Using Bio-mass Fuel for Industrial Boilers

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Content

- **Fuel specifications and combustion behaviours**
- **Handling system**
- **Combustion process**
- **Ash depositions or ash behaviours**
- **Boilers**
- **Emissions**

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Coal, wood properties

The main specifications (combustion related) in coal and wood are

- Moisture
- Ash
- Volatile matter
- Sulphur
- Ultimate (C, H, N)
- Calorific value (CV)
- Swelling propensity
- Ash fusion
- Ash compositions
- HGI (if for Pulverised fuel system)
- Size and size distributions
- Bulk density
- Angle of repose

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Important physical properties for coal

- **Bulk density**

Assessed by dropping coal into a container without any shaking. Bulk density varies depending on coal rank and size, ranging from 650—950kg/m3

Lignite: 650—850

Bituminous coal: 800—950

- **Angle of repose**

Assessed by forming a cone by free dropping the coal. The angle of the cone from horizontal is called as “Angle of repose”. It ranges between 42—50°.

- **Size grade**

Nuts: 25—50mm

Peas: 19—25mm

Chips: 19—6mm

Fines: <3.3mm

Slake: 0—50mm

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Typical analysis of the coal in Southland

	Ohai	Takitimu	Kai Point	New Vale
Moisture, %	20.0	28.1	29.5	41.3
Ash, %	3.5	6.5	4.9	3.2
Volatile Matter, %	34.0	29.4	31.8	29.2
Fixed Carbon, %	42.5	36.0	33.8	26.3
Sulphur, %	0.18	0.43	1.7	0.4
Calorific value, MJ/kg	23.5	18.97	20.00	15.04

Bulk density: 650—950kg/m^3

Angle of repose: 42—50°

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Bio-mass fuel

Wood pellets

Wood chip

Hog fuel

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Typical Analysis of Bio-mass fuel

	Wood pellets	Seasoned wood chip	Fresh wood chip	Hog fuel
Moisture, %	7.0	~35	60	~60
Ash, %	0.5	~0.8	0.3	~1
Volatile Matter, %	79.0	54.8	33.9	~33
Fixed Carbon, %	13.5	9.4	~6	~5
Sulphur, %	<0.01	~0.01	<0.01	<0.01
Calorific value, MJ/kg	18.8	~13.0	~8	7--8
Bulk density, kg/m3	~700	~350	~450	~450
Angle of repose, °	~32	80--120	80--120	80--120

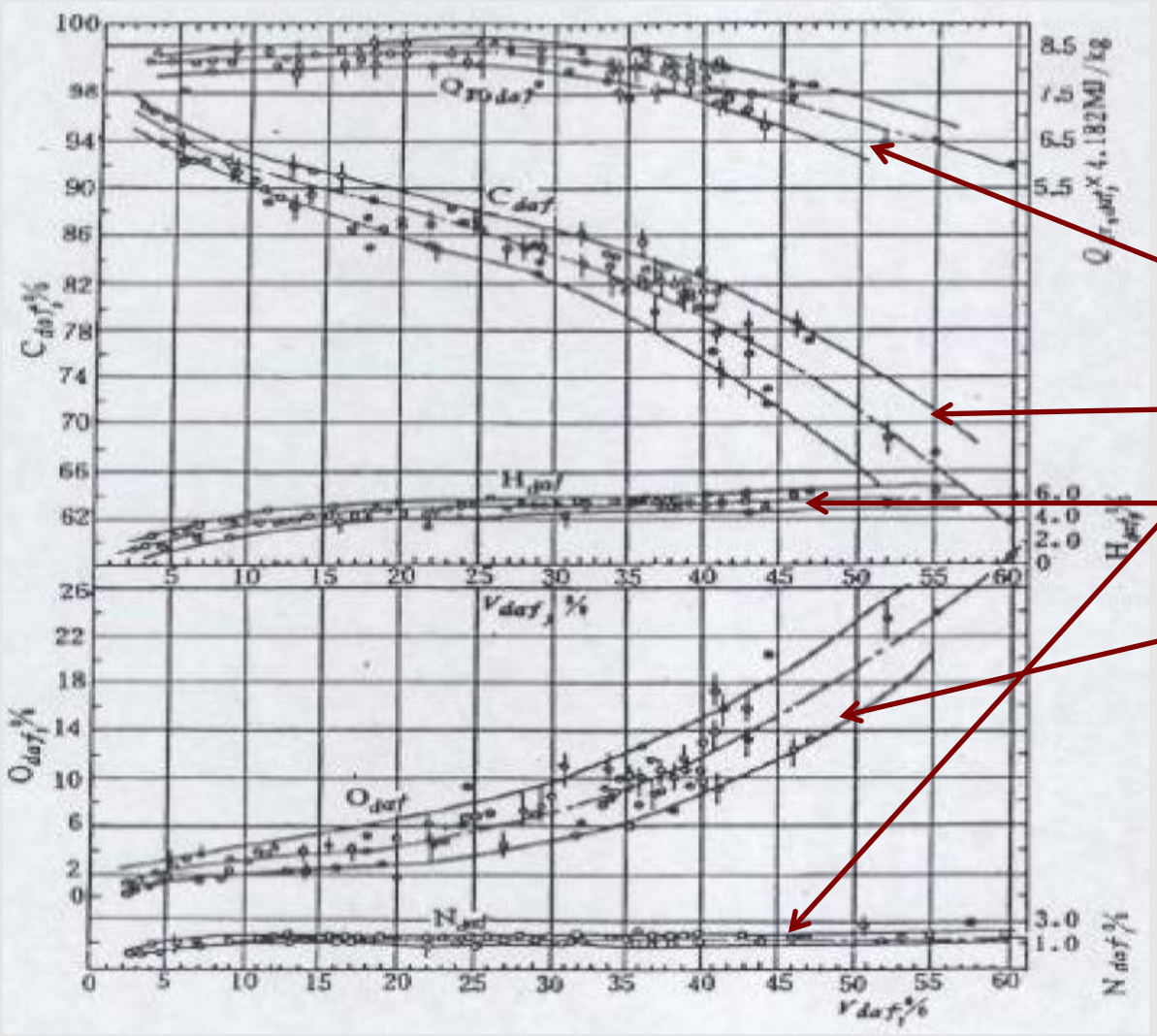
Difference between coal and Bio-mass fuel

	Coal	Bio-mass fuel
Moisture		could be much higher
Ash	Higher ash in general	Soil contamination could be a case
Volatile matter	40—50% on dry ash free basis	85% on dry ash free basis
Fixed carbon	Much higher in general	
Sulphur		Much lower in general
Calorific value	higher	Much lower, for wet wood
Bulk density		Much lower
Angle of repose	Lower in general	High except wood pellets

Properties on dry ash free basis

	Ohai	Wood pellets	Seasoned wood chip	Fresh wood chip	Hog fuel
Moisture, %	20.0	7.0	~35	60	~60
Ash, %	3.5	0.5	~0.8	0.3	~1
Volatile Matter, %	34.0	79.0	54.8	33.9	~33
Fixed Carbon, %	42.5	13.5	9.4	~6	~5
Sulphur, %	0.18	<0.01	~0.01	<0.01	<0.01
Calorific value, MJ/kg	23.5	18.8	~13.0	~8	7--8
VM on dry ash free basis, %	44.5	85.4	85.4	85.4	~84.6
CV on dry ash free basis, MJ/kg	30.8	20.3	20.3	20.2	~20.0

The Trends of C, H, N, O, and Calorific Value to Volatile Matter or Coalification



As volatile increasing,

- Calorific value is dropping
- Carbon is dropping
- H and N are reasonable steady
- O is increasing

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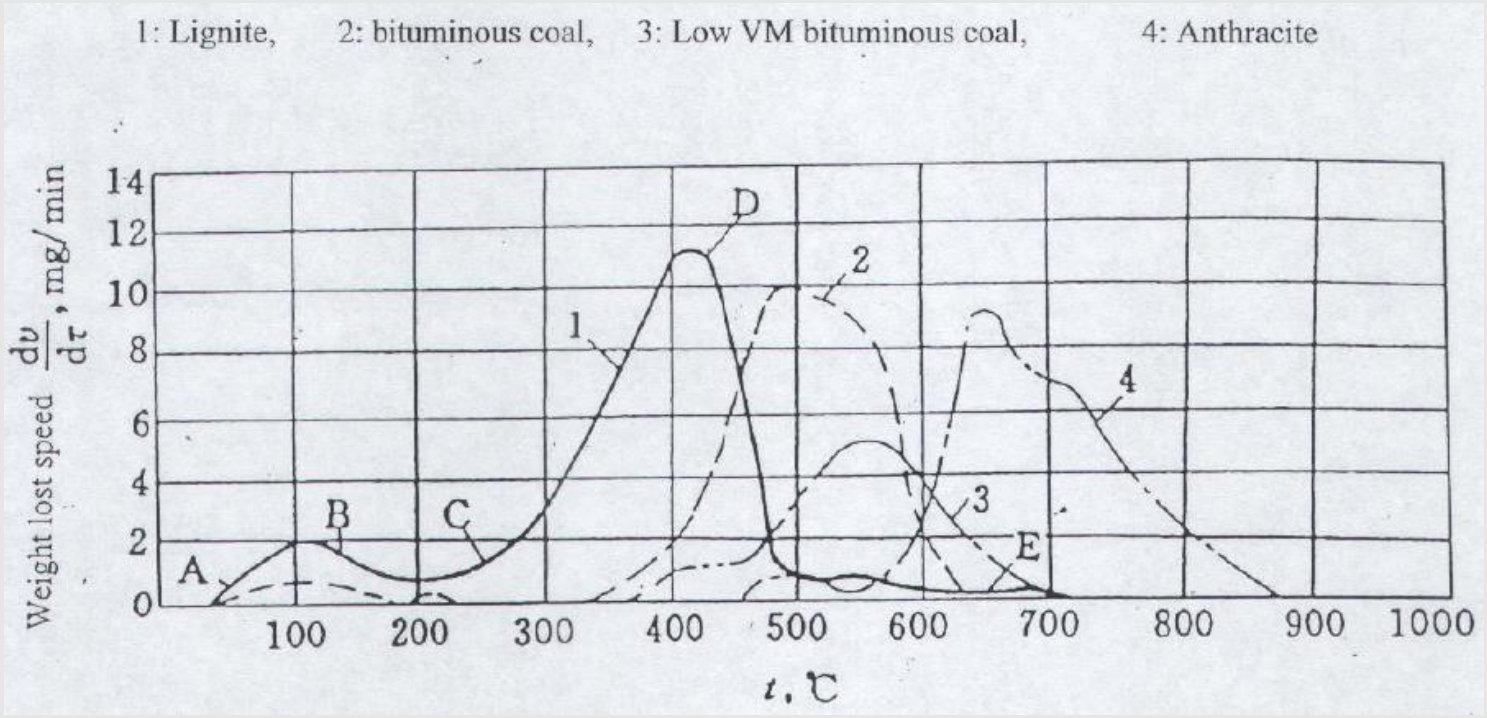
Combustion sequence from thermal Balance Analysis



