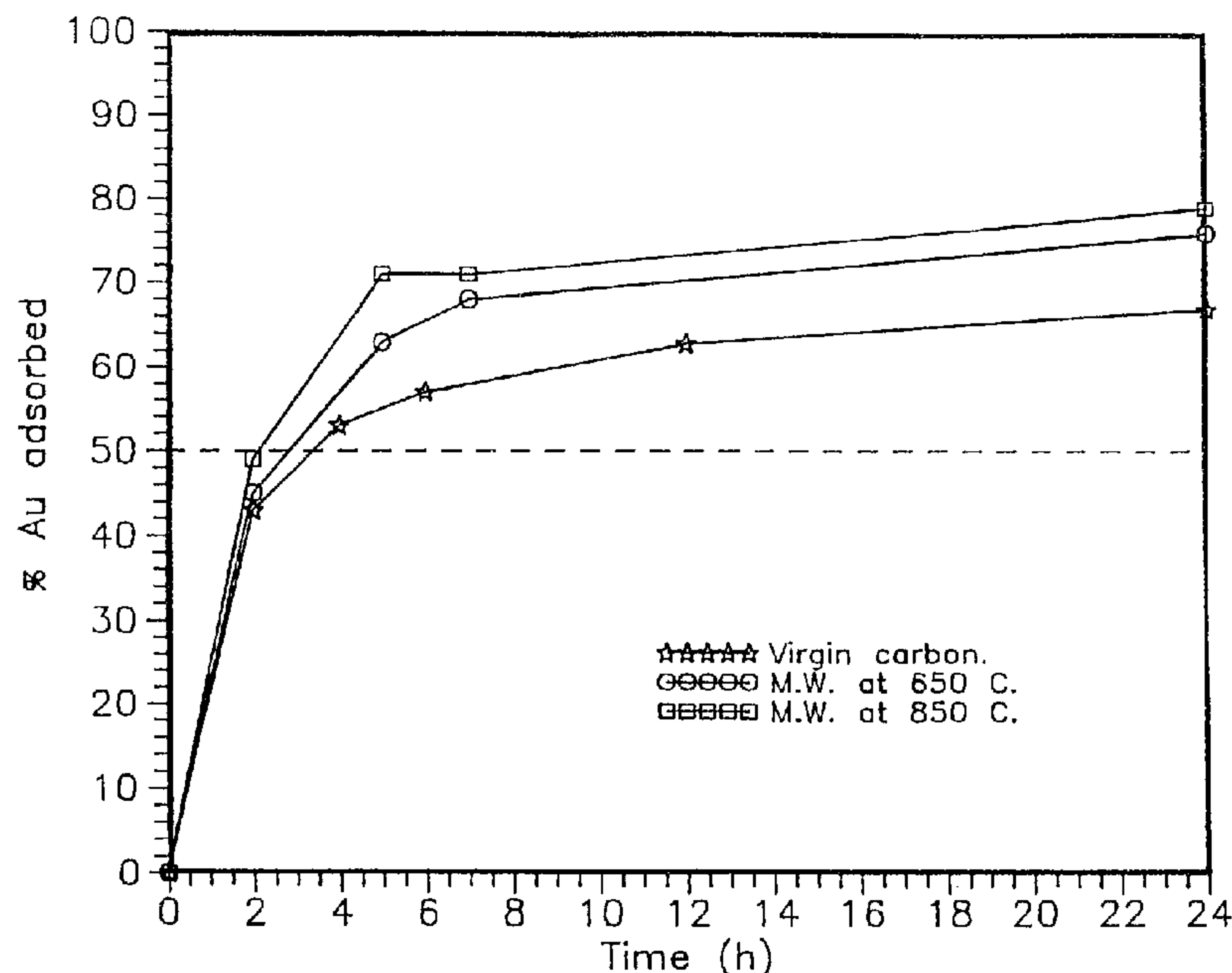


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(54) **ACTIVATION DU CARBONE A L'AIDE DE MICRO-ONDES**

(54) **MICROWAVE ACTIVATION OF CARBON**



Gold adsorption rates curves for Plant B - carbon (virgin and microwave regenerated) in cyanide leach liquor.

(57) A method is disclosed for the regeneration of spent carbon, which comprises the steps of acid washing the spent carbon, heating the washed carbon with microwaves 915 MHz or 2450 MHz to a temperature in the range of about 650° to 850°C in a nitrogen atmosphere, cooling the carbon to a temperature in the range of about 150° to 200°C, and thereafter quenching the hot carbon in air or water. The spent carbon to be regenerated may be that originating from a CIP (carbon-in-pulp) process for gold recovery or any process for the removal of environmentally toxic materials from solutions or gases.

2,008,242.

ABSTRACT OF THE DISCLOSURE

A method is disclosed for the regeneration of spent carbon, which comprises the steps of acid washing the spent carbon, heating the washed carbon with microwaves 915 MHz or 2450 MHz to a temperature in the range of about 650° to 850°C in a nitrogen atmosphere, cooling the carbon to a temperature in the range of about 150° to 200°C, and thereafter quenching the hot carbon in air or water. The spent carbon to be regenerated may be that originating from a CIP (carbon-in-pulp) process for gold recovery or any process for the removal of environmentally toxic materials from solutions or gases.

