THE USE OF WASTE AS AN ALTERNATIVE FUEL IN CEMENT FACTORIES

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I certify that in my opinion the thesis submitted by Farag M. Farag ABORAWI titled "THE USE OF WASTE AS AN ALTERNATIVE FUEL IN CEMENT FACTORIES" is fully adequate in scope and quality as a thesis for the degree of Master of Science.

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The degree of Master of Science by the thesis submitted is approved by the Administrative Board of the Graduate School of Natural and Applied Sciences, Karabük University.

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“I declare that all the information within this thesis has been gathered and presented in accordance with academic regulations and ethical principles and I have prepared this thesis according to the requirements of these regulations and principles, and cited all those, which did not originate in this work.”

FaragM.Farag ABORAW

ABSTRACT

M. Sc. Thesis

THE USE OF WASTE AS AN ALTERNATIVE FUEL IN CEMENT FACTORIES

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Cement production has advanced much in the last decade years. The types of fuel used in conventional furnaces are coal, oil, petroleum and coke. About energy costs and natural subjects, cement organizations worldwide, say waste materials, for example, waste oils, re-used blend of plastic and paper, the biological waste materials and important waters such as wastewater can take the place of traditional fuels.

The clinker termination procedure is suitable for Alternative Fuels (AF) in Cement factories; our goal is enhancing control and choices of alternative fuels-usage and maintaining clinker item-quality. Substitution of fossil fuels, and different power in the formation of the cement clinker, cement manufacturers are both extraordinary importance for society. Because, fossil fuels because biogenic gaps, reduce greenhouse gas emissions by maintaining more space.

This study found that the use of tires derived fuel in cement factories is easier to transport, store and manage than coal, that the feed rate is easily regulated, that dust prevention and suppression during storage is not require, fuel economy is increased and costs are reduced.

Key Words : Cement industry, cement production, urban and modern waste, tire derived fuel, alternative fuels.
Science Code : 914.3.026

ÖZET

Yüksek Lisans Tezi

ATIKLARIN ÇİMENTO FABRİKALARINDA ALTERNATİF YAKIT OLARAK KULLANILMASI

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Çimento üretimi son on yılda çok büyük ilerleme kaydetmiştir. Geleneksel fırınlarda kullanılan alışılmış yakıt türleri kömür, yağ,petrol ve koktur. Enerji maliyetleri ve doğal konular hakkında, dünya çapındaki çimento organizasyonları, atık maddeler, örneğin atık yağları, yeniden kullanılmayan plastiklerin ve kağıtların harmanları, lastikler, biyolojik atık malzemeleri ve önemli derecede atıksu gibi unsurların geleneksel yakıtların yerini alabileceğini söylemektedir. Çimento fabrikalarında klinker sonlandırma prosedürü, alternatif yakıtlar (AF) için uygundur; burada klinker kalemi kalitesini koruyarak alternatif yakıt kullanma seçeneklerini geliştirmek hedeflenmektedir. Çimento klinkerinin oluşumunda alternatif yakıtlar ile fosil güçlerinin ikame edilmesi, hem çimento üreticileri hem de toplum için olağanüstü önem taşımaktadır. Çünkü fosil yakıt, biyojenik boşluklar nedeniyle, daha fazlasını muhafaza ederek gaz emisyonlarını azaltmaktadır. Bu çalışma ile çimento fabrikalarında lastikten türetilen yakıt kullanımının taşıma, depolama ve yönetiminin kömürden daha kolay olduğu, besleme hızının kolayca düzenlenebilir olduğu, depolama esnasında toz önleme ve bastırmanın gerekli olmadığı, yakıt ekonomisi sağladığı ve maliyetleri azalttığı tespit edilmiştir.

Anahtar Kelimeler : Çimento endüstrisi, çimento üretimi, kent ve modern atıklar, lastikten türemiş yakıt, alternatif yakıtlar.

Bilim Kodu : 914.3.026

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ABBREVITIONS

BDF : Biomass-Derived Fuel
EPA : Environmental Protection Agency
ESM : Environmentally Sound Management
HAP : Hazardous Air Pollutant
ID FAN : Induced Draft Fan
LCA : Life Cycle Assessment
LHV : Lower Heating Value
MBM : Meat And Bone Meal
MCF : Messebo Cement Factory
MSW : Municipal Solid Waste
PAH : Polycyclic Aromatic Hydrocarbon
PCB : Polychlorinated Biphenyl
PCDD : Polychlorinated Dibenzo-P-Dioxin
PCDF : Polychlorinated Dibenzo-Furan
POHC : Principal Organic Hazardous Constituent
RDF : Refuse Derived Fuel
TEQ : Toxic Equivalent
THC : Total Hydrocarbon
TLV : Threshold Limit Value
TOC : Total Organic Compounds
TPD : Tons Per Day
USD : Us Dollar
WAP : Waste Analysis Plan
VFB : Vertical Fixed Bed
VOC : Volatile Organic Compound
XRF : X-Ray Fluorescence

APCD : Air Pollution Control Device
ASR : Automobile Shredder Residue
BSE : Bovine Spongiform Encephalopathy
CDM : Clean Development Mechanism
CFD : Computational Fluid Dynamics
CKD : Cement Kiln Dust
CSS : Combustible Solid Substances
CV : Calorific Value
DRE : Destruction & Removal Efficiency
DTG : Time Derivative Of Thermosgravimetry
EGA : Evolved Gas Analysis
ESP : Electro Static Precipitator
FTIR : Fourier Transform Infra-Red Spectrometer
HCB : Hexa Chloro Benzene
HHV : Higher Heating Value
HWF : Hazardous Waste Fuel
ID :Induced Draft
LA :Low Alkaline
LHW :Liquid Hazardous Waste
MBM : Meat & Bone Meal
NOK :Norwegian Krone
PCDD : Poly Chlorinated Di-Benzo Dioxins
PCDF : Poly Chlorinated Di-Benzo Furanes
PE : Poly Ethylene
PET : Poly Ethylene Terephthalate
PHD : Process History Database
PP : Poly Propylene
PS : Poly Styrene
TDF : Tire Derived Fuel
AF :Alternative Fuels

PART 1

INTRODUCTION

The primary need for building and improvement materials is cement. The global bond market is going up. Bond producers are trying to extend their capability, which resulted in the importance of unrefined materials and fuels. In the same way, the use of Alternative Fuels (AF) has adequately extended in a general sense, yet further possibilities still exist inauxiliary forms (Universal Vitality Organization (IEA), 1999). The bond business needs conservation of resources and biological confirmation that extended recently because of quick development of significant countries including India, China and other South Asian countries (Laszlo ets.,2006). This business is now very important. Figure 1.1 and Table 1.1, showcase the foreseen overall bond:

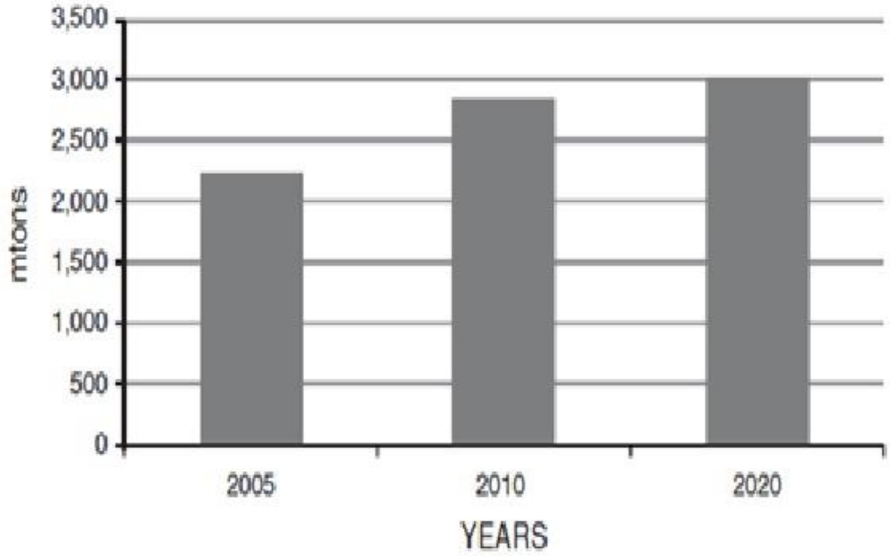


Figure 1.1.World cement demand trends (IEA, 1999).

Table 1.1. The cement demand in the future Madlool et al (2011).

Cement demand	2010 (Mtons)	2020 (Mtons)	Growth (%)
World cement demand	2,836	3,020	4.75
Western Europe	235	355	2.22
North America	210	310	2.92
Other regions	510	610	4.72
Asia	1,920	2,220	5.22

The usage is assessed at around 2 for each penny of global total, and 5 for each penny of meter total. The fuel blend in the business is genuine carbon, which generates CO_2, so that its share is about 5 percent (IEA, 1999; Madlool ets., 2011).

In 2008, the bond production in the EU was 210 million tons, which means approximately 7 percent of the entire global production. Europe's 160 million tonCO_2 was produced out of bond plants, which was 38.4 percent of the mechanical release in Europe and 3.21 percent of the total European CO_2 releases. In a bleeding-edge bond plant, 60 percent of the CO_2 emanated by a concrete production line, which occurs as a result of limestone-calcification while 30 percent invigorates in the heater and 10% during other plant-operations (Bosoaga et al., 2009).

The efficiency is created through overhauling, using beneficial apparatus, controlling fuel-waste and reducing the CO_2 emissions (Bosoaga et al., 2009).

Numerous experiments have demonstrated that the utilization of squanders as AF by concrete production lines and it is both financially and environmentally advocated. The utilization of AF will help diminishing the cement production costs. The energy needs to generate every ton of cement is around 3.31 Giga Joule (GJ) that is equivalent to 121 kg coal while its calorific estimation will be 28 Mega Joule/Kilogram. Vitality cost represents 32-40% of bond generation expenses. The substitution of AF for non-renewable energy sources will help diminishing vitality costs if there is a vital edge.

Besides, less waste should be created that will require fewer dumping sites. In this way, the utilization of waste inferred by concrete industrial facilities, which is hazardous to nature. The conditions in revolving ovens, for example, outrageous heat, gas flow and molecular stockpiling time, assure biologically-sheltered AF utilization. Co-preparing strategy is ideal for concrete business because it recuperates energy and separates waste. The possibility of using wasted substances as fuels exists because the specific and needed wastes are easily available, and besides, their cost of processing and reusing as fuels is just a fraction of petroleum price.

This part lists the project objectives and a general overview of alternative fuel types usable in a cement kiln. Part 2,fuels used in the cement industry. Part 3, includes short explanation of cement manufacturing process, key processes and the combustion. in part 4, Cement kiln emissions and their environmental significance are discussed. In part 5, the case study, rotary kiln fruition and its phenomenon has been presented. in part 6, The full-scale combustion experiments with a modern feeding system, study and conclusions are presented. Finally, part 7 presents the conclusions and recommendations for the future work.

PART 2

FUELS USED IN THE CEMENT INDUSTRY

Cement production is an energy intensive process and an average kiln needs energy from 3.22 to 5.1 (Lemieux et al., 2004). The decarbonization of limestone and dehydration of kaolinite, which is highly endothermic, need approximately 2.2 MJ/kg that is used in exothermic reaction for producing C3S, C2S, C3A, and C4AF; (Observe 3.1), which let out around 0.46 MJ/kg energy. In the drying-out process, approximately 50% of the energy is required for chemical reaction and the remaining is left for rays damage (roughly10-12.5%), exhaustion of air (nearly 10%), exhaustion of gas (approximately 22%), and for clinker (nearly 2.1%) (Willitsch et al., 2009). Cement manufacturers are using diversity in their inputs but still, the most familiar kinds of energy sources are assorted coal, fuel oils, natural gas, petroleum and coke (Jacott et al., 2003). It is believed that energy costs about 28-39% of the cement production cost (Rasul, Widianto & Mohanty, 2005).

The cement manufacturers around the globe are employing waste materials and other substitutes to exchange fossil fuels in cement factories (Gossman, 2007) to decrease the energy costs, lessen emissions, reduce the landfill needs, and lessen the CORP2-footprint of exhausts.Researchers believe after research for long time that the cement factories can reuse waste for tinkering operations and cement manufacturing. Industrialized states have more than three decades of fruitful practice of using alternative fuels. In the United States, cement factories gained 25-68% energy using alternative sources (Murray & Price, 2008).

Cement furnaces work excellent with alternative fuel produced from wasted materials because chemical makeup of many wastes is similar and compatible withthe recycle tables used to produce portland cement.

The waste products in cement furnaces are given below:

1. A cement kiln gets good enough temperature specifically for clinking, which is almost 1700 {E|T|P} and temperature of flame range is normally 1627-1827°C, which is higher than the needed temperatures for heating highmolecular hydro-carbons, and for de-chlorinating dioxins (Mokrzycki, Uliasz-Bochenczyk & Sarna, 2003).
2. Long time on high temperature guarantees a great efficiency of Arctic destruction: A temperature above 1486 °C is maintained in this zone whereas the gas at above1197 centigrade between 4. 1 and 5. 0 s (Mokrzycki, Uliasz-Bochenczyk & Sarna, 2003).
3. Surplus oxygen during and after combustion (Karstensen et al., 2006).
4. The process is increased by an alkaline environment that tends to wash combustion gases: neutralization and capturing HCl acid or other substances (Giannopoulos et al., 2007).
5. Heavier minerals promotes the immobilization of the heavy materials inside a clinker since it is finally transformed into concrete, so no output of any by-product including ashes, slag or fluids is left behind (Karstensen et al., 2006).
6. Extremely turbulent nature creates homogenized blend: Gas moves throughhigh-temperature regions range 12.2-13.6 m/s (Mokrzycki,Uliasz-Bochenczyk & Sarna, 2003).
7. Large area of the furnace and continuous energy supply

In addition to above factors, the cement kiln dust (CKD) and particles in the exhaust gas are gathered through electrostatic precipitators and they are later recycled using a device (Giannopoulos et al., 2007). Moreover, the ecological economic and personal benefits are associated with alternative energy in cement kilns. All those benefits and other factors are discussed below.

2.1.UTILIZED AS A PART OF THE CEMENT INDUSTRY

1. Higher carbon dioxide and other carbon emissions lead to higher environmental greenhouse and warming.

2. PZ-Clinker's expenses reduce because of cheaper fuel.
3. Lesser dependence on fossil/non-renewable energy.
4. Sensible substance-reusing strategy.
5. Deposit-free burning, without ash, and ground/sewage pollutants ash, and sewage.
6. Dangerous materials will no longer exist because of heat and other factors.
7. Higher thermal efficiencies in process.
8. Adequate disposal of wasted substances.
9. Better ecological balancing.

2.2. CLASSIFICATION OF ALTERNATIVE FUELS UTILIZED IN CEMENT KILNS

Presently we have solid and Fluidfuels that it is employed in cement manufacturing. We have 3 major energy sources:

1. Natural/agricultural products (natural oils sawdust, barks and so on.).
2. Artificial products (old tyres, rubber-based wastes, rejected products and plastics, etc).
3. Other things (pieces of destroyed vehicles, rejected fuels, trash, and many other things).
4. Fluid fuels are divided into.
5. Fluid-alternatives; toxic acidic tar, essential oils and residual fuels, etc.
6. Fluid fuels and harmful liquids (poly-aromatic hydrocarbon (PAH) polychlorinated biphenyl (PCB), and so forth).

Generally, the amount of fossil fuel or other fossil energy is determined by their calorific values, their water content in comparison with the fossil fuel. A general illustration of average quantities needed to substitute a ton of coal as shown in Figure 2.1. (Values are based on material's energy and water content. Exchange assumes coal has LHV 26.3 GJ/ton). While LDPE shows the requirements to replace one ton of coal, and the sludge needs in higher quantities because of high moisture content.

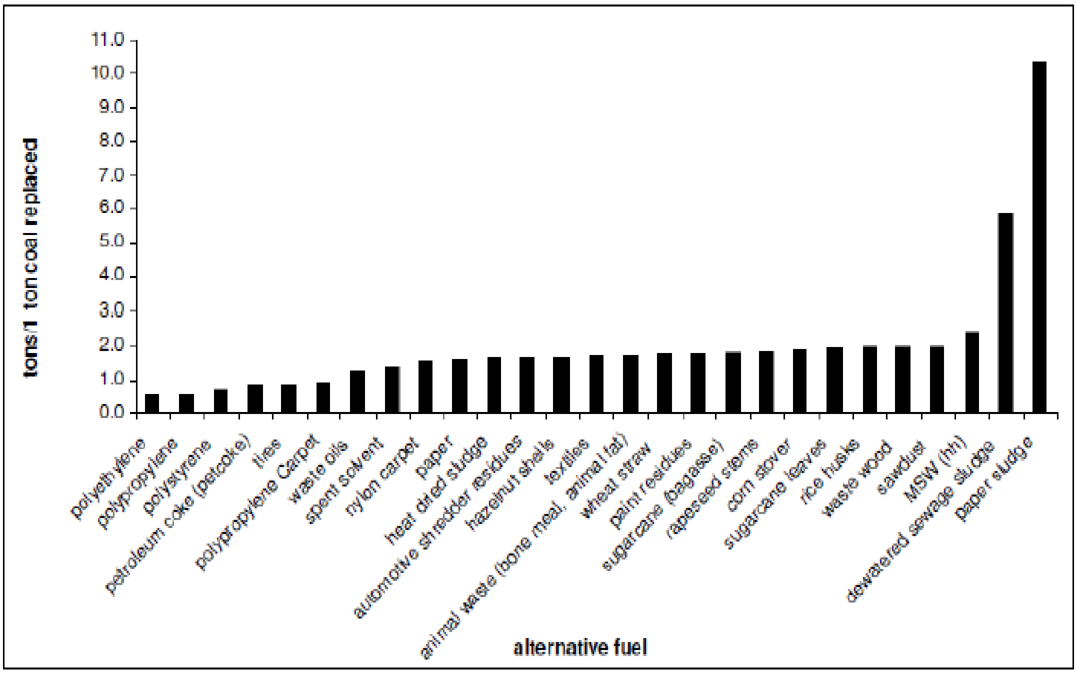


Figure 2.1.Quantity of alternative fuel needed to exchange 1 ton of coal (Murray & Price, 2008).

2.3. TIRE-DERIVED FUELS

Tires are the oldest supplementary solid waste fuel employed for cement production. The gross annual generation rate of used car tires in Norway is about 15,000 tons. The disposal cost received for whole car tyres is typically NOK 500/ ton and 200/ton for the disposed of tyres (Tokheim, 2000).

2.3.1.Material Analysis

The composition of tyres is variable according to grades of bracing materials in the tyres. The makeup can also change with manufacturer and tyre wear (Twigger et al., 2001) Generally, TDF is very good quality energy having 30-35 MJ/kg about the same as a superior quality coal. TDF's nitrogenous content is lesser as compared to coal but its chlorine content is higher (Barlaz, Eleazer & Whittle, 1993). TDF typically has 0.5-2 % sulfur, which is less than or equal to l for black coals and coke. TDF may have metals such as lead, cadmium, and zinc(Constans & Gossman, 1997).

2.3.2. Material Pre-Treatment, Storage & Handling

TDF can be provided in a variety of forms. Few advantages and disadvantages are tackled in the Table 2.1 and several forms of tyre-derived fuels are shown.The storage area of tyres is needed according to the size and type of tyres.Sorting and storage can be carried out at the site or by the supplier. Although the storage is typically undertaken in wide-open stockpiles, sometimes, they are delivered in trailers or multi-trucks that work as storage containers and can be fed straight to the kilns or conveyor belts. In the same way, some operators use a warehouse to avoid water ingress in the kiln. Chipped tyres have a greater density and therefore, they can be easily stored in warehouses. Today, many systems have been fully involved in conveying, weighing and discharging. For whole tires, mechanical transfer is a very important technique for controlling the addition/feeding rate, with which, used tyres are fed to the kiln.The conveying of the disposed off tyres into the kiln is typically done by mechanized means, for example, seatbelt and roller conveyors, with entry into the kiln by many sluices or clapper valves. Some systems include rotary valves, for example, three-wayvalves, which allow other fuel additions to the shredded tyres (Twigger et al, 2001).

Table 2.1. Advantages and disadvantages of different forms of tyre-derived fuels (Constans & Gossman, 1997).

Form	Advantages	Disadvantages
Ground Tyres (crumb)	- The steel in the bead and radial bands can be removed via air classification. Then the crumb can be blown in with powdered coal directly substituting for the powdered coal. - The transportation, storage and management is easier than coal	- The removal of the steel is unnecessary (disadvantage) since cement kilns have a need for iron in its process - Producing the crumb is quite expensive Dust suppression and fire suppression on storage may be required due to bulk processing
Tyre chips (from 2x2 to 15x15 cm2)	- Feed rate can be easily regulated - There is very little manual labor involved in handling chips versus tires	- Expensive - The wire in the bead and radial belts do not shear smoothly when the tires are chipped. Consequently, the chips are ragged with these wires hooking onto everything they come in contact with. - Utilizing tire chips after several months of use will clog or shut down the mill. - Dust suppression and fire suppression on storage may be required
Whole tyres	- No processing costs - Do not migrate throughout the facility - Dust suppression and suppression on storage are not required	Transportation, storage, and management of whole tires requires more logistical care and more manual labor, and the hadling process is difficult-to-automate

2.3.3. Feeding & Process Requirements

TDF can have different structures. Few points of interest and hindrance-handling are shown in the Table 2.1.

The capacity of entire tires depends on size and type. Sorting and capacities can be assured on-site by the provider. Entire tire requires more stockpiling in case of less mass thickness. Despite the fact that the capacity is commonly embraced in open stockpiles, some of the time is employed in trailers or multi-tracks that work as capacity compartments and they can be sent straight to the ovens or transport lines to keep away from the heap fire. In a similar time, a few administrators do not let water seep in either in the entrance or the oven. Chipped tires have a more noteworthy mass thickness and subsequently, they can be easily placed in any kind of circumstances in a warehouse. Today, a large number of frameworks have been completely incorporated into passing on, weighing and releasing. For entire tires, the critical methods are mechanical exchange from the capacity region, controlling the expansion rate in the oven and limiting the air by twofold pendulum folds or safeguards.

Passing on tires to the furnace is commonly done by automated means, for example, safety belt and roller transports with passage into the furnace using number of floodgates or clappers. A few frameworks incorporate three-way turning valves.

2.3.4.Product Quality And Stack Emissions

As indicated by the hypothetical contemplations, sulfur discharges in the burning tyres/coal as fuel is processed in calcinated limestone, which shapes gypsum that is crucial substance for manufacturing cement. It is anticipated that different nitrogenous oxides get diminished once TDF is substituted for coal; however, a few plants may likewise encounter changes in Sox. NOx levels rely on when and where the TDF is used, which changes the oxygen levels.

In the trials done by Tokheim (2000), with the entire auto tires are heated in the oven at a highest sustaining rate 1t/h, a 25 % NOx diminishing takes place and the Sulfur focus in the pre-calcinated dinner expands from 4 % to a level of around 6 %. In a similar way, the destroyed auto tires in the furnace, the channel indicates lessened NOx discharge by 30-50% and collection of sulfur in pre-calcinated dinner. The measurable investigation done by Prisciandaro, Mazziotti and Veglio' (2003) shows that if less than 20% of the consistent fuel is provided in form of tires, the stack emanations including SO_2, NOx, and CO will somewhat expand. The NOx and SO_2 was clarified by real air supply, distinctive dampness and burning of tires. Mokrzycki et al. explained expansion in discharges, which happens just if the option fuel is added to the furnace (Conesa et al., 2008).

The antacid condition of a concrete furnace finishes most of the HCl corrosion. As Conesa et al. (2008) described, the process included 24% expansion in SO_2, 11% abatement in NOx and 37% increment in CO while utilizing a mix of tires and coal. The experiment showed 45% discharge rate of dioxides and furans. According to Tokheim (2000), there are no critical increments in the emanations of dioxins/furans or substantial metals when destroyed auto tires were fed in the oven. In any case, in a review published by Hsu and Ling, levels of dioxins and furans increased in the concrete while adding tires to the furnace. Likewise, the discharge of VOC and PAH increments when more tires are added to the furnace presumably because of the bolstering point (Conesa et al., 2008). A uniform usage rate of scrap or chips will enable the administrator to build the furnace, which will allow addition of entire tires at one to two-moment interims, and that will create a CO spike as well as an oxygen dunk in the gases exiting the oven. This can be adjusted by expanding the typical furnace (Constans & Gossman, 1997).

The accessible information on risky waste ignition in furnaces proposes that the metals from concrete delivered in tire-fed ovens will be negligible. The nearness of iron in dab and outspread belts in tires decrease the need to buy a press, since it is raw material of the bond production. Conesa et al. (2008) have found that the addition of nickel is helpful while using tires as a fuel. They believed that it may be because of the tire's bolstering point that had minerals. The measurable examination done by Prisciandaro, Mazziotti and Veglio' (2003) has revealed the expansion of Zn, which was clearly distinguished and no factual contrasts were observed.

PART3

CEMENT PRODUCTION

The cement production involves rotational furnace, which are recommended by the EU Contamination Prevention and Controls and it is one of "Best Obtainable Methods" in cement/limestone factories (IPPC, 2001), CEMBUREAUs BAT report 1998. The British Environment Agency "fused contamination controls and prepared guidelines for cement & lime units (Environment Protection Agency (EPA), 2001).

3.1. CEMENT PRODUCTION

3.1.1.Key Processes

This process relies on 4 fundamental courses for managing concrete-utilization in the furnace in dry/ semi- dry/ semi-wet/ wet methods. Many fundamental components are depicted in the accompanying sections; concrete generation utilizing vertical-shaft furnacesare/kilns can be managed independently to a limited extent 3. In any case, regular procedures have the following sub-forms (Figure 3.1):

1. Quarrying.
2. Assessment of raw-material
3. Fuel-planning
4. Clinker-consumption;
5. Mineral-readiness;
6. Cement transportation and pounding.

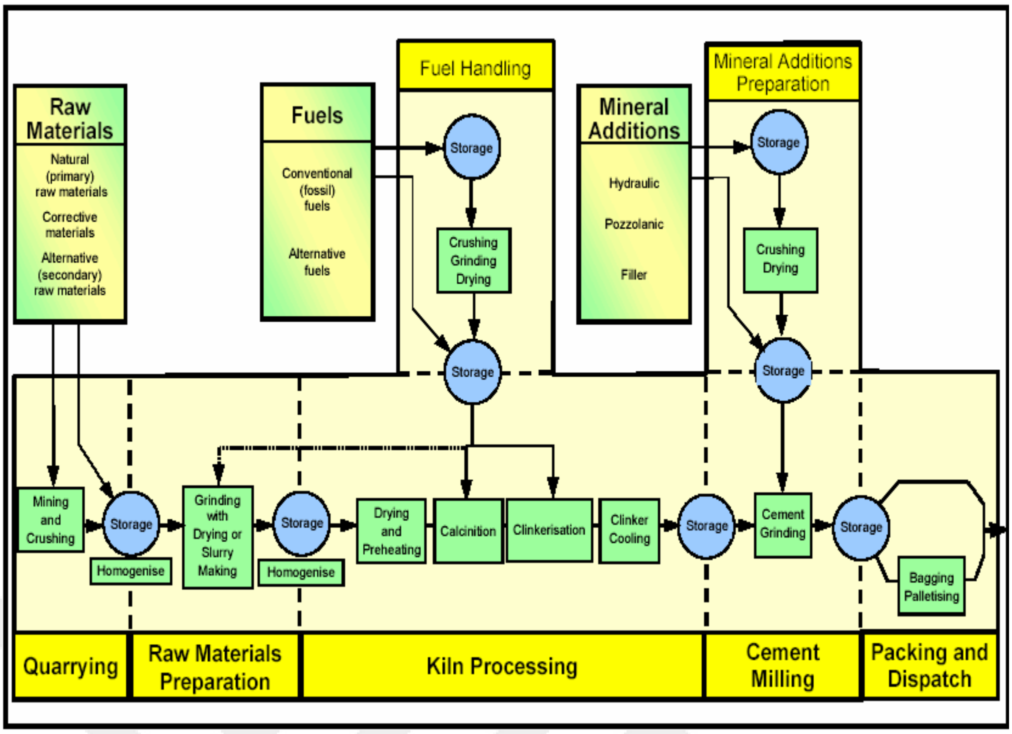


Figure 3.1.Processes and system of cement production utilizing rotary kilns (Environment Agency, 2001).

Production-operations utilize rotating furnaces (EPA, 2001) .

Quarrying-characteristic: Some essential rawmaterials, for example, lime and mud are separated and they are normally found near the band factory. During the post-extraction stages, these crude substances are processed in the quarry process and then sent to bond factory for middle stockpiling, homogenizing and later arrangements.

"Remedial" substances, for example, bauxite/press metal are needed for adjusting the synthetic crude blend organization.These remedial substances are used in lesser quantities alongside major rawmaterials. Optional raw substances can be swapped with characteristic raw substances. Other than substituting conventional rawmaterials, they can be used as quarry grinders, which helps managing the raw materials for producing cement.The present day mechanized strategies are used to assess them and to improve the raw material supplychain in the long-run and consequently the production of cement.

3.1.2.Preparation Of Crude/Raw Substances

When moderate stockpiling and homogenization, the crude substances are dehydrated and crushed in fully-controlled way. This helps dry/semi-dry supper preparation. In case of wet/ semi-wet handle, raw substances are crushed with adequate water that creates slurry. Depending on available mechanical procedure/s, extra strides might be required. A subsequent middle item, which may be feast/slurry is put away for additionally homogenizing the crude dinner storehouses, stockpiling canisters or slurry bowls for uniform compound structure before putting it in the kiln/furnace. As a dependable guideline, around 1.55-1.65 ton crude substances are needed to create 1ton of the clinker.

3.1.3.Fuel Preparation

Ordinary fuels including coal are used for bond production. These fuels also include petcoke and oil as well; however, flammable gases are seldom utilized because of their higher costs. "Elective" powers – i.e. non-renewable energy resources obtained from mechanical (wasted) resources are broadly utilized for using instead of customary petroleum derivatives.

Power management – i.e. squashing, drying, granulating, and homogenizing – generally happen closer to each other. Particular establishments are required, for example, coal plants, storehouses and capacity corridors for strong fills, tanks for fluid energizes, appropriate transport and sustainable ovens. The warm fuel utilization is largely reliant on the consumption of clinker.

