
KERONE
Microwaves for Coal Quality Improvement

This presentation has been prepared as a proposal of Kerone Coal Processing Concept for Century Rayon Ltd, Mumbai

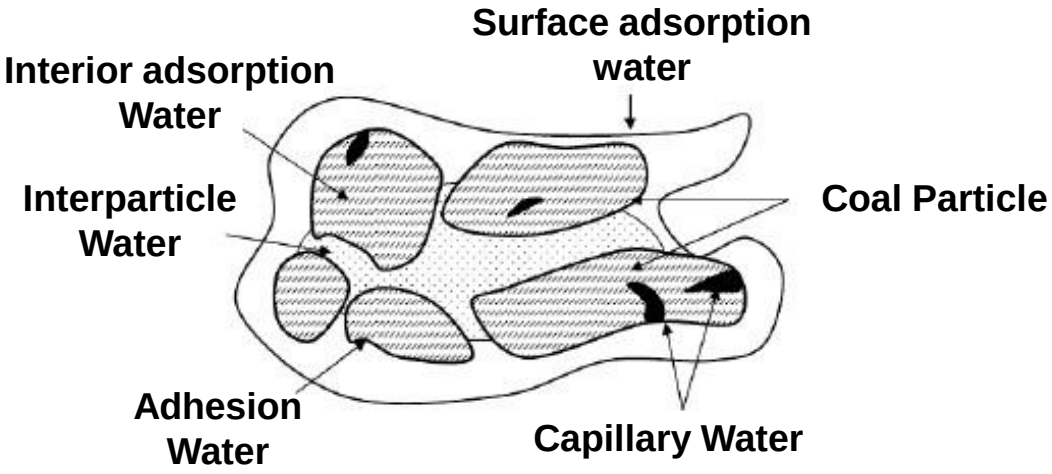
Introduction :

Coal is a raw material for many chemical syntheses as well as a fuel. Depending on its initial moisture content, coal is dried to increase its calorific value and simplify loading, unloading, transport, and improve boiler combustion efficiency.

Coal is also dried for briquetting, coking, gasification, carbonization, liquid fuel synthesis,

if coal is pre-dried. Direct dryers (e.g., rotary, pneumatic, fluid bed, vibrating fluid bed, shaft dryers, etc.) are used commonly with hot air or combustion gas at 700–9008C before the dryer and at 60– 1208C after the dryer.

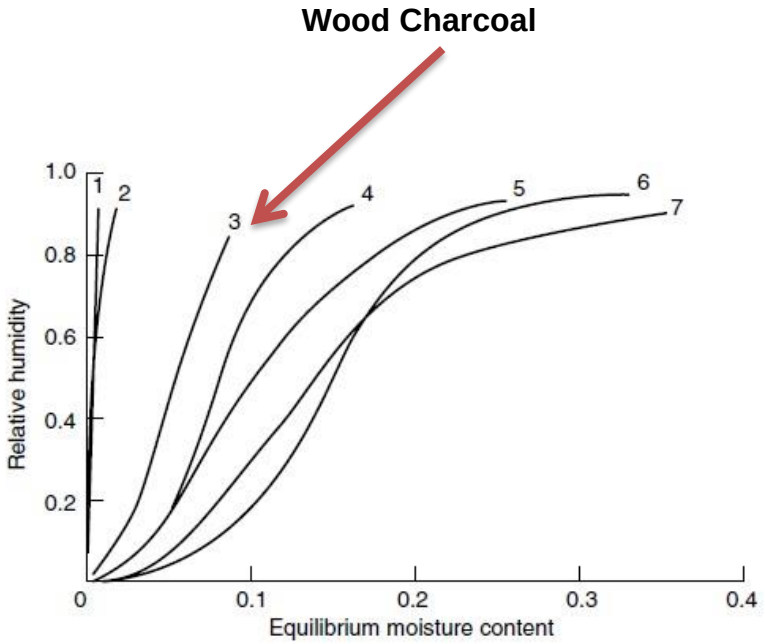
Various forms of water associated with coal particles