This invention relates to a process for regenerating spent carbon, particularly for use in a CIP (carbon-in-pulp) process for the recovery of gold values from gold ore. More specifically, this invention relates to an improved process for regenerating spent carbon by the application of microwave radiation.

The CIP process is a proven technology for gold recovery from gold leach pulps (Muir, D.M.; "Recovery of Gold from cyanide solutions using activated carbon: A Review"; Carbon-in-Pulp technology for the extraction of gold seminar; Aus. IMM Perth and Kalgoorlie branch and Murdoch University; July, 1982). Desirable features of activated carbon for the CIP process include hardness, graphitic structure, extensive macro and microporosity, high surface area and the availability of oxysites such as hydroxyl, phenol, ketone, aldehyde, carboxyl, lactones, quinones,

ethers, hydroperoxides, anhydrides or chromenols
(Muir, D.; "Recent advances in gold metallurgy";
Research and Development in Extraction Metallurgy;
The Aus. IMM Adelaide branch; May, 1987).

Structurally, graphite consists of flat
sheets of benzenoid rings (i.e. sp^2 hybridized
carbon) stacked in layers. The sheets of benzenoid
rings are held together by Van der Waal's forces.
Generally, the degree of structural imperfection is
high in activated carbon, and it is these sites of
imperfection that are the major reactive sites.

It now appears that activated carbon
can exhibit various characteristic properties
including oxidation, reduction, salt formation,
complexation, physical adsorption through Van der
Waal's force and even adsorption through π -
electron interaction of the sp^2 hybridized
benzenoid carbons.

Generally, activated carbon can adsorb

various chemical species from solution. However, in the presence of common metallic species in the solution it is often specific to gold. Because all adsorbed species are not removed from the activated carbon during gold stripping, the activity of the spent carbon is always lower than that of virgin carbon.

Hitherto, in order to reactivate spent carbon it was thoroughly acid washed and then heated in a rotary kiln at a temperature in the range of 650° to 850°C. The thermal activation process removed all moisture, carbonized the organic matter and enlarged the pore size. After thermal activation the hot carbon was quenched, preferably in water. However, with the thermal activation of carbon, inadequate power input and poor heat transfer often result in insufficient residence time and lower activation.

Microwaves, especially of frequency 915

and 2450 MHz, are finding increasing applications such as in the food industry, sterilization of agricultural products, vulcanization of rubber, vitrification of advanced ceramics and digestion and calcination of chemicals and minerals (Walkiewicz, J.W., G.Kazonich and S.L. McGill; "Microwave heating characteristics of selected minerals in compounds"; Minl. Metall. Process 5(2); 39-42; Feb. 1988). An important characteristic of microwave heating is its material specificity; that is, materials which absorb microwaves are heated preferentially, such as, for example, water, pyrite, carbon, CuO and NiO (Haque, K.E.; "Microwave irradiation pretreatment of a refractory gold concentrate"; Proceedings of the International symposium on gold metallurgy; Aug. 23-26, 1987; Winnipeg, Canada; 1987). Furthermore, microwave heating is much faster (5 to 10 times) and more efficient than thermal heating; the power input is

immediately controllable and can be directed through the wave guide.

It has previously been reported that carbon (graphite or amorphous) can be treated with microwaves (Walkiewicz, J.W., G. Kazonich and S.L. McGill; "Microwave heating characteristics of selected minerals and compounds"; Minl. Metall. Process 5(2); 39-42; Feb. 1988).

United States Patent No. 3,935,006 (Fischer) teaches a method for the recovery of gold and/or silver values which have been adsorbed onto activated carbon from a processing solution. The method comprises eluting the activated carbon with water-soluble alcohol or ketones as well as the optional addition of a strong base to further facilitate elution. The spent carbon is reactivated by washing with water.

United States Patent No. 4,256,607 (Noack et al) describes a process for the thermal

regeneration of charged activated coke or activated carbon granulate. The process comprises preheating the granulate in a preheating zone, heating the granulate in a travelling bed by direct contact with a stream of heated desorption gas, and cooling of the granulate in a cooling zone.

United States Patent No. 4,778,519

(Pesic) teaches a method for recovering gold and silver from precious metal-bearing materials involving a thiourea leach, carbon adsorption of the metal values, and a thiosulfate wash to desorb the values therefrom. Spent carbon is recycled back to the beginning of the process whereby the decrease in pH reactivates the carbon.

It is an object of this invention to provide a method of regenerating spent carbon which is simple and overcomes inherent disadvantages of prior methods. It is a further object of this invention to provide a method of regenerating spent

carbon from a CIP (carbon-in-pulp) process for gold recovery or from processes for the removal of environmentally toxic materials from solutions or gases, such as water treatment, decolorizing and deodorizing processes and processes for the removal of toxic liquid and solid particles.

It is a still further object of this invention to provide a method of regenerating spent carbon through the application of microwave radiation.