A: Drying of moisture
B: Volatile matter releasing
C: Volatile matter igniting
D: Fixed carbon burning
E: Carbon burnout

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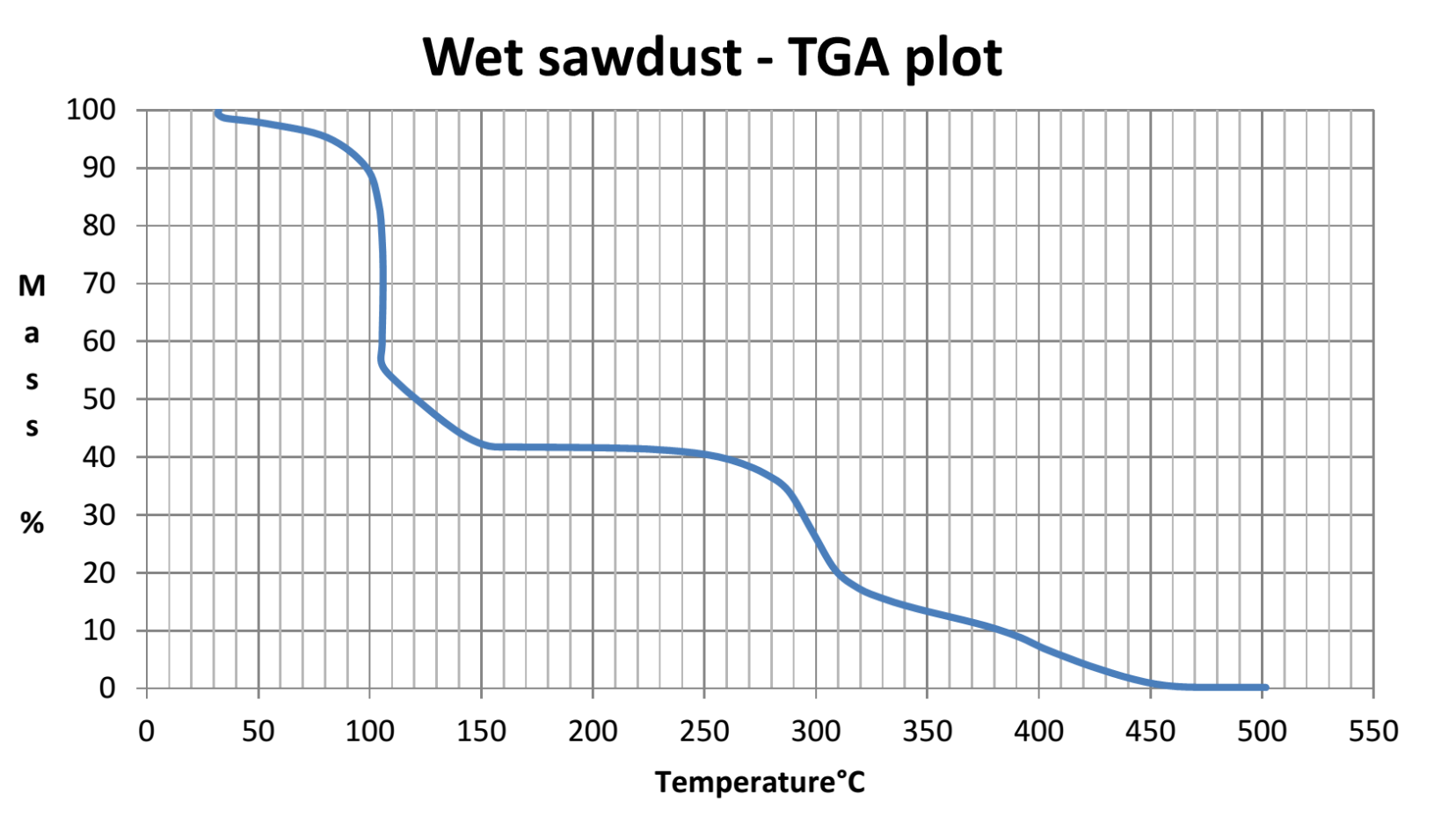
TGA for Bio-mass fuel



Igniting Temperature of Coal

- **Peat** 225°C
- **Lignite** 250—400°C
- **Bituminous coal** 400—500°C
- **Anthracite** 700—800°C

For bio-mass fuel, the ignition temperature is lower than coal

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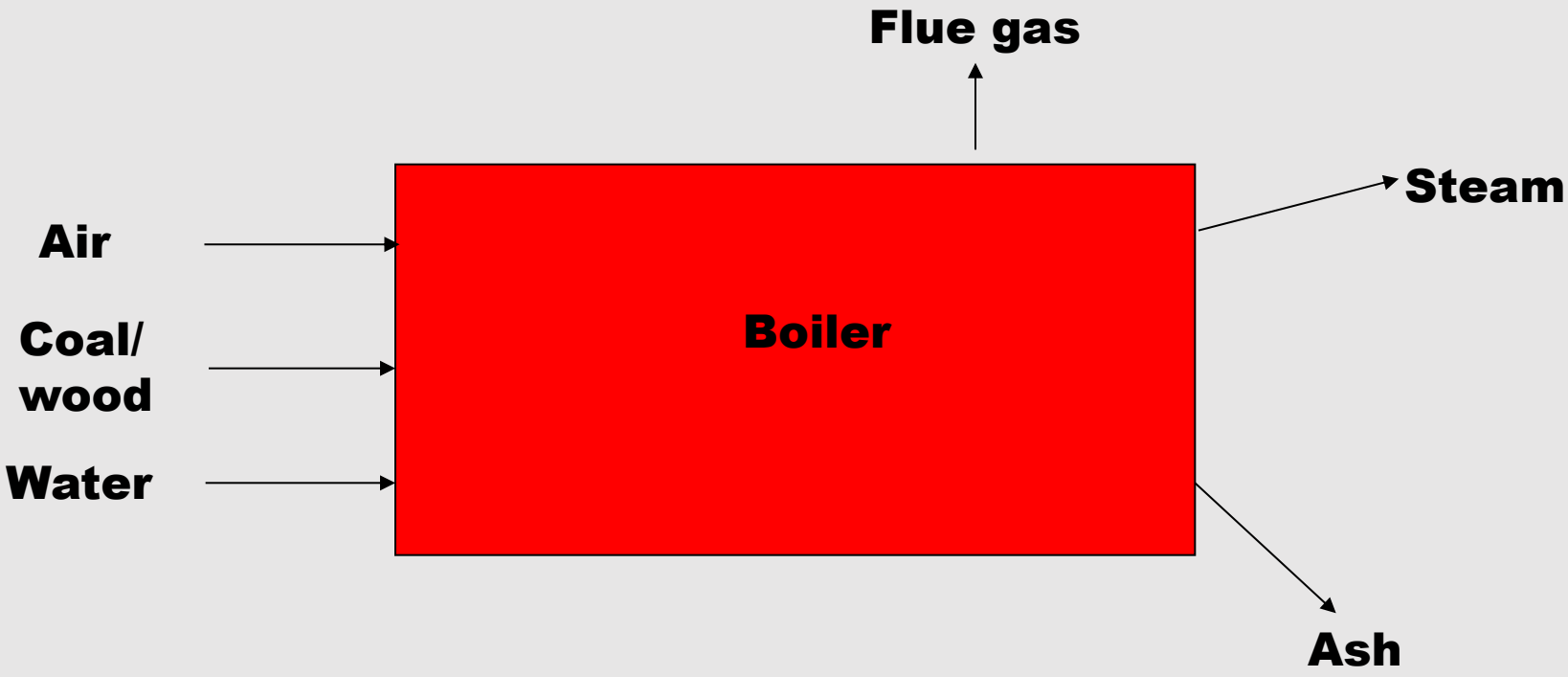
Flame temperature

- Flame temperature is determined mainly by the calorific value of the fuel.
- The flame temperature from coal ranged from 1300°C for lignite coal and 1380°C for sub-bituminous coal in the normal excess air condition.
- The flame temperature from wet wood could be around 1000 –1050°C.
- Heat transfer in the furnace occurs mainly in radiation form, which is determined by the flame temperature ($Q=f * \text{surface area} * T^4$)

General Process



Process associated to coal:

Coal handling, Coal burning, Ash deposition and Emissions

Coal handling facility-1

- Hopper/ bunker

- Auger

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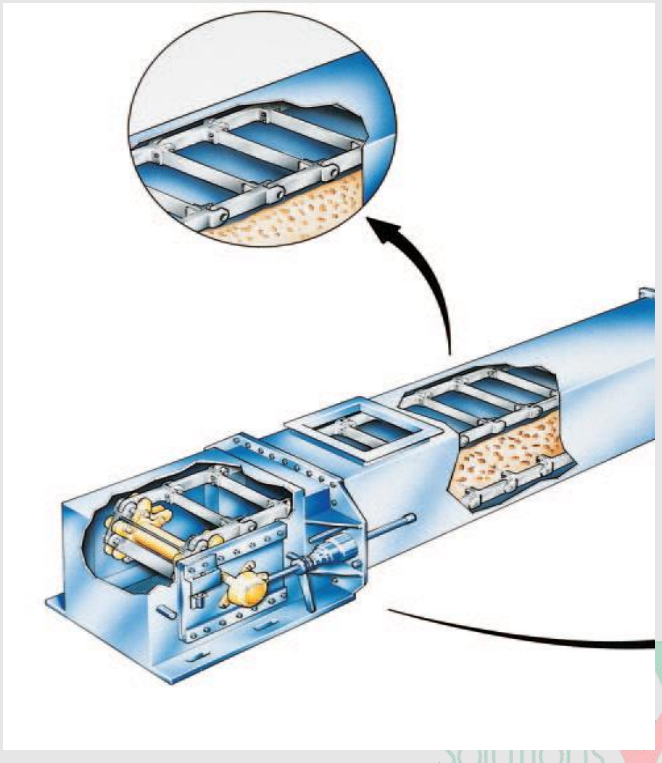
Coal handling facility-2