The fills are utilized as a part of a concrete plant, which is strong, fluid or vaporous and it decides the limits of the capacity, and terminating mechanisms both for regular petroleum products and for optional power. Fundamental fuel inputs must be delivered in specific shape, which permits uniform/solid metering, and helps ignition. This is normally the case with all pummeled, fluid and vaporous energies. A restricted contribution (about 36%) can be done through particular focus. Coal/petcoke can be purified in coal factories including tube-mills, vertical rollers or other types of plants. The entire coal and the processing framework should be secured from flames or any kind of blast. Specific fuels might be burned in the burner (excluding halfway stockpiling/measuring framework and that is a usual procedure that might be put away in fine coal storehouses with satisfactory measuring frameworks. The oil, which is used as fuel, is stored inside extensive tanks placed nearby. Oil is heated at 81°C and burning starts 125-145 °C, which diminishes consistency.

Petroleum gas is supplied through dispersion frameworks without on-location stockpiling. Before ignition in the oven, the weight of the gas must be diminished. Vaporous, fluid, or pummeled fuels can be used in the furnace framework depending on petroleum derivatives specified previously. Coarsely destroyed or cumbersome substances can be pre-heated or pre-calcinated. The bond plant provides the capacity and right inputs on location. Elective fuel plants are frequently used as multi-purpose" plants keeping in mind the end goal of final assortment.

3.1.4. Clinker Burning

Crude/raw substance is placed in a furnace and exposed to heat-treatment handle which has successive strides for processes like moisture removal / preheating / calcination (for extraction of carbon dioxide from lime), and sintering (of clinker elements at 1440°C). Used item "clinker" can be later chilled with air having temperature range between 95-198 °C, and later that can lead to halfway stockpiling.

Furnaces operate with/without pre-heaters (or "pre-calciners") and its choice depends on the kind of procedure. The rotating oven itself is a slanted steel tube with a length to width proportion 1:4. The slight slant (2.5 to 4.5%) together with the moderate turn (0.5–4.5 cycles for each moment) provides a material transport adequately long to help the required change of form. Depleted warmth from the oven is used to dry raw materials or for mineral augmentations in the plants. Depleted gasses are removed utilizing electrostatic precipitator or pack-channel frameworks a little earlier than their discharge (Figure 3.2).

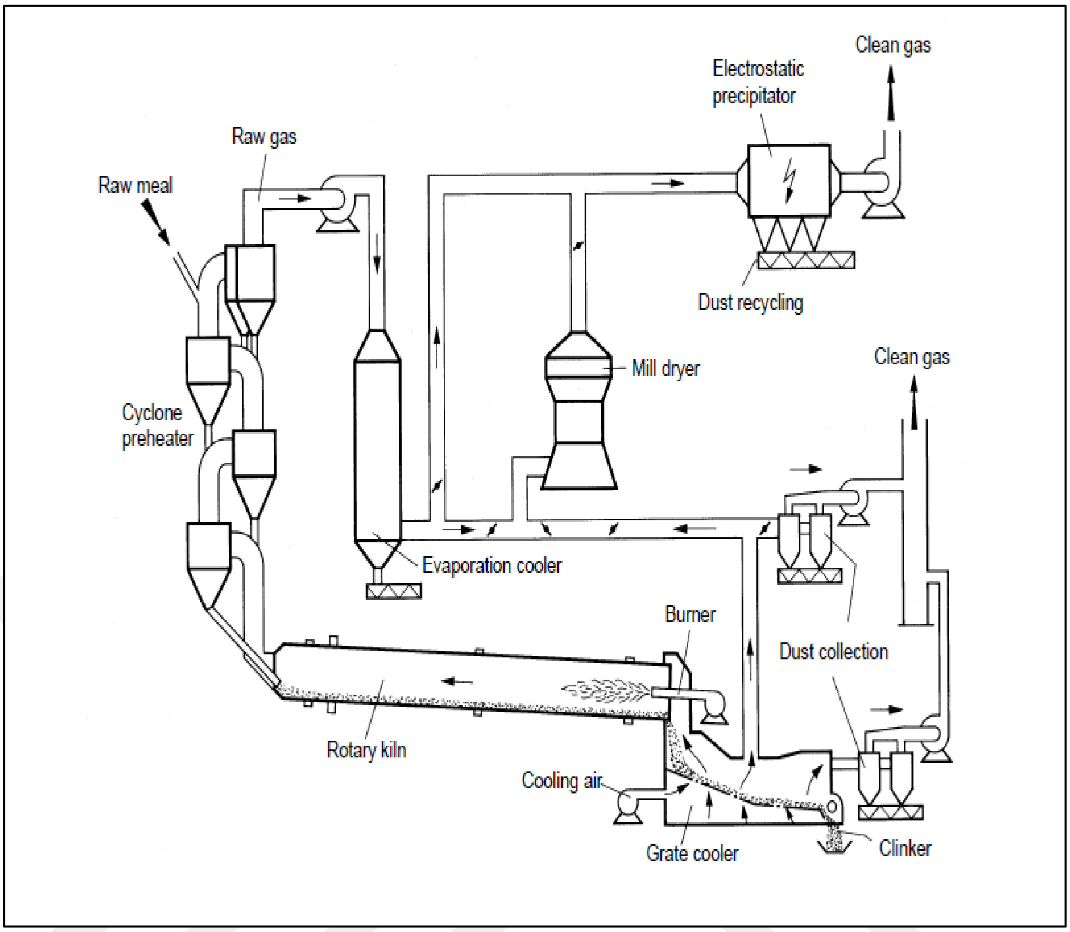


Figure 3.2. Rotary-furnace with "cyclone pre-heater" and gas dust removal (Cembureau ,1999).

3.1.5. Grinding Cement

The in-grinding bond clinker receives Portland cement and processes it with about 2% gypsum. Mixed bonds (or "composite" cement) contain different constituents, for example, granulated impact heater slag, common or modern-pozzolana or idle fillers, for example, lime stone.

Minerals in mixed bonds can be inter-ground by using clinker or separately-ground substances, and then they are added to the Portland cement. Distinctive bond types must be placed in cement storehouses then they are packed and dispatched.

3.1.6. Preparation Of Mineral-Additions

Mineral-additions from normal/modern sources can be utilized as a part of mixed concretes, which should be dried, squashed or ground in isolated establishments on location. Isolated "granulating plants," where mineral additions and mixed concretes are delivered, can be at a distance from the clinker production site. Mineral augmentations are utilized as mixed bonds but later, their capacity, blending, smashing, drying and sustaining capacities are checked and assured. Ordinarily-utilized mineral additions incorporate normal substances, for example, volcanic-rocks, lime or calcinated-earth, and substances obtained from mechanical sources, for example, slag, silica or fly fiery.

Prior de-moisturizing is needed in case of material dampness. Rotating tube-driers or blaze-driers make exhaust gasses and fumes. Mineral-augmentations might be taking place with bond clinker in a cement factory or turned into powdered form for mixing with Portland cement. Isolated pounding and mixing is mostly connected within slag bonds. For particular pounding of mineral augmentations, similar establishments are utilized as in case of bond granulating.

3.1.7.Cement Dispatch

Bond might be shipped as mass cement or to some degree gathered as packs for dispatching. Dispatch strategies include variety of transports (road, railroad etc), which rely on some conditions and prerequisites.

3.2. SUBSTANCE PROPERTIES

Portland bond-clinker uses crude substances includingcalcium/silicon/iron/aluminum as fundamental components.

At the point when blended in the right proportions, new minerals show water driven properties and the purported clinker stages are brought after heating to the limit of clinker-station at 1450 °C.

3.2.1.Key Clinker Stages

The principle mineral-segments inside clinker include silicates, aluminates, and ferrous compounds and calcium. Major 4 oxides include namedalite, ferrite, belite, and aluminate.

1. Tricalcium silicate 3 CaO x SiO_2 C3S Alite.
2. Bicalcium silicate 2 CaO x SiO_2 C2S Belite .
3. Calcium-aluminate 3 CaO x $Al2O_3$ C3A Aluminate .
4. Calcium ferrite 4 CaO x Al_2O_3 x Fe_2O_3 C4AF Ferrite.

When everything described earlier is done, C3S is added for quality (from the first day) and expands the warmth of hydration; C2S adds to late quality (from 28 days); C3A likewise adds to early quality and warmth; C4AF, for the most part, influences the clinker shading.

The clinker development operation is separated in four stages:

1. Dehydrating and pre-heating (22 – 910°C): extraction of water;
2. Calcination (620 to 900°C): gathering CO_2 with the clinker-mineral;
3. Clinker-station (1245 – 1445°C): Calcium-silicates form;
4. Kiln interior cooling (1360 to 1210°C): crystallization of calcium-aluminates and calcium-ferrite.

Minor elements in cement clinker incorporate free calcium oxides, oxides of magnesium, and soluble-base sulfates. Extra synthetic components displayed in the crude materials, for example, Mn, K, or other metals are basically present in different clinker-stages.

Minerals and structure control clinker properties. A few components out of crude substances, for example, salts, sulfurous compounds, and chloride compounds are treated on high heats bringing about a changeless interior cycle of vaporization and buildup (circling components). An extensive piece of these components will stay in the furnace framework and will at last leave the oven with the clinker. A little part will be sent to the furnace that debilitates gasses. Unstable components and establishment of pre-heater "sidestep" can wind up noticeably important where some portion of the tidy loaded fumes of gasses of the rotating oven are separated from the framework. Both channel and sidestep tidy can be reused for the cement assembling operation.

3.2.2.Crude Blended/Mixed Components

A crude blend in clinker produces ordinary calcium-rich matter, which has less than 76% carbonates (limestone/chalk/marble/ calcareous marl), aluminum-rich elements, iron, dirt, silicon, and earth etc and restorative segments particularly enhanced with any of the following 4 elements (bauxite, press mineral, sand, and lime). Correctives are utilized as a part of little amounts just to change the concoctions of the crude blend for needed quality goals. Compound creation starts from mechanical resources.

The appropriate crude blend configuration depends on the situation of given crude materials, the procedure process necessities, and on ecological contemplations. A crude blend, sufficient fineness of the crude dinner and steady compound piece are necessary for quality-assurance and smoother oven function. Sufficient examining and substance investigation should control homogeneity or consistency.

The quality-assurance is necessary for regular and feasible oven usage. Both consistency and homogeneity can also be assured through compound examination.

3.2.3. Fuels

Principle non-renewable energy sources ("essential" energies) in the bond business include oil, petcoke, coal, and to a lesser degree petroleum gas as well. Other options include mechanical power, tires, used oils, plastic, and many others.These substances provide substantial energy and they can be used in the clinker; however, the compound arrangement of the blend of these substances must be carefully selected.

Metals can also be fused into the clinker structure to a certain degree. Special cases are those metals, which are mostly or totally volatilized in the furnace, for example, mercury or cadmium etc can be stick in the oven or escape with other outflows if attention is not paid to their outflow.

3.2.4.Cement Constituents

Portland cement manufacturing is done through inter-grinding clinker with 2% gypsum. In numerous countries, the expansion minor ingredients, for example, crude feast, limestone or channel clean is permitted up to 5 percent.

In mixed concretes, some portion of the bond comprises of mineral additions obtained through common or modern resources. They are pressure-driven and include silica, coal fly and calcinated mud. Their synthesis in the form of mixed concretes can be determined through bond gauges. The norms incorporate quality details for mineral-augmentations.

3.3. THE FOUR KEY PROCESS ROUTES IN ROTARY KILN CEMENT PRODUCTION

Clinker advancement can be described through transition of "wet" to "dry" process; however, "semi-wet" or "semi-dry" are also available possibilities. Turning furnaces were introduced in 1895 and they had long and wet ovens. Wet furnaces are less complex and more easily homogenize crude substances. With more robust present day innovation, it is conceivable to set up a homogeneous supper utilizing "dry" procedure. A primary favorable position of current dry procedure has lesser fuel utilization costs.

The 4 distinctive fundamental procedures can be quickly described as takes after:

1. Dry procedure: Dry crude supper is pre-heated in a pre-calciner furnace to extract out the moisture.

2. Semi-dry procedure: Dry crude feast processed with interior cross pre-heaters to extract out large part of moisture.
3. Semi-wet procedure: Crude slurry is first dehydrated through channel press then grate pre-heater is used on it preceding a pre-heater/pre-calciner furnace.
4. Wet procedure: The crude slurry processes in a long turning furnace having inward pre-heating system.

All procedures have a lot in common, and the material is de-moisturized in the first place, later calcinated through CO_2 release and then sintered at 1400-1450 ºC. In the whole procedure, roughly 33% of its unique dry mass is lost.

3.3.1.The Dry Operation

For dry/semi-dry furnaces, crude dinner is set up by dehydrating and granulating crude substances in tube-factories or roller plants for dehydrating (Figure 3.3) In suspension pre-heater ovens, the crude dinner is processed at the highest point of a progression of violent winds and hot fumes of gasses create cozy contact and proficient warmth between strong particles and hot gas. The violent winds in this manner separate solidified and gaseous substances.

Preceding the revolving oven, crude dinner is warmed up at 812-832 °C.
The fumes and gasses exit out between 310-358°C and they help the drying process.
Sulfur, chlorides or antacids are effortlessly volatilized in the furnace.
This information must be deliberately controlled;Exorbitant info may be required for the establishment of a framework, which permits some portion of the rotating oven gasses to sidestep the pre-heater.Consequently, some portion of the unstable mixes is removed.

The sidestep framework removes 6-16 % of the oven gasses and these gasses are heavy.

Present day suspension pre-heater furnaces typically have 4 typhoon stages with a most extreme limit constrained to roughly 4000 t/d. At times, to organize twister pre-heaters and arrange pre-heaters still operate. Oven frameworks having 5-6-arrange violent wind pre-heater are a standard innovation for latest factories.

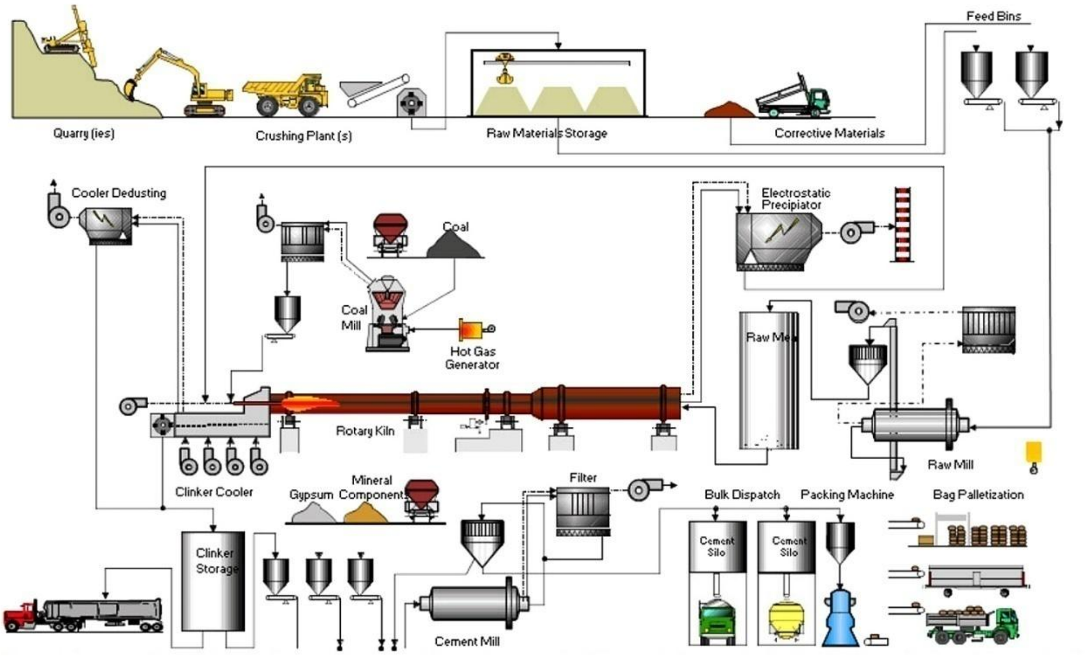


Figure 3.3. Production of cement by the dry operation (Cembureau, 2000).

3.3.2.The Semi-Dry Procedure

In this type, dinner is pelletized that contains 11-13% of water along a slanted pivoting table ("grinding plate") and bolstered to an even voyaging grate pre-heater before the rotational furnace. A higher level of calcination is done after consuming some fuel in the pre-heater. Hot fumes/gasses move through pre-heated. After de-dusting, they move through soggy pellets (Figure 3.4).

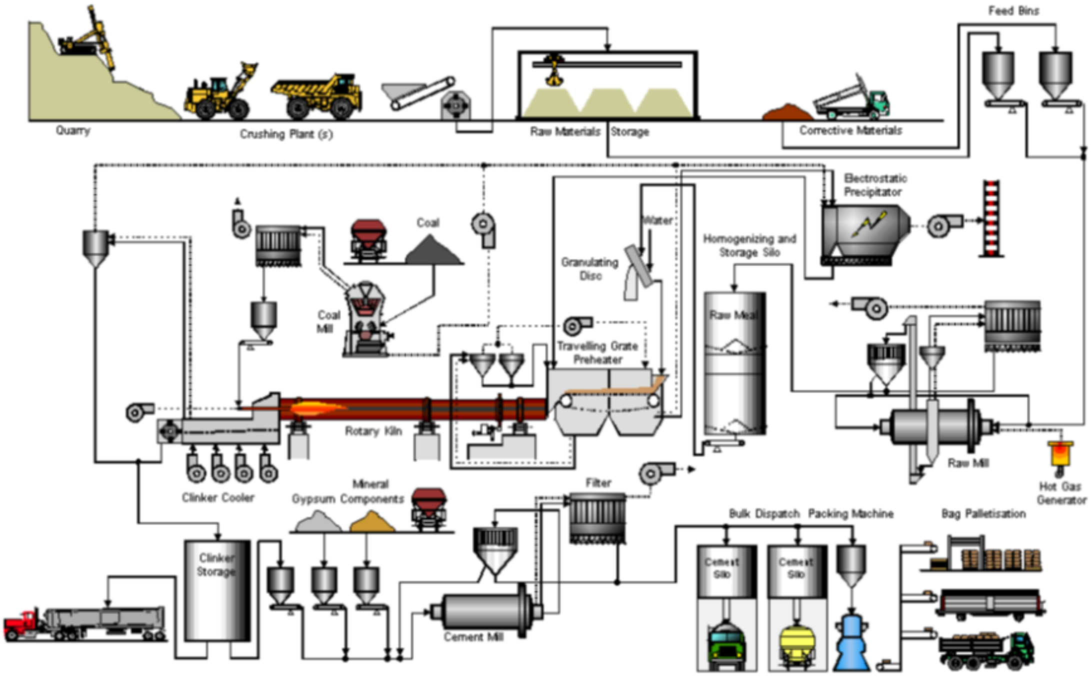


Figure 3.4. Cement production through semi-dry operation (Cembureau, 2000).

A disadvantage of the semi-dry operation is that the furnace debilitates gasses, which cannot be used in the crude super drying and pounding framework because of the low-temperature level. Present day establishments utilize the semi-dry operations as well.

3.3.3.The Semi-Wet Operation

In semi-wet procedures, the crude slurry is dehydrated through channel presses. Normally, chamber-filtration creates channel cakes with leftover dampness of 15-20 %. Before that, channel cakes were additionally prepared. In modern cement factories, slurry filtration takes place where crude substances have higher-than-normal dampness. Channel cakes are saved in the stockpiling canisters before warmed crushers or dryers process it. When dryers or crushers work all the day with oven the mechanical framework undergoes recuperation using furnace gasses and fumes (Figure 3.5).

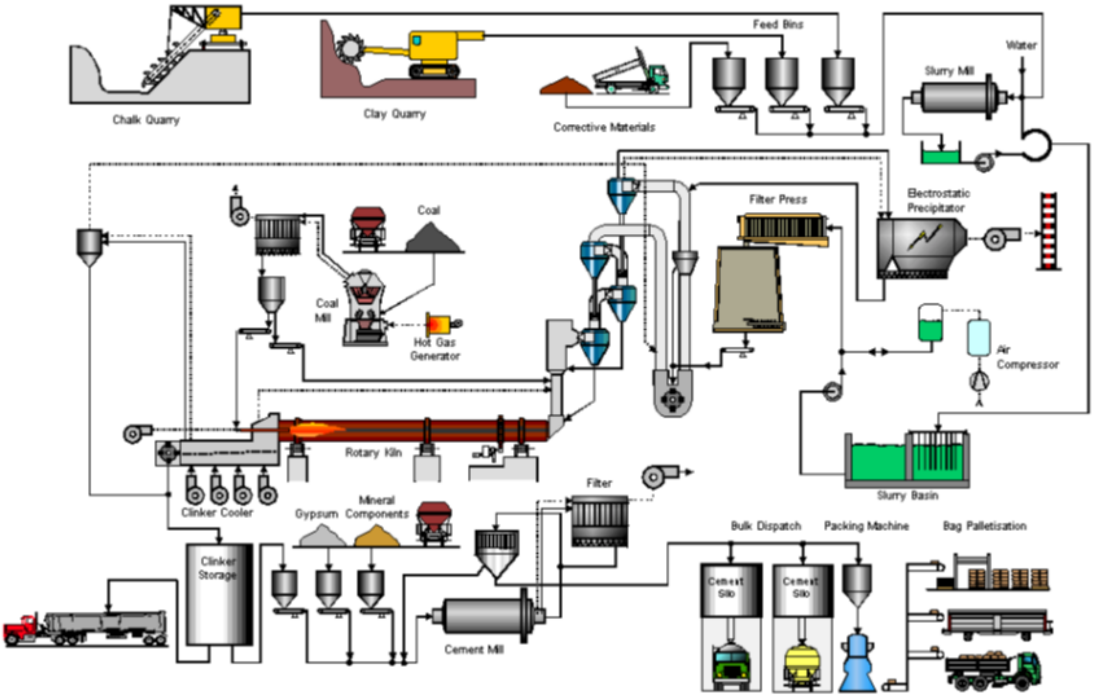


Figure3.5. Cement production by the semi-wet operation (Cembureau, 2000).

3.3.4.The Wet Procedure

Ordinary wet procedure ovens have revolving furnaces for creating clinker. These furnaces have crude slurry. Clump mixing as well as homogenization is accomplished in slurry-storehouses/bowls where compacted wind is used to ceaselessly blend the slurry. It is moved in the rotating oven. Regular non-dry oven innovation utilizes more warmth and generates more ignition gasses and vapors.

Modern wet furnaces sustain slurry and dissipate water before the entry of a violent wind in the pre-heater oven; therefore, modern wet ovens allow lower warmth utilization as compared to regular wet furnaces (Figure 3.6).

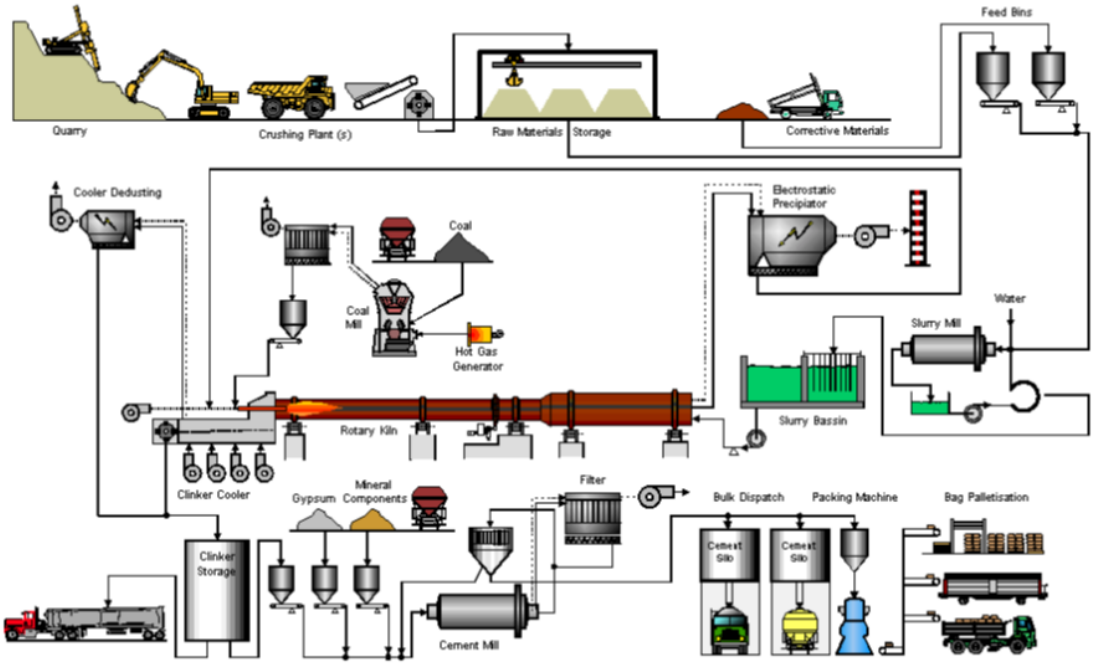


Figure 3.6. Cement production through wet operation (Cembureau, 1999).

3.3.5.Circulating Elements

Unpredictable segments, for example, soluble bases, sulfur/chlorine may increase issues in furnace procedure. Arranging for pre-heating through violent winds may prompt diminished furnace efficiency.In this way, the contribution of these unpredictable parts is precisely for operational/monetary causes.

Unpredictable segments, for example, soluble bases, sulfur/chlorine in crude substances, which might increase the issues. Developing arrangements in the pre-heater through violent winds or rings may prompt lower furnace accessibility and efficiency. In this way, the contribution of these unpredictable parts is precisely for monetary factors. Input controls are needed for higher cement quality.

3.3.6. Clinker Coolers

Clinker without revolving oven on 1190-1240°C must be chilled quickly to permit additional movement and it helps warming the clinker through pre-heating air, which is utilized as ignition inside primary burners Furthermore, quick cooling avoids undesired compound responses that adversely influence the output quality/grind-ability.

Following are types of clinker-coolers:

1. Rotary.
2. Planetary.
3. and Grind coolers.

Rotary/tube coolers are placed under the furnace-outlet, which makes the utilization of indistinguishable material possible. This type has been seldom utilized as a part of the bond business these days. In planetary/satellite coolers, some 9-11 tubes are placed on the turning-oven end. Since they have outline, they are vulnerable to heat.

Grind coolers ideally act as a part of current establishments. Cooling takes place through the clinker-layer voyaging gradually for responding grate that consists of punctured plates. It has a "recovery zone" shown in Figure 6: Bond production through wet procedure (CEMBUREAU, 1999).

Depending on instability, antacids, sulfurous compounds/chlorides finish within sintering part of rotational furnace and it re-condenses the structure. Using crude feast, an "inward" cycle with "unstable circling" components develops. Creating a balance amongst info and yield, a noteworthy piece of unpredictable segments will leave the framework joined in the clinker.

Some portion of the unpredictable segments may frame new mixes, for example, salt chlorides or antacid sulfates and other halfway stages, for example, spurrite, which will then add to the development wonders specified above by creating "sticky" crude feast glue to violent wind dividers of the violent winds but little bit of components, which are left, are cleaned.The extreme contribution of unstable components might leave some circling components.

3.4. COMBUSTION AND FLAME

A principle function of turning furnaces in mineral/substance industries is to change raw/unusable substances (metal) into helpful items. Some procedures include substances' physical specs, which are financially feasible and work at high temperatures at the same time. We should get vitality into the procedure and concentrate the stuff. It is unrealistic to provide mechanical vitality for temperature-exchange, which is good for running this kind of operations. In spite of the fact that a modest bunch of little size in warmed ovens may utilize electrical power gained through non-renewable energy source.

3.4.1. Combustion

Ignition is the change of petroleum derivative into concoction mixes (or items) by consolidating with the help of an oxidizer using oxygen in the air. Ignition is exothermic response:

Fuel+Oxidizer→ combustion product+Energy

So, oxidizer and fuel act as reactants. These reactants create burning items and energy. Heat discharge during burning relies on the fuel-type. Fills are assessed in light of the measure of energy-discharge for every unit of mass/volume or mass/mole. Warmth discharge might be shown through heat-energy or glow.

Regular fills include substances like coal, coke, used oils, or gaseous petroleum In the US Boiler and Industrial Furnace (BIF), which is used for utilization of wasted energies to get additional non-renewable energy. Renewable energy can be generated through tires, defiled oil clothes, and fluid solvents, for example, alcohols, and esters etcetera named as liquid-burnable materials (LBMs) because of their high combustible carbon content.

Because of the vaporous energizes, it is basic practice to examine the blend for the segment gasses and to report the examination as far as volume (or mole) percentage is concerned. This is fundamental because most vaporous fills are blends of just a couple of substance-mixes. On the other hand, easily available or cheap natural fluids/solids (for example coal) having complicated atomic/molecular structures can be used as fuels. C:H:N:O:S are all elements, which are used as fuels.

3.4.2.Mole AndMass Fractions

Fuels are tested on the basis of their masses/moles.
C:H:N:O:S have moles = 12:2:28:32:32 kg/lbm.
Mass of the blend (mfi) is calculated throughmi, the mass of the segment, mi.

The formula is as follows:

$$\text{mfi}=\frac{m_i}{m} \tag{3.1}$$

where the sum of the mass fractions of all components have to equal 1, as

$$\text{mf1+mf2+mf3+ ……=1} \tag{3.2}$$

An analogous definition for the mole fraction of a component, i, xi, is the ratio of the number of moles of i, ni, to the total number of moles in the mixture, n, that is,Where

$$\text{xi}=\frac{n_i}{n} \tag{3.3}$$

$$\text{n=n1+n2+ ….. and n1+n2+……=1} \tag{3.4}$$

Reorder and recall Equation (3-3) describes the average molecular weight, that is,

$$M= \frac{m}{n}= \text{x1M1 + x2M2 + …….} \tag{3.5}$$

Mass-fraction of component i:

$$\mathrm{mf_i} = \frac{\mathrm{n_i M_i}}{\mathrm{n_1 M_1 + n_2 M_2 + \cdots}} \text{OR} \ \ \mathrm{mf_i} = \frac{\mathrm{x_i M_i}}{\mathrm{x_1 M_1 + x_2 M_2 + \cdots}} \quad (3.6)$$

For mixtures at certain temperatures and pressures, the ideal gas law proves:

$\mathrm{pV_i = n_i RT}$

pV = nRT for mixtures.