It has been found that the application of microwaves at suitable intensity and temperature to spent carbon from a CIP process will regenerate up to 97% of the adsorptive capacity of the activated carbon with respect to the virgin carbon. In comparison with the conventional method of thermally reactivating spent carbon the quality of the microwave activated carbon in terms of adsorption capacity is at least equal or better.

Furthermore, the activation of carbon by microwave energy is achieved from 5 to 10 times faster and is effected without the need of convection and/or surface conductance.

Accordingly, the invention provides a method of regenerating spent carbon, which comprises acid washing the spent carbon, heating the washed carbon with microwaves of about 915 MHz or 2450 MHz to a temperature in the range of about 650° to 850°C in an inert atmosphere, such as nitrogen, or in vacuo, cooling the red hot carbon to a temperature of about 150° to 200°C and thereafter quenching the carbon in air, or more preferably in distilled water. Generally, oxygenated reactive sites are formed during quenching operations. Water quenching is preferred as it provides further cleaning of the pores in the activated carbon.

The acid washing step typically

involves the heating of a 1:3 mixture of spent carbon and slightly acidic water to about 80 to 90°C for about 4 to 8 minutes with constant stirring at 100 rpm. After the separation of the carbon from the mixture it is further washed with distilled water until the wash water measures neutral pH. In a preferred embodiment the acidic water used for the acid washing of the spent carbon is 3% HCl or HNO₃.

The activation temperature in a typical CIP operation ranges from about 650° to 850°C, this temperature range is also suitable as the lower and upper limit, respectively, of the activation temperature for microwave treatment. Spent carbon generally contains adsorbed cyanides which may evolve during activation. Accordingly, efficient scrubbing devices should be incorporated in the activation system for the removal of volatile cyanides. The peak temperature is preferably

maintained for about 45 to 60 seconds. Total microwaving time including heating time might generally be in the range of 1.5 to 2.5 minutes for 100 g of dry carbon.

Nitrogen gas is advantageously employed as the inert atmosphere and is sparged through the reactor to drive off air (particularly the oxygen content thereof) in order to prevent any burning of the carbon with ash formation. Microwaving of the carbon under vacuum can alternatively be employed to serve the same purpose.

Generally, microwave activation occurs much faster with dry spent carbon than with wet spent carbon. For example, it was found that from 0.2 to 0.25 KWh of microwave power input was required to heat 100 grams of dried carbon from room temperature to 650°C, whereas the same mass of wet carbon of approximately 50% moisture required from 0.4 to 0.6 KWh.

It should be noted that while the frequencies of 915 MHz and 2450 MHz have been utilized for the inventive process, other frequencies ranging from about 900 MHz to about 22 GHz would also be suitable. However, current international convention has allocated the 915 MHz and 2450 MHz bands for industrial, scientific and medical applications of microwaves, and use of microwaves outside of the permitted bands would be illegal under prevailing regulations.

For the successful regeneration of spent carbon, it is necessary to restore, at least to a degree, certain specific physico-chemical property characteristics of the original virgin carbon. Such properties include physical stability and high adsorption capacity. Physical stability of an activated carbon is characterized by measuring various parameters. Apparent density (AD), ash content, attrition loss and pH are

particularly relevant to CIP applications. The following Table 1 compares apparent density, ash content, attrition loss and pH data for virgin, thermally activated and microwave activated carbons from two gold metal plants, respectively. Virgin and spent carbons were obtained from two operating gold mills in Northern Ontario. These coconut shelled carbons are designated as Plant A and Plant B carbons throughout the disclosure.

Table 1.

Parameters	Plant A - Carbon			Plant B - Carbon		
	Virgin	Thermally Activated	Microwave Activated	Virgin	Thermally activated	Microwave activated
Apparent Density, AD (g/ml)	0.467	0.51	0.520	0.49	0.541	0.531
Ash content (wt %)	0.9	12.31	11.23	1.1	0.96	0.89
Attrition loss (wt %)	1.5	0.67	0.71	1.3	0.97	0.83
pH	10	-	10.6	9.6	9.0	9.3

Apparent Density (AD) is the mass of a unit volume of activated carbon including its pores and interstitial voids. As can be seen from Table 1 above, both thermal and microwave activation of spent carbon results in an increase in the apparent density due to a shrinkage or compaction in the graphite structure.

Ash is the inorganic residue that remains after combusting the organic compounds present in carbon. The reactivation of carbon results in a slight decrease in ash content in both thermally and microwave activated carbons. In Table 1, Plant A carbon contained more ash than Plant B carbon due to the fact that Plant A spent carbon was not acid washed prior to activation.

Loss of carbon due to attrition in a CIP process circuit is directly related to the hardness of the carbon. In general, gold adsorption capacity decreases with an increase in

carbon hardness. The attrition data of Table 1 were obtained by conducting tests on the respective carbon according to the published procedure (Davidson, R.J., W.D. Douglas and J.A. Tumilty; "The Selection of granular activated carbon for use in a carbon-in-pulp operation"; Carbon-in-Pulp for the extraction of gold seminar; The Aus. IMM, Perth and Kalgoorlie branch and Murdoch University; July, 1982). In a typical CIP operation carbon losses due to attrition range from 1% to 8% (Geldard, D. and L.D. Mann; "The introduction and application of carbon-in-pulp in a heap leach project"; CIP-seminar; The Aus. IMM, Perth and Kalgoorlie branch and Murdoch University; July, 1982). The data of Table 1 demonstrates that loss due to attrition decreases with carbon activation which in turn increases the hardness or AD of the carbon.