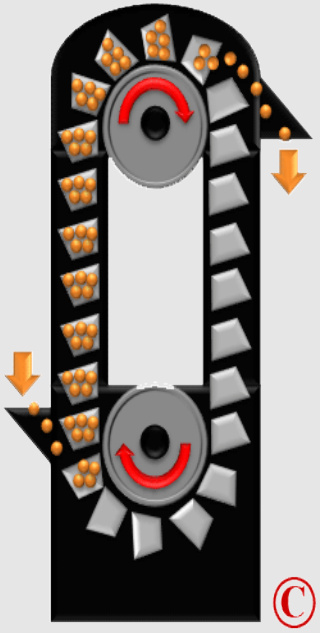
- Conveyer belt

- Drag chain

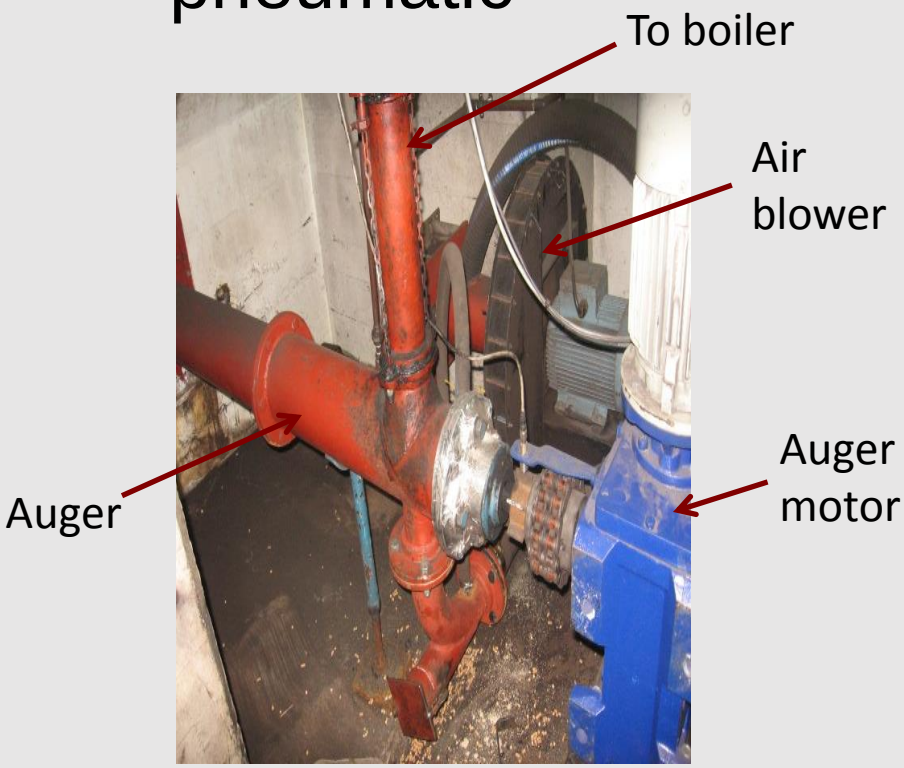


Coal handling facility-3

- Bucket elevator



- pneumatic



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Moving floor for bio-mass fuel

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Moving floor is specially used for handling material with larger angle of repose

Combustion Process

- **Drying**: remove moisture and warm up
- **Volatile release**: volatile matter is released once the temperature reaches a certain threshold level
- **Ignition**: flaming starts once the concentration of volatile matter around the coal reaches a certain level
- **Carbon burn out**: occurs slowly due to limited oxygen access because of the surface area

Determination of a good combustion

- Combustible gases, CO, CH_4 ,H_2 in flue gas are low
- Unburnt carbon or combustible material in fly ash is low
- Unburnt carbon or combustible material in bottom ash is low

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How to achieve a good combustion

With reasonable excess air burning under **3T**

- Suitable **T**emperature level
- Long enough **T**ime
- Fuel and air mixing well, **T**urbulence

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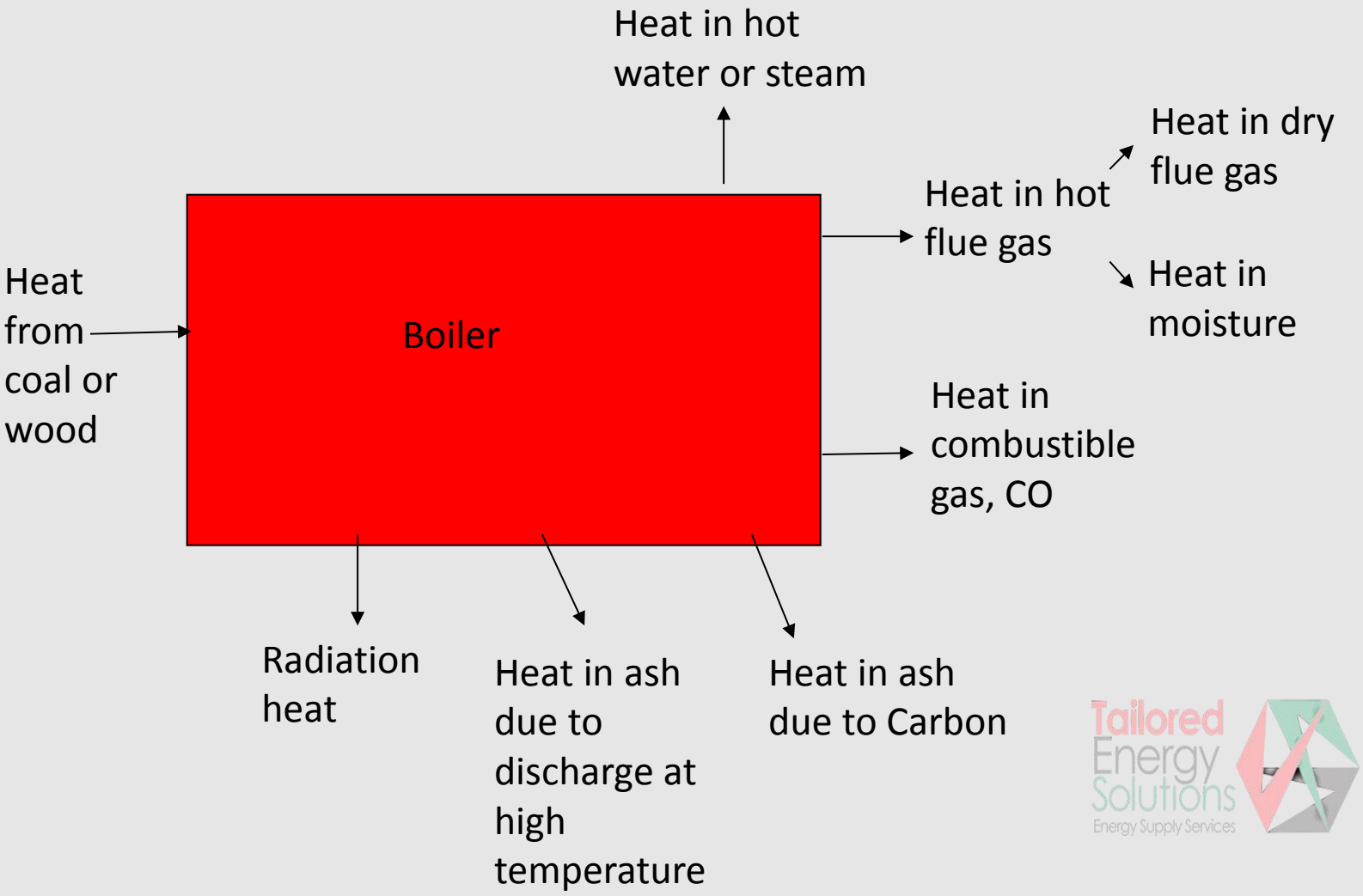
Energy Balance



Typical Boiler Efficiency

- The boiler efficiency on gross calorific value basis from burning bituminous coal and sub-bituminous coal is at ~80%.

- The typical boiler efficiency from burning lignite coal such as New Vale coal is at approximately 75% because of the higher moisture which eventually takes heat away to the chimney for its vaporization.

- The typical boiler efficiency from burning wet wood fuel is at approximately 60% because of the higher moisture content.

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Slagging

- Slag or clinker forms at high temperature, near the grate or within firebox

- It is determined by ash composition, or minerals, ash fusion, combustion conditions and temperature level.

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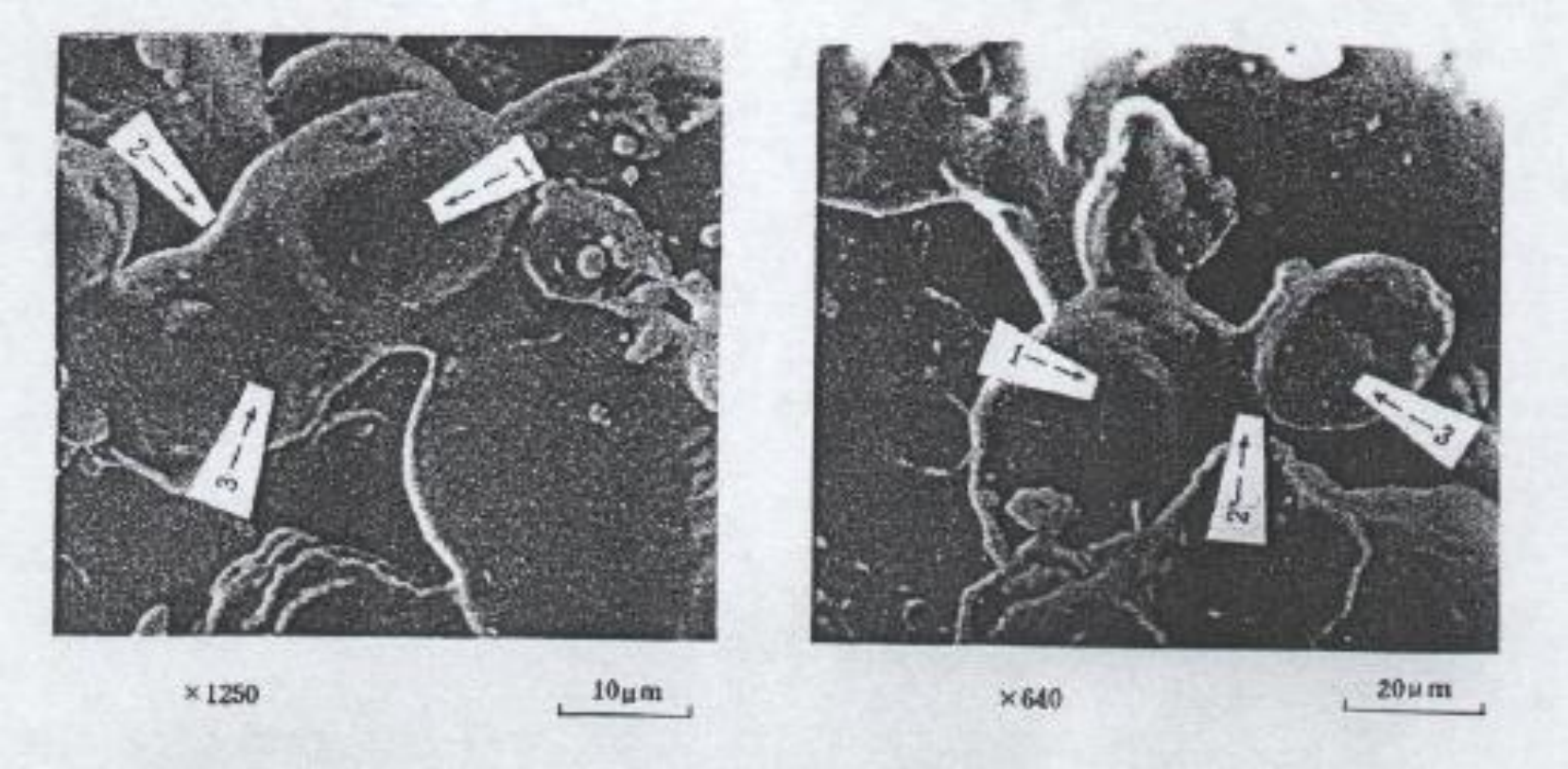
Slagging Structure