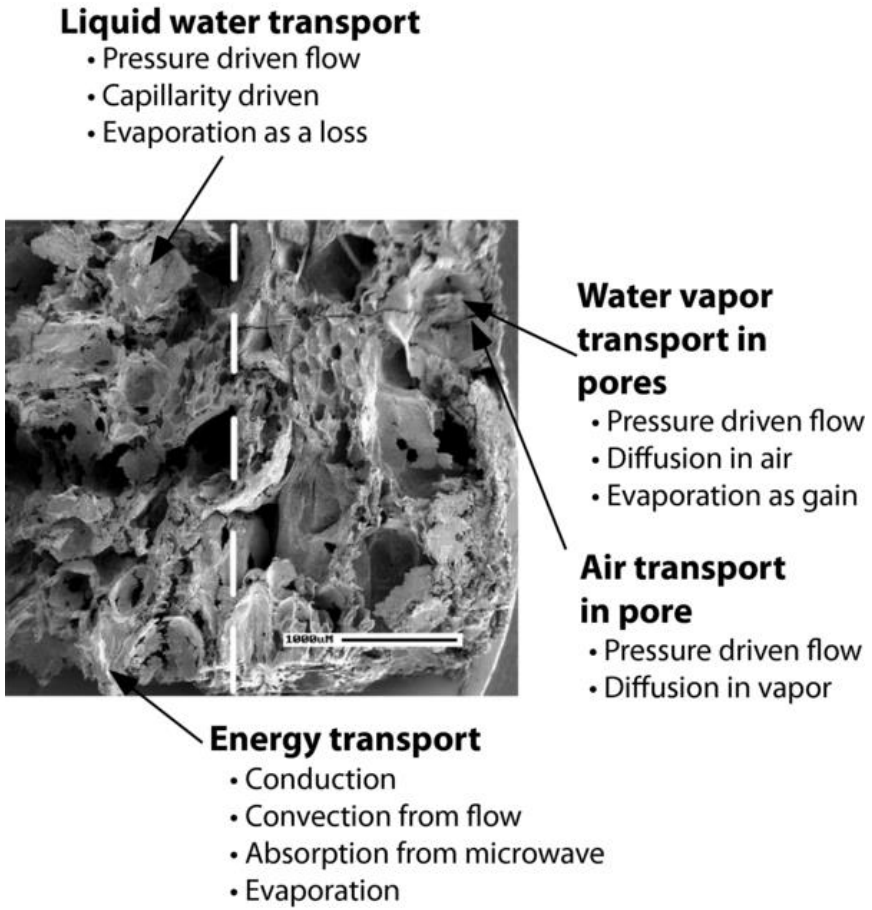
Different forms of moisture in coal are, as bulk, capillary, physical or chemical sorbed

Interior adsorbed water in micro pores,
Surface adsorbed water in forms of layer adjacent to coal molecules,
Capillary water in small cleats
Inter-particle water between some particles,
Adhesion water as a layer around the surface of coal agglomerates

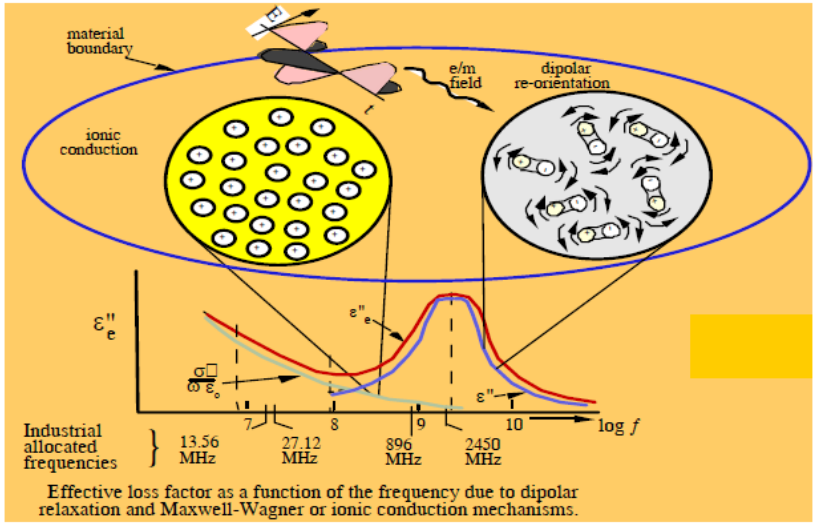
Dry coal is called hygroscopic if it is able to bind water with a simultaneous lowering of vapor pressure.