The characterization of activated carbon in terms of its gold adsorption capacity was

determined by following the standard procedure (McArthur, D., C.G. Schmidt and J.A. Tumilty; "Optimising carbon properties for use in CIP"; Proceedings of international symposium on gold metallurgy; August 23 to 26, 1987; Winnipeg, Canada). The adsorption capacity of carbon (K) is a measure of the amount of gold adsorbed (mg Au) on a unit mass of carbon (1.0 g) at equilibrium with gold in solution (1 mg Au/L). Gold adsorption tests were conducted on the carbons with a standard aqueous solution of pure $K[Au(CN)_2]$.

From plots of gold adsorbed on activated and virgin carbons (mg Au/g carbon) as a function of equilibrium concentration of gold (mg Au/L), the adsorption capacities of the carbons (i.e., K-values) were calculated. The K-values of the spent carbons from Plants A and B were determined from similar adsorption isotherms in an equivalent manner. Table 2 compares calculated

values of adsorption capacity K (kg Au/tonne carbon) for virgin, spent and microwave activated carbons.

Table 2. Adsorption capacity data (K-values) in K Au(CN)₂

Adsorption capacity - K	Plant A - carbon				Plant B - carbon			
	Virgin	Spent	Mw 650°C	Mw 850°C	Virgin	Spent	Mw 650°C	Mw 850°C
kg Au/tonne C*	26	18.0 (69%)	19.0 (73%)	22.0 (85%)	23.0	18.0 (78%)	21.0 (91%)	22.4 (97%)

*Percent of adsorption capacity regenerated with respect to virgin carbon whose capacity is arbitrarily taken as 100%.
MW = microwave

The data of Table 2 reveals that the higher the temperature of activation the higher the K-values. For example, K-values of 22.0 kg Au/tonne carbon for Plant A and 22.4 kg Au/tonne carbon for Plant B were obtained by microwaving of the respective spent carbons at 850°C, whereas the K-values of the same carbons activated at 650°C were 19.0 kg Au/tonne carbon and 21.0 kg Au/tonne,

respectively. If the K-values of the virgin carbons are considered to be 100% then the K-values of the carbons activated at 850°C would represent 85% and 97% of regeneration of adsorption capacities.

Generally, the adsorption capacity of thermally activated carbon ranges from 3.0 kg Au/t carbon to 12.0 kg Au/t carbon (Anderson, S.J.; "The gold rush of the 1980's; Can. Min. J. 110(4), 13-21; 1989). This essentially represents 60% to 85% regeneration with respect to the capacity of the virgin carbons of the respective mill.

The rate of gold adsorption on activated carbons was studied using pure $K[Au(CN)_2]$ solution and was calculated according to equation (1) below (Davidson, R.J., W.D. Douglas and J.A. Tumilty; "The selection of granular activated carbon for use in a carbon-in-pulp operation". Carbon-in-Pulp for the extraction of gold seminar;

The Aus. IMM, Perth and Kalgoorlie branch and Murdoch University, July, 1982). Gold adsorption rate curves containing adsorption isotherms for microwave activated carbons at 650°C and 850°C from Plants A and B were plotted. Equation (1) is as follows:

$$\text{Carbon loading (mg Au/g carbon)} = (C_0 - C_t) V/m \quad (1)$$

where C_0 = initial gold concentration (mg/L), C_t = gold concentration (mg/L) after time t (hour), V = volume of gold solution (L), and m = mass of carbon (g).

Based on calculations using equation (1) it was revealed that Plant A carbon activated at both 650°C and 850°C had identical gold adsorption rates. Furthermore, these carbons adsorbed gold at a faster rate than virgin carbon, during the initial hour of adsorption and that

within 45 minutes 50% of the gold was adsorbed from solution. However, both regenerated carbons took more than double the time (i.e., 8 h) to reach a maximum 97% of the adsorption capacity of the virgin carbon.

From gold adsorption isotherms for Plant B carbon activated at both 650°C and 850°C, it was evident that high temperature (i.e., 850°C) activated carbon adsorbed gold slightly faster than the carbon activated at the lower temperature (i.e., 650°C). However, both the activated carbons required 8 hours to reach the highest level of adsorption (98%). As well, both activated carbons required only 45 minutes to reach the level of 50% adsorption of the dissolved gold.

These test data lead to the conclusion that if the gold adsorption operation is continued for 8 hours or more then carbon activation at lower temperatures (e.g., 650°C) would be adequate.

Characteristic R-values were determined from the linear Langmuir equation as follows (Davidson, R.J., W.D. Douglas and J.A. Tumilty; "The selection of granular activated carbon for use in a carbon-in-pulp operation". Carbon-in-Pulp for the extraction of gold seminar; The Aus. IMM, Perth and Kalgoorlie branch and Murdoch University, July, 1982):

$$t/(x/m) = t/M + 1/R \quad (2)$$

where; t = time in minutes, x/m = gold adsorption on carbon (mg Au/g carbon), M = reciprocal of slope, and R = reciprocal of the intercept at zero time on y-axis.