Ratio between the two equations:

$$\mathrm{xi} = \frac{\mathrm{V_i}}{\mathrm{V}} = \frac{\mathrm{n_i}}{\mathrm{n}} \quad (3.7)$$

For a given volume of gas-mixture:

piV = niRT and at the same time, pV = nRT. So their ratio is:

$$\mathrm{pi} = \frac{\mathrm{p_{n_i}}}{\mathrm{n}} = \mathrm{pxi} \quad (3.8)$$

Air has 21% percent O2, 78% N2, and 1% rare gases. So, 79 divided by 21 gives 3.76 moles of N2

$$\mathrm{Mair} = \sum \mathrm{n_i M_i} = 0.79\mathrm{MN2} + 0.21\mathrm{MO2} = 0.79(28) + 0.21(32) = 28.84 \quad (3.9)$$

Oxygen and nitrogen mass-fractions are:

$$\mathrm{mf_{O2}} = \frac{\mathrm{n_{O2} M_{O2}}}{\mathrm{M_{air}}} = \frac{(0.21)(32)}{28.84} = 0.233$$

$$\mathrm{mf_{O2}} = \frac{\mathrm{n_{N2} M_{N2}}}{\mathrm{M_{air}}} = \frac{(0.79)(28)}{28.84} = 0.767 \quad (3.10)$$

3.4.3. Combustion Chemistry

Next Equation (3.11) is the chemical reaction of combustion for methane.

CH4 + 2O2 = CO2 + H2OΔH (192kcal⁄mol) (3.11)

For coal, the next reactions describe the combustion.

$CH_4 + 2O_2 = CO_2 + H_2O + \Delta H$ (192 kJ⁄mol) (3.12)

$2H_2 + O_2 = 2H_2O + \Delta H$ (285 kJ⁄mol) (3.13)

$2C + O_2 = 2CO + \Delta H$ (110.6 kJ⁄mol) (3.14)

$S + O_2 = SO_2 + \Delta H$ (297 kJ⁄mol) (3.15)

CO_2 is shaped during entire burning. Fragmented burning yields CO, which is a poisonous gas but convertible into CO_2.

The quantity of iotas of every component must be noted during a response. Since the quantity of molecules of every component can't transform, it takes after the mass of every component.

$CH_4 + 2O_2 = CO_2 + 2H_2O$

$$[\![12 + 4(1)]\!] + 2(32) = [12 + 2(16)] + 2[2(1) + 16] = 80 \quad (3.16)$$

Moreover, 2 moles H_2O 1 mole CO_2 exist each in 3 moles of combustible products. Therefore the mole fraction of water and carbon dioxide in the combustion products are:

$$x_{H_2O}= 0.667 ; x_{CO_2} = 0.333 \quad (3.17)$$

2(18) MU (mass units) H2O, 44 MU CO_2 exist in 80 MUs of products.
In this way mass fractions will be 36/80 & 44/80:

$$mf_{H_2O} = 0.45 ; \qquad mf_{co_2} = 0.55 \quad (3.18)$$

Every mole of oxygen is accompanied by 3.76 moles nitrogen in the air, so the methane reaction will be:

$$CH_4 + 2O_2 + 2(3.76)N_2 = CO_2 + H_2O + 2(3.76)N_2 \tag{3.19}$$

Consequently, 2 moles H_2O exist for every 10.52 moles ignition item

Ignition items release stack/pipe gasses. Under specific situations, water vapors within the vent-gas can move as fluid. Higher warming quality or HHV of fuels relates to the warming an incentive, so water remains in vaporous form,

$$HHV = LHV + \left(\frac{m_{H_2O}}{m_{fuel}}\right)h_{fg} \ [\mathrm{kJ/kg}] \tag{3.20}$$

$h_{fg}$is the represents latent heat of water-vaporization

3.4.4. Practical Stoichiometry

While deciding about burner for rotating furnace/anyother ignition, measuring air is needed. This will guarantee ideal investment with least ecological poisons.The pragmatic stoichiometry is mostly about air-usage for ignition items.

Largely, one can find adjusted stoichiometric relation for a CHNOS-fuel-air framework using the following equation:

$$\begin{aligned} &C_uH_vO_wN_xS_y + \left(u + \frac{v}{4} - \frac{w}{2} + y\right)(O_2 + 3.76N_2) \\ &\rightarrow uCO_2 + \frac{v}{2}H_2O + ySO_2 + \left[3.73\left(u + \frac{v}{2} - \frac{w}{2} + y\right) + \frac{x}{2}\right]N_2 \end{aligned} \tag{3.21}$$

Negative w demonstrates need for lesser oxygen for oxidation process because O_2 molecules are now present in the fuel. Mostly, it is helpful to standardize the genuine stoichiometric blend for the fuel-oxidizer. The standardization is actually a number that shows the veering of the blend piece from stoichiometrical situations.

As an outcome, the dormant temperature of vaporization of the water is discharged and turns out to be a piece having warming quality. So, here we find Φ characterized as:

$$\Omega = \frac{m_{fuel}/m_{air}}{\left(m_{fuel}/m_{air}\right)stoich} \tag{3.22}$$

or, on a molar basis,

$$\Phi = \frac{n_{fuel}/n_{air}}{\left(n_{fuel}/n_{air}\right)_{stoich}} \tag{3.23}$$

With this definition, blends with Φ<1 means fuel-lean while Φ>1 means fuel-rich. Here we determine hypothetical air% and abundant air %, which are 100/Φ and 100(1/Φ − 1) respectively. Accordingly, a blend that has Φ= 0.8, which means 125% hypothetical air or 25% overabundant air.

3.4.5. Adiabatic Flame Temperature

The adiabatic fire happens whenever ignition chamber has no warmth. A pinnacle adiabatic fire temperature is approx Φ =1.

Figure 3.7 is a normal diagram of heat for a gas–air blend. When air burns, we veer off from the stoichiometric situation and extra air is warmed. Accordingly, it will reduce the heat. It means that increasing stoichiometric situations using fuel reduces the fire demonstrated by Figure (3.7).

Despite the fact that we have shown temperature with 100% stoichiometric air, same principles are valid for all burning conditions. Its usefulness lies in the fact that it permits temperature-controls using air-fuel blend. With a specific end goal to keep up the fire temperature in any condition, one must proportionally add fuel and air.

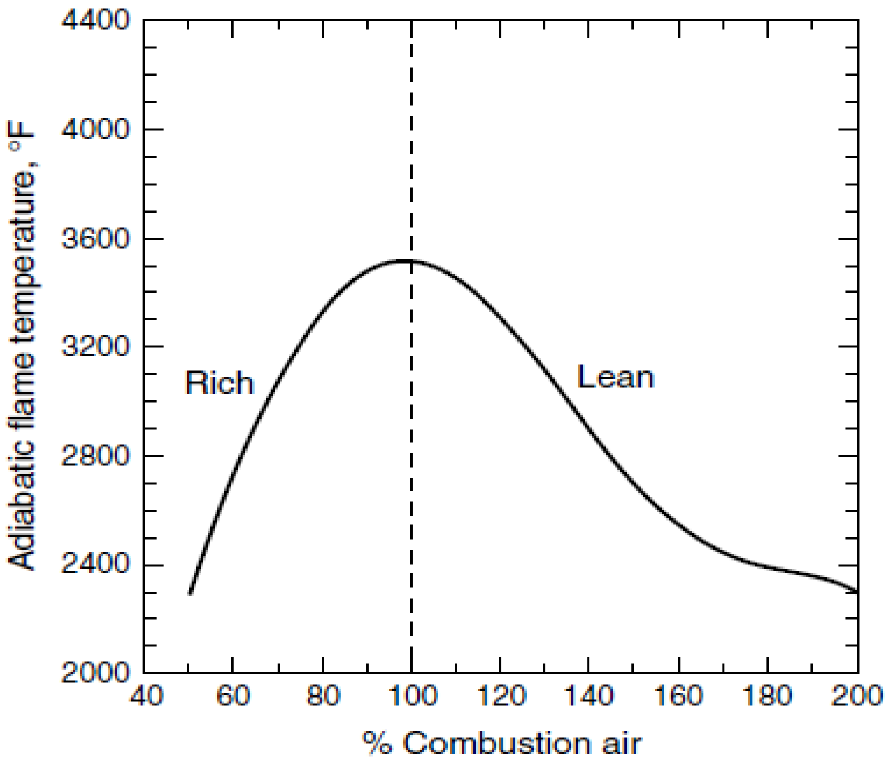


Figure 3.7. Flame temperature versus air-fuel ratio (Guruz &Bac.1981).

Increasing only fuel or air will not give us the required end results and the function will be like carburetors of vehicle motors.

Laminar Bunsen burner stream fire is shown in Figure 3.8. The illustration demonstrates 4 frameworks to acquit air with the spout-fuel. They incorporate spout blend, pre-mix, combine with air, and utilize fuel without air circulation.

Figure (3.8) speculatively shows the normal fire geometry for vaporous fuel as essential air circulation reduces from 100% to 0; which will assure sharp-light-blue flame.

A fire consuming 75% air has the shape of a longer twofold blue cone.

Using 25%fuel atoms toned time to find oxygen from air and it will be yellow in shading. At the point when fuel is scorched with no premixing, the fire is typically worn out with long and full-yellow flame.

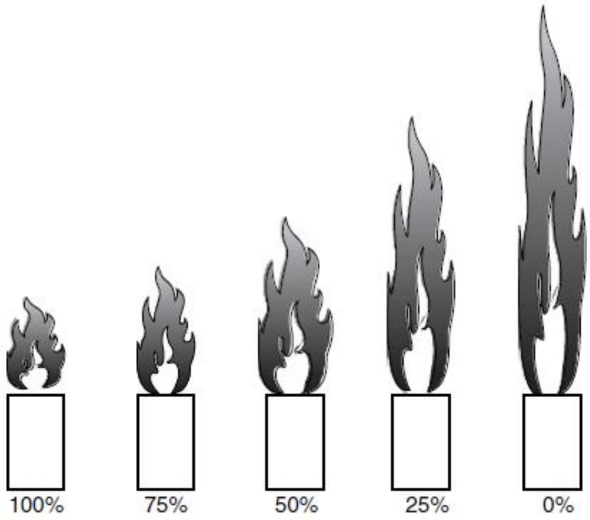


Figure 3.8. Airingeffect on flame shape (Guruz&Bac.1981).

3.4.6.Types Of Fuels Used In Rotary Kilns

Kilns use gas,oil,power, or their mix. Since a large portion of the rotational ovens need higher temperatures, fires and radiation shift to the substance. Radiation additionally boosts due to the round and hollow nook of the freeboard space. Subsequently, fills having high sediment have a tendency to enhance heat output and fuel utilization. Due to the high cost and the straightforward way of gaseous petrol blazes, rotating furnaces have strict natural limitations of CO_2 emanations. Most revolving ovens utilize pummeled fuel, ordinarily coal or oil coke as the essential fuel for burning. In this area, we will analyze the source and sorts of these powers and furthermore the elements that amplify their burning in rotational furnaces.

3.4.7.Coal Types, Rankings, AndAnalyses

Coal comprises perplexing substances. Differences exist in coal varieties because of vegetation, from which, the coal started and shaped. Minerals in coal affect the properties/characteristics (Table 3.1).

American Society for Testing Materials (ASTM) set up positioning framework, which grades coal-types as anthracite, bituminous, sub-bituminous, and lignite. Lowgrade coal has low carbon but higher oxygen. Two sorts of examination of coal-structure are available: proximate and definitive.

The former investigation includes thermo-gravimetric or TGA, in which, the specimen is persistently warmed without oxygen, so, no further weight-reductionhappens.

Table 3.1.Analysis of a US Coal-types (Watson, 1992)

Source	Rank	M(%)	VM(%)	FC(%)	A(%)	S(%)	KJ ⁄Kg
Schuylkill, PA	I	4.5	1.7	84.1	9.7	0.77	29644.874
McDowell,WV	II	1.0	16.6	77.3	5.1	0.74	34227.094
Sheridan, WY	III	25.0	30.5	40.8	3.7	0.30	21736.473
Mercer,ND	IV	37.0	26.6	32.2	4.2	0.40	16875.132

The investigation reveals dampness, cinder, unpredictability and carbon percentage. A definitive investigation is a concoction examination that gives the natural mass divisions of C, O, N, H, and S for the most part on a dry and cinder-free premise.

m = mcomp + mash + mmoist

$$\frac{m_{comp}}{m} = 1 - A - M \tag{3 .24}$$

In this way, a condition for wet/shy unstable substance, which can be examined in dry, slag-free situations with the help of the following formula:

$$\begin{aligned} VM_{as-fired} &= \left(\frac{m_{comp}}{m}\right)(VM)_{dry,ash-free} \\ &= (1 - A - M)(VM)_{dry,ash-free} \end{aligned} \tag{3.25}$$

3.4.8. Scrap Tire Combustion

More than 300 million tires are produced every year in the US, More than 105 million of them are utilized like a fuel and many of them are scorched as supplement fuel in bond/ revolving furnaces.

A concrete procedure is especially helpful for tire burning in light of the fact that the fortified wire inside tires can be used in bond industry. Ovens consuming tires must conform to the EPA's Kettle and Mechanical Heater Act and subsequently, they are intensely controlled because they can be a source of contamination.

Table 3.2 shows a run-of-the-mill creation of tires provided by the US rubber producers.

Table 3.2. Tire Configuration(Rubber Manufacturers Association of (Amerika, 1997).

Material	Chemical formula	Percent Composition	
		Car	Truck
Natural rubber	C_5H_8	12.43	24.57
Styrene	C_8H_8	5.63	2.99
1,3-Butadiene	C_4H_6	18.34	9.75
Fabric	-	15.47	14.85
Carbon Black	C	24.86	25.48
Steel (belt and bead)	-	18.13	17.40
Fillers	-	5.16	4.95
Water (in tires)	H_2O	0.00	0.00

Average heating value≈34890 kJ⁄kg

Ignition of scrap tires and, besides, substances like biomass, coal, or coke continues in 2 stages, To begin with, the natural strong polymer experiences pyrolysis at 255–305 °C to discharge unstable substance and strong buildup (burn) (Figure 3.9).

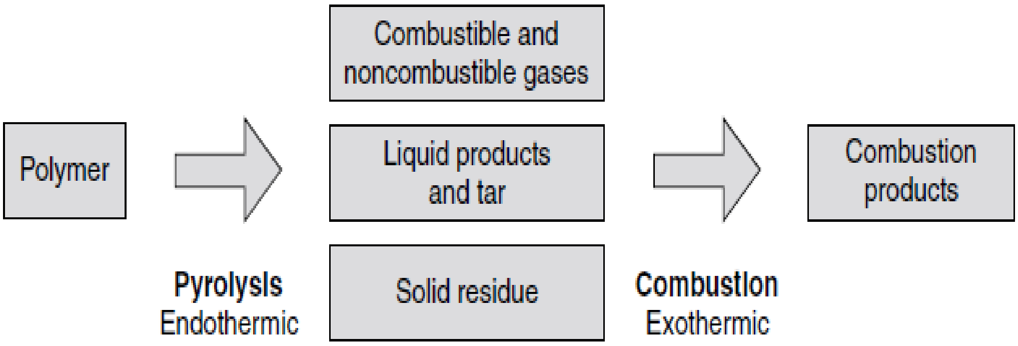


Figure 3.9. Machines of polymer decomposition and combustion (Henein, 1980).

Tire Pyrolysis releases non-condensable gases including CO and H_2, pyrolytic oil, and solids (Figure 3.10). Dark carbon is steady and hard-to-consume. An investigation in view of consuming just the unpredictable pysrolysis segment shows that 1 ton an hour of coal at 27 MJ/kg (11,600 Btu/lb) is consumed, which demonstrates a significant monetary preferred standpoint (Figure 3.11). At a coal cost of $37.5 per ton and tire cost at $20.50 per ton, it is a viable option.

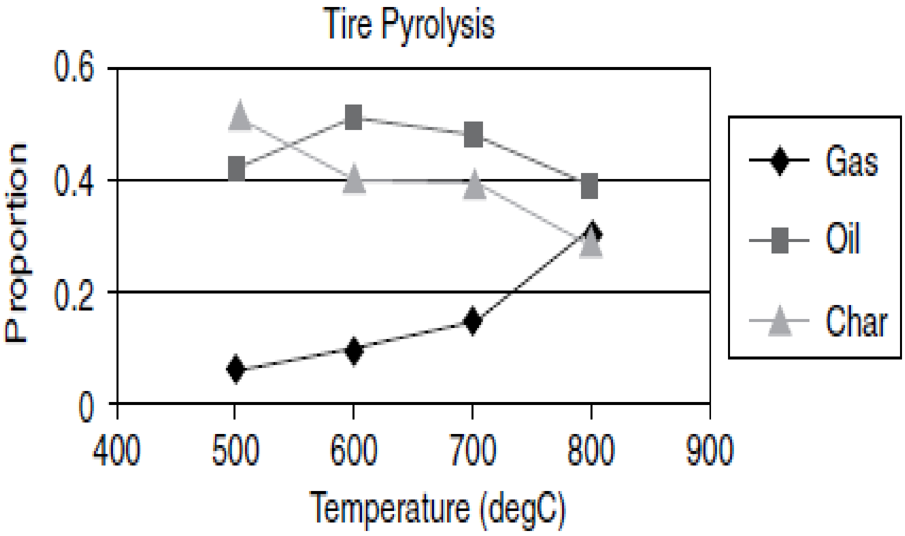
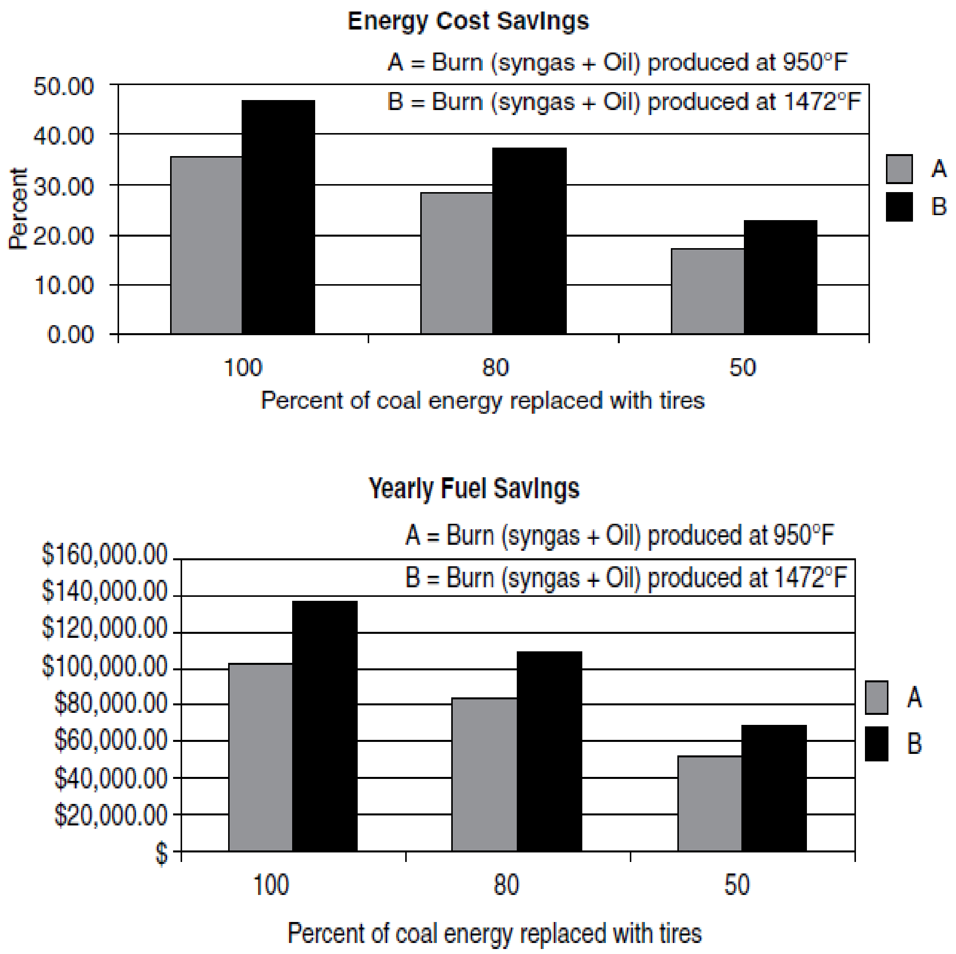


Figure 3.10. Tire pyrolysis products (UCLLNL-DOE—waste tires) (Henein, 1980).



Energy Cost Savings

Yearly Fuel Savings

Figure 3.11.Potential energy and yearly savings for scrap tire in LWA kiln (Guruz.and Bac, 1981).

PART 4

CEMENT KILN EMISSIONS

4.1. CEMENT KILN EMISSIONS

Bond emissions can be controlled through consistent and intermittent strategies. Persistent estimation is needed for dealing with NOx and SO_2. The accompanying depictions of outflows allude to present day oven plants in the light of dry process innovation.

4.1.1. Carbon Dioxide

During the clinker-consumption procedure carbon dioxide is produced, Its discharges are both related and vitality-connected, They are discharged from calcium carbonate ($CaCO_3 > CaO + CO_2$).

4.1.2.Dust

To fabricate every ton of Portland cement, around 1.45 to 1.65T crude substances, 0.1 ton coal and 1 ton clinker are used. Significant discharge of particulate segments takes place during the process at the rate 2,900 mg / m^3.

4.1.3.Nitrogen Oxides (NOx)

Clinker-consumption needs nitrogen oxides. 94% nitrogen monoxide (NO) and 5% NO_2 are present in the fumes. Most of the NO changes into NO_2. Measures to decrease them are primarily for smooth factory operation.

High heat is needed to change crude constitutions into Portland bond clinker. 1460°C heat is needed in the sintering of rotating furnaces but to achieve that heat, firtemperature 1980°C is essential.

For clinker-quality, consuming procedure happens under oxidizing situations, under which, oxidation of nitrogen takes place. It is named as warm "NO development." On low heat,warm NO development is impossible.

Here CO diminishes NO to atomic nitrogen:
$2 CO + 2 NO \rightarrow 2 CO_2 + N_2$.

4.1.4.Sulfur Dioxide (SO_2)

Sulfur is part of clinker consuming procedure. Inputs include sulfur in the form of sulfide or sulfate. Greater SO_2 discharges through ovens in the concrete industry are plainly oxidized to shape SO_2 between 360 °C and 430 °C in the furnace pre-heater. Sulfur converts into SO_2 in the rotating oven. In pre-heater/furnace, SO_2 interacts with antacid sulfates.

4.1.5. Carbon Monoxide (CO) And Total Carbon

The CO emissions and naturally-bound carbon are produced through adding natural constituents. They change over amid oven pre-heating when carbon oxidizes to become CO and CO_2. In this procedure, little segments of natural gasses (add up to natural carbon) are formed as well. In the event of the clinker consuming procedure, CO and natural follow gasses may not be easily identifiable with burning conditions.

4.1.6. Dioxins And Furans (PCDD/F)

Rotational furnaces in bond business or exemplary cremation plants and they contrast as far as the ignition conditions are concerned. Furnaces and turning ovens deplete gasses passing through the counter-stream and they are completely blended. So, temperature and time in rotational ovens manage the cost of natural mixes. Hence, just low-convergence dioxins and furans are present in gas fumes in concrete rotating furnaces.

4.2. ENVIRONMENTAL IMPORTANCE OF PRODUCING CEMENT

Basic natural effects of bond-making are as follows:

1. Dust out of stack discharge;
2. Emissions of CO_2, NOx, SO_2, and VOC et cetera;
3. Miscellaneous discharges including smell,water,creationsquanders,and so on.

4.2.1. Dust

Verifiably, the outflow of tidy – especially from furnace stacks – has been the fundamental ecological worry in bond fabricate. "Point source" dust discharges begin from the production factories, oven, clinker-cooler, and bond plants.

Common components of these procedure actions are hot fumes of gas or air. The way of the particulates are produced is connected to the source substances, i.e. crude substances, clinker and bond.

Tidy emanations in sophisticated bond industry are extensively decreased during the recent 2 decades, so, best reduction methods are now accessible (electrostatic precipitators, sack channels), which result in stack outflows - irrelevant in a cutting edge concrete plant.

Tidy from scattered sources in the plant territory may begin predominantly from material-stockpiling and taking care of transport frameworks, stockpiles, acking, and so on. Procedures for control and regulation of criminal tidy incorporate de-dusting material exchanges, shut capacity establishments with appropriate ventilation, vacuum cleaning gear, and so forth.

When the concoction and structure of tidy in a cementfactory are like normal rocks, it results in "aggravation". Tidy-reduction/control needs satisfactory administration; however, it is not a specialized issue.

Furnace tidy gathered out of cleaner gadgets is exceptionally antacid and it can have some components like metals found in the source materials. In few cases, it is unrealistic to reuse furnace tidy or totally sidestep the tidy. This leftover tidy is discarded or some factory owners sell it to different ventures.

Sidestep clean removed from the furnace framework might be exceedingly advanced in salts, sulfates, and chlorides and comparatively to channel tidy, which can't be reused in the procedure.

4.2.2.Gaseous Atmospheric Emissions

Vaporous furnace emissions discharge in the air but they are matter of concern for the cement industry because they contain dangerous oxides of carbon, nitrogen and sulfur, as they are harmful because of their discharge in significant amounts.

Different vaporous emissions, for example, hydrochloric or hydrofluoric corrosives have scrubber impact on the pre-heater concrete furnace. Common crude materials utilized for clinker creation may contain unstable parts in little amounts. These segments will be volatilized and generated in the pre-heater.

4.2.3.Carbon Dioxide

Carbon dioxide discharges emerge as a consequence of calcination of crude substances or burning of petroleum derivatives, CO_2 emission out of fuel ignition can be decreased,CO_2 emission have been cutback approximately by 30% over the last 25 years.

4.2.4.Nitrogen Oxides

NOx is undeniable outcome of heated ignition andsynthesis of crude substances. Nitrogen oxides emit when oxidation of sub-atomic nitrogen takes place ("warm" NOx entirely contains nitrogen oxides NO_2>88 %; NO< 12%). Warm NOx emerges at 1380°C.

1. The role of fuel NOx is very less in a burner-fire as compared to warm NOx.
2. A pre-heater/calciner, approximate fire-heat of 1180°C creates warm NOx.
3. Regular crude substances like mud or shale are likely to have nitrogenous mixes/compounds.
4. Some nitrogen can discharge and oxidize in the oven and substantially increase the aggregate NOx outflows.

NOx discharges vary between 500 and 2000 mg/ m^3. There is no data accessible on the NOx arrangement components and discharges within vertical-shaft furnaces.

4.2.5.Sulfur Oxides

Sulfurous mixtures go in the furnace framework through fills or crude substances. They exist in the form of sulfates, for instance, calcium sulphate ($CaSO_4$) and sulfides (FeS_2). Some SO_2 consolidates in soluble bases and gets fused with clinker while the remaining part moves back to the cool oven parts.

Inorganic/natural sulfur mixes undergo warm disintegration, oxidation to SO_2 and reaction with salts. Later, all the sulfur will leave the oven in the form of vaporous SO_2. Sulfides (and natural sulfur mixes) in crude materials disintegrate and oxidize at 420 to 620°C, which generates SO_2. Later, 28 to 88% of that outstanding SO_2 will absorb in the particles of the crude plant.

In mesh pre-heater ovens, sulfur dioxide retention remains high because gas moves through mesh stream. In long-dry/long-wet ovens, synthetic assimilation of SO_2 is less effective because of the decreased contact between furnace fumes and crude materials. In these furnaces, a wide range of sulfur may add to SO_2emanations, which might increase the general discharge.

In VSKs frameworks, a wide range of sulpur may somewhat increase SO_2discharges, which makes the discharges greater than the dry pre-heaterovens. Vaporous discharges, for example, SO_2 or VOC are to an expansive degree depending on crude substances utilized and not on fuels. Emanations remain minimal when crude substances are pure.

4.2.6.Organic Compounds

Common crude materials, for example, limestone or shale can have about 0.8% w/w of pure kerosene. It might be volatilized within the oven between 400-600°C.

Oven tests with crude suppers of various starting points have exhibited that around 83-94% of crude substances change over to CO_2 because of 3% overabundant oxygen in the furnace fumes while 4-16% is oxidized as CO. Little, generally under 1% of the aggregate natural carbon ("TOC") substance might be discharged as unstable hydro-carbons.

VOC outflows in the stack gas normally remains in the range 10 and 100mg/N m^3, while just a few of them are 500 mg/N m^3. The CO fixation can be 1000mg/Nm^3 surpassing 2000mg/Nm^3 on regular occasions. The CO and hydrocarbons depend on crude substances and they do not show a deficient ignition.

Natural substances in contact with the principle burner will be totally obliterated because of excessive heat and longer maintenance time taken by the ignition gasses.

No data is accessible on the VOC emissions for vertical-shaft furnaces.

VOC discharge can develop dioxins or furans noticeable all around contamination control gadget of a VSK and they should be examined.

4.3. PCDD/F EMISSIONS

Stockholm Convention obliges cement producers and factory owners to decrease and dispense persevering natural contaminations not letting their accidental accumulation to take place. Bond ovens dealing with dangerous materials are termed as "mechanical sources with potential hazard."

Another organization WBCSD (World Business Council for Sustainable Development) also expressed concerns on POP emanations in bond-making and emphasized on controlling/limiting the hazardous discharges (Karstensen, 2006).

Total 2300 PCDD/F estimations, numerous PCB-estimations, and some HCBs were conducted and the information was used to prepare guidelines for wet & dry operations, ovens, and basic working conditions. Vertical-shaft furnaces could not be managed because of the absence of discharge information.

The PCDD/F information assessment demonstrates that:

1. Most cement ovens meet emanation at 0.11mg TEQ/N m^3;
2. Combined handling option fills or crude substances, added to a burner, oven or pre-calciner have no impact on POPs emissions;
3. Dry pre-heater and pre-calciner bond furnaces data demonstrates low discharge levels of 0.1mg TEQ/N m^3.
4. Modern dry pre-heater and pre-calciner data shows that they had much lesser emissions than the wet ovens.

The US Emanation information of 80s and early 90s showed the waste of fuel and supplementary fuel in bond ovens with considerably greater PCDD/F outflows as compared to ovens co-preparing safe squanders or utilizing regular fuels. EPA has clarified that the most reasonable justification for these discoveries, in particular that bond furnaces generating dangerous waste were typically tried under "most noticeably bad" situations including capacity to handle waste-sustenance and heat.