Typical equilibrium moisture isotherms at room temperature for selected substances: ***wood charcoal***



Principle of Microwave heating



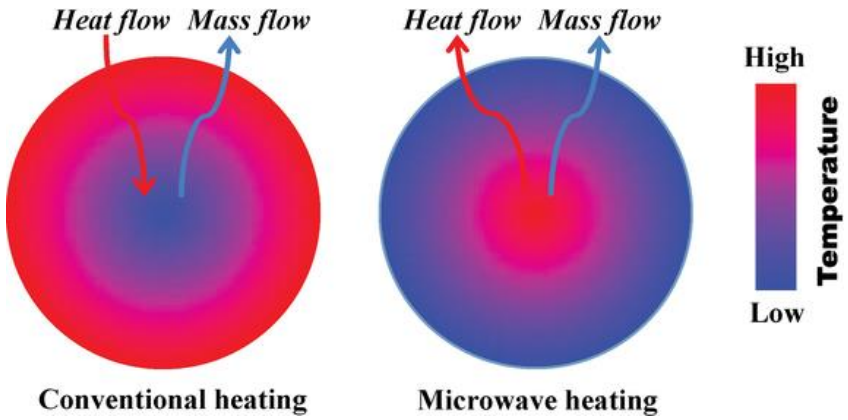
Effective loss factor as a function of the frequency, the dipolar re-orientation and conductive loss mechanisms

MW frequency regime, there are primarily two physical mechanisms through which energy can be transferred to a non-metallic material. At the lower microwave frequencies conductive currents flowing within the material due to the movement of ionic constituents, such as salts for example, can transfer energy from the microwave field to the material. This loss mechanism is characterized by an equivalent dielectric conductivity term σ, giving effectively a loss parameter of $\sigma/\omega\varepsilon^{o}$.

Microwave heating spectrum, around 3000 MHz, the energy absorption is primarily due to the existence of permanent dipole molecules which tend to re-orientate under the influence of a microwave electric field.

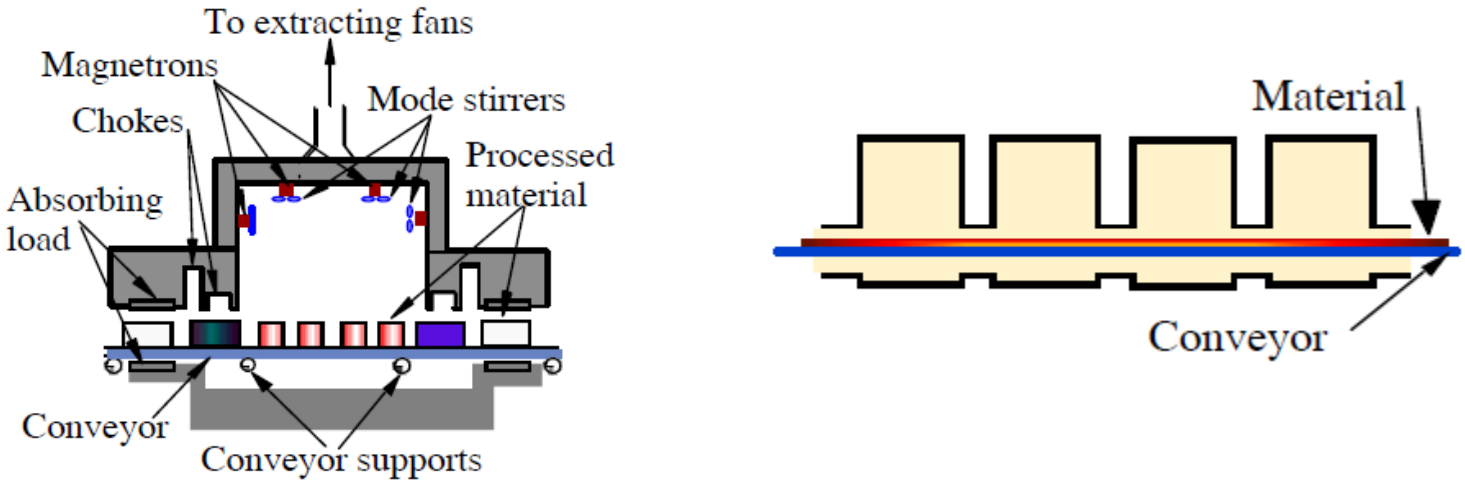
This re-orientation loss mechanism originates from the inability of the polarization to follow extremely rapid reversals of the electric field.