Generally, the R-value is a measure of the rate of gold adsorption on carbon (i.e., mg Au/g carbon/min) or kg Au/tonne carbon/min); and the higher the R-value the faster is the adsorption rate under the test conditions. The R-values were

determined from plots of $t/(x/m)$ versus time (t) at intercepts at zero time on the y-axis. Table 3 shows calculated R-values of the carbons activated at 650°C and 850°C from both Plants A and B.

Table 3. Adsorption rates (R) in $K[Au(CN)_2]$ solution

Adsorption rate - R	Plant A - carbon			Plant B - carbon		
	Virgin	Mw* 650°C	Mw* 850°C	Virgin	Mw* 650°C	Mw* 850°C
kgAu/tonne carbon per minute	0.33	0.20	0.20	-	0.20	0.33

*Microwave activated

The adsorption rate data in Table 3 demonstrate that Plant A carbons activated at 650°C and 850°C had the same R-values; that is, 0.20 kg Au/tonne carbon/min. In the case of Plant B

carbon, however, the R-value was much higher (0.33 kg Au/tonne carbon/min) for the carbon activated at 850°C as compared to the carbon activated at 650°C.

On the basis of R-values of the activated carbons the total time required for achieving the K-values of the respective carbons in Table 2 can be calculated. In the case of activated carbons for Plant A, 95 and 110 minutes would be required for the adsorption of 19.0 kg. Au/t carbon and 22.0 kg Au/t carbon respectively, whereas the activated carbons for Plant B would require 68 minutes and 105 minutes for the adsorption of 22.4 kg Au/t carbon and 21.0 kg Au/t carbon respectively. Although R-values do not represent true Langmuir adsorption rates they are generally accepted as adsorption rates of soluble gold species on the activated carbon.

Embodiments of the invention will now be described, by way of example, with reference to

the accompanying drawings, in which:

Figure 1 shows a schematic frontal view of an apparatus embodying the invention;

Figure 2 shows a plot of percent of gold adsorbed on carbon versus adsorption time; and

Figure 3 shows a plot of $t/(x/m)$ as a function of t (Time) in accordance with the above equation (2).

Referring now to Figure 1, the apparatus comprises a silica crucible 1 in which a known quantity of spent carbon 2 is placed. The silica crucible 1 is contained within a cylindrical unglazed clay pot 3 provided with a refractory lid 4 which loosely covers the clay pot. A type K thermocouple 5 for accurately measuring the carbon temperature passes through the refractory lid 4 and into the centre of the mass of carbon. Nitrogen gas enters at 6 through a glass tube 7 and enters the clay pot 3 at 8. Nitrogen gas leaves the clay

pot 3 at point 10 through a tube 9. The whole assembly is placed in microwave oven 11 which is operated in pulse mode.

The following Examples further illustrate the invention.

EXAMPLE 1

With reference to Figure 1, a known quantity of wet carbon 2 of 2mm (average) particle size was placed in the silica crucible 1 within the cylindrical unglazed clay pot 3. The clay pot was loosely covered with the refractory lid 4. A type K thermocouple 5 was introduced through an opening in the refractory lid 4 into the mass of carbon 2 and nitrogen gas was introduced through the glass tube 7 into the clay pot 3. The assembly was then placed in the microwave oven 11 (model BPH.6000-P4 - SP, Cober Electronics, Inc. U.S.A.) and flushed with nitrogen gas for 10 to 12 minutes before the application of microwave radiation. The

microwave oven was operated in pulse mode.

The temperature of the carbon (after drying) increased rapidly at a rate of approximately 150°C/minute with the application of 3 KW of microwave power per 100.0g dry carbon. Initially, the wet carbon remained at ambient temperature until completely dried, at which point its temperature began to increase rapidly. The carbon was heated to a temperature in the range of 650° to 850°C. The red hot carbon was then allowed to cool to a temperature in the range of 150° to 200°C in a nitrogen gas atmosphere. The cooled carbon was then quenched in distilled water. The weight loss that occurred in the carbon samples during the application of microwave radiation was in the range of about 2.0 to 5.0%. The microwave power requirements were in the range of about 3.4 to 5.5 KWh per Kg carbon. The experimental procedure and the microwave equipment used enabled

only a rough estimate of the power consumption.

EXAMPLE 2

Microwave activated carbons were used to adsorb gold from cyanide leach liquor of a typical gold ore. A cyanide leach liquor containing 11.80 ppm Au, 4.3 ppm Ag, 25.0 ppm Fe and 15 ppm Cu was treated with Plant B carbon microwaved at 650°C and 850°C, respectively. Adsorption data were computed to fit the above equations (1) and (2).