- Ash particles (1, 3) stick together by surface tension force
- Richer Na_2O, K_2O, Fe_2O_3 in the liquid phase (2)



Minimizing Slagging Options

- Lower the combustion thermal intensity
- Avoid localised zones of higher temperature
- Oxidising atmosphere
- Soot blowing, with air or steam, or water
- Good match between fuel properties and boiler design

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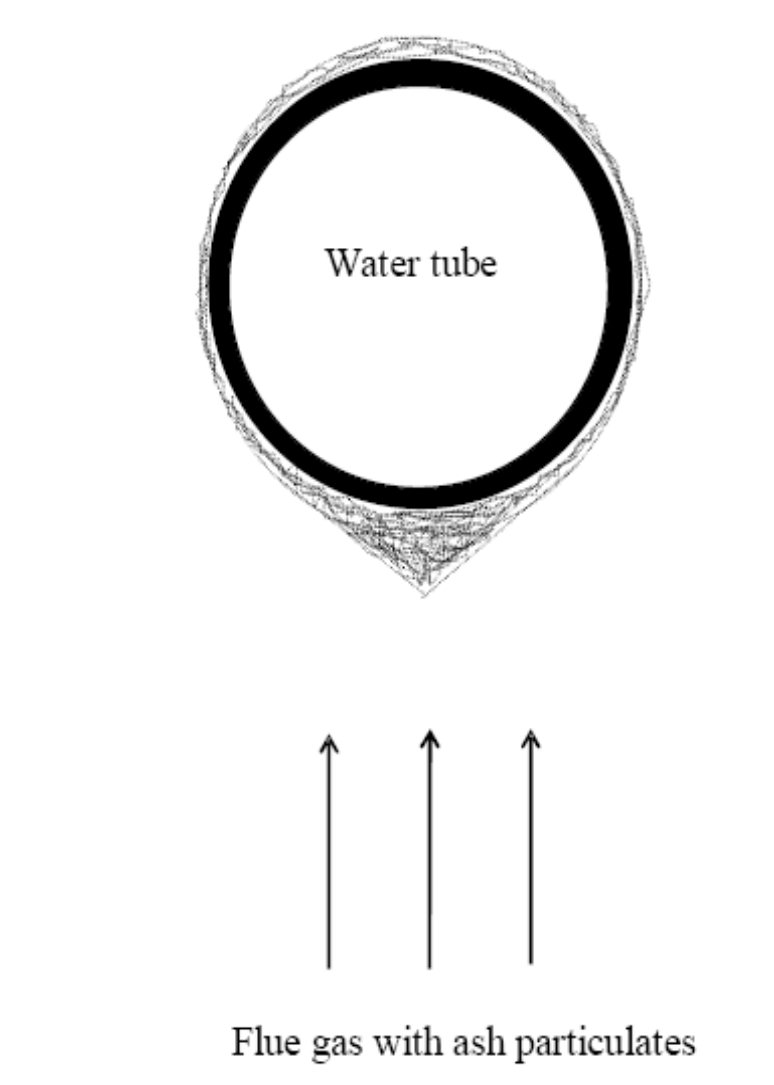
Fouling

- Ash deposited on the water or fire tubes.
- It is generally accepted that fouling build-up is initiated in the cooler convective heat transfer sections by the deposition of a thin layer of material made up of condensed vapours.
- It usually involves the release of alkali metals (sodium and potassium) from the firebox in the form of oxides which react primarily with sulphur gases and chlorine to form alkali metal sulphates & chlorides. These slats impact with tubes as sticky condensation products which then capture a high proportion of any subsequently impacting particles.

Ash Deposit Character on Water Tube



- Wedge shape
- White crystal scale on the tubes

Minimising Fouling Options

- Soot blowing, with air or steam
- Flue gas re-circulating
- Change coal with lower alkali metals and sulphur content

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Boilers

Combustion type:

- Combustion in layer state
- Combustion in suspended state
- Combustion in fluidised state

Boiler type

- Stoker
- Pulverised fuel---PF
- Fluidised bed or circulated fluidised bed---FBC or CFBC

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Popular Mechanical Stokers

- Underfed stoker
- Chain grate stoker
- Coking stoker
- Sprinkler stoker
- Vekos boiler

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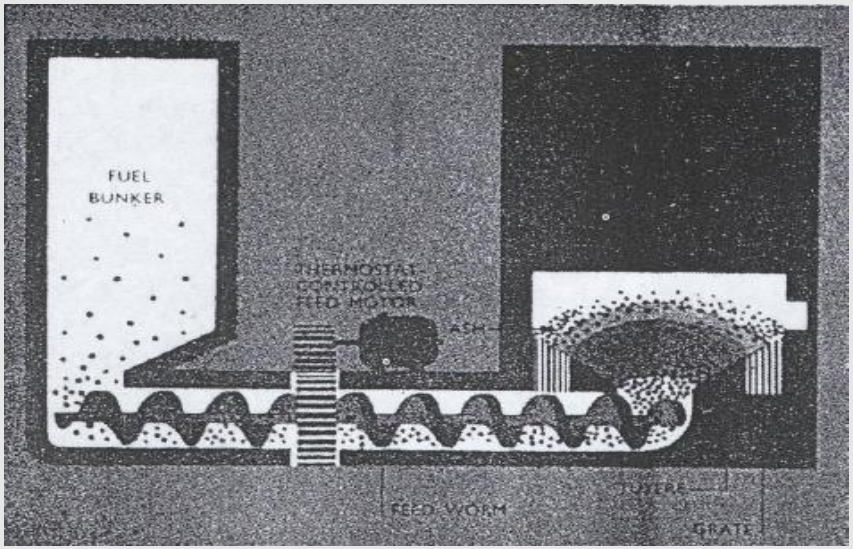
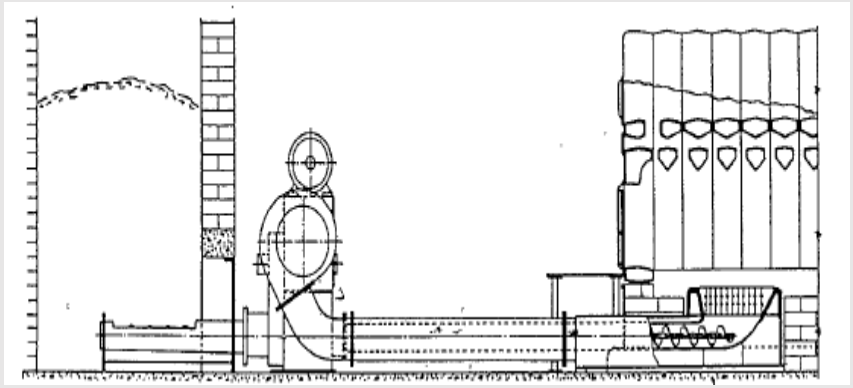
Underfeed Stoker



Underfeed stoker with cylinder type boiler



Under feed stoker with sectional boiler

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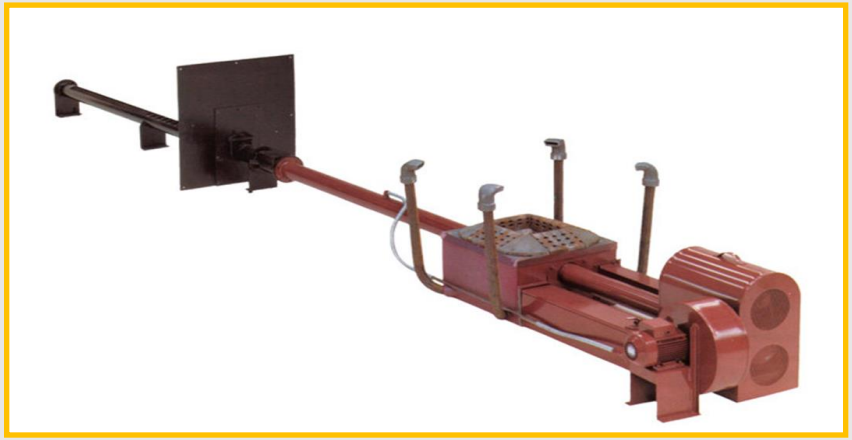
Underfeed Stoker boilers

Cylinder (fire tube) boiler



Typical Underfed stoker—An example of a set up from Taymac

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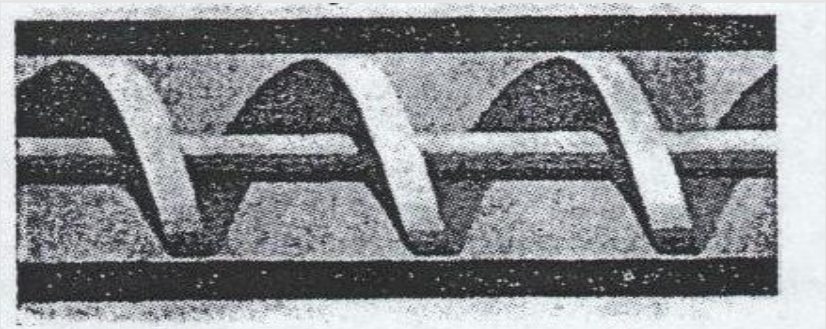
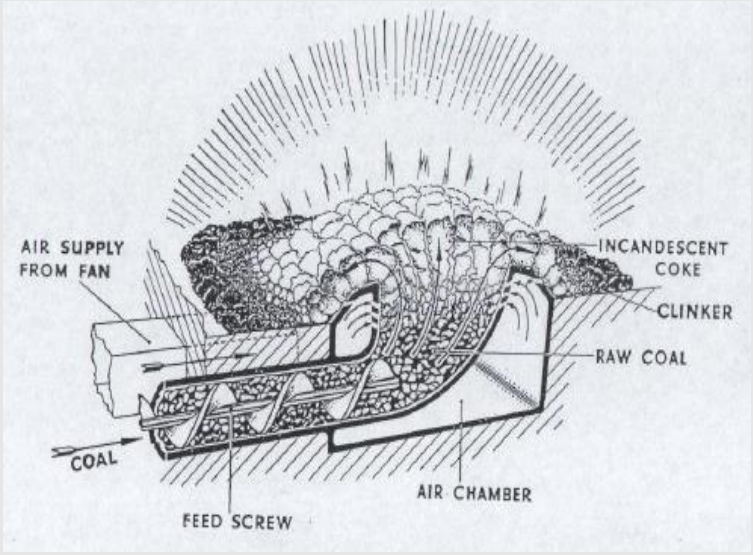
Underfeed Stoker Feeding Auger and Bed