At such high frequencies therefore the resulting polarization phasor lags the applied electric field. This ensures that the resulting current density has a component in phase with the field, and therefore power is dissipated in the dielectric material.



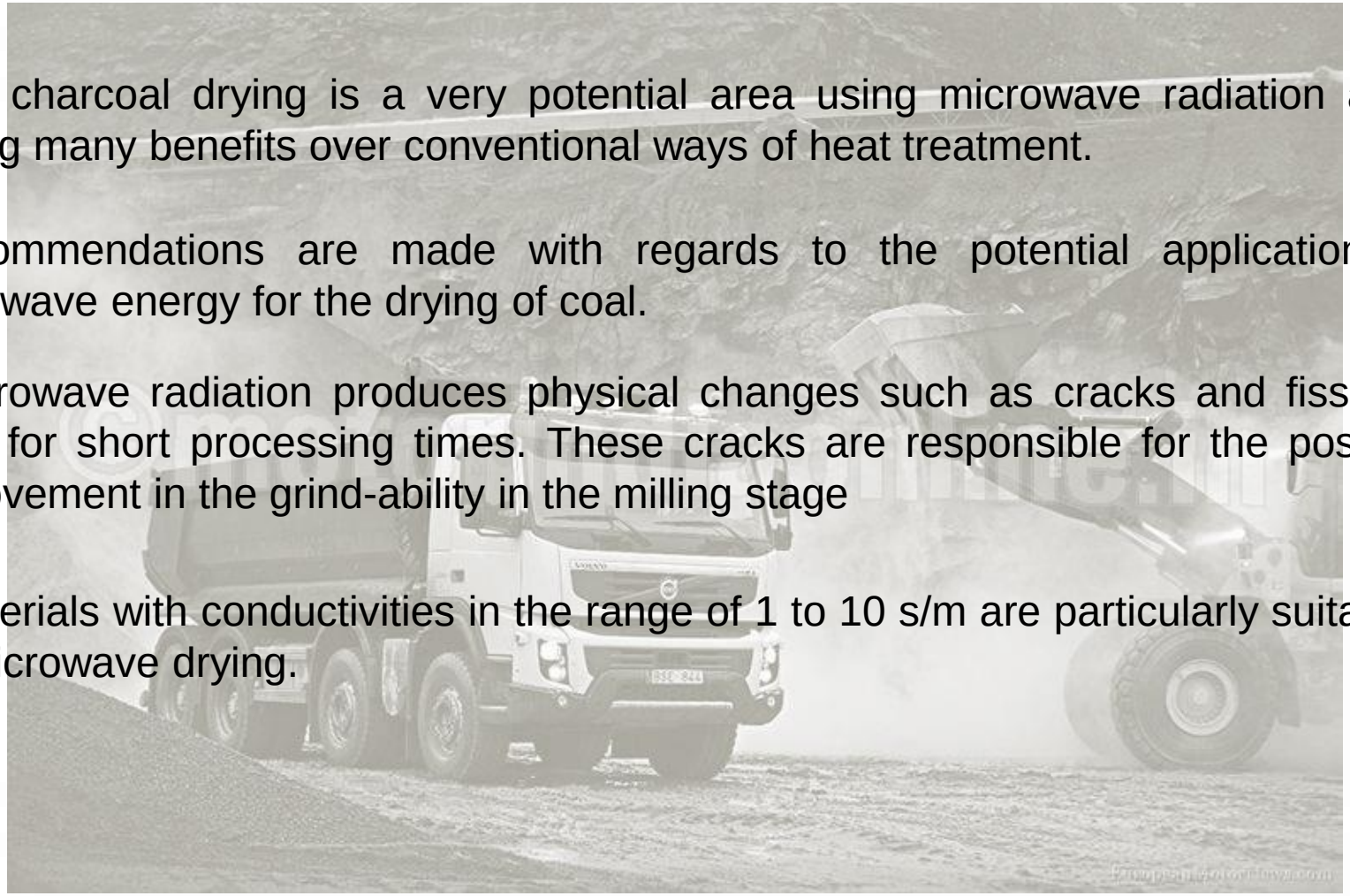
Applicators

Multimode resonant applicators consist of a metallic enclosure into which a microwave signal is coupled through a slot and suffers multiple reflections. *The superposition of the incident and reflected waves gives rise to a standing wave pattern or mode. In a given frequency range such an applicator will support a number of resonant modes.*



(a) basic multimode applicator with four magnetrons (b) modular system