Referring now to Figure 2, the adsorption profile reveals that the gold adsorption rate and overall loading capacities were significantly greater with the microwave activated carbons than with the virgin carbon. The peak gold adsorption percentages during the 24 hour experimental period were 75% and 80% for carbon activated at 650°C and 850°C, respectively as compared to 66% for the virgin carbon. However,

adsorption time was not optimised. Further, Figure 2 also reveals that the microwave activated carbons adsorbed gold at a much faster rate than virgin carbon. For example, with reference to Figure 3, for 50% gold adsorption, 2.0 and 2.7 hours were required by the carbons activated at 850°C and 650°C, respectively, whereas 4 hours was required by the virgin carbon.

The adsorption rates (i.e., R-values) of the microwave activated carbons were determined from the intercepts of the straight line plots at the y-axis at zero times in Figure 3. The adsorption rates were determined to be 0.10 kg Au/t carbon per minute for the virgin carbon and 0.012 kg Au/t carbon per minute for the microwave activated carbons.

EXAMPLE 3

A determination of the actual microwave power utilized by the microwave oven of Example 1

in the activation of the carbon was not possible. It appears that a major portion of the microwave energy may have been wasted. However, with a measurement of the total input of microwave power a tentative cost estimate was effected, the results of which appear in Table 4. The conversion efficiency of electrical energy into microwave energy at a frequency of 2450 MHz is approximately 50%. The calculated estimates were based on an electrical power cost of \$0.04/KWh. The cost data compare poorly with an energy cost of \$0.15/kg carbon for an operating gold mill in Northern Quebec. However, if utilization of the microwave energy were to be optimised, the cost data might compare more favorably with the activation cost at a CIP mill. The operating costs would be even more attractive if carbon activation were to be conducted at 915 MHz as the conversion efficiency of electrical energy into microwave energy at this

frequency is $\geq 80\%$.

Table 4. Power consumption and the activation cost

Carbon	Activation temperature °C	Total microwave power; kWh/kg carbon	Total electrical power; kWh/kg carbon	Cost for electrical power; \$/kg °C*
Dry	650	3.44	6.88	0.275
Dry	850	3.50	7.0	0.280
1:1 H ₂ O-C	700	3.8	7.6	0.304
1:1 H ₂ O-C	850	5.48	10.96	0.438

*Unit cost of electrical power: \$0.04/kWh

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method for the regeneration of spent carbon which comprises:

acid washing the spent carbon;

heating the washed carbon with microwaves to temperature in the range of from 650° to 850°C in an inert atmosphere or in vacuo;

cooling the carbon to a temperature in the range of from 150° to 200°C; and

thereafter quenching the carbon in air or water.

2. A method for the regeneration of spent carbon as claimed in claim 1, wherein the microwaves have a frequency from 900 MHz to 24.5 GHz.

3. A method for the regeneration of spent carbon as claimed in claim 2, wherein the microwaves have a frequency of 915 MHz or 2450 MHz.

4. A method for regeneration of spent carbon as claimed in claim 1, 2 or 3, wherein the spent carbon is derived from a CIP (carbon-in-pulp) process for gold recovery.

5. A method for the regeneration of spent carbon as claimed in claim 1, 2 or 3, wherein the spent carbon is derived from a process for the removal of environmentally toxic material from a solution or gas.

6. A method for the regeneration of spent carbon as claimed in claim 1, 2 or 3, wherein quenching of the cooled carbon is effected by water.

7. A method for the regeneration of spent carbon as claimed in claim 1, 2 or 3, wherein quenching of the cooled carbon is effected in air.