Bond ovens consuming safe waste or traditional petroleum derivative were tried under ordinary situations but no "most exceedingly terrible" situations were observed.

Decreasing the heat is a variable, which affects dioxin-arrangement and emissions from concrete furnaces,The EPA found in 1999 that dangerous wastes in bond furnaces do not affect PCDD/F development since they are shaped after combustion, i.e. noticeable all around contamination control gadget.

The review likewise gives several estimations relevant to PCDD/F existing in items/buildups in the bond business. Modern cement factories are updated for highly accessible systems to generate bond clinker through dry procedure.

The most critical essential measures is achieving emanation level around 0.1ng TEQ/Nm^3, which depletes gasses at 200 degree centigrade in long-wet or long-dry ovens. Current pre-heater/pre-calciner furnaces possess this feature. As PCDD/F is the main POPs gathering, which regularly needs to be managed. Almost 50 PCB estimations presented in this report show that the quantities should be beneath 0.4µg PCB TEQ/m^3, numerous at a couple nanogram level or underneath as far as possible.

4.3.1.Trace Elements

In clinker-consumption procedure, minerals existing in substances change after getting heated in sintering part of furnace. Burning cinders are fused into the clinker minerals. So, bond furnace frameworks don't produce burning cinders.

Thus, fuels can replace some crude substances. For a decent clinker quality, the fiery debris must be considered in the crude blend. Some components, including metallic substances are present in trace quantities in crude substances and fuels used for bond production. Conduct of metallic substances in their consumption is dependent on their stability/instability. We must consider the following:

1. Stable metallic components remain inside an item and consolidate with the clinker's mineral structure.
2. Semi-unstable components, for example, cadmium or lead can volatilize with heat in sintering part of oven. Noteworthy cadmium or lead pieces consolidate within the clinker.
3. Volatile metallic substances, for example, mercury/thallium gathered at 290-360°C, mercury at 130-160°C. Thallium exists in clean particles but mercury gathers in the channel.

.

No data is accessible on metal outflows from vertical shaft ovens.

4.3.2.Other Emissions

Substantial hardware and expensive fans are utilized in the bond making process.

Smell discharges are sometimes an issue with a busy plant. In extraordinary cases, nitrogen mixes in the crude substances, which can prompt alkaline outflows that cause smell.

Handle water in concrete assembling will be mostly vanished or reused. Filtered water is utilized as a part of semi-wet procedure. Crises, for example, fire, blasts or spillage/spillage are to a great degree uncommon in the present day bond industry yet minor blasts can happen if the coal/coke has unstable substances.

4.4. NORMAL EMISSION LEVELS FROM ROTARY KILNS

Normal outflow information (specs and qualities) in EU-made revolving bond ovens in operation are outlined in given Table 4.1. Given figures show inner parts of furnaces but individual furnaces may work quite differently depending on their ageing and type of crude substances.

Table 4.1.Emission-rates from EU cement kilns in long-run (Cembureau, 1999).

Emission	mg per standard cubic meter (mg⁄Nm^3)
Dustes	20-200
NO_X	500-2000
SO_2	10-2500
Total organic carbon(TOC)	10-100
CO	500-2000
Fluorid	< 5
Chlorides	< 25
PCDD⁄F	< 0.1(mg⁄Nm^3)
Heavy metal	
Class 1 (Hg, Cd, Tl)	< 0.1
Class 2 (As, Co , Ni, Se, Te)	< 0.1
Class 3 (Sb,Pb,Cr,Cu,Mn,V,Sn) incl. Zn	< 0.3

4.5. AIR POLLUTION CONTROL IN CEMENT PRODUCTION

Particles generally named as tidy, are essential discharge for producing concrete. Keeping the discharge gauges clean depends on the force and temperature of the effluents. In all the modern ovens, the fumes cause air contamination. Today, two sorts of tidy separators are utilized as a part of the advanced bond production, which include electrostatic-precipitators, and pack channels.

In the cement business, violent winds are for implementations with rotational ovens, incredible clinker coolers, crushers, dryers, pounding plants, transports, and so forth. They are tidy gatherers, without moving parts, and can be outfitted with stubborn linings for great heats up to 980°C. Typhoons can be intended for high weight drop and additionally for medium throughput, and high clean gathering proficiency.

Twisters work with widths from 330 to 2280mm in courses of action of one, two, four or six unit blends. Tornado speed depends on the clean load, the molecule estimate and additional tidy properties.

Units of violent winds might be introduced in parallel for huge gas volumes, and in an arrangement for higher efficiencies, or in blends of arrangement and parallel high productivity. In accordance with air contamination directions, the multi-cyclone is a noteworthy segment in the tidy accumulation from furnace gasses, grind clinker coolers, dryers, pounding factories, and so forth.

However, in countries with stricter clean control directions, the multi-cyclone serves generally as an essential tidy gatherer. Texture channels in bond business are mostly consisting of tubes with 300 mm width or less, and up to 10m height; they comprise of woven or felted materials produced using normal or manufactured filaments.

Texture channels can deal with little particles in the submicron run at high efficiencies of 99.95%. These channels are linked with gas-temperatures up to 285°C. The cleanly loaded gas moves through a permeable medium – the channel texture – and stores particles in the voids.

In the wake of filling the voids, a cake begins to develop on the texture's surface, which does sifting process. Amid the pre-coating timeframe, which keeps going just for minutes, the effectiveness may drop. When the tidy layer on the texture is too thick, the expansion in weight drop comes about; this requires cleaning of the texture(Figure 4.1).

Depending on the tidy and the kind of the texture, there are four techniques for channel cleaning:

1. Bag swinging: A strategy, which bestows a delicate swaying movement to the highest points of the channel packs; this ousts the tidy cakes.
2. Reversing air: It creates gaseous tension, subsequently discharging the channel cakes.

3. Pulse weight: It provides 7 kg/cm packed quality. It creates a stunning wave for flexing texture, consequently removes the tidy cakes.
4. Sonic cleaning: It utilizes sound <210 Hz/sec., force 110-160 dB, which creates vibrations, and they clean the tidy from the texture.

Along these lines for nonstop programmed clean accumulation, a texture tidy has one section in excess of the limit needed by the gas volume. Pack channel execution is not vulnerable to "CO crests".

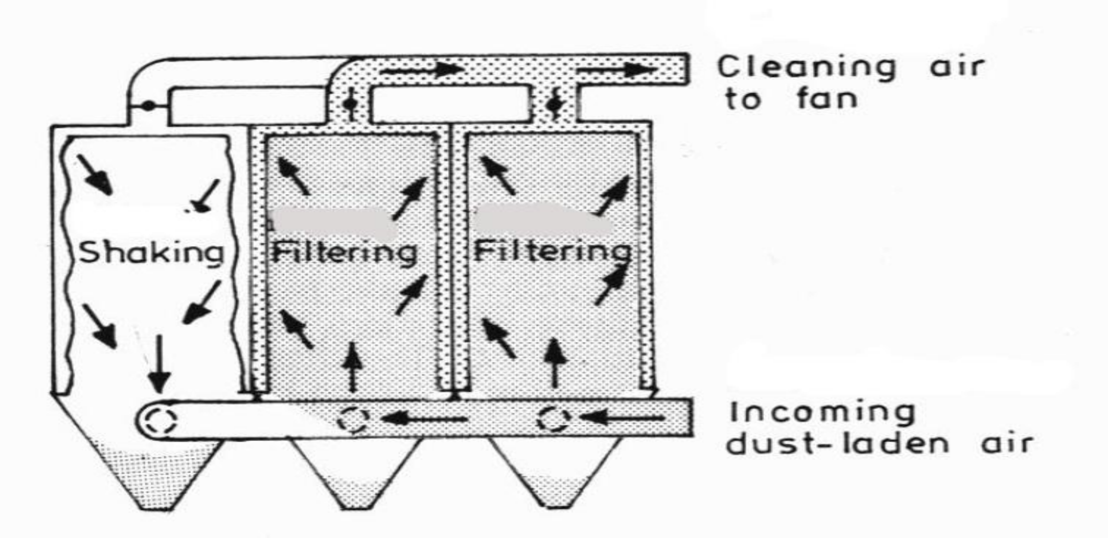


Figure 4.1. Principle of bag filter (Duda, 1985).

Electrostatic precipitators isolate the tidy from fumes. Using methods for release cathodes, the tidy specs adversely charge and become isolatable on terminals.

They are later released out of gathering anodes and deposit in tidy containers.

As opposed to packing channels, the outline of electrostatic precipitators permits both fine and coarse specs. ESP's are vulnerable to carbon monoxide (Figure 4.2).

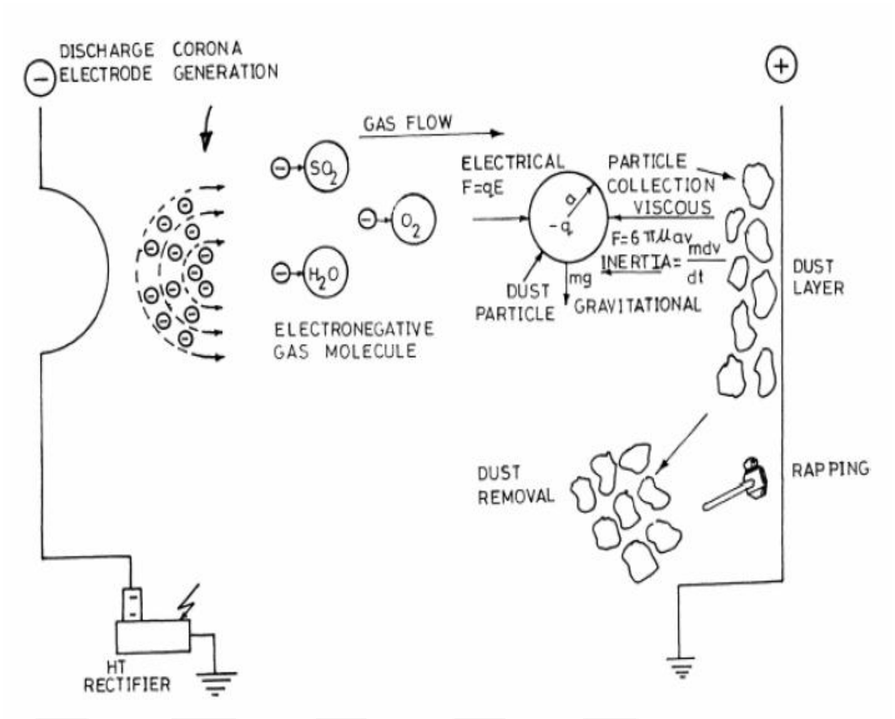


Figure 4.2. Principle of electrostatic precipitators (Dada.1985).

Gathered tidy gathered is shifted back for reprocessing through making it part of crude substances or sending it to the sintering part (Figure 4.3).

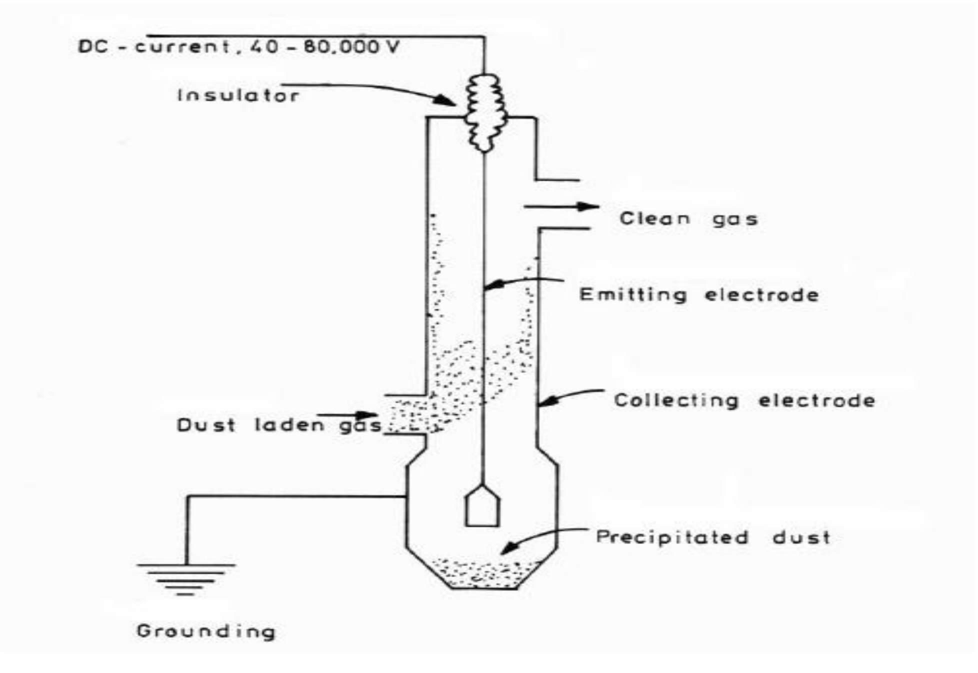


Figure 4.3. Function of electric precipitator(Duda, 1985).

When salt components gather in bond-clinker, furnace cleaning should be done. The electrostatic precipitators leave behind some salt, so all the tidy will be rejected.

4.5.1.Inherent "Scrubbing" Of Exit Gases In Pre-Heater Kiln

In furnaces, ground crude substances move towards heated ignition gasses.

In this manner, it acts flawlessly for cleaning fumes by acting like a "dry scrubber".

The alkaline crude supper with its specific surface type holds gas inside the furnace. For example, calcinated or halfway calcinated crude supper with responsive calcium oxide acts as a corrosive gas.

Suspension pre-heater ovens having between 4-6 tornado levels are particularly appropriate for creating a "scrubber" impact, particularly while working with a crude plant (compound operation) (Figure 4.4).

No less than 5 scrubber stages work in the arrangement at various temperature levels between 110-820°C expending at the rate 1 kg retentive (crude supper/hot dinner) per Nm^3 of fumes.

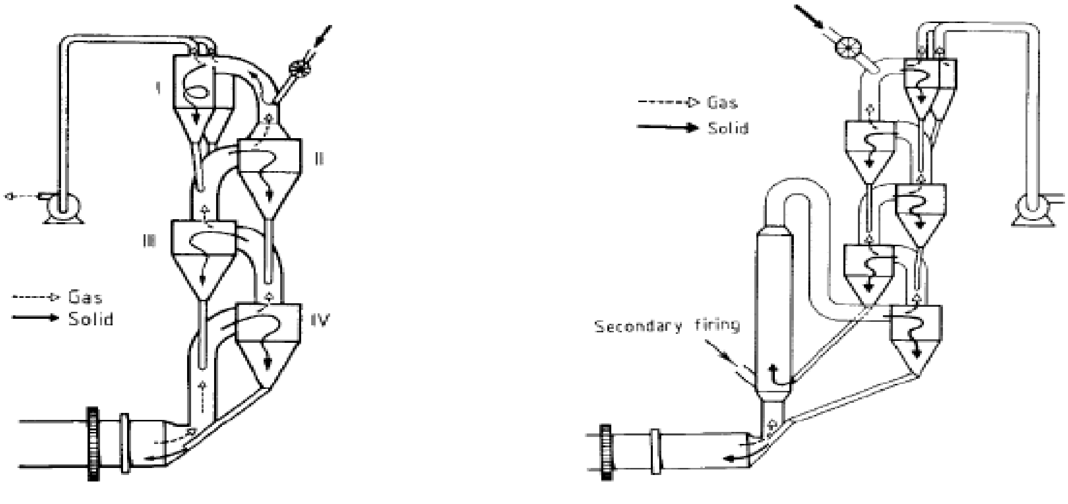


Figure 4.4. Diagrams of pre-heaters (IPPC, 2001).

4.5.2.Emission Control In Vsks

VSK outflows are stopped at the highest point in a furnace and they mainly include tidy and carbon monoxide (because of deficient burning/reductive conditions) (Figure 4.5).

Tidy convergences of 2000-4000mg/Nm^3 exist in VSK in different spots (Viacroze, 2005). Tidy discharges are dependent on oven process; therefore, proper furnace conditions decrease the emissions (Figure 4.6).

Air-contamination controlling gadgets in vertical-shaft furnaces typically utilize violent winds or sack channels. Tidy gathered in these gadgets is difficult-to-reuse in the procedure. The Chinese channel frameworks are less productive and damp with the leftover gas that makes cleaning very difficult.

Electrostatic precipitating devices uncommon in vertical-shaft ovens because of possibility of blast (controlling CO is difficult) and existence of damp gases.

Figure 4.5. Bag filters used to clean gasses in VSKs (Viacrozc,2005).

Figure 4.6. Cyclone and filter for cleaning exit gasses in VSKs (Viacrozc,2005).

4.6. RESOURCE UTILIZATION IN CEMENT PRODUCTION

Cement assembling needs expensive assets like crude substances, warm fills and electricity.

Crude substances and power requirements for producing every ton of concrete and CO_2, They are shown in Figure 4.7.

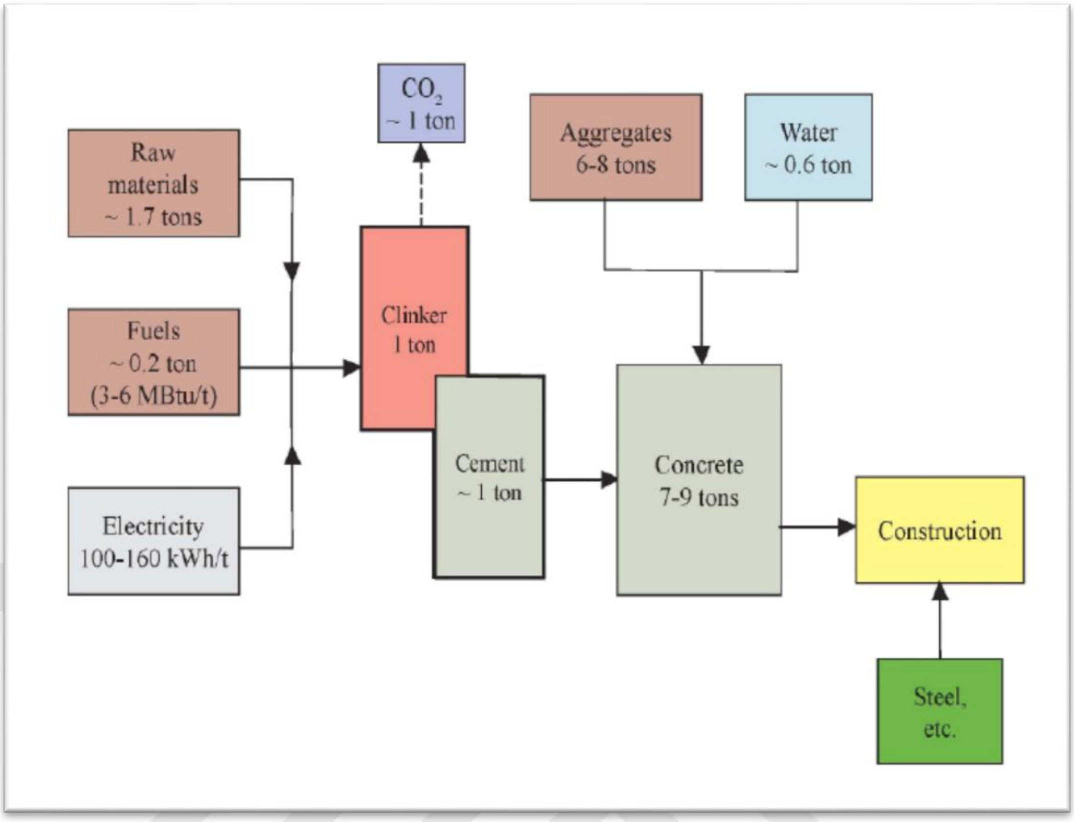


Figure 4.7.The flow rate of crude substances, fuel & power (US Geological Survey,2004).

PART 5

RESEARCH METHOD

This research is based on exploration questions:

1. What can be ecological, human wellbeing, social, and monetary ramifications of utilizing option vitality origins as compared to using conventional non-renewable energy (coal, oil or coke) in bond fabricating?
2. Considering ecological, human wellbeing, social and financial viewpoints, what are positive and negative impacts of cement manufacturing, waste reuse, and reusing recuperations? These examination inquiries will from now on be tended to, separately, as RQ(I) and RQ(II).

5.1. PROJECT APPROACH

This unit talks about the approach to find the answers to the exploration questions. Extra topics requiring special attention are accessible in the final segments.

5.1.1. Overall Approach

The initial step of the venture was the writing appraisal. The important records were recovered from scholarly databases, institutional and expert reports, contextual analyses and distinctive research series considering the objective to find RQ(II) discoveries, which have their own effects.

Environmental and social effects:

1. Source utilization/protection.
2. Global warming.

3. CACs/Non-unsafe poisons.
4. Metals and HAPs.
5. Operations Waste.
6. Health and social effect: The effect on human wellbeing, its recognition, and acknowledgment.
7. Eutrophication potential: The capability of abundant supplements in getting water bodies that trigger extreme plant development.
8. Economic and specialized effect.
9. Economic effect.
10. Technical/showcase achievability: Attainability and market acknowledgments.

5.1.2.Analytical Approach

As demonstrated, this review considers both life-cycle appraisal (LCA) and non-LCA literature. Non-LCA studies are examined, and the principle discoveries were explained. The significant LCA (recognized by Martineau et al., 2010), an efficient survey of the LCA writing on optional fills in concrete assembling were investigated and their discoveries conformed findings of others. Martineau et al. finished in January 2010; hence, all pertinent LCA concentrates distributed in 2009 and this second stage were included.

Both LCA and non-LCA studies urge the researchers to investigate the issues from two distinct perspectives. LCA researchers believe that systemic evaluation of the optional powers, considering fuel's life cycle and distinctive end-of-life choices; non-LCA studies clarify impacts of utilizing option fills.

Expanding enthusiasm for the theme in some previous decades and, consequently, a more noteworthy number of distributed records were distributed before 1990 but those outdated but established reports have authenticity.

5.2.ALTERNATIVE FUELS

As in Section 5.2, eight classes of optional powers were examined, which are appropriate in their utilization in concrete ovens. Some wastes including IC&I deposits, diverse waste (e.g., solvents and rugs) are incorporated. Notwithstanding, the characterization of fuel sort was completed on the basis of available definitions.

In fact most of the options are biomass fuels (e.g., creature and bone supper, biosolids, wood, and so forth.). All the biomass fuels are not officially included, for example, rice husks and cotton seed oils.

5.3. STATE OF THE LITERATURE

In this unit, scholastic, institutional and expert databases were examined to make the best learning available. Due to quick advancement of innovation in this field, just records distributed from 1990 to 2010 have been consulted. A few issues are highlighted in this report.

5.3.1.The Methodology Used For Literature Retrieval

The report is based on:

1. Academic papers
2. Institutional reports
3. Practitioners' reports
4. Case studies

Efforts were made and a database inquiry was conducted to reply to questions RQ(I) and RQ(II) (see Table 7.1). Seven distinct factors were examined for RQ(I) including concrete assembling, elective fills, non-renewable energy sources, ecological effect, financial effect, wellbeing effect, and social effect, from which, eight inquiry series were produced.

The refinement of the outcomes was additionally conducted to incorporate just LCA concentrates distributed in 2009 (Martineau et al. 2010). One scan string was made for RQ(II) and it was based on end-of-life choices of alternative fuels.

5.3.2.Academic Papers

For this paper, we looked for scholarly papers and searched 10 scholastic databases.At first, papers were viewed as important for RQ(I). Duringthe amendment stage, some significant papers were studied before writing investigation. These papers contain quantitative discoveries. Similarly, for RQ(II), some papers were found pertinent, so they were used.

5.3.3.Institutional Reports

Many institutional databases were consulted including those of consulting associations, concrete producers' organizations, universal research establishments, and legislative associations.

From these inquiries, 19 records were found important for RQ(I); 16 were assessed as possibly significant for RQ(II).

5.3.4.Practitioner's Reports

The exploration for records in experts' databases was done only for RQ(I) as it was accepted that data about the flipside of option fills was not accessible. Ten bond producers provided the information, giving 20 possibly significant responses.

Distributions that included contextual investigations and manageability reports were recognized. For assuring high standards of research, other records (e.g., official statements and site pages) were ignored. The lion's share of data was found in studies of 2007 and 2009, which shows increase during recent years.

5.3.5.Case Studies

There were not very many records and only independent contextual investigations were taken in consideration. Two records were applicable and relevant to RQ(I).

5.3.6.Other Documents

Extra records proposed by the Guidance Committee and the LCA concentrates announced in a previous stage (Martineau et al., 2010).

5.4. CEMENT PRODUCTION USING ALTERNATIVE FUELS

In this unit, the discoveries in case of RQ(I) are combined and depicted for every optional fuel class. Each finding matches an effect class. Eleven effect classifications were done on the basis of findings.

5.4.1.Used Tires

Exchanging petroleum products with used tyres is far-reaching in the concrete business because they are actually quite effective alternative fuel.

5.4.2.Environmental AndHuman Health Impact

Utilizing used tyres reduces fuel utilization. Indeed, scrap tyres regularly supplement non-renewable energy sources, for example, coal (LaFarge, 2003) and, consequently, reduce the need for crude substances in the industry (UK Environment Agency,2002; U.S. Ecological Protection Agency, 2009). Since traveler auto tires have 18.5% biomass division and truck tires contain 29.3% biomass (Clauzade, 2008), SO reduction in CO_2 discharges as compared to petroleum fuels is higher (International Energy Agency, 2008; Portland Cement Association,2009).

Varying outcomes exist for SO_2 and NO_x emanations, recommending that the issues are case-particular. Prisciandaro et al. (2003) broke down the discharges from an

Italian bond plant utilizing oil coke with 22% tires. Through factual investigation, the review attested that tyre-ignition using oil and coke in bond ovens increases SO_2 and NO_x emanations. The review found that the expansion of NO_x discharges are most probably linked with different states of the furnace, and specifically with overabundant air. Expanded discharges of SO_2 are evidently brought on by the inadequate ignition of tires, even when the sulfur content in the oil-coke blend and tires is way lesser than the content in oil and coke alone. Carrasco et al. (2001) studied Canadian bond industrial facilities utilizing coal and additionally a mix of coal and scrap tires. That review found a reduction in NO_x outflows despite expansion in SO_2 and particulate emanations. They didn't refer to the quantity of used tyres, which were utilized as fuel; however, they specified that the burning effectiveness was one of the fundamental drivers of toxin emanations.

The UK Environment Agency (2009) directed a review on a concrete assembling factory in Dunbar (utilizing 26% tires), which demonstrated NO_x effect-diminishment computed through an ecological remainder. For SO_2 and particulate discharges, the circumstance was unverifiable and case particular, as later discoveries demonstrated both increments and reductions. The report reported the fact that this was expected because of pyritic sulfur substance of crude substances, which have a significant impact on discharges. The report additionally reported a similar conduct in four other UK concrete industrial facilities.

A U.S. Ecological Protection Agency report (2006) expressed that NO_x outflows depend on the ignition procedure, while SO_2 emanations are dependent on sulfur substance in the fuel. The report found that using tires as fuel did not diminish NO_x outflows and it didn't give promote clarification about the technique of the examination. Another U.S. Natural Protection Agency report (2008) stated that fuel usage of scrap tires in bond furnaces diminishes NO_x outflows.

An IEA report (2009) claimed that consuming tire-inferred fuel in bond ovens, rather than petroleum products, diminishes both NO_x and SO_2 emanations; however, the report did not provide details of the findings. A LaFarge report (2003) included a contextual investigation on scrap-tire usage in concrete ovens. A bond plant in Atlanta that utilized 20% used tires diminished NO_x discharges by 4.6%.

At last, two reports published by Portland Cement Association in 2008 and 2009 claimed that NO_x, SO_2, and particulate outflows were lower when scrap tires substituted a segment of the non-renewable fuels. Later, no noteworthy contrast in those outflows was found.

Additionally, the writing uncovered contrasting outcomes regarding discharges of metals, dioxins and furans. Conesa et al. (2008) demonstrated that discharge of dioxins and furans expanded when yearlong trials were conducted in a real plant. By differentiation, the Carrasco found that utilizing used tyres in bond ovens decreased the dioxin & furan production. Information was gathered from 31 bond plants that utilized tire-based fuel and discovered noteworthy declines in the dioxin/furan emanations. Prisciandaro demonstrated that the discharges of dioxins and furans were comparative (and well beneath confinement limit) for bond ovens, which sustained with 100% oil coke and for furnaces, using 80% oil-coke and 20% piece tires. Abad et al. (2004) concentrated three Spanish concrete plants and found no factual contrasts between the information acquired from plants that utilized ordinary powers or those, which utilized a mix of petroleum products and utilized tires (9.4% in vitality gave). This is also acknowledged in the UK Environment Agency report (2008).

Carrasco et al. (2002) found that exactly opposite to petroleum derivatives, consuming utilized tires in concrete ovens expanded HCl emanations. There was wider acknowledgment in the accessible literature that utilizing old tyres to replace fuel in concrete production diminishes the requirements for extra crude substances (tires contain press and, if recuperated, could lessen the requirement for iron mining and/or sourcing of option iron sources) (UK Environment Agency, 2008; Portland Cement Association, 2008; U.S. Natural Protection Agency, 2008).

The same kind of acknowledgment was found regarding the diminishment of air discharges when compared with petroleum derivative ignition (UK Environment Agency, 2008; LaFarge, 2003; LaFarge, 2008).

Old and used tyres are a naturally solid end-of-life administration choice for bond-furnaces. It stays away from blemishes and uncontrolled consumption (Portland Cement Association, 2008), decreases landfill request (Heidelberg, 2007b; LaFarge, 2008; LaFarge, 2003; U.S. Ecological Protection Agency, 2008). Consuming piece tires have no adverse wellbeing impact (U.S. Natural Protection Agency, 2008).

5.4.3. Economic Impact

Used tires have a higher vital content than coal (UK Environment Agency) and their utilization as fuel makes factories more economically empowered due to less spending on coal (LaFarge, 2003).

Not all furnaces are reasonable to use entire tires, and using destroyed tires increases fuel costs (U.S. Natural Protection Agency, 2008). Besides, extra pre-handling hardware might be required (UK Environment Agency, 2001).

The used tire availability is easy but this is not the situation in Canada (especially in Quebec), where the used tyre availability for concrete assembling is getting constrained.