Continuous Microwave Drying for Charcoal



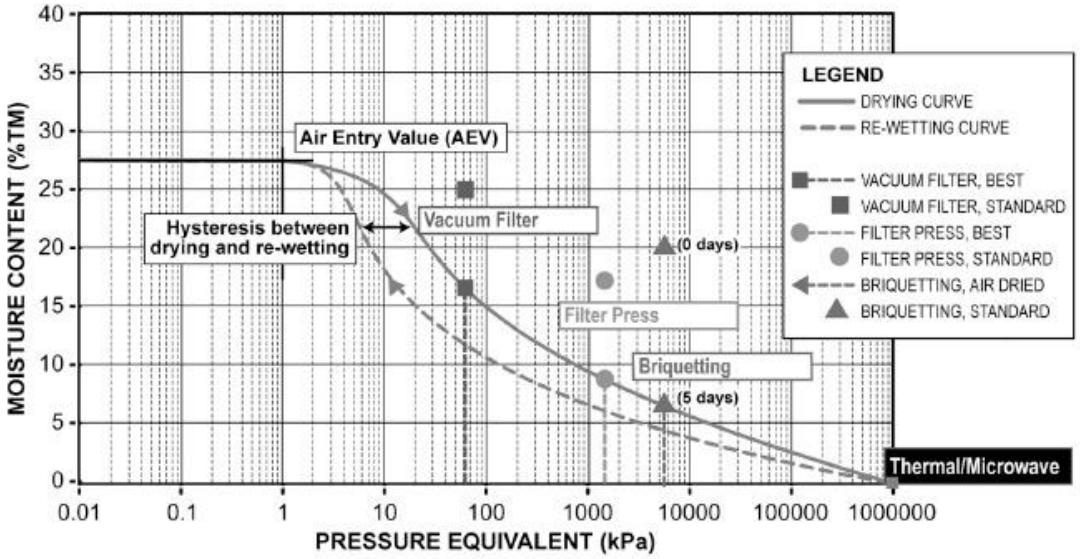
- The charcoal drying is a very potential area using microwave radiation and having many benefits over conventional ways of heat treatment.

- recommendations are made with regards to the potential application of microwave energy for the drying of coal.

- microwave radiation produces physical changes such as cracks and fissures even for short processing times. These cracks are responsible for the positive improvement in the grind-ability in the milling stage

- Materials with conductivities in the range of 1 to 10 s/m are particularly suitable for microwave drying.