8. A method as claimed in claim 1, 2 or 3, wherein the washed carbon is dried prior to microwave treatment.

9. A method according to claim 1, 2 or 3, wherein the inert atmosphere comprises a nitrogen atmosphere.

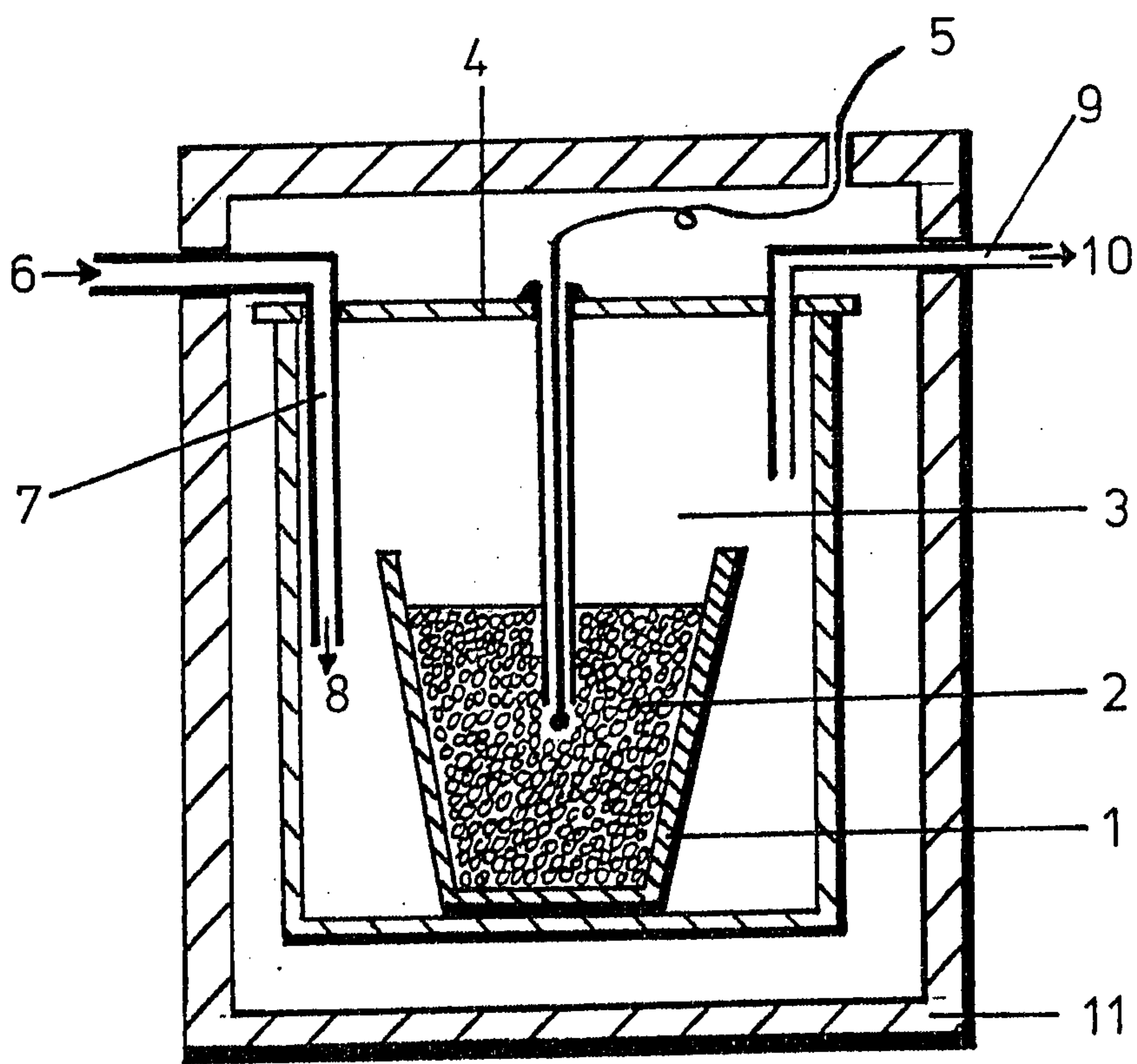
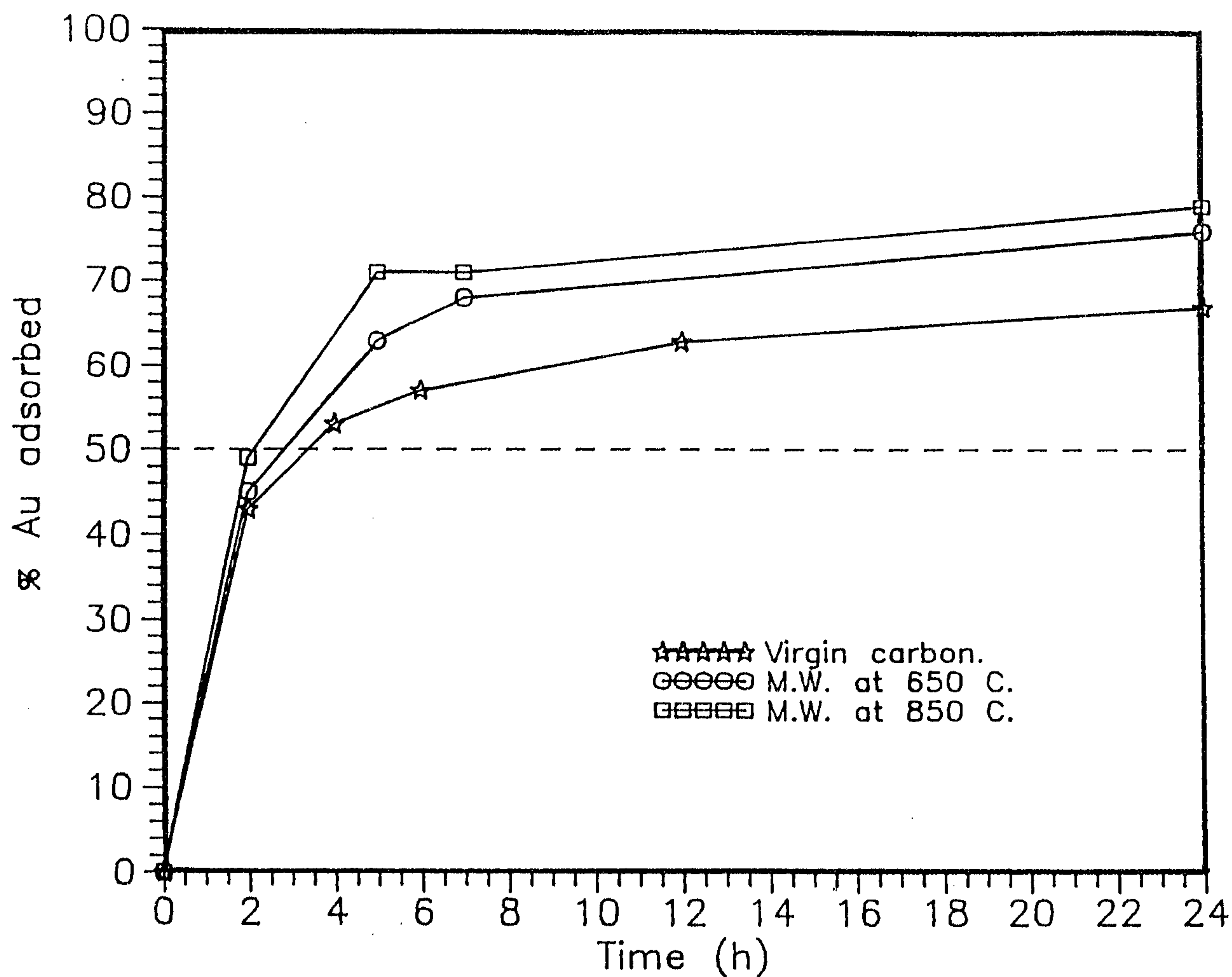