5.4.4. Other Social Impact

We found some official records but no extra documentation pertaining to social issues was found.

5.5. THE ROTARY-KILN EVOLUTION AND PHENOMENON

This part acquaints the user with rotating furnaces as a contrasting option to other unit operations. The history and advancement of the turning oven and a few procedures that have discovered applications throughout the years are exhibited.

5.5.1. The Rotary Kiln Evolution

Turning ovens have been synonymous with bond and lime furnaces because of their advancement. Bond stores discovered by Israeli geologists in the 1970s show that bond-making was done in 12,000,000 BC (Blezard, 1998). Around 300 BC, the bond development was proceeded by the Egyptians who utilized mud blended with straw to tie dried blocks for monstrous ventures, for example, the pyramids. Chinese did further advancement when they utilized cement-like materials for building the Great Wall. Ventures, for example, the working of the Appian Way by the Romans later prompted concrete utilization in Pozzuoli, Italy, which is located close to Mt. Vesuvius.

The innovation that uses the consumption of lime was reintroduced during the 13th Century. In the United States, activities, for example, water channel construction in 1818 made use of cement on large scale. By 1824, Joseph Aspdin invented Portland cement in early days, stationary ovens were utilized and it is said that the sintered item was inefficiently permitted to cool after each consumption before granulating. The historical backdrop of concrete (Blezard, 1998) dates back to 1870s when Thomas Millen and his two children created Portland bond in South Bend, Indiana, which was first consumed for sewerage pipes. By 1885, an English architect, F. Ransome, used a tilted even oven that could be pivoted so the material could move steadily from one end to another. Since this new kind of furnace was better, it replaced the ovens used for cement manufacturing. A huge surge of Portland bond was observed between 1880 and 1890, which was around 44,000 to 340,000 barrels, and it led to rotating furnace development (Blezard, 1999). Like most early developments, it is said that Thomas A. Edison played a part in promoting rotating furnaces. He is credited for presenting the primary long furnaces at his Edison Portland Cement Works in NJ, in 1902. His ovens are accepted to have been around 150 ft long as compared to previous length around 60–80 ft. Today, a few furnaces are 500 feet or more with applications extending far more extensive than concrete and lime-making. By the 1900s, advances in bond and lime furnaces had experienced a methodical development since the times of the ancient Egyptians. So practically, endless varieties of licensed ovens were designed albeit few ovens never had helpful applications. Any reasonable person would agree that furnaces have developed from the supposed field or pot ovens that were roughly built of stone and slopes to vertical shaft and rotational furnaces with every advancement step completed with the change of work, profitability, blending, warm exchange, and item quality as a top priority.

Taking after bond, different businesses additionally contributed to that temporary fad. For instance, the rotational furnaces are prepared for making lightweight doors (LWA) and they were introduced by Stephen Hyde in the mid-1900s in Kansas City, Missouri. In the extended shale industry, regular lightweight totals had been utilized to make lightweight cement since the times of the early Greeks and Romans, yet it was not until the discovery of extended shale, made by the rotating oven handle, that a lightweight one with adequate quality was accessible in the form of strengthened cement.

As of now, rotating furnaces are utilized by the industry to do a wide exhibit of substance preparing operations; for instance, lessening of oxide mineral, recovery of hydrated lime, calcining of oil coke, risky waste recovery, et cetera.

This across-the-board utilization depends on variables such as potential to deal with differed feedstock, crossing slurries to granular materials, and ability to deal with different situations, for example, decreasing conditions inside the bed existing together with an oxidizing freeboard (a turning oven that is not effortlessly accomplished in different reactors). A rotating oven, which permits 2–5s time and 1725°C temperature, which makes such furnaces a suitable option. Revolving ovens are not without issues. Tidy era, low warm effectiveness, and non-uniform output quality are some challenges that still affect rotating furnace operations. The long habitation time of the substance inside the furnace (regularly more prominent than 60 minutes) helps accomplishing an acceptably uniform item as the early clients had proposed, there is a significant extension for enhancing this part of oven. For this, a quantitative comprehension of transport inside the bed substance was needed to facilitate molecular movement, which decides the warming rate for individual particles.

Essentially, rotating ovens are warmth exchangers, in which, the bed substances remove the hot gas. During its entry in the furnace, the bed substance will have different warmth. Long furnaces are drying, warming, and giving compound responses that cover an expansive scope of temperatures. In spite of the fact that non-contact (i.e., remotely warmed) revolving ovens are utilized for specialized work, most furnaces permit the freeboard gas and bed substance to come in contact as appeared in Figure (5.1). Highly recognized configuration is a counter-present stream where the quaint little streams are in inverse direction, although co-current stream might be good for some kinds of occurrences, for instance, revolving driers.

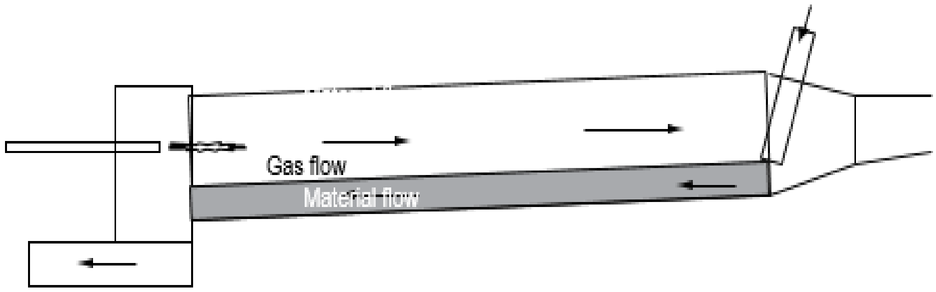


Figure 5.1. Diagram of countercurrent flow rotary kiln configuration (SCI,1998).

5.5.2. Comparison Of The Rotary Kiln With Other Contactors

The rotational furnaces were developed since the times of ancient Egyptians. Enhancements allowed decreased work, expanded profitability, blending, warmth exchange, and item quality. Mineral handling furnaces can be delegated vertical, flat, or different incidental blended sorts (Table 5.1). Vertical furnaces work in the stuffed bed mode where the substance being prepared (calcinated) with a top container, in which, the static bed moves. A case of an annular shaft furnace schematic is presented in Figure (5.2).

Here the charge can be either in countercurrent or in a parallel stream to the ignition gasses, which exchanges warmth to the solids (e.g., limestone). To augment warmth and mass movements in such gadgets, abundant voidage inside the particulate charge is essential. This guarantees uniform flow of hot gasses through the pressed bed.

Sustainable molecular size and appropriation must be chosen to guarantee an ideal output.

Table 5.1. Standard Characteristics of Rotary and Other Contact Kilns (SCI,1998).

Vertical kilns	Horizontal kilns	Other⁄ Mixed
Traditional shaft – type kilns Indirect gas-fired kilns or flash calciners Large capacity, mixed feed, center burners Parallel flow regenerative type Annular/ring type	Conventional long wet- dry rotary kilns Direct or indirect fired Noncontact externally heated small capacity kilns used for niche applications Modern with cooler recuperators Pre-heater kilns, Cylindrical rectangles etc.	Fluidized-bed type kilns Gas suspension type Rotary hearth with traveling grate/ calcimatic kilns Horizontal ring type Kilns,etc. Cylindrical

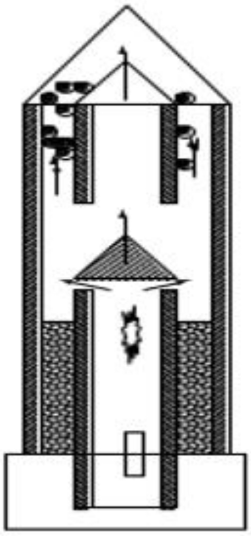


Figure 5.2. Diagram of annular shaft kiln (SCI,1998).

At the other extraordinary to pressed beds, as experienced in vertical-shaft ovens, are fluidized while the charged particles are suspended by the hot gasses in a weaken stage (Figure 5.3).

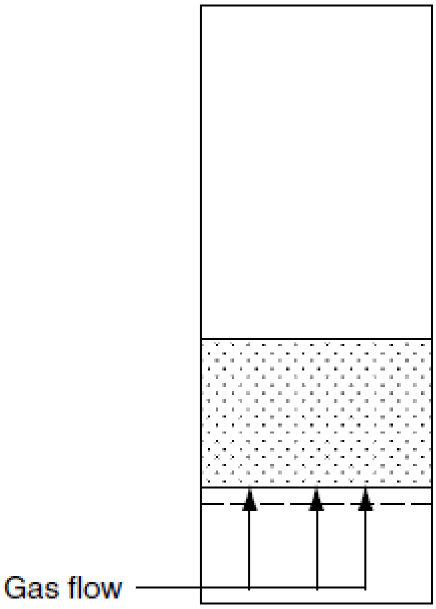


Figure 5.3. Diagram of a fluidized bed calciner (SCI,1998).

In liquid bed suspension furnaces, the void portion can be 60–90 percent. The hot gasses perform two capacities, that is, they fluidize or suspend the particles, and exchange warmth to the particles. Exchange of heat is effective at the molecule level, and a gigantic measure of vitality is needed to keep the bed in suspension and to move the charge. As fluid is part of molecule size, nourished particles must be sustained as fines. In the middle of both the extremes are even turning ovens (Figure 5.1) that offer a particular situation for burning gasses (freeboard) and the charge (bed). Dissimilar to pressed bed vertical furnaces, some level of bed blending is accomplished by oven revolution and related marvels. Revolving ovens have advanced as most mineral procedures show a tradeoff between the stuffed and suspended methods of operation permitting substantial limit for few process challenges.

Despite the refinements depicted in the diagrams, most ovens, vertical or flat, when utilized for hot processes, for instance, calci-country, oxidation, lessening, et cetera, in a nonstop operation will have particular regions along with their pivotal length.

These will incorporate a pre-heating chamber where the particles are pre-heated, an ignition region that typically matches with the area along the vessel where the burning or the fire is made, and the release or cooling region exists behind the fire.

The degree of the planned response and that is concerned with item quality, is most affected by the ignition conditions where heating should be provided to the solids, for instance, in limestone calcination above the separation temperature. For item quality purposes, it should be guaranteed that the temperature in the calcining zone is kept uniform with no hot or frosty spots. Of all the heater-types depicted, one can state that the rotational oven has great potential to control the temperature profile.

5.5.3. Types Of Rotary Kilns

Turning furnaces come in a few structures and shapes. The dominant part comprises of straight, barrel-shaped vessels, dumbbell-molded plans (Figure 5.4) exploiting the advantages that variable drum sizes can provide.

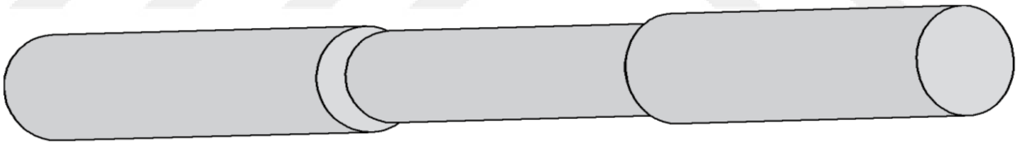


Figure 5.4. Schematic diagram of dumbbell-type rotary kiln (SCI,1998).

In case of inner oven installations, most direct shot furnaces are fixed with obstinate substances for a few causes yet the main roles are to protect and ensure the external shell, in high-temperature applications. Furnaces may likewise be outfitted (Figure 5.5) for making the substances move and sometimes to enhance molecule-blending accomplished through surface re-establishment. Table 5.2 introduces vitality sparing preferences of utilizing lifters in different applications and procedures.

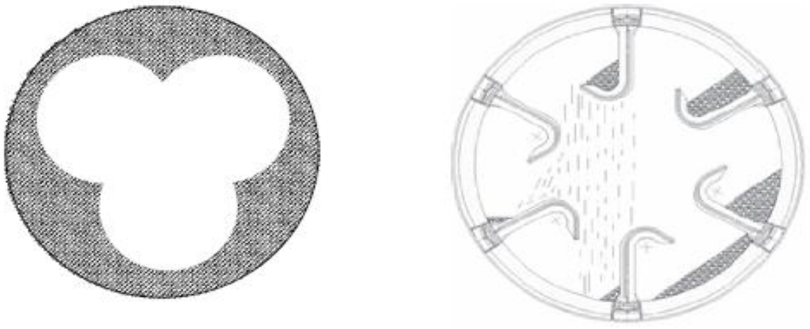


Figure 5.5.Schematic diagram of kiln internal fixtures: trefoil (left) and-lifter (right) (SCI,1998).

Table 5.2. Advantages of utilizing lifters (Data in imperial units) (SCI,1998).

	Before Lifters Installed	After Lifters İnstalled	Percent Change
12 x 250 ft LWA kiln	Added 3 rows of lifters + 3 dam		
Product rate (STPD)47	650	970	
Specific heat Consumption (MBTU⁄TON)	2.6-2.8 35	2	-
Exit gas temp F39	1200	730	
Kiln speed (rpm)70	1.6	2.7	
11 x 175 LWA kiln	Added 3 rows of lifters + 1 dam		
Capacity (TPD)14	550	625	
Specific heat Consumption (MBTU⁄ton)	2.53 12	2.24	-
Exit gas temp F	1050	850	19
Kiln speed (rpm)	1.75	2.3	31

Attributable to the warm effectiveness of prior long ovens and the requirement for fuel productivity, most outlines are made for boosting blending and warmth exchange. To achieve this, furnaces are frequently furnished with recuperates, for example, pre-heaters, in which some fumes gas is recouped to pre-heat prior to its entry in the oven. Of the innovative rotational furnaces, the accompanying equipments can be recognized: wet ovens, long dry furnaces, short dry furnaces, coolers and dryers, and backhanded terminated furnaces.

5.5.3.1. Wet Kilns

Wet furnaces normally sustain with slurry substances. Wet ovens are typically long with furnace lengths of 160–190m.

The bolster end is generally outfitted with chains that fill in as a hot "flywheel" by recovering the warmth in the fumes gas for pre-heating for drying. Chains are likewise used to separate any knots that the substance may shape in the transition from the slurry to solids after drying. In the concrete business, these ovens are not proficient and they are turning into relics of past times. Some applications that are not manageable to utilize long dry ovens, for instance, lime mud furnaces found in the mash and paper industry and some other applications.

$$N = \pi \times (D + d + 2)/(d + 1) \tag{5.1}$$

These are shorter than wet furnaces with lengths 90–120 m (around 300–400 ft). For long dry ovens, as with wet furnaces, the drying, pre-warming, and calcination happen in the one single vessel (Figure 5.6).

Figure 5.6. Wet, long cement kiln (SCI,1998).

They function admirably when the particles are substantial. Applications incorporate lime ovens and lightweight total furnaces where the mined stones are pounded to around 1.4–5 cm before putting them into the furnace.

5.5.3.2. Short Dry Kilns

Short dry ovens are typically joined by an outside pre-heater or pre-calciners, (Figure 5.7), in which, the substance is dried, preheated, or even calcinated prior to going into primary power source (furnace). Therefore, the warm load on the furnace is lessened. Subsequently, ovens outfitted with pre-heaters or pre-calciners have a tendency to be short about 16–76 m depending on the procedure. The shorter ovens are those, in which, the entering substance is nearly calcinated. Applications incorporate concrete and some lime. The present day lime furnaces have pre-heaters, which work as a pressed bed of stone with a countercurrent stream of oven fumes gas, which works exactly opposite to the run-of-the-mill twister pre-heaters.

Figure 5.7. Cement kiln equipped with cyclone pre-heaters (SCI,1998).

5.5.3.3. Coolers And Dryers

A few coolers and dryers can be in a type of contractors, for example, the rotational furnace itself, albeit some are pressed-bed contactors, for example, grind coolers. Revolving coolers can be either in-line or connected (Figure 5.8).

$$N = \pi \times (D + d + 2)/(d + 2) \tag{5.2}$$

Where D and d are the individual distances across of the oven and the cooler. Appended coolers put an additional mechanical load that must be represented in outline estimations. They likewise introduce upkeep challenges. Rotational coolers and dryers ordinarily have tumblers or lifters, which assure better solid-gas contact

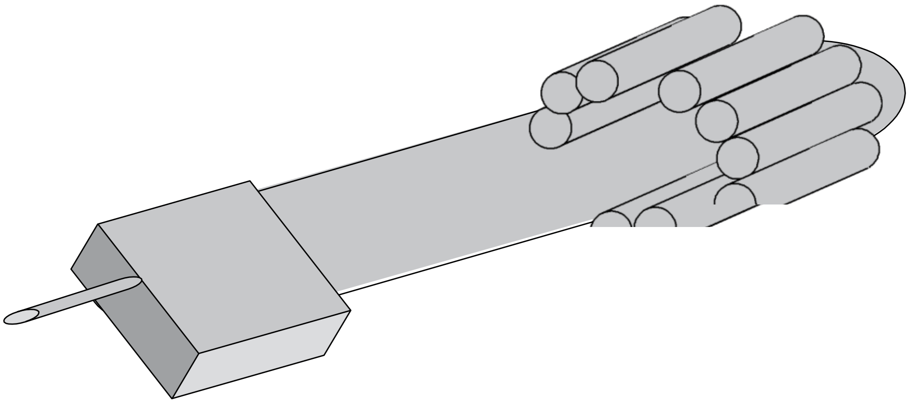


Figure 5.8. Schematic diagram of an attached cooler arrangement (SCI,1998).

5.5.3.4. Indirect Fire Kilns

Aberrant oven are typically intended for applications where the substance and heat-producing-gas contact is undesirable. For this situation, the warmth source is outside the oven (Figure 5.9). Any inner streaming gas that is utilized for cleansing any unpredictable substance or gas emitting out of the bed. On account of their low warmth, remotely warmed furnaces are little typically up to 1.4 m wide and they are utilized for specific applications like calcinating.

An exceptional component of aberrant terminated rotational ovens is different and compartmentalized temperature control regions that are electrically warmed or gas is independently released. Consequently, they operate at higher temperatures. Sometimes, for instance, graphite heaters can attain 2400 × C. Run-of-the-mill applications incorporate calcination, lessening, controlled oxidation, carburization, strong state responses, and cleansing, including waste remediation on a little scale, that require high temperatures and tight control.

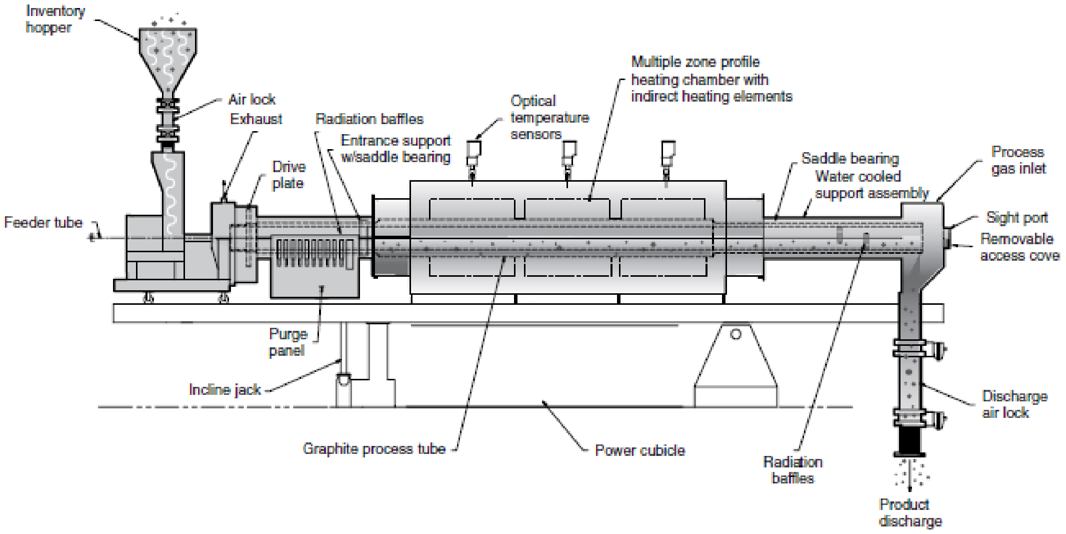


Figure 5.9.Indirect-fired small rotary kiln used for niche applications (Courtesy of Harper International, Lancaster, NY).

5.6. BASIC DESCRIPTION OF ROTARY KILN OPERATION

As found in Figure 5.10, unit operation hardware and other components are included to frame the rotating oven framework for substance handling. Maybe the most vital are the revolving reactors. The turning reactor is normally a long level chamber tilted on its hub. In most rotational oven handle applications, main target is driving the particular bed responses, which, for either active or the body dynamic causes, frequently needs temperatures, for instance, some bond furnaces may approach as high as 472C. For directly terminated furnaces, it is vitally important to raise the bed temperature to the needed level, for instance, the endothermic calcination of limestone, to drive the responses themselves, originates with igniting hydrocarbons close to the burner. This warmth is exchanged between the freeboard and the bed, as shown in Figure (5.10). The warmth exchange between is somewhat unpredictable (Figure 5.10). All these show themselves into a consolidated transport wonder with the different transport forms becoming an integral factor in one application.

The expository apparatuses have been the subject of impressive research.

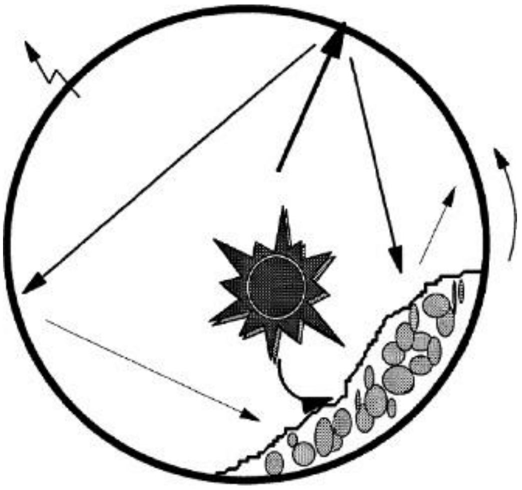


Figure 5.10. Radiation heat exchange in the cross section (Henein,1980).

The capacityTo reproduce the freeboard conditions has a tendency to surpass ability for deciding conditions inside the bed. For instance, the zone technique (Guruz and Bac, 1981) for deciding radioactive warmth exchange, and business programming for figuring liquid stream (and every so often ignition forms too). Along these lines, the cooperative energy between the freeboard and the bed is exchanged but the expected outcome of a procedure doesn't appear.

Researchers expect that at each pivotal position, a bed blends in the casual plane, that is, the bed substances are isothermal in any transverse segment of the furnace; however, numerous oven operations endure impressive trouble in creating a uniform item, for example, lime furnaces, which encounter ceaseless issues in forestalling dead-consuming big parts while completely calcining the better particles.The objective is connecting a freeboard marvel to the bed.

5.6.1. Bed Phenomenon

Amid the warm handling of granular substances in revolving ovens, warm exchange inside the bed material happens by indistinguishable systems, for example, shaft furnaces. Warm exchange ways at play can be molecule-to-molecule conduction and radiation, and between stitial gas-to-molecule convection (Figure 5.11). Element-development superimposes a segment for vitality transport, which can possiblycommand warmth transfer.

Thus, the key component of a revolving granular bed is the movement in the casual plane, which gets the pivotal stream under way and the level of fill (furnace volume).

Since the reactor is typically round and hollow and mostly filled, gener-partner consists of 2 scattering instruments, one is pivotal blending, and the other in the transverse heading.

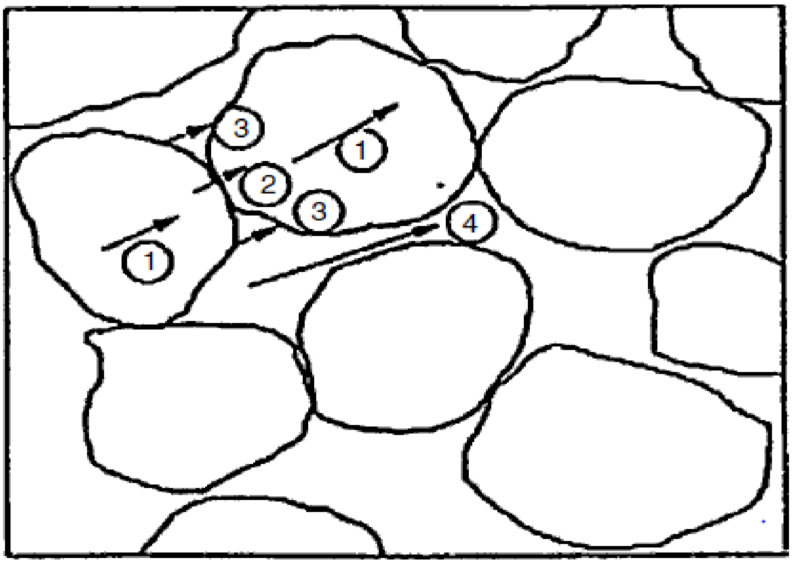


Figure 5.11. Bed heat transfer paths (Henein,1980).

1. Internal conduction.
2. Particle-to-particleconduction.
3. Particle-to-particle radiation.
4. Anti-particle convection.

The transverse heading is connected with a spiral-blending coefficient. The pivotal blending part works with the general convection components, and makes the heft of the material move from the delta of the round and hollow drum to the outlet with a normal speed equivalent to the attachment stream speed. The outspread blending segment includes instruments at the little scale that causes neighborhood imperatives on individual elements and results in speed segments both within the hub-heading and the transverse bearing. Both pivotal and transverse blending coefficients tend to increment with an expansion in oven's rotational velocity. For low values of the pivot, one is for time-dissemination due to its speed profile (Wes et al., 1977). Drum-estimates, molecular rheology, and drum interior components are significant. The impact of drum's rotational speed on the transverse stream will be described later.

For the time being, we exhibit the rotational reaction components using quantitative portrayal of the scattering instruments, the resultant impacts of which are basic to bed warm exchange in substance preparation.

5.6.2. Geometrical Features And Their Transport Effects

The key geometrical component is the vessel measure is the length-to-width proportion L/D and furthermore the incline. Other germane components, for example, choking dams and lifters, have effect on arrangement time. It is,

$$\tau = \frac{0.23L}{sN^{0.9}D} \mp 0.6\frac{BLG}{F} \tag{5.3}$$

where is the slope (ft/ft), N is the kiln rotation speed in revolutions per minute (rpm), L&D are the respective length and diameter in ft, G represents freeboard gas-velocity in lb/hr/ft^2, and F shows feeding lbs of dry materials/hr/sq ft in the cross-sectional area. B is a constant depending on the substance and is approximately defined as

$$B = sd_p^{-0.5}$$

Since the vessel is halfway filled and pivoting on its flat hub, the freeboard or open space depends on the bed's profundity on the furnace stacking (% fill). Free surfaces are needed depending upon the operational prerequisites, that is, the encourage rate, the drum rotational rate, and the substance properties. Therefore, the measuring of the rotating oven depends on the encourage rate (limit) and related transport properties, for example, temperature, gas stream rates, and bed substance speeds that at last will dissuade the living arrangement time. For instance, in dry preparing applications, barrel length-to-distance across proportions of 5–12 normal relying upon whether the warmth trade is contact or non-contact. Such L/D proportions can bring about habitation times in the 20–120 moment on the furnace rotational speed.

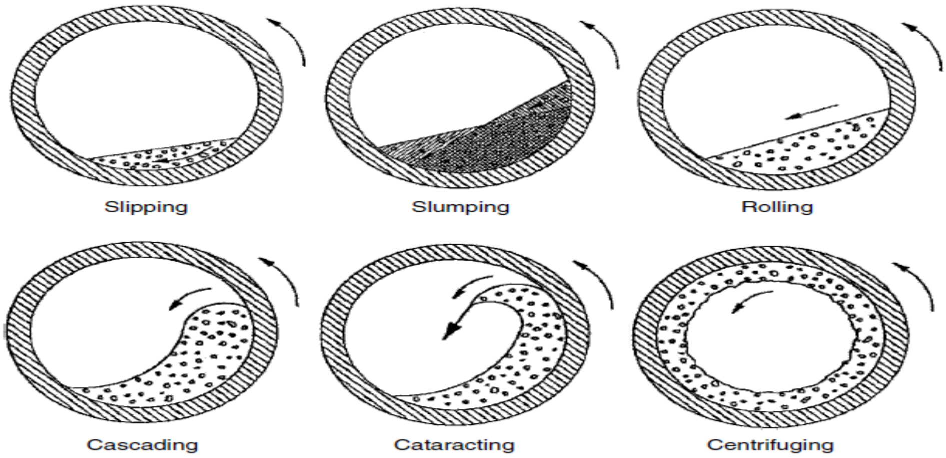
This kind of inner flights, and the inclined in the longitudinal bearing, 1–3× charge development in a turning chamber, which can be settled into two parts specified before, is a hub-bearing development. It decides the arrangement time, and transverse plane development, which affects essential bed procedures, for example, material blending, warm exchange, and response rate (physical or synthetic), and additionally the hub advance. It operates despite linkage between molecular movement in the transverse plane and molecule speed within the hub-course (Boateng, 1998).

5.6.3. Transverse Bed Motion

Depending on a furnace's rotational rate, the bed movement in the transverse plane might be portrayed as centrifuging, which happens at basic and high velocities, which is an extraordinary condition, in which, all the bed substance turns with the drum divider. Falling, which additionally happens at generally high rates of revolution, is a condition in which the edge stature (shear wedge) of the powder transcends the bed surface and particles course or shower down on the free sur-confront (Figure 5.12).

Albeit working the revolving furnace in both of these conditions is uncommon in view of weakening and cleaning issues.

Certain drying applications, which exploit the high molecule-to-warmth exchange, for instance, beginning at the other outrageous at low rates of revolution and moving continuously to higher rates, the bed will normally move from slipping, in which, the main bedsubstance slips against the divider towards dropping. A section of the mass substance at the shear wedge winds up as noticeably unsteady, produces and purges down the slope to motion, which includes a consistent release onto the bed of sur-confront. In the drooping mode, the dynamic edge of rest differs in a repeating way while in the moving mode rest corner stays consistent (Rutgers, 1965). The dynamic similitude of the turning drum conduct, and consequently the kind of transverse bed movement that happens amid powder handling needs rotational Froude number, Fr, is characterized as:



Mode	Fr(=ω2R/g) at φ=35°
1. Slipping	Fr <1.0×10–5
2. Slumping	1.0×10–5<Fr<0.3×10–3
3. Rolling	0.5×10–3<Fr<0.2×10–1
4. Cascading	0.4×10–1<Fr<0.8×10–1
5. Cataracting	0.9×101<Fr<1
6. Centrifuging	Fr >1.0

Figure 5.12. Bed motion in cross-sectional plane. Froude numbers (Fr) are assigned to different modes (Henein, 1980).

$$\mathrm{Fr} = \omega^2 R/g \tag{5.4}$$

Where the basic condition for centrifuging infers Fr = 1. The scopes of Froude numbers appear in Figure (5.12).