UNDERFEED STOKER. *In this case the coal is conveyed into the boiler, usually by a screw feed, propelling the fuel under the static incandescent fire-bed.*



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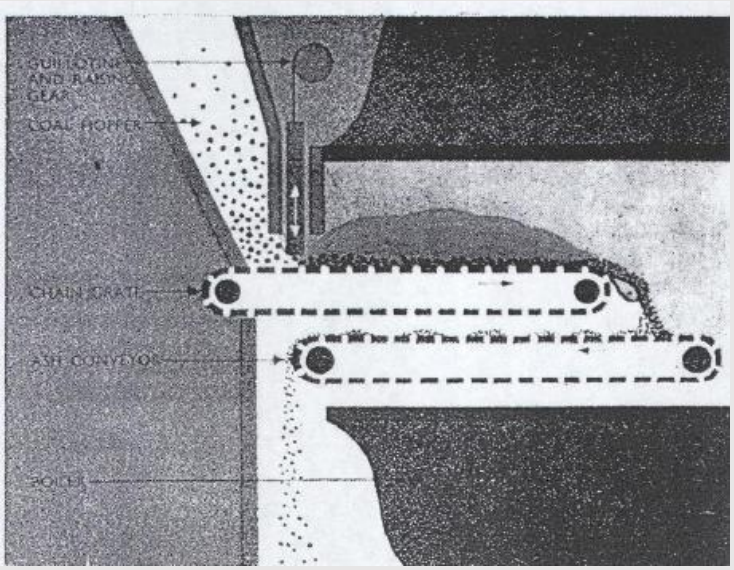
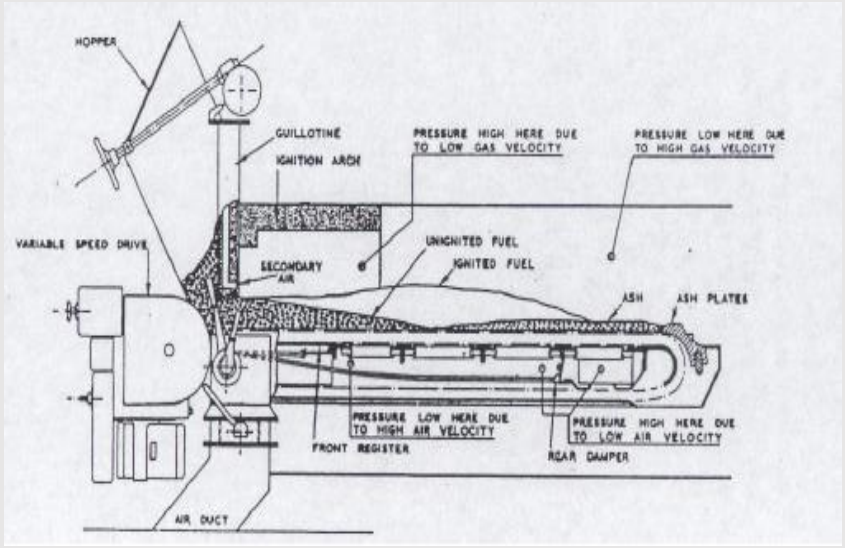
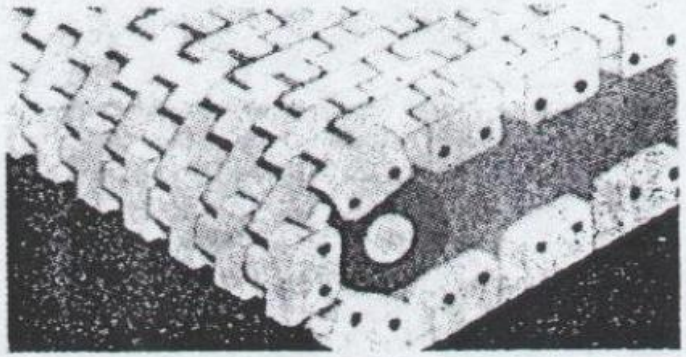
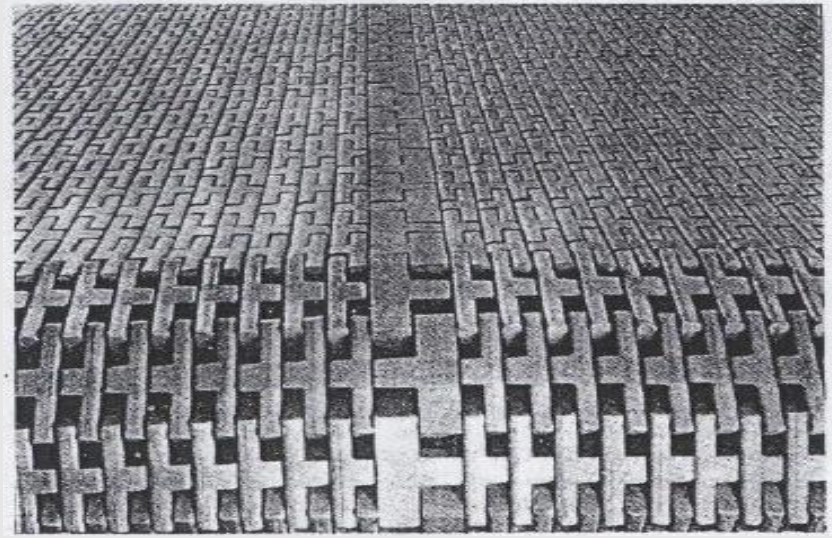
Chain Grate Stoker