Coal water characteristics curves for drying and re-wetting

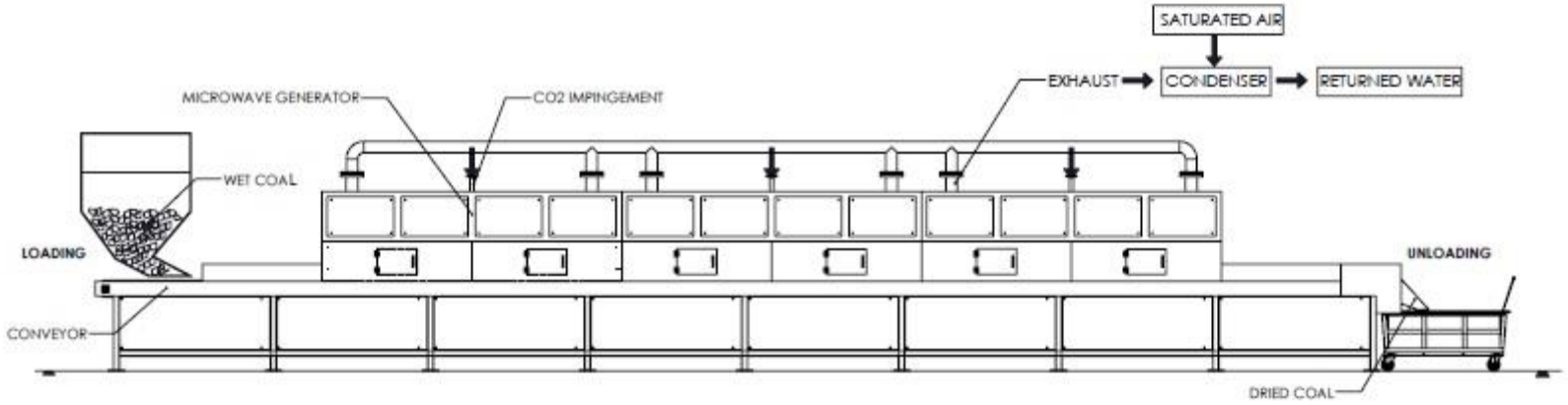


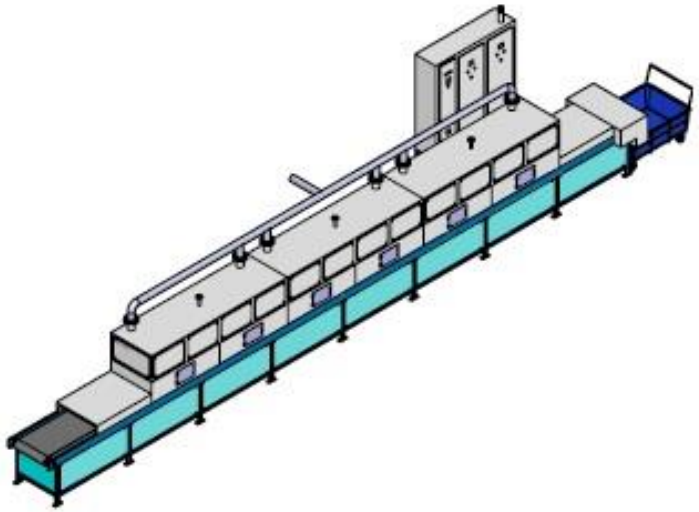
Air Entry Value (AEV)- the point beyond which the coal is unable to remain saturated, and air starts to replace further moisture loss

The hysteresis between the drying and rewetting curves occurs as a result of the coal re-saturated after drying, but at a much lower pressure than was required to drain moisture during the drying cycle.

Microwave drying is capable of producing zero moisture, where as , use of conventional thermal drying is generally limited by an environmental approval requirements, like the risk of fire, and the risk of detracting from dried coal's thermal and other properties by overheating.

KERONE Coal Processing Concept





A general advantage of microwave radiation heating is the way energy is transferred into the coal matrix. Normally the heat energy supplied by steam or hot fumes penetrates the sample from surface to the core known as convective drying. On the other side, **microwave radiation** is able to penetrate the coal completely and transmit the energy direct to dielectric components defined as volumetric drying. Due to this effect energy can be saved, because the coal agglomerates are not heated up completely, only the water is heated and vaporized.

To avoid the overheating, which may be the results of uniformity sometimes due to standing waves or other factors also; the CO2 impingement arrangement is being done to produce carbon mono oxide (CO). It can be confidently assumed that progress of the Boudouard reaction (eq 1) and evolution of CO is more facile in microwave compared to conventional heating at the same gasification condition.

$$2CO \rightleftharpoons CO_2 + C \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

Effect of gas flow rate: The formation of carbon mono oxide depends on gas flow rate at different temperatures as well as coal particle sizes

Conclusion: The evolution of CO from CO2 conversion during the microwave heating time had an immense performance over conventional electric heating.