In the moving mode (Figure5.13), where turning drum blending is maximized, two unmistakable districts can be perceived, the shearing locale, called the dynamic layer, framed by particles near a free surface, and the aloof or attachment stream area at the base where the shear rate is zero. The specific mode decided for an operation depends on their application. A review of different rotating drum sort operations (Rutgers, 1965) showed that most operations are in the 0.04–0.2 scope of N-basic, which is well underneath the centrifuging mode and presumably the falling mode as well.

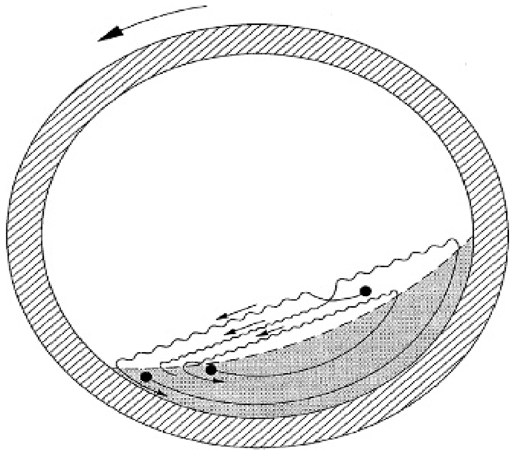


Figure 5.13. Rolling bed (Henein,1980).

The geometric common moving beds are portrayed in Figure (5.14). Beds are subtended at the persistent point of rest while freed surfaces are subtended at 2. Henceforth the bed's cross-area is taken by substance. The harmony length, Lc, the longest separation gone by particles on freed-up surfaces (way of soak est not too bad), can likewise be characterized as far as this edge. The cross-sectional territory possessed by substance is the furnace stacking.

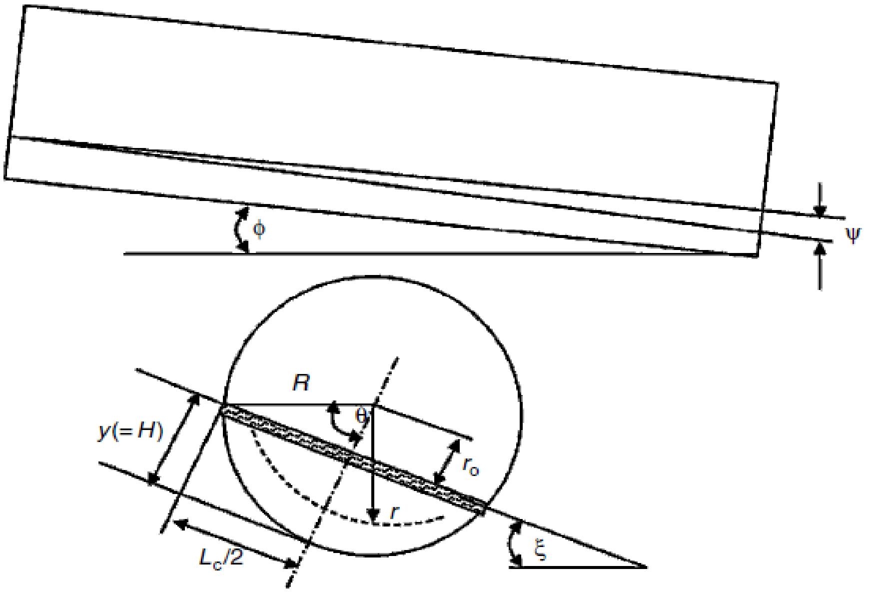


Figure 5.14. Rolling bedfill geometry (Henein,1980).

This is normally characterized as the volume percent involved by substance in the vessel, for which the oven length should be consistent while a fill is a section of cross-sectional region of the chamber (% fill). The division filled relates to the edges at any transverse area:

$$\mathrm{f_c} = \frac{1}{2\pi}\left(2\cos^{-1}\left(\frac{\mathrm{R}}{\mathrm{R-H}}\right) - \sin\left[2\cos^{-1}\left(\frac{\mathrm{R}}{\mathrm{R-H}}\right)\right]\right) \tag{5.5}$$

Sailor (1951) did estimation for the hypothetical residence-time taken by a shallow bed (gently stacked oven) and a hypothetical relationship for the furnace's stream rate for profound beds (intensely stacked furnaces). In any case, no reasonable definition has ever been given about the operational scope included by the two instances of oven loadings. Sailor's approximations prompted the conclusion that ovens are vigorously stacked when the fragmentary cross-sectional fill of solids surpasses at around 5 percent.

As appeared in Figure 5.13, two locales of the transverse plane can be observed: (i) the dynamic district near the bed's top place where surface recharging happens, and (ii) the latent area underneath the dynamic locale. The dynamic district is normally more slender than the inactive area since particles there are speedy and unlimited.

Since beds exist inside the barrel's geometrical space, the laws of preservation of mass (i.e., particles going into the dynamic layer must originate from the fitting stream district) need that the dynamic-area profundity should be lesser than the profundity of inactive locale. This is because of higher molecule speed in spite of whole other world of this wonder than straightforward mass protection. Major blending in the drum cross-area and furthermore separation responses happen in the dynamic layer. The more profound the dynamic layer, the better the blending.

Building dynamic layer profundity is fundamental to expand oven speed. Tracer examinations showed that the particles advance along the furnace just through the dynamic district (Ferron and Singh, 1991). The oven's longitudinal slant is typically little (1/2–3/4 in. per foot which is comparable to 3–4×) and not as much far as the material edge of rest (normally 36–40×). Subsequently, forward movement can't be managed by the gravitational segment of the burdens alone, which shows that the furnace's pivotal slant helps this forward movement, however, it doesn't operate it

For each furnace revolution, the bed material makes a few journeys (potentially 3 or 4) in the cross segment, bringing about a hub progress. Expanding the furnace speed will bring about an expansion in the quantity of journeys and eventually in the expanded blending. Furnace speed increments will diminish the home time of the material, since the bed will move speedier. It is imperative for furnace-administrators to know the application, what the basic home time and end-goals are. Preparation-control by oven speed is basic for satisfactory blending and keeping up an adequate home time to handle the material.

There are numerous methods for evaluating how the bed conduct will be. One such instrument is a bad conduct outline (Henein, 1980), which introduces a normal conduct for a sand bed for a 42cm breadth pilot furnace (Figure 5.15). Given the rest-point, furnace geometry, and speed, clients of such charts can anticipate what bad conduct to expect inside the oven cross-segment should be. Since these depiction bends were produced at room temperature, their modern utilization has been restricted. Regardless of this weakness, the bed conduct graph can be useful for drying and generally, the pre-heating region of long furnaces. In the calcination region, nonetheless, any softening of the substance that expands stickiness or agglomeration of the material will bring about an expansion in rest-point. As a consequence, we will expand our research on moving bed conduct.

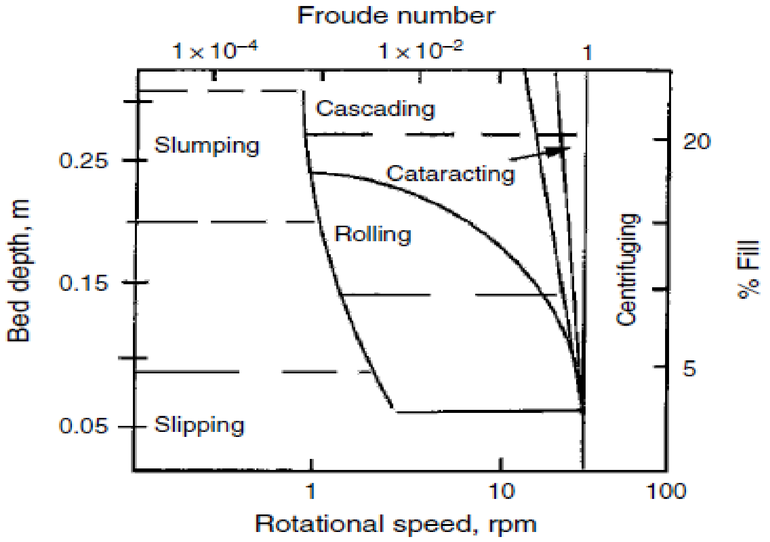


Figure 5.15. Bed behavior diagram - Mapping of bed behavior regimes for different Operational conditions (Henein, 1980).

5.6.4. Experimental Observations Of Transverse Flow Behavior

The key stride in all particulate handling applications is solids' blending. Blending is fundamentally used to decrease the non-consistency in the piece of the mass to accomplish uniform mixing or as an initial step to enhance the convective/advective and dispersion segments related with warmth exchange to a particulate bed during warm handling. A watch-stream part and transport wonders in turning ovens, providing bits of knowledge into particulate stream conduct, which prompt precisely expressing the scientific issue or displaying the rotating furnace transport marvels, are portrayed. Depending on bed profundity and the operational conditions, the stream conduct in the transverse plane can be simply stochastic, absolutely deterministic, or a mix of both; so, blending can be displayed by an arbitrary stroll for exceptionally shallow beds (Fan and Too, 1981). It is very much characterized by mass-speed profile assessed by shear streams like limit layer issues (Boateng, 1993).

Early specialists utilized traces to watch and portray blending (Zablotny, 1965; Ferron and Singh, 1991; and others). Recently, such works have been reached out to utilize non-intrusive methods, for example, atomic attractive reverberation (NMR; Nakagawa et al., 1993) and positron emanation molecule.

For mass handling, fiber-optic tests were employed for setting mass-speed profiles, and permitted evaluations essential for mass-convection of warm substances (Boateng, 1993). Boateng utilized investigations on the ceaseless stream of granular substances in the transverse plane of a turning drum to illustrate the rheological conduct of granular substances in rotating furnaces. Interestingly, such work gave information to numerical display of the granular stream in the limits of a revolving furnace. Utilizing granular materials that differs specifically the polyethylene pellets, long grain rice, and limestone, the mean profundity, and surface speeds were measured utilizing optical fiber tests (Boateng, 1993; Boateng and Barr, 1996).

From these, granular stream conduct including the speed changes and the direct concentration of particles could be figured out. The rotational drum contains a steel chamber of 1m distance across and 1 m length. It had a glass end piece with an inside opening giving access to stream estimations.

In the light of the layer shape and thickness, tests remain limited to the perception of the general conduct of substancestream in the cross segment. It was found that the attachment stream movement particles are ceaselessly sharing, not just depends on the substance's point of rest, for example, compensation-of-the-substance coefficient.

Since shear stresses produced in the actuated stream include collision, particles with a moderately low point of rest, for instance, polyethylene pellets make a simple move from the potential vitality position in the fitting stream to dynamic vitality in the dynamic layer. The low coefficient of compensation of substances like limestone have a moderately high contact point and the vitality scattering is less for polyethylene pellets. Therefore, high potential vitality is developed amid the move and is joined by substance development before discharge into the dynamic layer.

Stream hazards result, which shows themselves into the arrangement of various dynamic points of rest with precarious speed dispersion at the uncovered bed surface. The dynamic layer profundity and bed stream properties are dependent on compensation coefficient of the substance. The stream properties of intrigue incorporate granular temperature, which is a measure of motor vitality in the irregular movement of particles, and enlargement. The granular temperature was observed to be high at locales of low fixation with high mean velocity. In any case, its thickness is dependent on materials' features and the operational parameters, for example, rotational rate.

In the wake of exchanging from the connect stream locale to the dynamic layer, particles quickly move up to surface mid-harmony before decelerating with spilling, motor, and gravity impacts assuming different parts of energy exchange.

For profound beds, surface speeds can reach as high as 4.5–7.5 times the drum speed. Comparable perceptions have been watched utilizing non-intrusive stream estimation procedures (Parker et al., 1997).

5.6.5. Axial Motion

Hub scattering is based on transverse scattering. For every journey inside the cross segment, a molecule traveling along the harmonious length makes a pivotal move either in reverse or forward. This is due to arbitrary way of stream inside the dynamic layer. The forward progress is dependent on the barrel slant in the pivotal direction and in addition, the forward edge. Some geometric connections to the living arrangement time for particles going from one to the next furnace corner have been inferred by different examiners since Seaman's work (1951). Although these inferences don't possess thoroughness of a genuine granular stream, they have combined key observational connections to give outline recipes, which are part of production process even now. Nicholson (1995) gathered some germane recipes to portray pivotal mass development in furnaces that are simply in light of geometrical contemplations (Figure 5.14).

For a little oven incline, and the dynamic edge of rest, the expression for the pivotal development per course Zo, is given as:

$$Z_O = \frac{L_C(\phi+\psi\cos\xi)}{\sin\xi} \tag{5.6}$$

Nc can be calculated by:

$$N_C = \frac{\pi}{\sin^{-1}\left(\frac{L_C}{2r}\right)} \tag{5.7}$$

Where r is the molecular span in the bed. Duplicating the hub transport remove per course by falls per upheaval and the furnace rotational speed yields the normal pivotal transport speed, uax, for a molecule at position r anyplace in the spiral plane

$$u_{ax}(r) = nL_c\left(\frac{\phi+\psi\cos\xi}{\sin\theta}\right)\left(\frac{\pi}{\sin^{-1}\left(\frac{L_C}{2r}\right)}\right) \tag{5.8}$$

Where "n" represents the rotational speed of furnace. For delicately stacked furnaces (10–12 percent fill or less), one can make the accompanying estimation as follows:

$$\sin^{-1}\left(\frac{L_c}{2r}\right) \to \frac{L_c}{2r} \qquad (5.9)$$

The mean axial transport plug-flow velocity, uax, ata point along the kiln length can be calculated by the following expression:

$$u_{ax} = 2\pi rn\left(\frac{\phi+\psi\cos\xi}{\sin\theta}\right) \qquad (5.10)$$

The normal living arrangement duration may be assessed from Equation (5-10) knowing the oven length, L,

$$u_{ax} = 2\pi rn\left(\frac{\phi+\psi\cos\xi}{\sin\theta}\right) \qquad (5.11)$$

For beds with a lower degree of fill and end construction dams, one can practically assume a uniform bed depth throughout the entire kiln lengthy=H and,ϴ→0.The residence time expression can be reduced to:

$$\tau = \frac{L\sin\xi}{2\pi rn\phi}\tau = \frac{L\theta\sin\xi}{L_c\omega\tan\xi} \qquad (5.12)$$

Equation (5-12) looks like the empirical recipe for the assurance of habitation time, and Equation (2.1) was created by the US Geological Survey.

One can likewise decide the extreme limit of the oven by the same geometrical contemplations if the stream zone can be evaluated. From the geometry (Figure 5.14), the harmony length can be found as follows:

$$L_c = 2(r^2 - r_o^2)^{1/2} \qquad (5.13)$$

$$udA = 4\pi n\left(\frac{\phi+\psi\cos\xi}{\sin\theta}\right)(r^2 - r_o^2)^{1/2} rdr \qquad (5.14)$$

Integrating Equation (5.12) from r = ro tor = R gives an expression for the average volume triaxial transport rate as:

$$q = \frac{4\pi n}{3}\left(\frac{\phi+\psi\cos\xi}{\sin\theta}\right)(r^2 + r_o^2)^{3/2} \qquad (5.15)$$

The rate of change of bed depth can be estimated in terms of the subtended angle is:

$$\frac{dr_o}{dz} = \frac{3q\sin\xi}{4\pi n\cos\xi\left(R^2-r_o^2\right)^{3/2}} - \frac{\phi}{\cos\xi} \qquad (5.16)$$

Nicholson (1996) discovered great assertion between such hypothetical figures and test information for barrels with and without tightening influences at the release end.

A few early and late examiners have inferred varieties of the output/produce, hub speed, and time expressions (Hogg et al., 1973; Perron and Bui, 1990). Seaman's appearances given here have discovered most viable applications and they are prescribed for modern furnaces, as there are no genuine granular stream models for finding bed conduct as are accessible for liquids of isotropic substances.

5.6.6. Dimensionless Residence Time

Using the same geometric factors by Seaman, dimensionless residence time and flow rate may be derived (McTait et al., 1995) as a function of f(y/R) (Figure 5.16). Recognizing that this derivation might be convenient for estimating these parameters for all kilns.

Using Lc=y2R−y and
Sin Ɛ=Lc/R, the dimensionless time is:

$$\tau_d = \frac{\tau n D\tan\phi}{L\sin\xi} = \frac{\sin^{-1}[(2-y/R)y/R]^{1/2}}{\pi[(2-y/R)y/R]^{1/2}} = f(y/R) \qquad (5.17)$$

Similarly, using As=R2−LcR−y dimensionlessvolumetricflow can also be expressed as bed depth, recognizing that q=LAs, which is

$$q_d = \frac{q \sin \xi}{nD^3 \tan \phi} = \frac{\pi}{4}[(2 - y/R)]^{1/2} - \frac{\pi}{4} \frac{(2-y/R)(1-y/R)y/R}{\sin^{-1}[(2-y/R)y/R]^{1/2}} \tag{5.18}$$

dy/dz→0,

$$q_d = \frac{\pi}{6}[(2 - y/R)\, y/R]^{1/2} \tag{5.19}$$

Attachment stream estimations can be based on geometric furnace shape utilizing the balance points, the genuine residence time can totally vary from these appraisals.

This is due to irregular way of solids' movement suggested before. For each course or outing, a molecule can push the forward geometric projection as examined, or in reverse because of a few elements including changing material dynamic edge of rest.

Proof of this lies in the circumstance where substantial agglomerated particles (famously called in business as logs) which frame in high-temperature ovens have been seen to go forward/backward without being released. Likewise in the cross-sectional plane, particles in the connect stream can rise to the dynamic layer in agrouping (Ferron and Singh, 1992). Thus living arrangement time is an aftereffect of pivotal scattering, which is dependent on transverse scattering and it is really a conveyance function. It is a subject of numerous tracer tests. Parker et al. (1997) believed that utilizing the PEPT for molecule imaging showed that the dispersion of pivotal relocation takes after a Gaussian conveyance. They have seen in their tests a link from the spiral section of a tracer molecule to its exit inside a bed of mechanically prepared materials.

The fluctuation is divided by normal voyaged by particles on the free surface (some division over the harmony length, Lc) can be considered for geometric inferences from an operational outlook (McTait et al., 1995).

These connections between living arrangement time and bed profundity can be a part of the oven plan.

Given the measurement, oven slant, and craved L/D, the habitation duration and sustain rate that will result in a coveted bed profundity at a pre-defined furnace speed is computed utilizing these connections. Along with process information, these can be controlled to accomplish ideal furnace measure and working conditions. A dimensionless home time and stream rate for a 3.66m (12 ft) oven, L/D = 10, a furnace slant of 3×, and 40× edge of rest working at 1rpm are exhibited in Figure 5.16. From these, the real residence time and related fluctuation and furthermore the greatest volumetric stream rate for a regular modern substance with 1600 kg/m^3 100 lb/ft3 thick mass is calculated for configuration purposes (Figure 5.17).

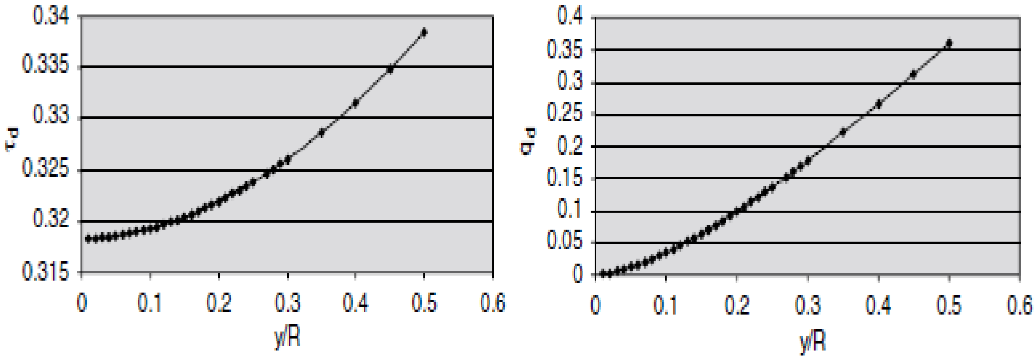


Figure 5.16. Dimensionless residence time and flow rate for 3.66m diameterkiln with L/D = 10_ slope = 3_, and material angle of repose = 40_(Henein,1980).

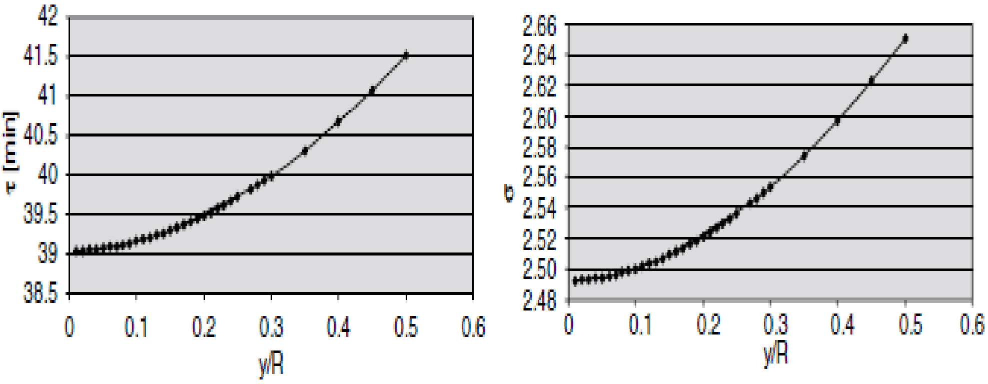


Figure 5.17. Calculated mean residence time and variance for 3.66m diameterkiln with L/D = 10_ slope = 3_, and substance angle of repose = 40_(Henein,1980).

Note: When elective powers become a part of concrete ovens, a few options should become the option fuels. In the old bond ovens, some plan changes should work with optional fuel, which has an extra and higher cost.

PART 6

PRESENTATIONS AND DISCUSSION

The generation of Portland bond needs a high level of warm vitality (Table 6.1). Consuming of 1kg PZ-Clinker out of crude substance parts limestone and dirt requires 1.75MJ warm vitality in fundamental figuring.

This prerequisite depends on endothermic responses of Decarburization of limestone and drying through Kaolinits (an estimation of approx. 2.22 MJ/kg) and exothermal response of stage framing (C35, C23, C3A and C4AF (esteem approx – 0.46 MJ/kg). The viable necessity of warm vitality is approx. 3.3-6 MJ/kg, which is dependent on the procedure. Energy needed for the production of 1 ton of Cement is shown in Table 6.1.

Table 6.1. Crude substances and energy needed for the production of 1ton of cement.

CrudeSubstances (kg)		Energy Consumption	
Limestone	1,095	Fuel (*1)	105
Clay	204	Electric power (kWh)	99
Silica	78	(*1): 1kg of coal equivalent, where HHV of coal is 6,220kcal/kg.	
Iron-ore	30		
Gypsum	34		
Total	1,441		

The dry-handle is part to approx. half for concoction response and approx half-in radiation (approx. 10-12%) fumes air (around 10%) fumes gas (up to 20%) and clinker (approx. 2%).

The warmth recovery is from the fumes air through the crude substance drying, coke-impact heater slag, and so forth. The burning proficiency can be 80%. For the creation of serviceable PZ-Clinker, fuel must be placed in an oxidizing environment to approx. 1450°C (sintering). So a base temperature of about 1800°C at 3% Oxygen O_2 substance is needed. Basically, fumes gas temperature should be at 2000°C. At an optional air temperature of lower than 800°C, a calorific estimation of least of 13 MJ /kg fuel that is appropriate for the previously mentioned case.To secure a consistently running operation, the calorific estimation should not confine at 18 MJ /kg fuel.

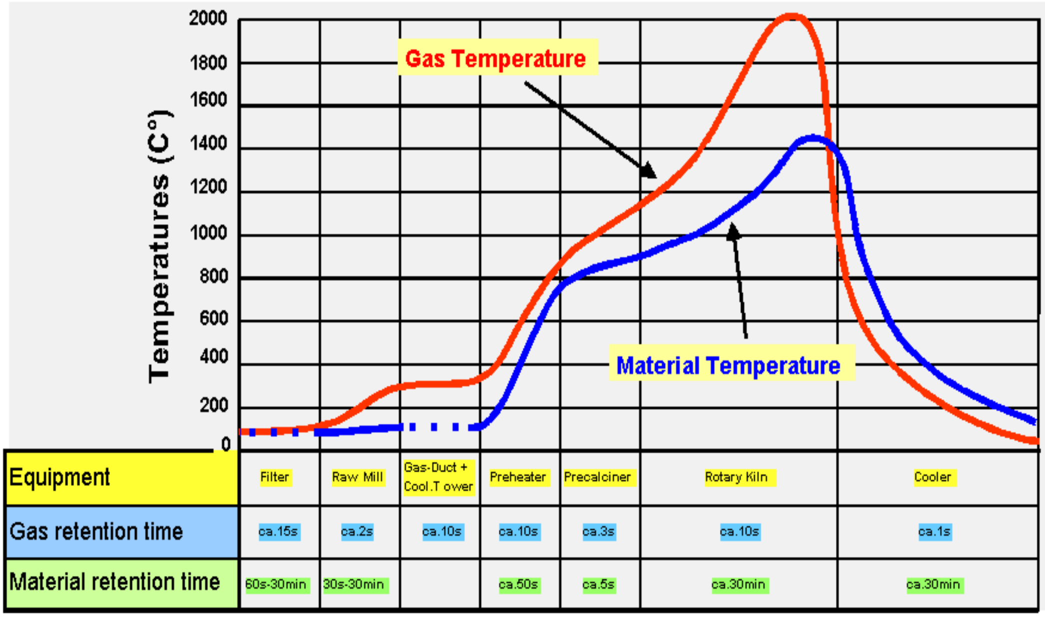
At auxiliary burning, the calorific estimation could be underneath 10 MJ/kg. The standard utilized energizes in the bond industry are gas, heater oil, random coals and pet-coke. The utilized crude feast blends with fiery debris. Because of the regular burning of fuel (combustibility because of unpredictable parts) with option fuel, the required calorific qualities can be accomplished. Depending on fuel-type, a substitution of up to 80% is possible and up to 100% in some cases. Using alternative/option fuels for clinker, the concrete business takes its chances to lower its expenditure (Figure 6.1_6.2).

The claim of the waste industry about pulverizing of natural substances in controlled procedures and additionally the evasion of adverse deposit (fiery remains, slag) as a result of presence of metal in clinker segments, most harmless fixation will be completely secured.

Accentuating Advantages of Utilizing Alternative Fuels:

1. Reduction of CO_2-Emissions (Kyoto-target):

   1.1. Dynamic waste utilization impact will take place.
   1.2. By burning in ignition factory, extra CO_2 discharge happens.
2. Cost diminishment of PZ-Clinker because of utilizing cheap fuel.
3. Preservation of assets – bring down utilization of fossils.
4. Reasonable optional utilization of substance.
5. Residue free ignition – because of no existence of slag, soil, and sewage.
6. No critical change of emanations.
7. Hazardous substances will be devastated as a consequence of the procedure – high-temperature levels, long gas deposit time, alcaline substance will burn, counter stream standard and oxidizing climate will be possible
8. High heat-output.
9. Fulfillment of generous dump transfer.
10. High yielding natural adjustments.



Equipment	Filter	Raw Mill	Gas-Duct + Cool.T ower	Preheater	Precalciner	Rotary Kiln	Cooler
Gas retention time	ca.15s	ca.2s	ca.10s	ca.10s	ca.3s	ca.10s	ca.1s
Material retention time	60s-30min	30s-30min		ca.50s	ca.5s	ca.30min	ca.30min

Figure 6.1.Temperature – Relation-time diagram of clinker production (Cembureau,1999)

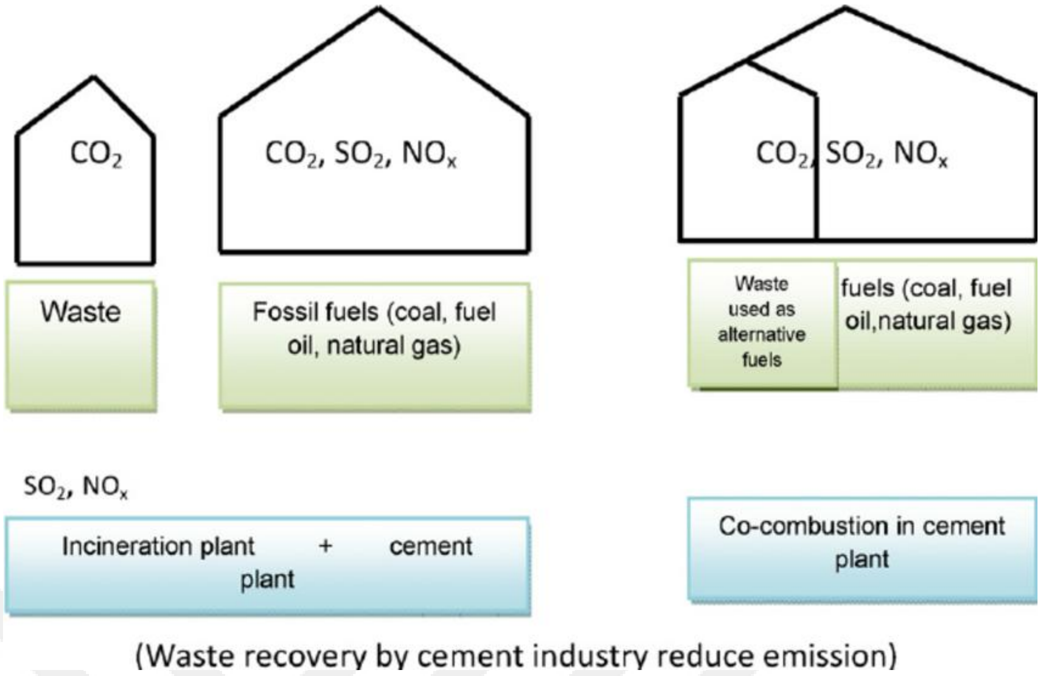


Figure 6.2.Benefits of co-combustion of alternative fuels in a cement plant (Cembureau,1999).