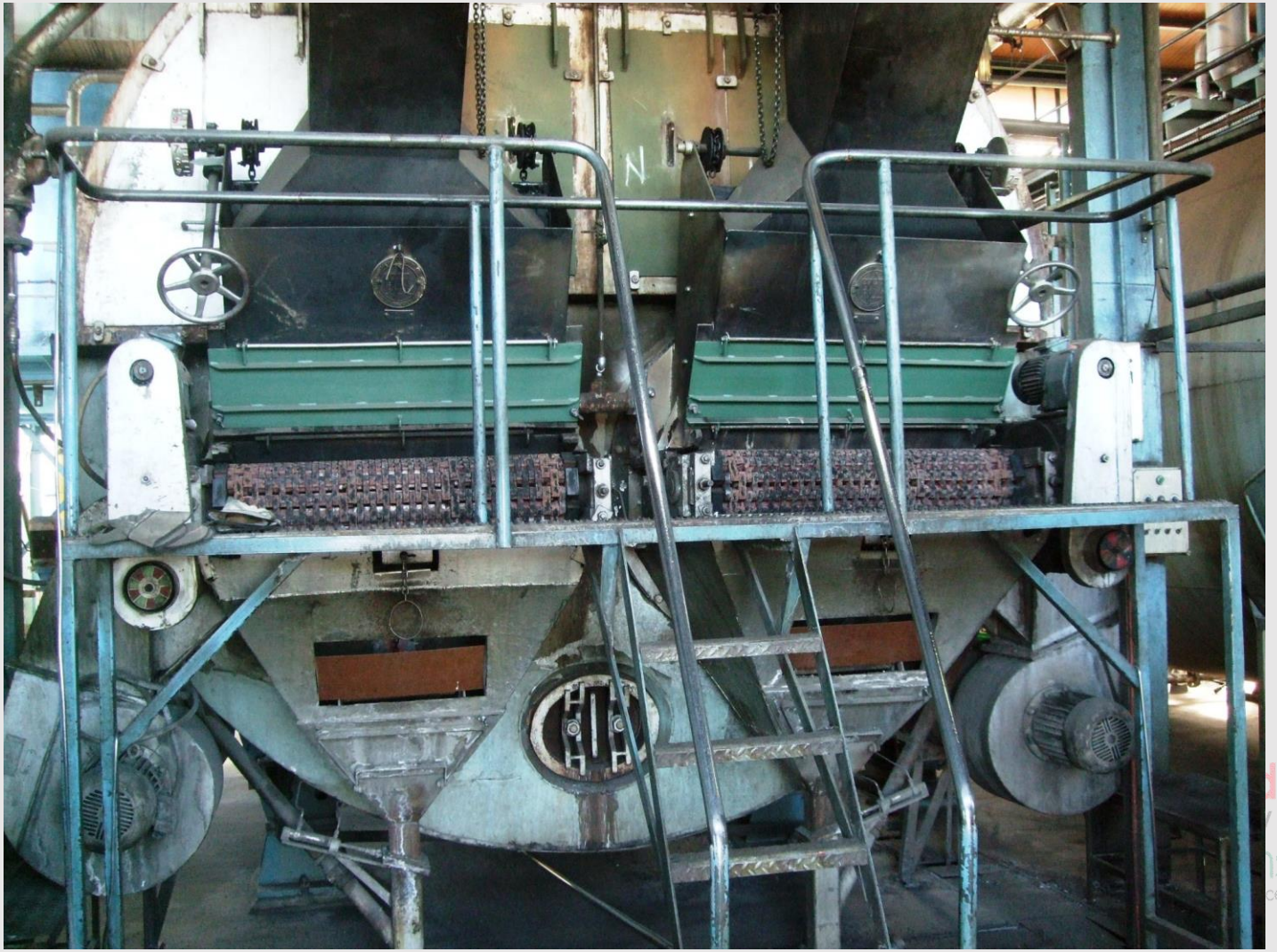




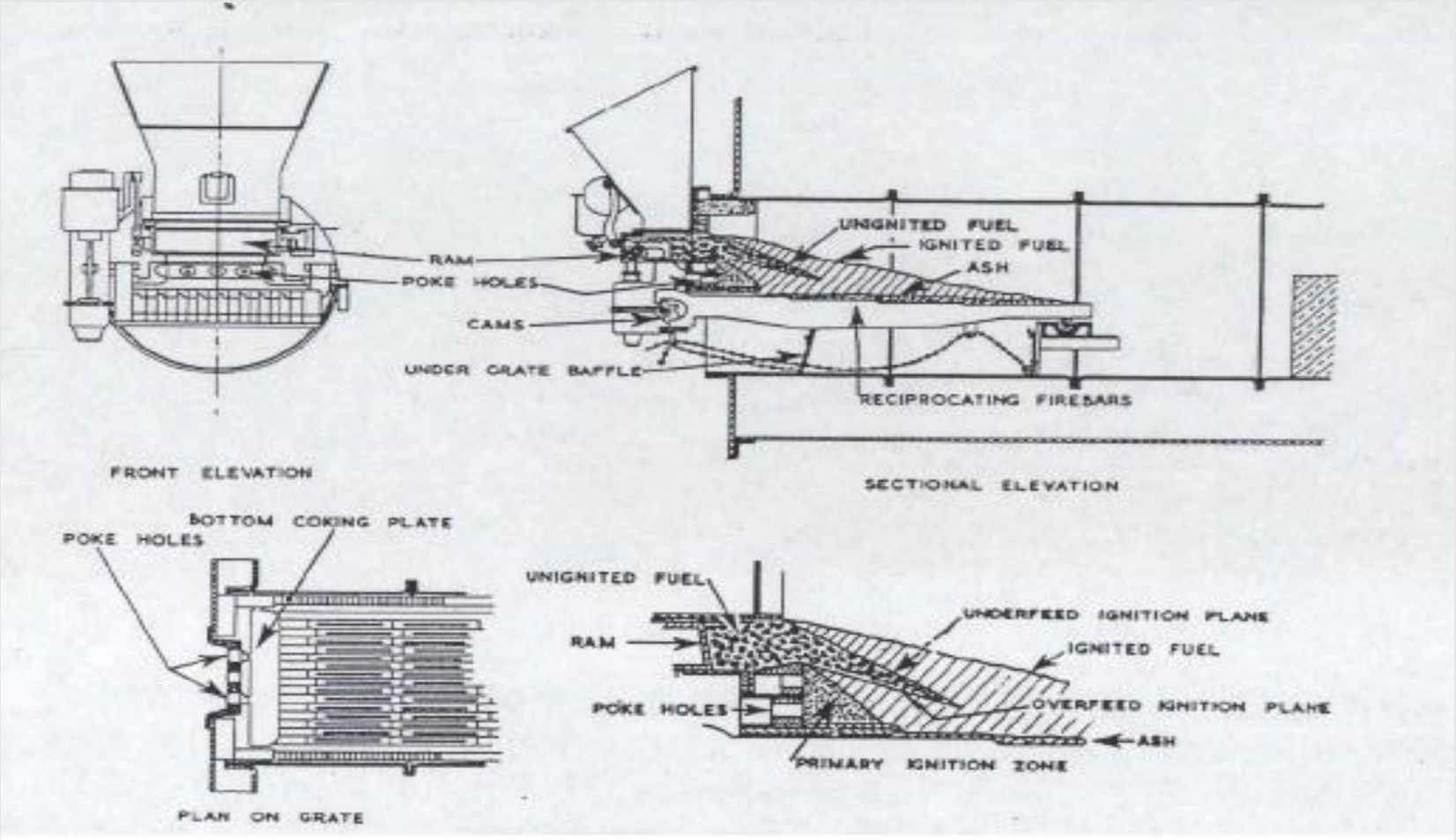
CHAIN GRATE STOKER. *Coal is spread evenly and automatically on to the fire-bed which consists of a continuously moving conveyor.*



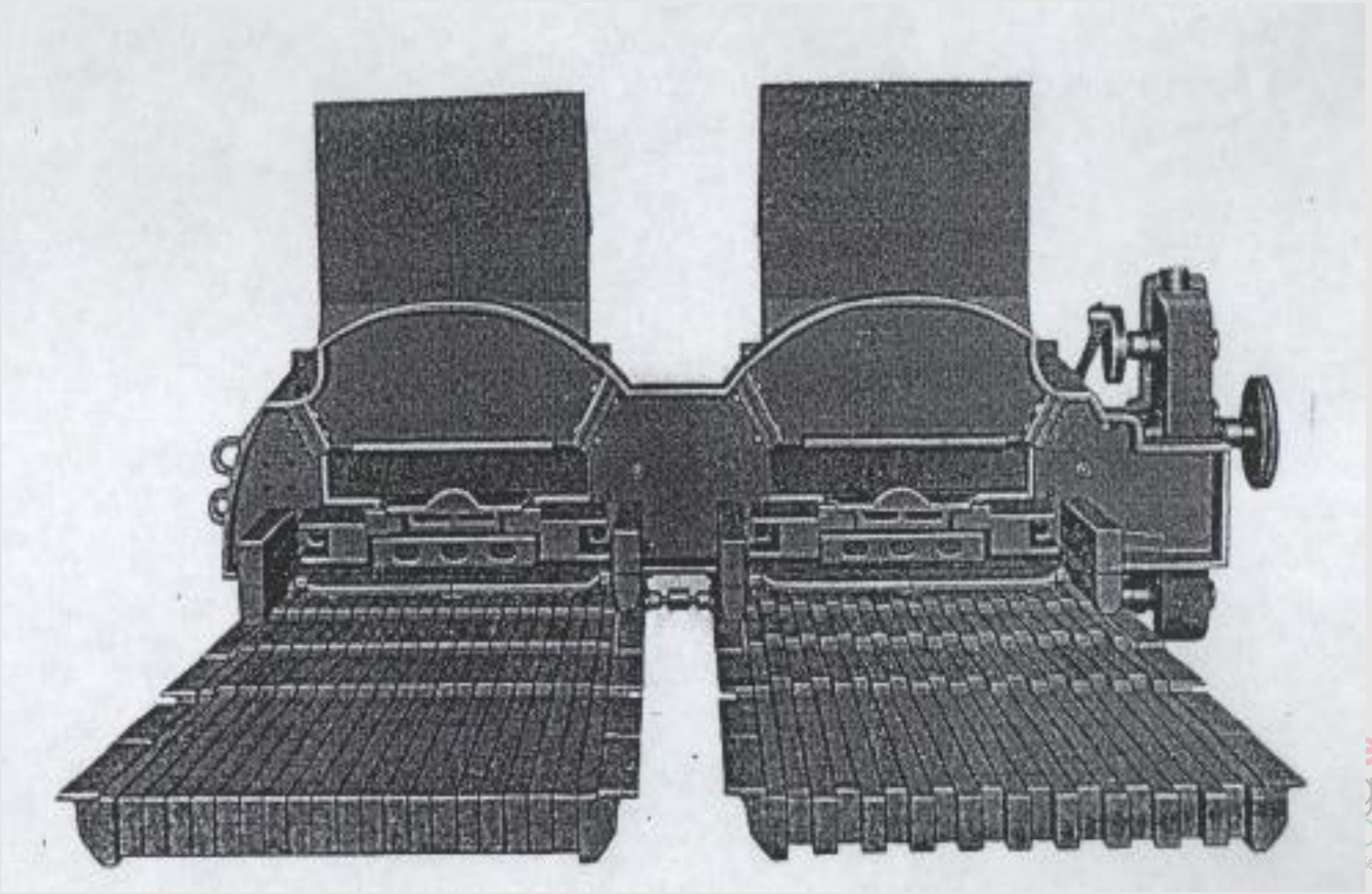
Twin Chain Grate Stokes On One Boiler



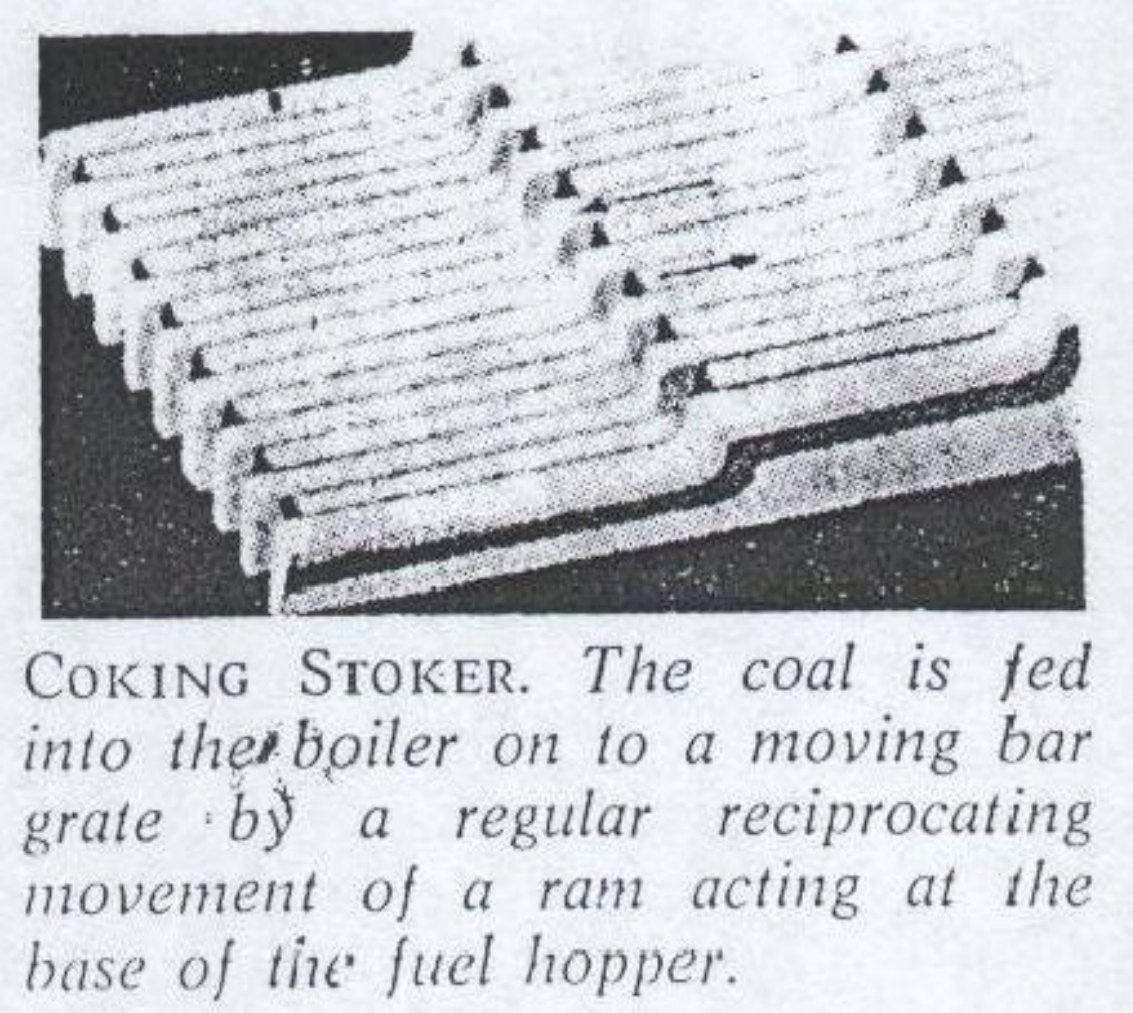
Coking Stoker / Ram Stoker



Twin Ram Stokers On One Boiler



Ram Stoker Fire Bars



COKING STOKER. *The coal is fed into the boiler on to a moving bar grate by a regular reciprocating movement of a ram acting at the base of the fuel hopper.*