Percentage mass Loss, moisture fraction and drying rate

water could be removed continuously from the given coal matrix by applying microwave power as the heating source.

percentage mass loss (f) is the proportion of water evaporated, calculated as the ratio of the difference between the initial mass (M0) and the final mass (Mt) to the initial sample mass

$$f = \frac{M_0 - M_t}{M_0}$$

The moisture fraction (X)

$$X = \frac{M - M_e}{M_0 - M_e}$$

M is the moisture content at any time and Me is the equilibrium moisture which equals the obtained constant moisture content after drying at a specific temperature and humidity content,

The drying rate (r) is the change of moisture fraction in a unit of time per unit area of evaporating surface as given by

$$r = \left(\frac{dX}{dt}\right)\frac{1}{M_0}$$

Energy efficiency and specific energy consumption

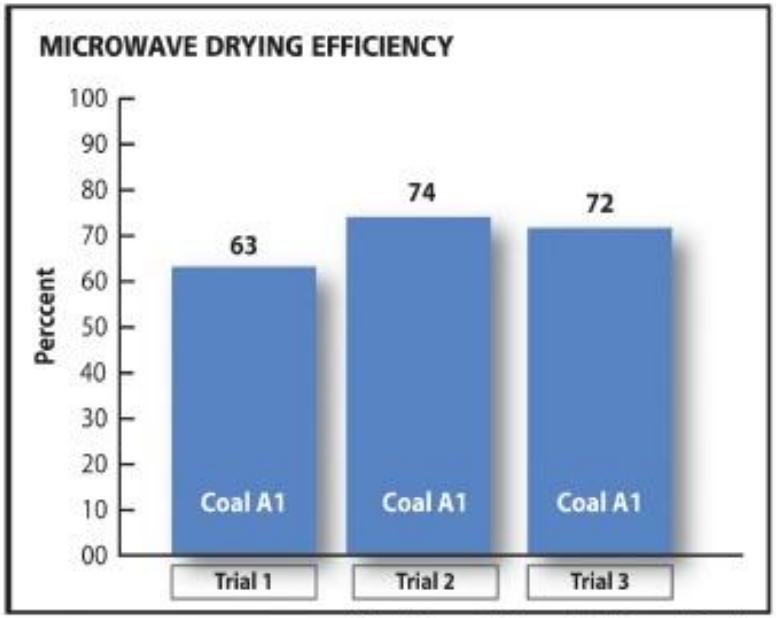
The drying efficiency can be defined as the ratio of energy utilized for evaporating water from the sample to the energy supplied by the heat source

The effective energy required to remove the water from the matrix is the energy required to heat the water from the initial sample temperature to the boiling point (100 degree C) and then to transform the liquid water to vapor.

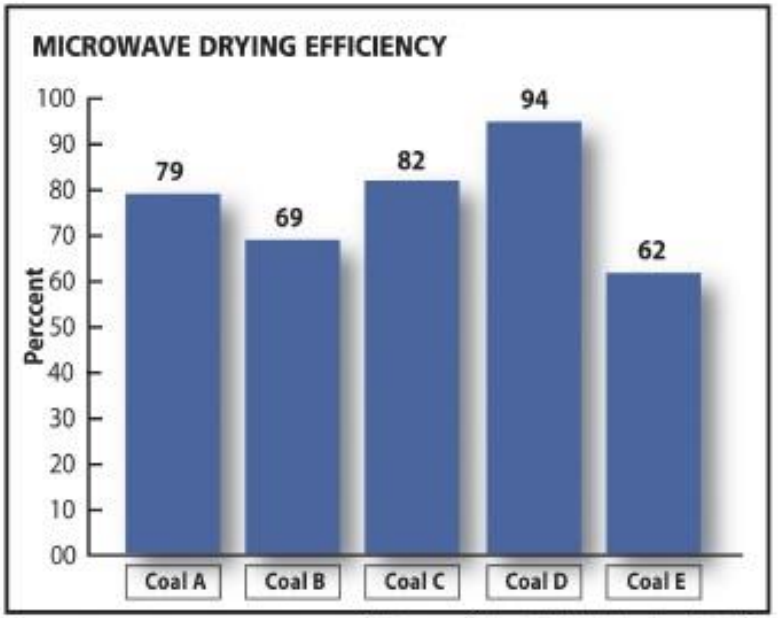
$$\eta_{MW} = \frac{C_p m_w \Delta T + m_w \lambda_w}{P_{MW} \varphi \bullet t} \times 100$$