6.1. IMPORTANT FUELS IN THE CEMENT INDUSTRY

Optional energies comprise mostly 3 segments and their impact can take place. They are:

1. Water – as dampness.
2. Natural parts .
3. Minerals –fiery remains and content.

The accompanying timetable shows the most regular optional powers in European Cement Industry. In Table 6.2, the conceivable tainting appeared by changed components, potential dampness contents and calorific qualities.

Table 6.2. Calorific values and significant impurities of alternative fuels(PMT,2005).

Material	Significant contamination	Calorific value (MJ/Kg)
Residual oil & solvents	Pb ,zn ,cl	As per water content to 34
Contaminated wood and process waste from wood	Cl ,cd ,pb , zn According to the contamination	According to humidity-levels 11-18
Tyre, rubber waste	Zn, s	Ca. 25
Plastic waste	Cc ,cd , pb , zn	According to the blend to 29
Animal meal	Pb ,cl	12 to 16

The components' properties bolstering as ignition fuels in oven framework must be assessed depending on sullying-level (Table 6.3.). The question is: which move and in which frame and esteem should that be possible?

Table 6.3. Standard properties of elements.

Transfer principle into the clinker	Clinker-mineral-elements low-volatile metallicsulfur	Aluminum,Selenium,Calcium, Iron,Chrome,Zinc,Lead.Nickel, Arsenic, ect, Sulfer of Fuel
General transfers through exhaust air	Volatile metals (as long used without additional filter) combustion gases	Mercury, non-incineratedorganics,Sulfer of raw meal
Transfer to filter-dust & external-circulation through rawmeal. As long as periodical Release of circulation due to additional grinding to the cement	Semivolatile metals	Thallium, Mercury (partlt), Cadmium (partly
Absorption due to a rawmeal in upperportion of cooler/s Recuperating process in the heated-kiln. inner-circulation. Because of implementation of a by-pass system, discharging elements through external-disposal is probable	Halogen, Alkalis	Chlorine, Natrium & Kalium, residuals are conveyed with the clinker

It is important to analyze some examination of the utilized ignition fuel, utilized optional fuel and crude supper – which has a ton greater mass stream (crude dinner/fuel = around 16:1) – to give a rough approximation of the response.

6.2. PREPARATION AND CONDITIONING OF ALTERNATIVE FUELS

For operation and burning procedure, some imperative criteria must be regarded for molding.

Creation of even PZ-Clinker requires a steady and ignites the utilized fuel. The oxidation of C and H runs any snappier if the cozy blend of fills and the particular surface is bigger to guarantee particularly because of fluid fuel, as its showering-in must be as smooth.

Promote critical focuses for the molding procedure particularly for reliable option fills are:

1. Even molecule dispersion.
2. As even as high calorific estimation
3. Free of influencing substance like metals, glass, minerals.
4. Low dampness.

These specialized burning prerequisites respect uncommon planning conditions for consistent alternative powers, which are given in the distinctive segments. Particular division of non-consuming fills as metals, glass, and mineral-portion should be focused.

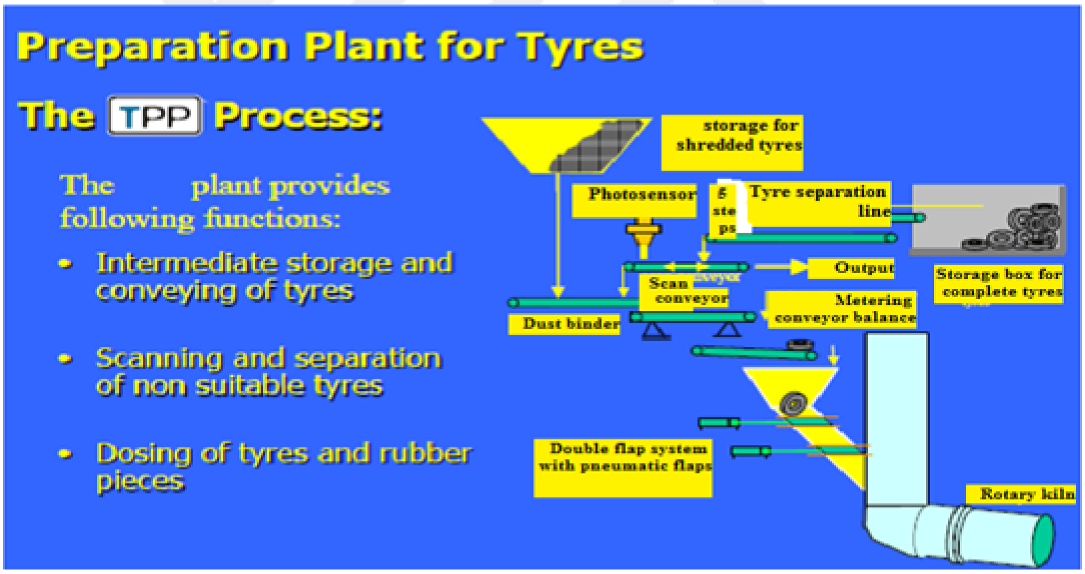
Determining status of natural defilement is relevant on grounds that a rottenness procedure can happen - possibly in the mix with dampness, which can bring about a response of microscopic organisms and core. Another standard for the molding plant is cleaning and security conditions for the working faculty.

An essential purpose of the molding is link among financial effectiveness and sensible ignition molecular measure. Being perfectly honest, bringing down molecular measure causes rise in molding expenses. The most ideal molecule estimate for ignition depends on optional fuel dosing, dosing mass and extent of handling.

PMT-Zyklontechnik GmbH discovered how to meet and match the prerequisites for molding of option powers in bond industry, developed as a kind of fuel through innovation and hardware. The molding usefulness at all operations is running mechanically and under hygienic conditions.

6.3. TPP-OPERATION

The TPP-operation (Tire-Preparation-Process) is intended for pulverizing of plastic, tires and plastic-like substances and plastic through the partition of entire tires and the gravimetric feeding of that substance in the oven (Figure 6.3).



Preparation Plant for Tyres

The TPP Process:

The plant provides following functions:

- Intermediate storage and conveying of tyres
- Scanning and separation of non suitable tyres
- Dosing of tyres and rubber pieces

Figure 6.3.Preparation plant for tyres (Taheyo enginerring,2012).

6.4. STORAGE, DOSING, AND FEEDING OF FUELS

6.4.1.Storage

The storage condition for alternative fuels relies on types of substances. Generally, emissions, technical and hygienic demands should be focused.

The following examples for storage should be deemed on the conditioning site.

1. Initial storage
2. Intermediate storage
3. Finished product storage

6.4.1.1. Initial Storage

The storage capacity depends on conveyed substance. Because of the strategic purposes behind introductory stockpiling, the zone is generally set-up specifically to the molding plant, yet depending on sort of substance and arrangement. The substance can be transported through trucks or by railroad. Substance blend with solid defilements (considerable biologic substance) and high dampness (up to 40%) is put away in exceptional outlined holders because of sterile tenets and directions.

Feast must be adapted in completely shut frameworks. It is transported using either pneumatically or by mechanical hardware according to the capacity. Fluid and slag elective energizes (squander oil, dissolvable and sewage slop) are put away in extraordinary compartments. Unique security rules (blast safe, and so on) are highly recommended.

Problems of storage:

1. Organic content.
    1.1. Odor.
    1.2. Bacteria ⁄ growth of mould.

    1.3. Development of heat.
    1.4. Solidification.
2. Humidity.
3. Jamming.
4. Voluminously-big storage space.
5. Not a nice sight.
6. Contamination.

6.4.1.2. Intermediate Storage

Middle of the road stockpiling is actualized in the molding plant for checking optional fuels after readiness handle for further preparing. The middle-of-the-road stockpiling is finished by utilizing some isolated containers (depending on the limit of the molding plant) yet in regards to:

1. Adequate space between each molding venture.
2. Stockpiling limit, until the work results are set.

In the event that the quality check gives negative outcomes, the substance is kept down for the encouraging to burning. Depending on rate of tainting, the administrator in control needs to choose while further utilization.

6.4.1.3. Finished Material Storage

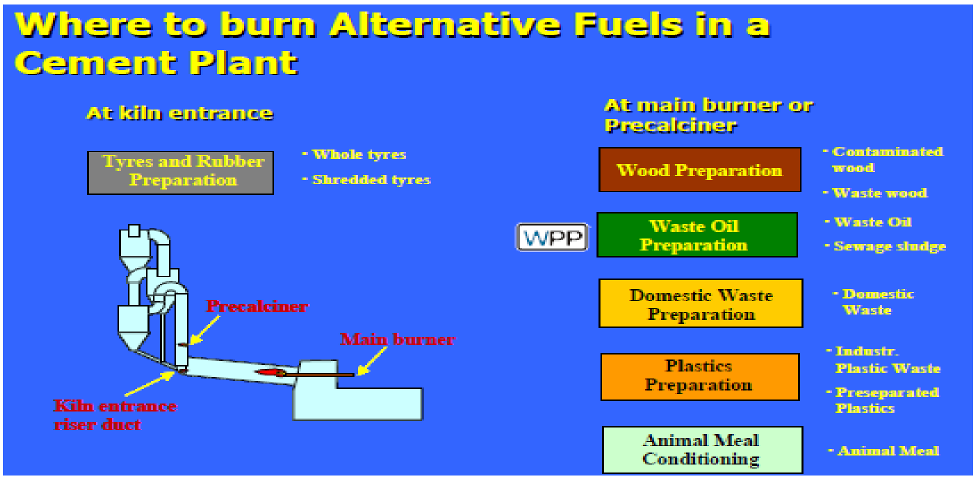
In the completed substance (item) stockpiling, the option energies, which are prepared for consuming, are put away. For avoiding normal impact, for example, mugginess, dampness, even rain, and so on, the material must be secured, or to be ensured ideally in some distribution center. The limit should be set according to the ignition limit and the arranged closed down period.

6.4.2. Dosing And Feeding

Most important points of dosage and discharge:

1. Material mixture and plastic- voluminously (ρ 200 kg/m^3)
2. Desagglomeration
3. Piping guidance
4. Abrasive material- material choice
5. Dosage accuracy
6. Constant dosage
7. Different densities of separate components-difficult discharge
8. Loading of the conveying air (kg/m^3 air)
9. Conveying air temperature (animal meal)

The dosing of strong option energies needs substances without property of sticking in the bolstering and dosing operation. For this situation, dampness is the huge part. Continuously keep a nearby hope to outline and development of the bolstering hardware. At pneumatic sustaining, it must be guaranteed that the passing on air limit is as low as could reasonably be expected (cooling the fire shape, NOx). Moreover, the burner wiring is critical and in addition scraped area property of the passed on materials must be controlled (Figure 6.4**)**.


Where to burn Alternative Fuels in a Cement Plant

At kiln entrance

Tyres and Rubber Preparation
- Whole tyres
- Shredded tyres

At main burner or Precalciner

Wood Preparation
- Contaminated wood
- Waste wood

Waste Oil Preparation
- Waste Oil
- Sewage sludge

Domestic Waste Preparation
- Domestic Waste

Plastics Preparation
- Industr. Plastic Waste
- Preseparated Plastics

Animal Meal Conditioning
- Animal Meal

Figure 6.4.Where to burn alternative fuels in a cement plant (PMT,2005).

6.4.2.1.Burner Conception And Combustion

A most present day multi-fuel burner needs to meet particular standards for controlling the temperature of the rotating oven and needs to ensure the greatest of potential outcomes for a few working conditions. Mostly, the terminating needs to run inconvenience free must be worked essentially and must have capabilities to deliver great clinker qualities even using a few Alternative Fuels.

This Multifuel-Burner is planned like a customary burner, yet has extra channels for Alternative Fuel and some other spout framework.

The particles come into a revolution because of digressively pointed airplanes – just before leaving the burner. The pictures below demonstrate the standard of a most present day Multifuel-Burners (Figure 6.5).

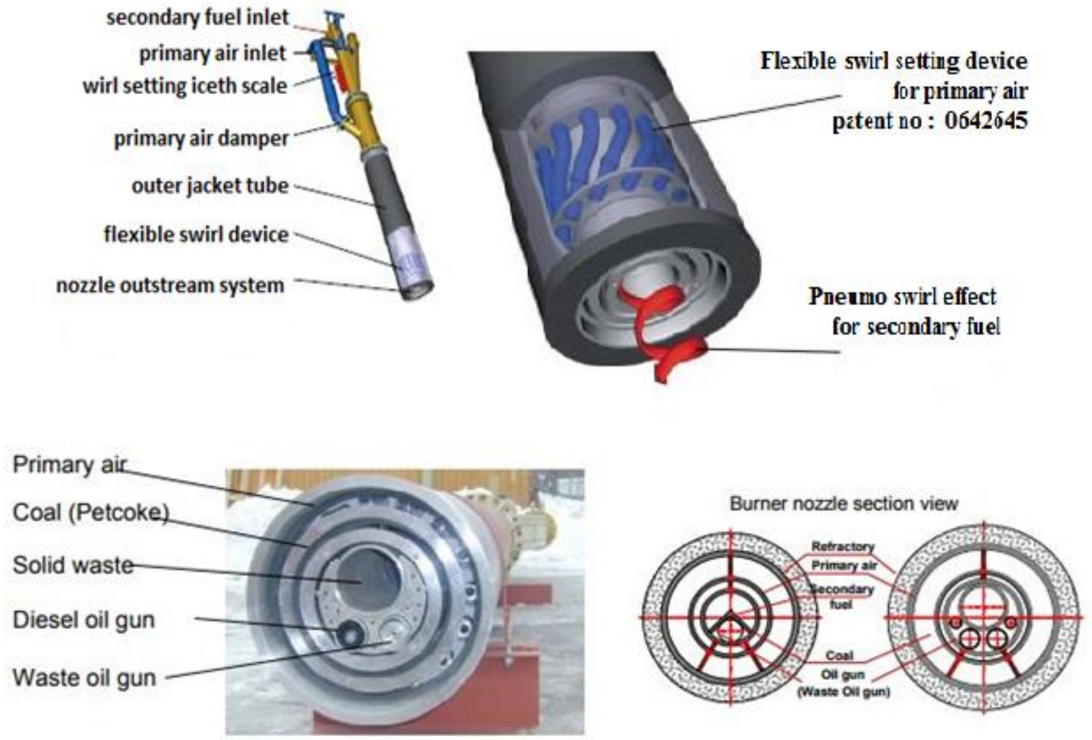


Figure 6.5.The principle of a most modern Multifuel- Burner (SCI,1998).

6.4.2.2. Dosage And Feeding Of Old Tires And Wood

The measurement of tires and tainted wood is finished by measure belt feeder with an exactitude of +-1% of the decided dosing esteem - the esteem appears on the terminal of the rotational oven. Related parameters to control are temperature are carbon-monoxide CO-estimation of the ignition gas (Table 6.3- Table 6.9).

6.5.CHINESE STUDY

Table 6.4.Summary of Chinese study (Cantoxm,2006).

fuel	substitution rate(%)	lower heat value (GJ/DT)	water content (%)	ash cont-ent (%)	C content (% by dry wt)	C EF (tonsC- eq/to)	ΔCO$_2$ (ton)/ton coal replacement	Associ-ated Emissi-ons	data source
tire	< 20%	27.8; 37.1	0.3			0.56	-0.83	NOx, SO$_2$, CO	(ICFConsulting 2006)

fuel	Substitutionrate(%)	energy content (LHV) (GJ/dry ton)	Carbonemissis factor (ton C/ton)	ΔCO$_2$(ton/toncoal replaced)	data sources
tires	<20	28; 37	0.56	-0.8	(ICF Consulting 2006)

Source:Alternative fuels in China’s cement manufacturing sector.

6.6.CANADIAN STUDY

Table 6.5.Summary of Canadian study (Pembına,2005).

Economic	Environmental	Social
1. Tires	1. Tires	1. Tires
2. Coal	2. Coal	2. Coal

Table 6.6. High priority alternative fuel options (PEMBINA, 2005).

Examples	Level of application	Key potential benefits to Application in western Canada	Key potential Barriers to Application in
Tire Derivd Fuel (TDF)lia	* Tires are most commonly used substitute fuels used in cement industry with utilization in no less than ten countries. Company Examples are: *Taiheryo cement corporation -Total consumption (2002) 100,829 tonnes -Rate of consumption (2002)4.5 kg/tonne of cement 37 *Cement Australias Gladstone Plant and blue Circle southern cement facility At Waurn ponds in Victoria. Takes up to 70% metropolitan Melboumes waste tires. Fuel substitution 20 to 25% percent is possible without affecting process/product/environment. *CEMEX-SpainItlacementi Group-Italy. *Castle Cements Ketton Plant (UK) was tested/ monitored byEPA, UK. In 1996, experiments were conducted to replace 25% in the pre-heater kiln and in 1998, Ketton Plant was authorized use used tyres on permanent basis. Lafarge Cauldron introduced chipped/used tires. In the ten years they used approximately 24.2 million tyres as fuel-substitute. *Holcium-waste tires constituted 17 percent of The 12.9 million tonnes Of alternative materials used in 2003	* Logistics – factories are opened near cosmopolitan centers (e.g,Calgary,Edmonton, Vancouuver) where old tyres are easily available *Economic –UK/EU governments recommended old tires for cement making as economically-attractive option. *Ash utilization-ash out of tyres eliminates ash disposal requirements. *Steel use – reinforcing Wire (from tires) Can be consumed asa replacement for purchased naturalresources or alternative materialsroad a containing iron *Broad applicability-The technology helps using older tyes in older/long kilns, , pre-heater and pre-calciner Units. *reduced landfill disposal *heating value-37.5 MJ/KG (HHV), 35.6 MJ/Kg(LHV)	*Cememt kiln Can accept TDF *potential Processing Requirements. *Environmental Impacts-some Scientific believe No basis for believing that burning used tyres in ovens/kilns is Safe *Public perception-kilns Public believes that their use is just like INCINERATORS, which have bad Reputation Concerning the Perceived Impacts on public health

Source: Compilation of reports by Pembina Institute

Table 6.7. Higher priority alternative fuel options (Pembina, 2005).

Alternative Fuel Type	Comments on further research requirements
Petroleum waste	
Petroleum Coke	Direct discussions between cement manufacturers and Syncrude, Suncor,and Husky can be highly effective.
Solvent Based Waste	
Paint related materials	Further research on volumes and locations required, and quality assurance and environmental impacts
Commercial Ink	Likely limited research required on quantity and availability(in non-confidential).need adetermination on whether it isConsidered a hazardous waste is required. Further environmental effects should be studied.
Solvent	Need to find if it is classified a hazardous waste Further research on volumes and locations required, and quality assurance and environmental impacts.
RUBBER WASTE	
TIRES	Readily available information on quantity assumed. Processing requirements should be considered. further environmental analyses required.
Plastic waste	
Industrial and commercial	Further information on quantities available and locations Required . information on quality and processing requirements also required, and air emission information
Househoid	As industrial – commercial
Livestock waete	
Meat & Bone Meal	Detailed information on locations and volumes required. Likely readily available. further consideration of quality (i.e. moisture content) required.

Source: Compilation of reports by the Pembina Institute, Canada

Table 6.8.Propertiesof non-recycled tire derived fuel (TDF) (PEMBINA,2005).

Fuel	Quantity	Quality	Price	Logistical Implications
Non-Recycled TDF	Estimated yearly used tire generation in 2004/05: Passenger Lite Tyre: 2.797million ‘tyre equivalents’. Mud/Farm Tyres: 1.137million ‘tyre equivalents’. 31,600 tonnes total, or 1.14 million GJ per year in B.C.29 (assume majority is recycled)	Assumed kiln suitability. Domestic/international precedence indicates acceptable quality.	Processed “TDF1” tyres @ $127.5/ton; and Whole Tyres “TDF2” @ $98.5/ton.	Collection systems are currently in place, however this would be fundamental for re-cycled tires. Non-recycled tire waste is costly to collect. Tilbury Cement has been using tyres despite negative public opinion.

6.7.DATA FROM US PLANES WITH AND WITHOUT TDF

Table 6.9. 2005 US final utilization of used tires (RMA,2006).

MARKET	# tires (millions)	kilo tonnes	Wt %
Tire Derived Fuel (TDF)	155.09	1945.62	59.31
Civil Engineering Ground	49.22	580.60	17.7
Rubber	37.47	501.24	15.28
Export	6.87	101.60	3.10
Cut/Punched/Stamped	6.13	91.18	2.78
Miscellaneous/Agriculture	3.05	43.17	1.32
Electric Arc Furnaces	1.34	18.35	0.52
TOTAL USE	259.17	3280.53	100.00

Source:RMA,2006

Cement kilns represent a prime user of TDF and the predisposition has shown anessential increase. The TDF utilization usage in cement furnaces depends on five prime agents (RMA, 2006) (Table 6.10- Table 6.15):

1. Increased power(fuel)values.
2. Convenient cost effects.
3. Lessened emissions of nitrogen oxides linkedwith other fuels.
4. The truth that TDF utilization is starting to be considered as “rote exercise.”

Table 6.10. Inputs & outputs for producing pulverized tyres through mechanical size-reduction (Corti and Lombardi, 2004).

Grinding Process		
Input	Output	Amount
Tires Electricity Water Steel Oil	Ground tires Iron scrap	1000 kg 170 MJ 150 kg 0.230 kg 0.011 kg 966 kg 34 kg
Crushing Process		
Input	Output	Amount
Ground tires Electricity Steel	Crushed tire 16x16 mm Iron scrap	1000 kg 573 MJ 0.010 kg 750 kg 250 kg
Mechanical Pulverization Process		
Input	Output	Amount
Crushed tires 16x16 mm Electricity Steel	Fine pulverized tires (<0.7 mm) Textile fibres Particulate matter	1000 kg 513 MJ 0.278 kg 630 kg 60 kg 0.026 kg

Source:Corti and Lombardi, 2004

Table 6.11.Inputs and outputs for the co-burning of coal and TDF in a cement kiln(Corti and Lombardi, 2004).

Input	Output	Amount
Tires Diesel Electricity Coal Iron Substances		1000 kg 6.05 kg 6 MJ -877 kg -250 kg

Source:Corti and Lombardi, 2004

Table 6.12.Extra emission agents in co-burning of coal and TDF in a cement kiln(Corti and Lombardi, 2004).

Fuel	SO_2	NOx	$NMVOC_2$	CH_4	CO	CO_2	N_2O	PM	Cr	Pb
g/GJ										
Coal Tires	25	575 -15 to 30%	15 -54%	15	 2 g/GJ	86	3.5 1	2.88 1	0.001 174%	0.000462 174%
Additional emission factors (g/ton tires)										
Tires		-21 to 43	-2		390				0.184	0.0851

Source: Corti and Lombardi, 2004

Table 6.13.Standardsused by Corti and Lombardi (2004) in their Eco-Indicator ’95 based LCA(Corti and Lombardi, 2004).

Environmental Effect	1	Greenhouse effect	kg CO_2
	2 3 4	Ozone layer depletion Acidification Eutrophication	g CFC_{11} kg SO_2 g PO_4
Hum an Health	5 6 7 8 9	Heavy metals Carcinogens Winter Smog Summer Smog Pesticides	g Pb g Benzo[a]pyrene kg SPM g C_2H_4 g Active substances
Resource Depletion	10 11 12	Water Consumption Energy Solid Waste	kg MJ Kg

Source: Corti and Lombardi, 2004

Table 6.14. Emission Factors (kg/tonne cement) (Cantox,2006).

Reference4	NOx		Sox		PM	
	w/o tires5	w tires6	w/o tires	w tires	w/o tires	w tires
1	3.00		4.90		0.50	
2a			0.53	0.41	1.87	1.67
2b	4.96	3.9	5.27	3.13	0.19	0.23
3	2.94	2.63	1.17	1.45	0.17	0.18
Reference	CO		Cl		Metals	
	w/o tires	w tires	w/o tires	w tires	w/o tires	w tires
1	0.11		0.36		4.7E-04	
2a						
2b	0.52	1.22				
3	0.26	0.36	1.6E-02	2.4E-02	3.75E-04	9.71E-04
Reference	Fe		Zn		TOC	
	w/o tires	w tires	w/o tires	w tires	w/o tires	w tires
1	8.5E-03		2.74E-04		0.014	
2a					2.0E-04	2.0E-04
2b					2.8E-04	2.2E-04
3	1.5E-03	2.74E-03	3.10E-04	2.25E-04	2.76E-04	2.46E-04
Reference	PCDD/F					
	w/o tires	w tires				
1	1.40E-09					
2a						
2b						
3	1.76E-06	9.40E-07				

3 σ = standard deviation

4 The references are: 1. EPA (2006); 2a. CANTOX (2006) Table A-6; 2b. CANTOX (2006) Table A-6a; and 3. Carrasco, Bredin, and Heitz (2002).

5 Emission factor without tires as supplemental fuel

6 Emission factor using tires as supplemental fuel

Table 6.15.Emission data for cement kilns (U.A.EPA 1997).

Reference CANTOX (2006)	units	NOx		SOx		PM	
		w/o tires	w tires	w/o tires	w tires	w/o tires	w tires
A-27	mg/m^3 stack	692	430	27.3	10.4	14.9	10.1
A-3	mg/m^3 stack	915	503	24	9	37.2	20.3
A-4	mg/m^3 stack	1754.4	1483.9	696.8	905.2	99.2	106.5
A-7	mg/m^3 stack						
A-11	mg/m^3 stack	281	281			2.2	2.2
A-12 (1)8	µg/m^3 stack	1.8	0.49	0.4	3.5	0.002	0.012
A-12 (2)9	µg/m^3 stack	2.5	1.3	0.6	5.4	0.003	0.017
A-14	mg/m^3 stack	114				25.9	
ReferenceCANTOX (2006)	units	CO		Cl		Metals	
		w/o tires	w tires	w/o tires	w tires	w/o tires	w tires
A-2	mg/m^3 stack	249	445	0.7	0.28	0.12	0.012
A-3	mg/m^3 stack	558	857	0.9	0.95	0.028	0.021
A-4	mg/m^3 stack	155.4	228	9.4	15.3		
A-7	mg/m^3 stack					0.042	0.042
A-11	mg/m^3 stack	225	225				
A-12 (1)	µg/m^3 stack	7	3				
A-12 (2)	µg/m^3 stack	8	4				
A-14	mg/m^3 stack	25.9					
A-26	mg/m^3 stack	67.4	161.1				
ReferenceCANTOX (2006)	units	Fe		Zn		TOC	
		w/o	w tires	w/o	w	w/o	w
A-2	mg/m^3 stack					14.2	61.5
A-4	mg/m^3 stack	0.87	1.86				
A-7	mg/m^3 stack			0.022	0.062		
Reference CANTOX (2006)	units	PCDD/F					
		w/o tires	w tires				
A-1	mg/m^3 stack		9.6E-04				
A-2	mg/m^3 stack	4.80E-	1.40E-				

7 These are the Table numbers in the CANTOX (2006) report from which data was abstracted

8 Data in μg/m^3 from operating 1 kiln

9 Data in μg/m^3 from operating 2 kilns

Table 6.16. Realizableaccomplishment levels for cement kilns(adapted from: Environment Canada, 2004).

Pollutant	Emission Concentration	Emission
Total particulate matter	< 15 mg/Rm^3	<0.04 kg/t
Nitrogen oxides (NOx)	3< 420 mg/Rm 30-day average	<1.0 kg/t clinker
Sulphur oxides (SOx)	3< 300 mg/Rm 30-day average	<0.7 kg/t
Total hydrocarbons	3< 17 mg/Rm (as carbon) 30-day average	<0.04 kg/t clinker
Hydrogen chloride (HCl)	< 25 mg/Rm^3	<0.06 kg/t
Carbon monoxide (CO)	No level	-
Metals	Class 111: < 1.5 mg/Rm^3 Class 212: < 0.5 mg/Rm^3	<3.6 g/t clinker <1.2 g/t clinker
PCCD/F	0 <.1 ng I-TEQ/Rm^3	<0.24 μg/t
Hexachlorobenzene	long-term goal is the Limit ofQuantification6 ng/Rm^3	14.4 μg/t
Benzene	< 4 mg/Rm^3	<9.6 g/t clinker

Source: Environment Canada, 2004

6.7.1.Air Emissions Data

Examination of discharges from furnaces using and not using TDF were conducted to assess the TDF effect impact but extensive number of sources were incorporated into this sort of assessment, so errors and fluctuations occurred.

6.7.2.Kiln-Specific Test Programs With And Without TDF

The discharge information was collected for this venture including TDF and Non-TDF emanations from seven concrete ovens. In these seven informational collections, minimum one and max ten separate analyses were conducted. The information is particularly useful in assessing (Table 6.16-Table 6.20).

6.7.3.The Impact Of Using TDF

Table 6.17. Effect of using TDF, Factory77 (PAA,2008).

Analyte	Emission Concentration Using TDF	Emission Concentration Without TDF	Percent Difference due To Using TDF
Nitrogen Oxides, ppmvd @ 7% O_2	444	380	16.8
Sulfur Oxides, ppmvd @ 7% O_2	207	293	-29.4
Carbon Monoxide, ppmvd @ 7% O_2	656	559	17.4
Total Hydrocarbons, ppmvd @ 7% O_2	104	127	-18.1

Source: The PCA Energy and Environmental Committee

Table 6.18. Effect of using TDF, Factory256 (PAA,2008).

Analyte	Emission Concentration Using TDF	Emission Concentration Without TDF	Percent Difference due To Using TDF
Dioxin – Furans, ng TEQ/nm^3	0.0019	0.0082	-76.8
Nitrogen Oxides, ppmvd @ 7% O_2	271	591	-54.1
Sulfur Oxides, ppmvd @ 7% O_2	257	377	-31.8
Carbon Monoxide, ppmvd @ 7% O_2	1247	1123	11.0

Source: The PCA Energy and Environmental Committee

Table 6.19. Effect of using TDF, Factory266 (PAA,2008).