Initially this is designed for burn bituminous coal

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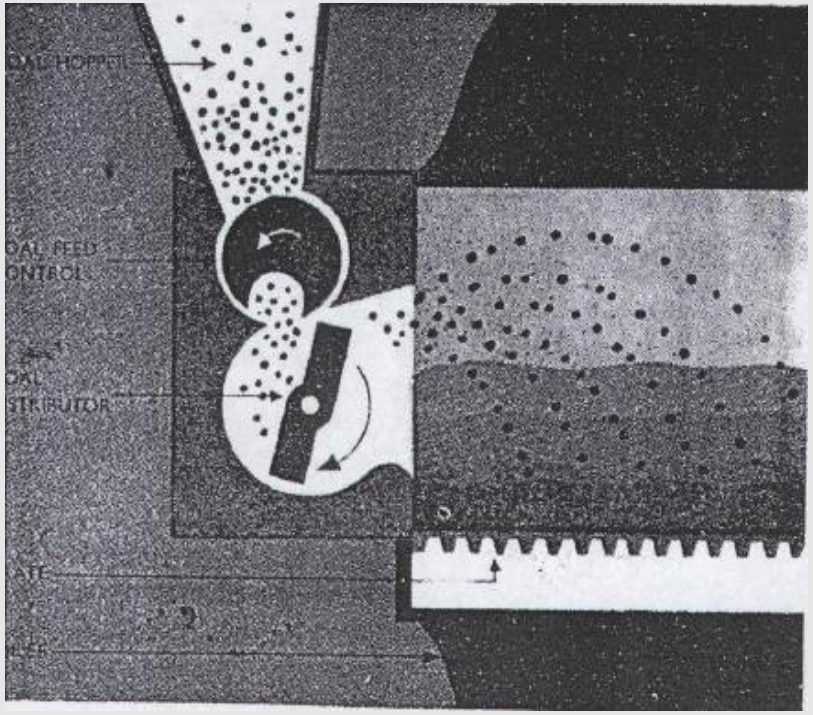
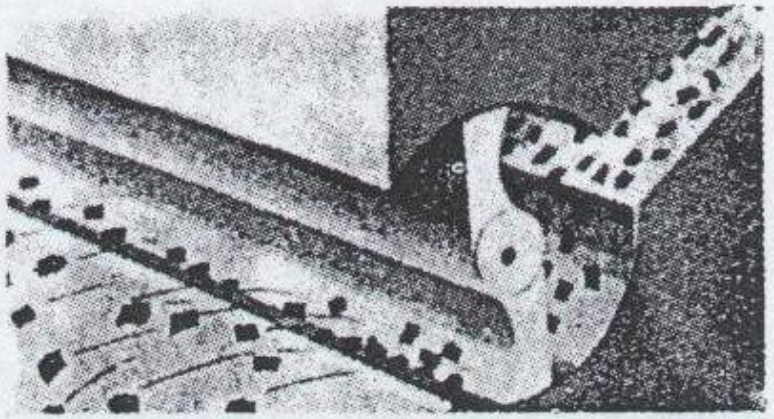
Sprinkler Stoker





SPRINKLER STOKER *or spreader type of stoker, as its name implies, projects the fuel in a regular thin layer over the grate which is normally fixed.*

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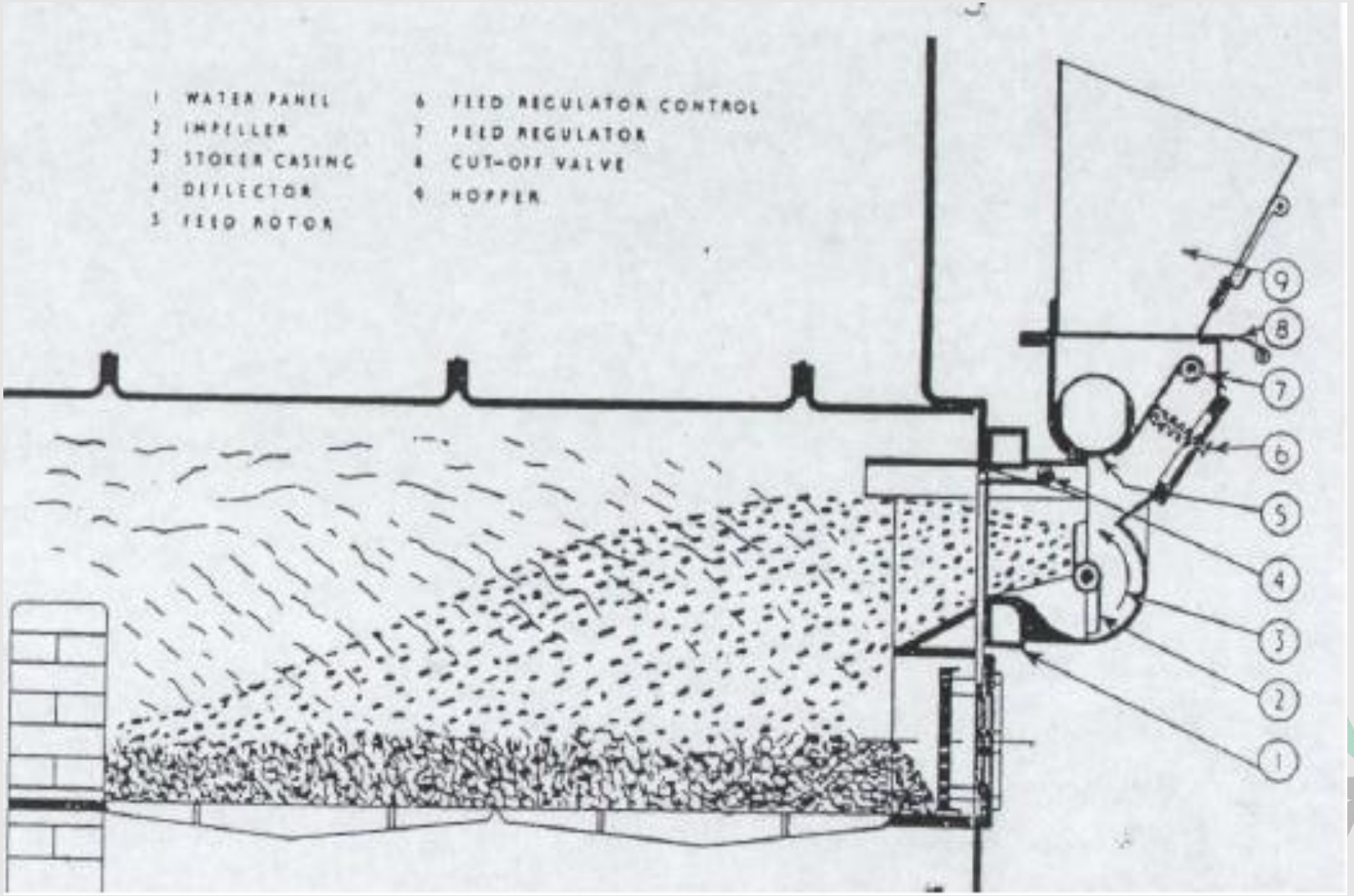
Sprinkler Stoker with a Fixed Grate



Spreader boiler with revised traveling grate (Fonterra)

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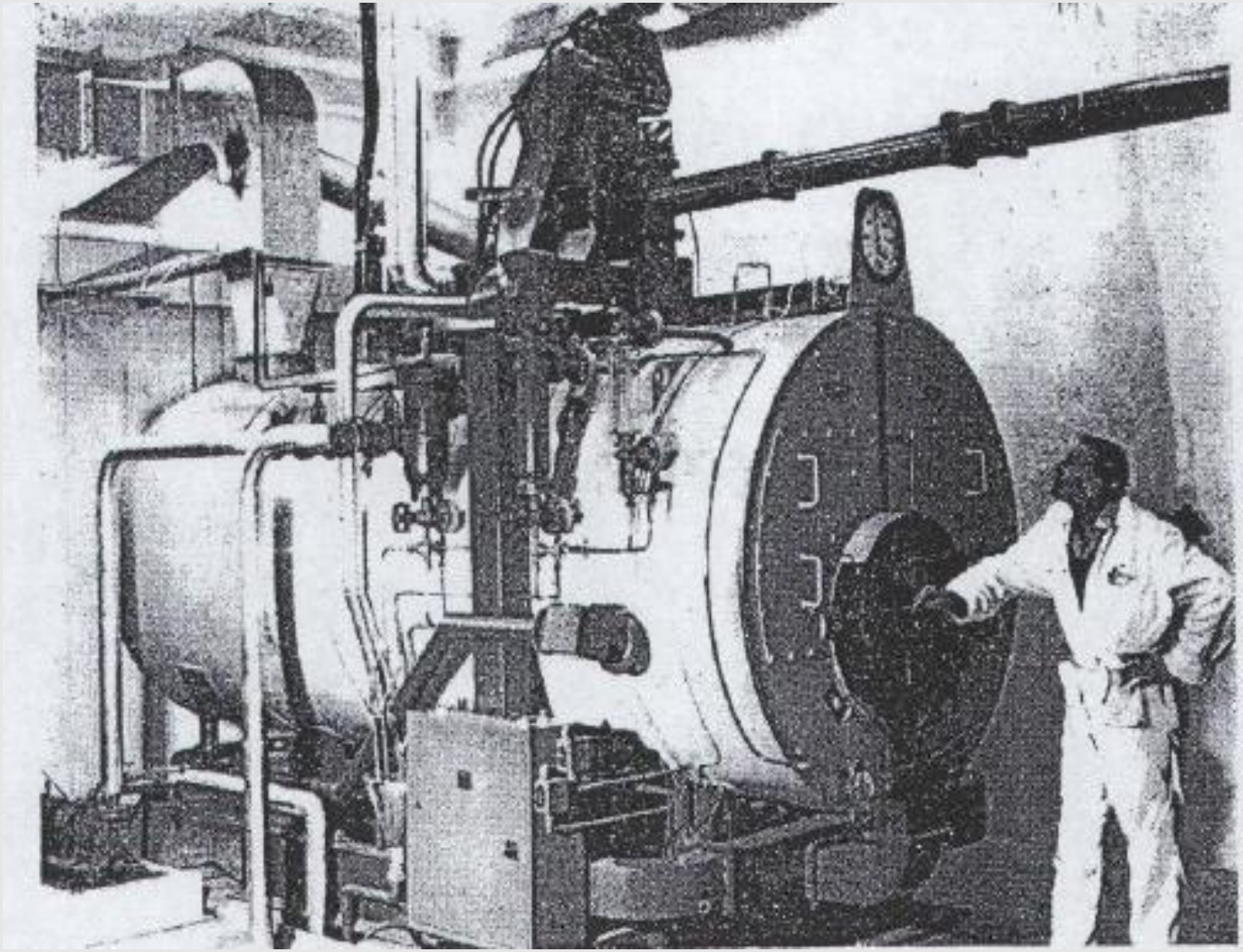
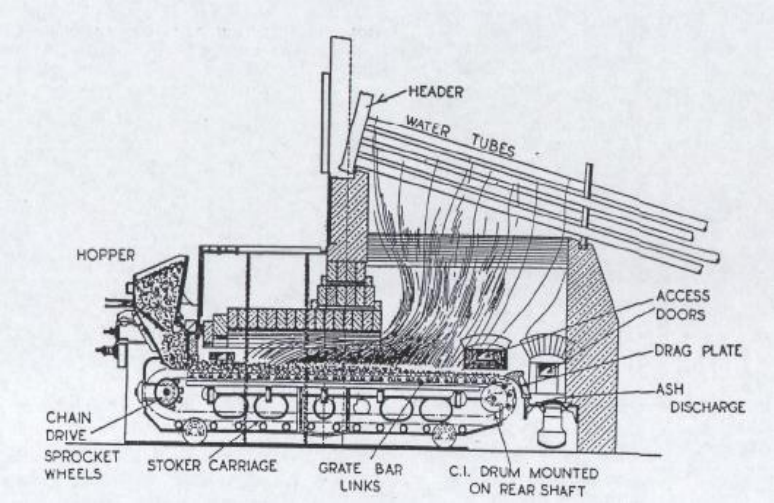
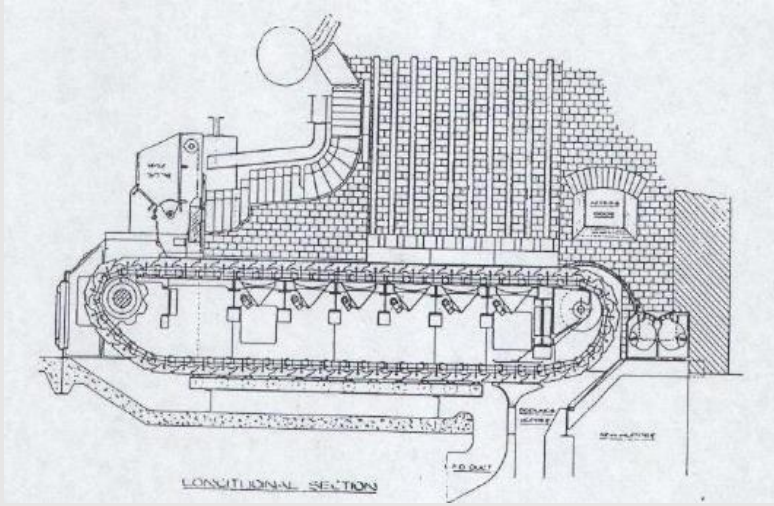
Vekos Boiler Over Feeding