Where η_{MW} is the microwave drying efficiencies in %; Cp is the specific heat of water (4.186 J/g degree C at 20 C); ΔT is the difference between the boiling point of water (100 deg C) and the initial sample temperature; m_w is the mass of the evaporated water in gram, λ is the latent heat of vaporization

Drying efficiency



(Single Type of Unwashed Thermal Coal)



(5 Types of Washed Metallurgical Coal)

Courtesy : Drycol, Australia

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Process is electronically controlled

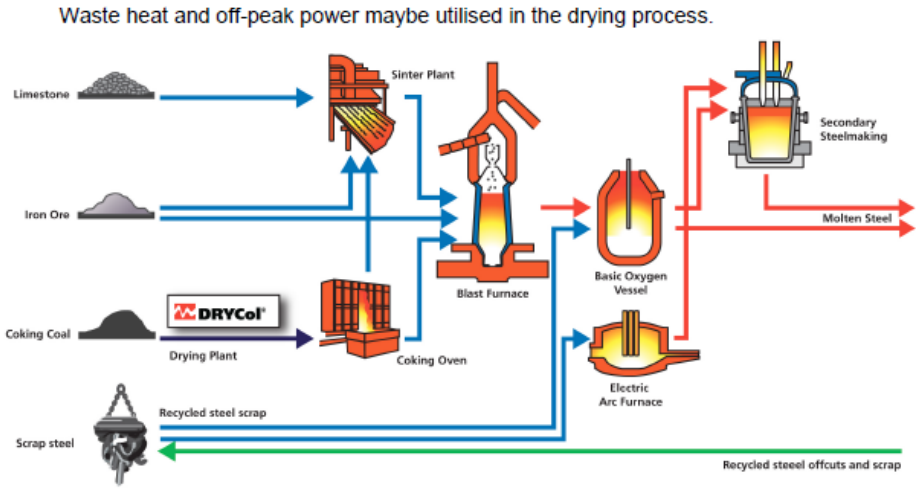
Environmental & Safety Perspectives :

Microwaves are a very promising for heating applications in many fields covering Food, agro products, paper & pulp, textile, ceramic sintering, pharmaceuticals etc and also in coal processing, where safety standards are very much crucial factor.

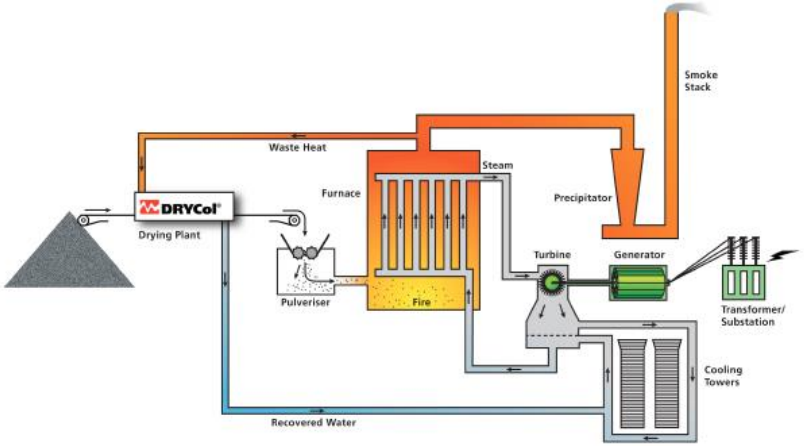
By Impinging of CO_2 in heating zone with precisely control flow rate.

Microwaves- a promising technology for many sector:

Steel Production :



Electricity Generation :



Courtesy : Drycol, Australia

Accreditations

Member of AIMCAL	Member of IHEA	Strategic Partners of Emitech Italy	Member of ICT
Recognized and Rated by CRISIL	CRISIL Verified	Member of A.M.P.E.R.E. (Europe)	ASCB(E) Certification for Best practice

ISO 9001:2008 | ISO 9001:2015 | OHSAS 18001 | EMS 14001

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