FIG. 1

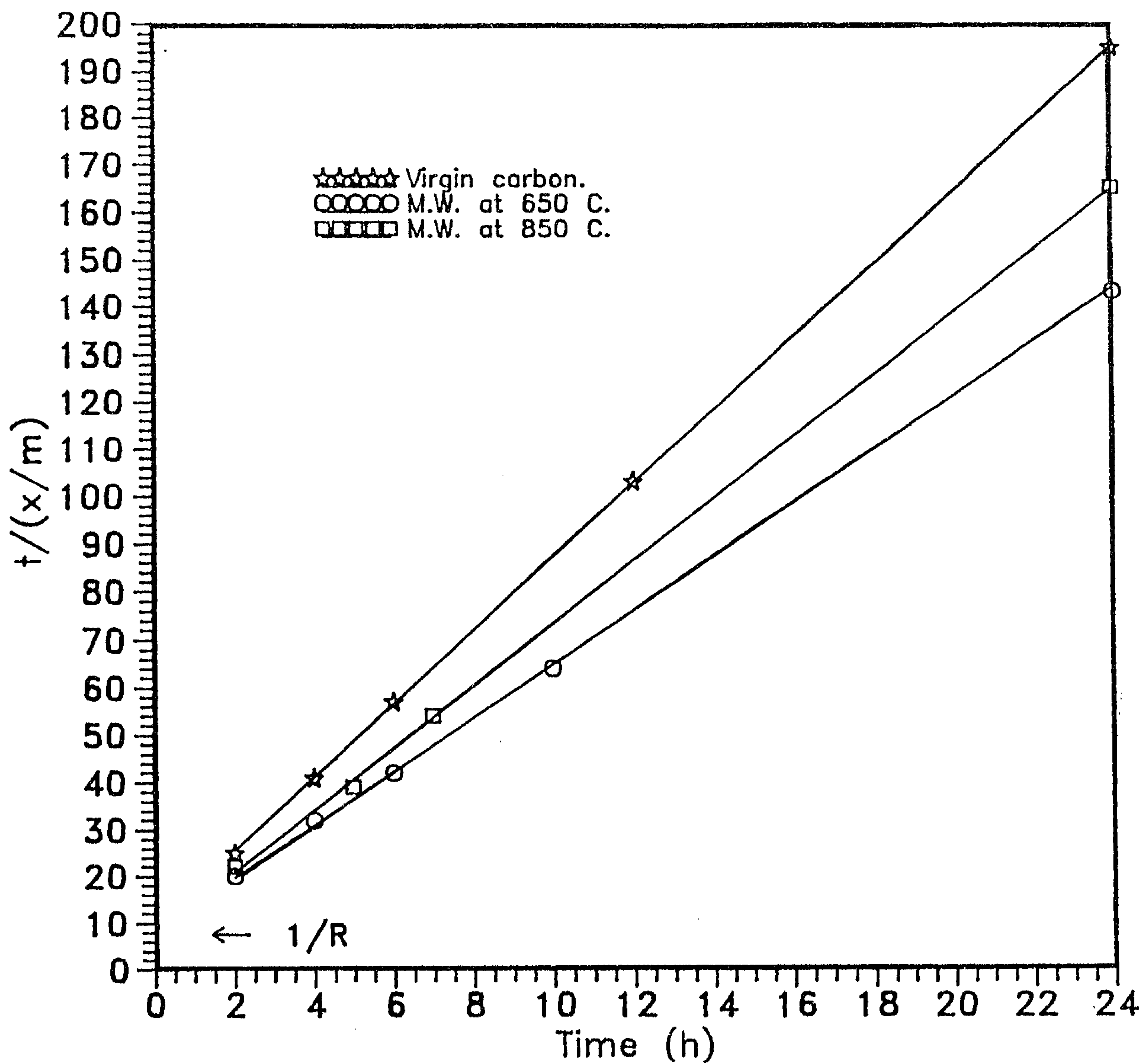
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Gold adsorption rates curves for Plant B - carbon (virgin and microwave regenerated) in cyanide leach liquor.

FIG. 2

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Linear adsorption rate for Plant B - carbon (virgin and microwave regenerated in cyanide leach liquor).

FIG.3