Chain Grate Water Tuber Boilers



Babcock Wilcox boiler at SFF Belfast and Alliance Mataura



John /Thompson boiler at CHH Whakatane

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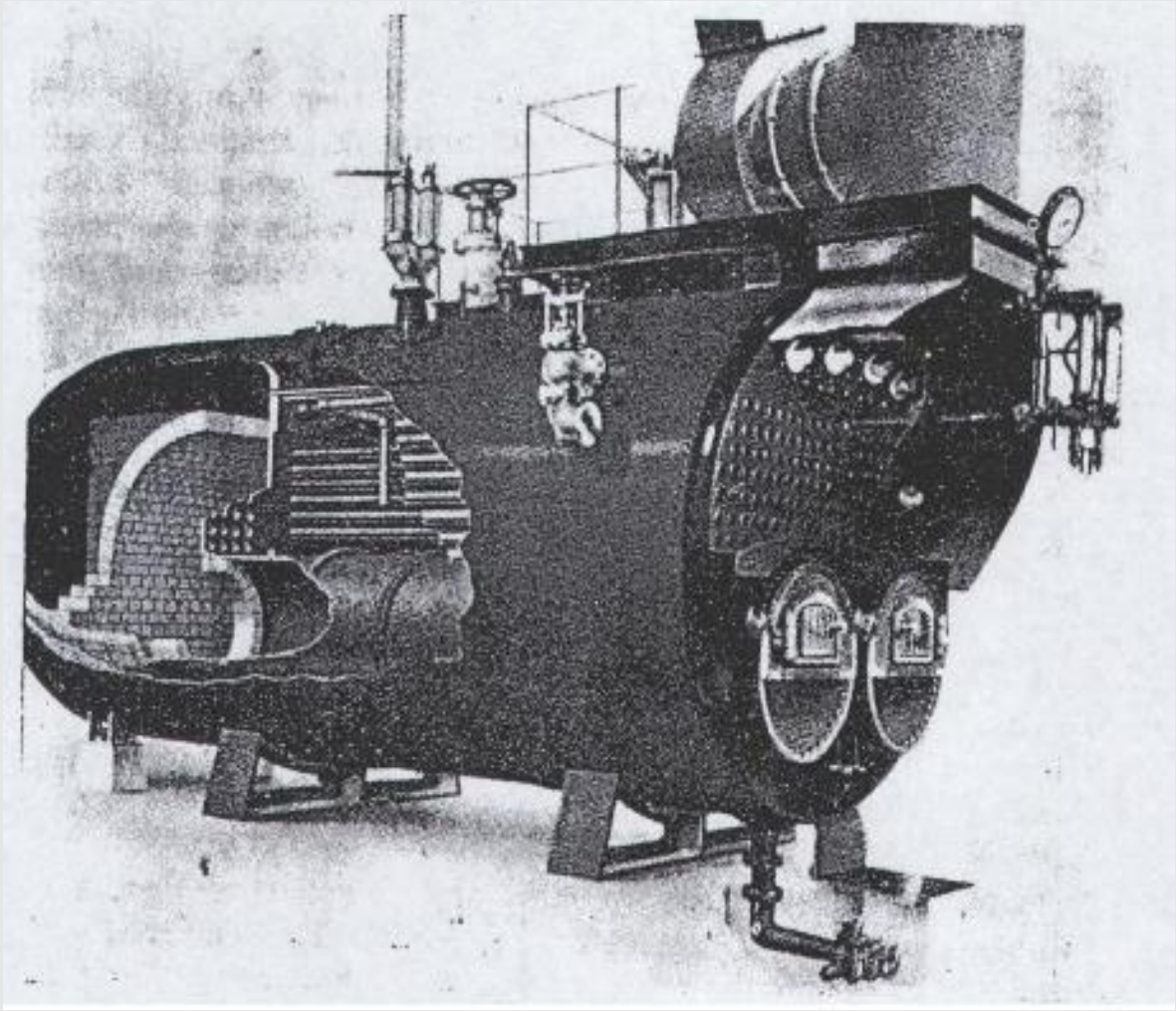
Two Pass Fire Tube Boilers



Southland Veneer,
Invercargill

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Industrial Boilers summary

Firing system	Coal feeding	Grate type	Heat capacity
Chain grate	Gravity/mechanical	Chain grate	Medium-large
Sprinkler stoker	Spreading	Revising chain grate	Medium-large
	Spreading	Dumping grate	Medium-large
	Spreading	Vibrating grate	Medium-large
	Spreading	Fixed grate	Medium-large
Ram stoker	Gravity/mechanical	Reciprocating Moving fire bars	Small-Medium
Underfeed stoker	Auger	Retort, fixed grate	Small
Vekos	Overfeeding	Fixed grate	Small-Medium

General Guide

- Under feed stoke, small size, <2MW
- Vekos boiler, small- medium size, 1—6MW, cheap boiler. it can burn any coal but no fines
- Chain grate stoke, Medium size, up to 20MW. Ignition is the key. It can take more fines, but a hotter coal
- Sprinkler, larger size, up to 40MW, it can burn any coal but less fines
- CFBC/PF boiler, 10MWh—1000MWe

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Use Bio-mass fuel for new heating plant

- Use a proper handling system.
- Design a proper fire ignition area or space to ensure enough heat available for drying.
- Design a proper boiler furnace so that the capacity is not compromised.
- Design a proper air distribution system to ensure low smoke or emission.

Use Bio-mass fuel on existing boilers Retrofit /modification requirements

- Continuously feeding to the boiler without blockage/bridging problem
- Reasonably good ignition
- Good evenness of bed for combustion
- Ensure there is sufficient secondary air flow available
- Heating plant has redundancy as potentially compromising the heat output

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For Retrofit------Continuously feeding

- The bridging and blockage are the potential problem, the handling system should be able to handle those issues.

  This is caused by the low bulk density and high angle of repose.

- The stoking system has plenty extra capacity to feed more volume of bio-mass fuel to match the similar heat input from coal.

  This is caused by the low bulk density and low calorific value.

For Retrofit------ Good ignition

- Of the industrial boilers, the chain grate boiler has the least amount of heat available to dry the fresh fuel due to the limitation of the heat source from the front arch.

- Other boilers such as spreader boiler, Vekos boiler, are good because the fresh fuel is landed on the hot bed.

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For Retrofit------ Bed evenness

- For a static combustion boiler, an even fuel bed is critical.

- If the bed is not even, hot spots, un-burned char-coal in bottom ash, high fly ash carry-over and potential high particulates emission, and lower boiler efficiency can be expected.

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For Retrofit------ Boiler performance

- The boiler efficiencies from burning bio-mass fuel could be lower depending on the moisture content in the fuel.
- The volume of the fuel delivered should be increased by a lot to replace coal, depending on the moisture content in the fuel.
- Using bio-mass fuel, the boiler capacity reduction can be expected.
- The ash generated from burning bio-mas fuel can be much less.

Co-firing with coal

- Pre-mixing evenly but the handling system must be able to handle bio-mass fuel. Fuel segregation could be an issue.

- Separated feeding system means a separate handling system and/ or stoker may be required.

- Maintaining bed evenness is most critical as bio-mass can finish burning much fast than coal.

Suitability between boiler and bio-mass fuel

Firing system	Coal feeding	Grate type	Ohai	New Vale lignite	Wood fuel
Chain grate	Gravity/ mechanical	Chain grate	Yes	No for most boilers	No
Sprinkler stoker	Spreading	Revising chain grate	Yes	Yes	Yes
	Spreading	Dumping grate	Yes	Yes	Yes, more bed leveling
	Spreading	Vibrating grate	Yes	Yes	Yes
	Spreading	Fixed grate	Yes	Yes	Yes, more bed leveling
Ram stoker	Gravity/ mechanical	Reciprocating Moving fire bars	Yes	Yes	Yes
Underfeed stoker	Auger	Retort, fixed	Yes	Yes, not very well, slow startup	Yes, safety devices needed
Vekos	Overfeeding	Fixed grate	Yes	Yes	Yes

Environmental Impact

Particulates

- It is determined by the fly ash removal system.
- Burning wood fuel tends to be lower due to lower ash content.

Sulphur dioxide

- It is mainly determined by the sulphur content in the fuel.
- Burning woody fuel can make significant reduction due to low sulphur.

CO_2 emissions

- CO_2 emission is in a level of 400g/(kW.h) from burning coal. But it is in ~12g/(kW.h) for woody fuel.

Conclusions

- Bio-mass fuel can be used as a boiler fuel to substitute coal alone or co-firing with coal.
- The fuel handling should be able to handle the bio-mass without bridging and jamming.
- The boiler stoker should have more extra capacity to feed more volume of bio-mass fuel to the boiler.
- The boiler should provide sufficient heat for drying and achieve a proper ignition.
- The boiler should have sufficient secondary air to burn bio-mass fuel.
- The boiler capacity could be reduced from burning bio-mass fuel.
- The emission from burning bio-mass coal could be reduced in terms of particulates, Sulphur dioxide and CO_2.

Thank you

Questions

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