Analyte	Emission Concentration Using TDF	Emission Concentration Without TDF	Percent Difference due To Using TDF
Filterable Particulate, lb/ton of dry feed	0.139	0.12	15.8
Nitrogen Oxides, ppmvd @ 7% O_2	318	252	26.2
Sulfur Oxides, ppmvd @ 7% O_2	165	151	9.3
Carbon Monoxide, ppmvd @ 7% O_2	1525	1234	23.6
Total Hydrocarbons, ppmvd @ 7% O_2	58	87	-33.3
Arsenic ,µg/m^3@7% O_2	0.99	0.88	12.5
Chromium ,µg/m^3@7% O_2	2.6	5.2	-50.0
Mercury ,µg/m^3@7% O_2	5.9	6.4	-7.8
Nickle ,µg/m^3@7% O_2	3.4	5.1	-33.3
Zinc ,µg/m^3@7% O_2	5.8	9.8	-40.8

Source: The PCA Energy and Environmental Committee

Table 6.20. Effect of using TDF, Factory276 (PAA,2008).

Analyte	Emission Concentration Using TDF	Emission Concentration Without TDF	Percent Difference due To Using TDF
Nitrogen Oxides, ppmvd @ 7% O_2	644	990	-34.9
Sulfur Oxides, ppmvd @ 7% O_2	27	27	0.0
Carbon Monoxide, ppmvd @ 7%	14	13	7.7
Arsenic ,µg/m^3@7% O_2	2.7	2.7	0.0
Chromium ,µg/m^3@7% O_2	9.7	30.6	-68.3
Mercury ,µg/m^3@7% O_2	53.2	4.4	1109.1
Zinc ,µg/m^3@7% O_2	23.1	76.2	-69.7

Source: The PCA Energy and Environmental Committee

Table 6.21.Effect of using TDF on dioxin-furan emissions, Factories11 and 90 (PAA,2008).

Plant	Emission Concentration Using TDF ng TEQ/nm^3	Emission Concentration Without TDF ng TEQ/nm^3	Percent Difference due To Using TDF
11	0.0173	0.023	-25.4
90	0.0005	0.0003	80.0

Percentage values calculated using the ‘without TDF’ value as a basis.

Source: The PCA Energy and Environmental Committee

Dioxin-Furan Air Emission Data Summary: Two hundred fifty-eight dioxin-furan discharge test values were added to venture databases. The test qualities were the aftereffects of a U.S. EPA reference technique test comprising of minimum 3 trials of three hours length. A rundown of the emanation test results is given in Table 6.22.

Table 6.22. Dioxin-furan emission data summary for kilns with and without TDF (PAA,2008).

Parameter	With TDF	Without TDF
Number of Emission Test Value	97	161
Average Concentration, ng TEQ/nm^3 @ 7% O_2	0.021	0.062
Median Concentration, ng TEQ/nm^3 @ 7% O_2	0.004	0.013
Standard Deviation, ng TEQ/nm^3 @ 7% O_2	0.054	0.119
Minimum concentration, ng TEQ/nm^3 @ 7% O_2	0.000	0.000
Maximum Concentration, ng TEQ/nm^3 @ 7% O_2	0.380	0.644

Source: U.S. EPA Reference Method 10 test

The normal outflow rate of 0.021 ng TEQ/nm^3@ 7% O_2 for TDF-terminating furnaces is quite less than the 0.062 ng TEQ/nm^3@ 7% O_2 esteem for non-TDF terminating ovens.

The distinction in the normal qualities of 2 classifications is expected, to some degree, to a few higher-than-normal dioxin-furan discharge test values in three reports (7, 16, 68) at factories not using TDF.

These eight test values diminished normal fixation amid non-TDF terminating to 0.045ng TEQ/nm^3@ 7% O_2, an estimate that is still well over the normal incentive for TDF-terminating tests. Mann-Whitney examination of both the classes of dioxin-furan emanations demonstrates that the lower outflows measured amid TDF terminating conditions are huge at more than the 99% level ($Z=-4.664$, $\sigma=0.000$).

The decrease in dioxin-furan emanations related with the TDF utilization fills is relevant to 3 noteworthy classes of furnaces. As demonstrated in Table 6.23 through 4-9, the normal and middle dioxin-furan emanations were lower for 3 noteworthy classes of ovens using TDF.

Table 6.23.Particulate matter data summary for kilns with and without TDF (PAA,2008).

Parameter	With TDF	Without TDF
Number of Emission Test Values	59	100
Average Concentration, Lbs.per ton of dry kiln feed	0.064	0.099
Median Concentration, Lbs.per ton of dry kiln feed	0.047	0.065
Standard Deviation, Lbs.per ton of dry kiln feed	0.059	0.113
Minimum Concentration, Lbs.per ton of dry kiln feed	0.002	0.000
Maximum Concentration, Lbs.per ton of dry kiln feed	0/262	0.658

Source:U.S. EPA Reference Method 5 test

The normal emanation rate of 0.064 pounds for every ton of dry oven sustain for TDF-terminating furnaces is quite lesser than the 0.099 pounds for each ton of dry oven bolster an incentive for non-TDF terminating ovens.

Mann-Whitney examination of both classes of filterable particulate matter discharges demonstrates that the lower outflows measured amid TDF terminating conditions are not noteworthy at the 90%confidence level (Z=-1.230, σ=0.219).

Nitrogen Oxides Air Emissions Data Summary: Thirty nitrogen oxides discharge test values were added to the venture database. Each test quality is the aftereffect of a U.S. EPA Reference Method 7E test. An outline of the outflow test results exhibited in Table 6.24.

Table 6.24.Nitrogen oxides emissions data summary for kilns with and without TDF (PAA,2008).

Parameter	With TDF	Without TDF
Number of Emission Test Values	20	10
Average Concentration , ppmvd@ 7% O_2	443	696
Median Concentration , ppmvd@ 7% O_2	409	707
Standard Deviation , ppmvd@ 7% O_2	189	408
Minimum Concentration , ppmvd@ 7% O_2	252	240
Maximum Concentration , ppmvd@ 7% O_2	1,055	1,563

Source:U.S. EPA Reference Method 6C test

The normal outflow rate of 443 ppmvd @7 % O_2 for TDF-terminating furnaces is lesser than the 700ppmvd @ 7% O_2 esteem for non-TDF terminating ovens. Mann-Whitney's investigation of these discharges with and without TDF demonstrates that the lower emanations measured amid TDF terminating conditions are not noteworthy at the 90% level (Z=-1.452, σ=0.155). The oven-to-furnace contrasts are too extensive to distinguish the TDF impact on nitrogen oxide outflows in the generally little accessible information.

Sulfur Dioxide Air Emission Data Summary: Thirty sulfur dioxide outflow test values were added to the venture database. These test qualities is the consequence of a U.S. EPA Reference Method 6C test. An outline of the emanation test results is shown in Table 6.25.

Table 6.25.Sulfur dioxide emissions data summary for kilns with and without TDF(PAA,2008).

Parameter	With TDF	Without TDF
Number of Emission Test Values	19	10
Average Concentration , ppmvd@ 7% O_2	153	200
Median Concentration , ppmvd@ 7% O_2	165	89
Standard Deviation , ppmvd@ 7% O_2	127	239
Minimum Concentration , ppmvd@ 7% O_2	1.5	0.0
Maximum Concentration , ppmvd@ 7% O_2	397	587

Source:U.S. EPA Reference Method 7E test

The distributed air emanations information concerning SO_2 discharges shows that TDF terminating more often than not has a slight advantageous effect. The information incorporated amid this review largely bolsters this inference. Notwithstanding, the fluctuation of sulfur dioxide discharges is too substantial to convincingly show the advantages of TDF terminating on emanations.

Carbon Monoxide Air Emission Data Summary:Thirty-one carbon monoxide discharge test values are entered in the venture database. Every quality is outcome of a U.S. EPA Reference Method 10 test. A rundown of the emanation test results is given in Table 6.26.

Table 6.26. Carbon monoxide emissions data summary for kilns with and without TDF(PAA,2008).

Parameter	With TDF	Without TDF
Number of Emission Test Values	20	11
Average Concentration , ppmvd@ 7% O_2	604	435
Median Concentration , ppmvd@ 7% O_2	409	182
Standard Deviation , ppmvd@ 7% O_2	565	494
Minimum Concentration , ppmvd@ 7% O_2	0.0	5.1
Maximum Concentration , ppmvd@ 7% O_2	1,525	1,234

Source: U.S. EPA Reference Method 10 test

Effect of Using TDF on CO Emissions. The air emanation test comes about for CO are blended. The general informational index shows that no big distinction in carbon monoxide discharges from furnaces was observed with or without TDF (Table 6.27**)**.

Table 6.27. Co emissions data summary for kilns with and without TDF (PAA,2008).

Parameter	With TDF	Without TDF
Number of Emission Test Values	22	7
Average Concentration , ppmvd as propane@ 7% O_2	48	37
Median Concentration , ppmvd propane@ 7% O_2	38	17
Standard Deviation , ppmvd propane@ 7% O_2	74	50
Minimum Concentration , ppmvd propane@ 7% O_2	0.4	1.1
Maximum Concentration , ppmvd propane@ 7% O_2	355	127

Source: U.S. EPA Reference Method 12 test

Effect of Using TDF on Total Hydrocarbon Emissions: The information gathered amid this venture and distributed outflows information, which demonstrates that TDF terminating does not altogether influence the discharges of aggregate hydrocarbons.

Any distinctions revealed are presumably due to the precision of the outflow testing technique and to routine inconstancy in the natural substance of crude materials.

Metal Emissions: This review incorporates the five separate metals. These metals exist in coal and TDF. They are metals having extraordinary volatilities and distinctive methods of outflow from bond furnaces.

1. Arsenic.
2. Chromium (Total).
3. Nickel.
4. Mercury.
5. Zinc.

Extra information about Hydrocarbon Emission Summary. Twenty-nine aggregate hydrocarbon outflow test values are part of the venture database. Every quality is the outcome of a U.S. EPA Reference Method 25A test. A synopsis of the outflow test results are shown in Table6.28.

Table 6.28. Total hydrocarbons emissions data summary for kilns with and without TDF(PAA,2008).

Arsenic	Baseline Test, Emissions in µg/m^3 @ 11% O_2	TDF Test (36%Btu replacement) Emissions in µg/m^3 @ 11% O_2
Arsenic	<0.2	<0.2
Chromium	0.2	0.7
Nickel	0.4	0.4
Mercury	4	4
Zinc	10	10

Source: U.S. EPA Reference Method 25A test Metals

Air Emissions Data Summary: Only two outflow test reports are included in this venture and they include information on metals discharges. The information of arsenic, chromium (add up to), nickel, mercury, and zinc are abridged in Table 6-29. The factory -to-factory contracts and fleeting varieties at particularfactories, there is inadequate information to assess the TDF effect terminating on metals emanations.

The sulfur substance of TDF and other option powers are less as compared to sulfur substance of most Eastern and Midwestern coals and lower than some coke fuel varieties. In like manner, the substitution of TDF for a segment of these energies has the potential for somewhat decreasing sulfur dioxide outflows. Various past reviews have demonstrated either unaltered SO_2 outflows or decreases of SO_2 discharges maximum 25%. [20, 21] Carrasco et al [22] found 24% expansion in SO_2 discharges with TDF; be that as it may, the deliberate fixations were moderately low.

Table 6.29. Metals data summary for kilns with and without TDF (PAA,2008).

Metal	Parameter	With TDF	Without TDF
Arsenic	Number of Emission Test Report	15.0	2.0
	Averag Concentration ,$\mu g/m^3$@7% O_2	1.8	1.8
	Median Concentration ,$\mu g/m^3$@7% O_2	1.3	1.8
	Standard Deviation ,$\mu g/m^3$@7% O_2	2.2	1.3
	Minimum Concentration ,$\mu g/m^3$@7% O_2	0.0	0.9
	Maximum Concentration ,$\mu g/m^3$@7% O_2	7.6	2.7
Chromium	Number of Emission Test Report	11	2
	Averag Concentration ,$\mu g/m^3$@7% O_2	4.3	17.9
	Median Concentration ,$\mu g/m^3$@7% O_2	3.1	17.9
	Standard Deviation ,$\mu g/m^3$@7% O_2	3.8	18.0
	Minimum Concentration ,$\mu g/m^3$@7% O_2	0.0	5.2
	Maximum Concentration ,$\mu g/m^3$@7% O_2	12.3	30.6
Nickel	Number of Emission Test Report	18.0	1.0
	Averag Concentration ,$\mu g/m^3$@7% O_2	5.9	5.1
	Median Concentration ,$\mu g/m^3$@7% O_2	1.9	5.1
	Standard Deviation,$\mu g/m^3$@7% O_2	10.9	7.2
	Minimum Concentration ,$\mu g/m^3$@7% O_2	0.0	5.1
	Maximum Concentration,$\mu g/m^3$@7% O_2	41.4	5.1
Mercury	Number of Emission Test Report	11.0	2.0
	Averag Concentration ,$\mu g/m^3$@7% O_2	18.0	5.5
	Median Concentration ,$\mu g/m^3$@7% O_2	10.1	5.5
	Standard Deviation ,$\mu g/m^3$@7% O_2	18.7	1.3
	Minimum Concentration ,$\mu g/m^3$@7% O_2	0.4	4.5
	Maximum Concentration ,$\mu g/m^3$@7% O_2	53.2	6.4
Zinc	Number of Emission Test Report	8.0	2.0
	Averag Concentration ,$\mu g/m^3$@7% O_2	10.8	42.9
	Median Concentration ,$\mu g/m^3$@7% O_2	7.8	42.9
	Standard Deviation ,$\mu g/m^3$@7% O_2	9.8	47.1
	Minimum Concentration ,$\mu g/m^3$@7% O_2	0.1	9.6
	Maximum Concentration ,$\mu g/m^3$@7% O_2	23.2	76.2

Source: U.S. EPA Reference Method 5 test

Effect of Using TDF on Metals Emissions: There is lack of data to assess the TDF effect on the discharges of metals, for example, arsenic, add up to chromium, mercury, nickel, and zinc.

6.8. SPECIFIC CONSIDERATIONS

The reception of a hazard administration system encourages test of the last three targets (5.7) of the present review:

1. To decide the mechanical and process changes important to utilize TDF as a supplementary fuel in Brookfield Lafarge band factory.
2. To recognize both process and innovative alternatives to relieve any ecological or wellbeing impact on TDF utilization.
3. To conduct a survey on the Management of Change (MOC) issues identifying with potential dangers and well-being of TDF utilization in a concrete plant.

The initial two things above identify with the administration of lingering danger and the execution of hazard decreasing measures (Fig. 6.4). Change is given in any modern operation today. Explanations behind change incorporate the need to stay up with the latest with current innovation, the yearning for a more proficient generation.

At whatever point a change is made – whether substantial or little, lasting or transitory – it is fundamental to research the outcomes of change. Administration of Change (MOC) is a precise technique used to do fulfill this errand. MOC takes after the general system given in Fig. 6.4 , where the distinguishing proof of risks is provoked by the presentation of an adjustment in the work environment.

In the present review, the tyre consumption in a bond furnace unmistakably speaks to an adjustment in the working procedure. The dislodging of coal by up to 20% warming an incentive with TDF is not a substitution in-kind; a hazard based MOC convention is thusly required to answer such central inquiries as:

1. What could turn out badly?

2. How likely is it to happen?
3. How might it be able to influence key receptors, for example, representatives, the encompassing group, nature, and so forth?
4. What are possible advantages and dangers presented by the change?

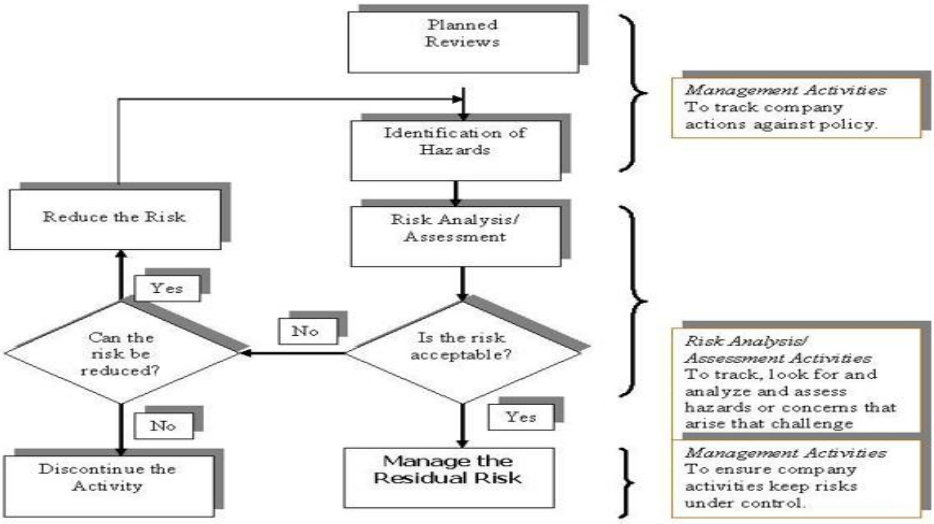


Figure 6.6. The risk management process (PAA,2008).

PART 7

THE CONCLUSION, OBSERVATIONS AND CONSIDERATIONS

The accompanying gasses are released by fuel ignition handle in the bond business:

1. CO_2: causes environmental imbalance, pollution and influences wellbeing.
2. SOx: results in corrosive rain and influences wellbeing.
3. CO: causes global temperature rise and influences overall wellbeing.
4. NOx: results in corrosive rain, influences wellbeing and affects ozone layer.

To get red of the above, the following steps should be taken:

1. Reduce the particular utilization to point of confinement of 770_- 780 kcal/T.
2. Take measures and gear to diminish gas discharges by utilizing gas metering and observing gas emissions using sophisticated gadgets.
3. Use of waste as an option to petroleum products.

The accompanying Table 7.1.,demonstrates number of gasses discharged from bond generation as a consequence of utilizing fuels.

Table 7.1. Gases released from production of cement using several types of fuel.

Used fuel	CO_2 (Kg/T)	CO (Kg/T)	NOx (Kg/T)	SOx (Kg/T)	Price ($/T)	Specific consumption (MJ/Kg)
DIESEL	917	2.2	3	1.3	400-1200	42.5
COAL	995	5.2	575	25	60-120	25
USED TIRES	85	1.5-2.1	2.5-5	1-5	30-70	37

Considerations for utilizing tyres for fueling cement production:

1. Factory outline and alterations.
2. Availability of utilized tires and costs.

The accompanying Table 7.2, demonstrates the normal fuel cost/each ton bond.

Table 7.2.The average price of fuel used to produce one ton of cement.

Used fuel	The quantity needed to produce one-ton cement (Kg)	The price of feul needed to produce one-ton cement($)
DIESEL	95	38-118
COAL	162	9-18
USED TIRES	106	3.5-8

We note that the used tires are the best option economically.

The significant conclusions of this report are as follows:

1. In 2005, 60% of all tires (on a weight premise) in the US were utilized as tire inferred fuel (TDF), while in Canada in 2003/4; just 22% of all piece tires were utilized as TDF.
2. TDF is used in Canada in bond ovens where entire tires can be infused in furnaces.
3. Potential modern applications inside Nova Scotia that could use TDF are mash and paper plants and the Point Aconi station. They couldn't utilized whole tires; thus some pre-processing (de-wiring and additional destroying) would be required.
4. The just industry inside Nova Scotia that could use entire utilized tires is Lafarge's Cement Plant at Brookfield.
5. From another point of view, fuel substitution is the slightest ecologically hurtful methods. Verifiable in this announcement is the presumption that discharges from offices utilizing TDF is safe for nature and human wellbeing than fuels like coal.
6. Results from the refered to LCA don't particularly assess quantitative life cycle impacts of using tyres as a supplementary fuel at the Brookfield Lafarge plant despite their normal patterns.
7. There is a significant substantial variety in all the outflow information.
8. It gives the idea that on account of NOx, unequivocal pattern for this contamination to reduction when tires become supplementary fuels. This perception was agreed upon by a few scientists (normal of 40% lessening; σ = 20%).
9. The effect of consuming tires (1% S) on the SO_2 discharge does not appear to connect; most of the SO_2 would originate from the mineral and the coal since the tires have generally low sulfur content, and they can supply just 20% of the fuel needs.
10. CO outflows are mostly higher (normal 35% higher, σ = 76%). This shows that the tires create a fuel-rich zone as they experience pyrolysis prompting a more fragmented ignition and a lower fire temperature in the furnace (predictable with the lower NOx emanations).
11. The arrangement and devastation, and therefore, the discharge rate of dioxins/furans are reliant on many elements: temperature-time profiles, fuel

management, price of the crude materials themselves and gas synthesis. Lamentably, there is no current possibility to calculate these impacts and hence, it gives the idea that the discharge rates are, in any event for dioxins/furans, very oven-particular.

12. Emanations for gauge operation of ovens (without tires included) have an extremely considerable range from 1 to around 400 pg (I-TEQ)/Rm^3 stack gas. Now, due to this expansive inconstancy, it is difficult to state what impact the tire-consumption has on the arrangement and emanation of dioxins/furans. Whatever impact there is, it is clear that substitution of tires with 20% fuel would change outflow levels in a critical way.
13. At Brookfield, the normal dioxin/furan emanation rate measured via Air Testing Services in 2004 was 21.3pg (I-TEQ)/Rm^3 while terminating coal was just 17.3pg (I-TEQ)/Rm3 when terminating coal and supplemental fuel (squander material). The outflow rate revealed throughout the years 2002-05 when NPRI was around 120 pg (I-TEQ)/Rm^3. To place this in setting, bond furnace information from the US and other European sources demonstrate varieties in discharges from a low normal of 6 to the high normal of 99 pg (I-TEQ)/Rm^3. An estimation of 100 pg (I-TEQ)/Rm^3 is viewed as a sensible objective right now. Expecting that the currently measured esteem is a more demonstrative of present-day hone, Brookfield is now in consistency with the proposed standard of 32pg I-TEQ/Rm^3.
14. Our audit of writing and test reports seems to strengthen the conclusion that utilization of entire tires in concrete ovens would have no more pernicious impact on emanations than consuming coal alone. It is verifiable that typical operation of bond ovens on coal has no such unfavorable impact on encompassing air quality. In the light of measured stack outflows and the scattering displaying of Conestoga-Rovers and Associates, the assessed ground level poison focuses for the Brookfield plant terminating coal and coal with supplemental fuel were all beneath acknowledged wellbeing models. Because of extensive changeability in the deliberate discharge information for plants utilizing TDF as supplementary fuel-source, it is essentially unrealistic to make forecasts with any level of assurance about emission changes.

Recommendations For Future Work:

1. For more exact outcomes in RDF portrayal tries, a legitimate testing system should be regularized to take agent tests as per CEN/TS 15442:2006(Method for determination of ash content). In the meantime, the lab test readiness should be done as per CEN/TS 15443:2006 (Method for determination of biomass content) for exact assessment.
2. It is recommended to assure instruments and techniques by performing them in an external research center.
3. More research facility tests should be conducted for particular disintegration technique/s with less latent RDF test (normal example) and explore the idle and fiery remains. The science behind the specific disintegration test needs to be discovered.
4. The manual sorting strategy for RDF portrayal can be completed with delegate test of unadulterated RDF. The example taken for the trial test in this review was not genuine RDF but rather a blend of RDF and SHW.
5. In the full-scale tests, it can be observed that the free lime substance is expanded with creature supper nourishing and two conceivable reasons have been brought up in part 6.
6. These two potential outcomes can be additionally examined to discover the genuine wonders behind their impact. i.e. complete a test under same conditions with another option fuel which does exclude Ca mixes
7. More full-scale investigations should be conducted on furnace 6; Norcem-Brevik, with new Pfister feeder framework and other option fuels (e.g. destroyed plastics, SHW, fuel blend, and so forth) in fundamental burners. The confinements and required alterations should be recognized for enhancement of the new option-bolstering framework. The issues, which were not discussed until now, should be additionally researched.
8. It is prescribed to break down the ignition attributes and stream administrations of the oven with optional/alternative fuel sources utilizing a CFD reproduction programming for enhanced comprehension of the procedure.

REFERENCES

1. Aboulkas, A., and Nadifiyine, M. “Investigation on pyrolysis of Moroccan oil shale/plastic mixtures by thermogravimetric analysis”, ***Fuel Processing Technology,*** 89(11): 1000-1006 (2008).

2. Ariyaratne, W. H., Melaaen, M. C., and Tokheim, L. A. “Determination of biomass fraction for partly renewable solid fuels”, ***Energy,*** 70: 465-472 (2014).

3. Barlaz, M. A., Eleazer, W. E., and Whittle, D. J. “Potential to use waste tires as supplemental fuel in pulp and paper mill boilers, cement kilns and in road pavement”, ***Waste Management & Research,*** 11(6): 463-480 (1993).

4. Boughton, B. “Evaluation of shredder residue as cement manufacturing feedstock", ***Resources, conservation and recycling,*** 51(3): 621- 642 (2007).

5. Conesa, J. A., Gálvez, A., Mateos, F., Martín-Gullón, I., and Font, R. “Organic and inorganic pollutants from cement kiln stack feeding alternative fuels*”,* ***Journal of Hazardous Materials,*** 158(2): 585-592 (2008).

6. Conesa, J. A., Font, R., Fullana, A., Martín-Gullón, I., Aracil, I., Gálvez, A., Gómez-Rico, M. F. “Comparison between emissions from the pyrolysis and combustion of different wastes*”,* ***Journal of Analytical and Applied Pyrolysis,*** 84(1): 95-102 (2009).

7. Constans, D., and Gossman, D. “Tire Derived Fuel Use in Cement Kilns*”* ***Library Gosmann Consulting Inc.*** (1997).

8. Constans, D.L., “Primary Aluminum Production Wastes Spent AluminumPotliner”, ***Library Gossman Consulting Inc.*** (1998).

9. Constans, D. “Liquid Hazardous Waste Fuel Particulate Size Reduction”, ***Library Gossman Consulting, Inc.***(1999).

10. Constans, D., & Gossman, D. “Tire Derived Fuel Use in Cement Kilns,*”,****Library Gosmann Consulting Inc.*** (1997).

11. Cozzani, V., Petarca, L., and Tognotti, L. “Devolatilization and pyrolysis of refuse derived fuels: characterization and kinetic modelling by a thermogravimetric and calorimetric approach*,”* ***Fuel,*** 74(6): 903-912 (1995).

12. Dalai, A. K., Batta, N., Eswaramoorthi, I., and Schoeman, G. J. “Gasification of refuse derived fuel in a fixed bed reactor for syngas production*,”* ***Waste Management,*** 29(1): 252-258(2009).

13. Dalton, J. L., Gardner, K. H., Seager, T. P., Weimer, M. L., Spear, J. C., and Magee, B., Demján, Z. “The possible impact of CO2 trading on competitiveness of cement industry. *,”**Linking the Kyoto Project-Based Mechanisms with the EU ETS, Vienna.***(2005).

14. European Cement Association,“Alternative fuels in cement manufacture: technical and environmental review”,***European Cement Association*** (2009).

15. Giannopoulos, D., Kolaitis, D. I., Togkalidou, A., Skevis, G., and Founti, M. A. “Quantification of emissions from the co-incineration of cutting oil emulsions in cement plants–Part I: NO x, CO and VOC.,*”* ***Fuel,*** 86(7): 1144-1152 (2007).

16. Gossman, D. “The reuse of petroleum and petrochemical waste in cement kilns,*”* ***Environmental Progress and Sustainable Energy,*** 11(1): 1-6(1992).

17. Gossman, D. “A comparison of metal emissions from cement kilns utilizing hazardous waste fuels with commercial hazardous waste incinerators.,*”**Proc. twenty-ninth international cement conference***: 159-168 (1993).

18. Gossman, D.,“New Developments in Treatment Options for Spent AluminumPotliner,”, ***Library GossmanConsultin Inc*****.** (2006).

19. Gossman, D. “Cement Kiln Alternative Fuels”, ***Library Gossman Consulting Inc.*** (2007).

20. Hansen, E. R. *“*Changing process priorities when firing alternate fuels,*”**Cement Industry Technical Conference:***219-230 (2003).

21. Jennifer L.,“Properties of Portland cement made from contaminated sediments”, ***Resources, conservation and recycling***, 41(3): 227-241 (2004).

22. Karstensen, K. H *“*Formation, release and control of dioxins in cement kilns,*”* ***Chemosphere,*** 70(4): 543-560 (2008).

23. Karstensen, K. H., Kinh, N. K., Viet, P. H., Tuan, N. D., Toi, D. T., Hung, N. H., and Thang, D. H. *“*Environmentally sound destruction of obsolete pesticides in developing countries using cement kilns,*”* ***Environmental Science & Policy,*** 9(6):577-586(2006).

24. Mantus, E. K.,“All fired up: burning hazardous waste in cement kilns”,***Delta Toxicology Inc.***(1992).

25. Marcilla, A., Gómez-Siurana, A., Odjo, A. O., Navarro, R., and Berenguer, D. “Characterization of vacuum gas oil–low density polyethylene blends by thermo gravimetric analysis”,***Polymer Degradation and Stability,*** 93(3): 723-730(2008).

26. Mokrzycki, E., and Uliasz-Bocheńczyk, A *.“*Alternative fuels for the cement industry,*”* ***Applied Energy,*** 74(1): 95-100 (2003).

27. Mokrzycki, E., Uliasz-Bocheńczyk, A., and Sarna, M. *"*Use of alternative fuels in the Polish cement industry,*" **Applied Energy,*** 74(1): 101-111(2003).

28. Murray, A., and Price, L. "Use of alternative fuels in cement manufacture: analysis of fuel characteristics and feasibility for use in the Chinese cement sector",***Lawrence Berkeley National Laboratory***(2008).

29. National Technical Experts, "Utilization of Alternative Fuel in Cement Production, A Feasibility Study Report, Promotion of renewable energy, energy efficiency and greenhousegasabatement(PREGA), ***National Technical Experts Team from Geosphere Technologies Inc.*** (2005).

30. Tokheim, L. A.,"Kiln system modification for increased utilization of alternative fuels at Norcem Brevik,*" **Cement international,*** 4(4): 52-59 (2006).

31. Tokheim, L. A., and Brevik, P.*"*Carbon dioxide emission reduction by increased utilization of waste-derived fuels in the cement industry,*"**Institutt for prosess-, energi- og miljøteknologi***(2007).

32. Twigger, L., Ritchie, A., Hudson, B., Laban, K., and Davies, C.*"*Solidwaste derived fuels for use in cement and lime kilns:An International Perspective. Environment Agency", ***Environment Agency*** (2001).

33. Van Loo, W.*"*Dioxin /furan formation and release in the cement industry,*".**Environmental Toxicology and Pharmacology,***25(2) :128-130(2008).

RESUME

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