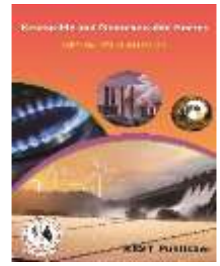
Renewable and Nonrenewable Energy

Vol: 5(1), 2026

REST Publisher; ISBN: 978-81-948459-2-8

Website: https://restpublisher.com/book-series/ese/

DOI: https://doi.org/10.46632/rne/5/1/17



Energy saving opportunity through Waste heat utilization in Cement Industries

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Abstract: *A large quantity of flue gases at high temperatures is produced by different parts of the heavy industries. They are purified internally by purifying equipment like Electrostatic Precipitators and are left into atmosphere. At the present condition the heat energy of flue gases is wasted. If we are able to trap the heat and thereby using the heat to produce steam, an efficient electric power generation can be achieved. As the heavy industries are located independently and in many cases, neither steam nor hot water is needed in their own plants. The recovery in electric power is most effective method. In the production of Clinker, the quantity of hot air exhaust is substantial. Hence it is proposed to do a study for generating electrical Power with this low temperature heat. The main objective of Waste Heat Recovery Power Plant project is to generate electricity by deriving from the organic Rankine process, which is essentially based on the use of an organic motive medium, which evaporates at significantly lower temperatures than water instead of using steam as the motive. The recovery plants can be constructed on the same basis of the thermal power plant with the only difference that flue gases for the production of heat in boilers replace the burning of coal. This difference makes the recovery plant most efficient and clean over conventional plant for same power rating.*

Keywords*: Flue gases, Electrostatic Precipitators, Clinker, Waste Heat recovery, Organic Rankine process.*

1. INTRODUCTION

The heat, which is generated from the process of fuel combustion or chemical reaction and thrown away into the environment although it could be reused for some useful and economic purpose is said to be Waste heat. The procedure of how to regain this heat depends partially on the temperature of the waste heat gasses and the financial matters included. Boilers, Kilns, Ovens and Furnaces will generate high amount of waste heat, the great amount of essential fuel could be spared. The energy lost in waste gases can't be completely recovered. Waste heat found in the exhaust gas of different procedures or even from the fumes stream of a conditioning unit can be utilized to preheat the approaching gas. This is one of the essential systems for recovery of waste heat. Dismissal of unneeded cold (as from a warmth pump) is likewise a type of waste heat. Instead of being "wasted" by discharge into the surrounding environment, once in a while waste heat (or cold) can be used by another procedure, or a segment of warmth that would some way or another be wasted, can be reused in the same procedure if make-up heat is added to the system. Anthropogenic waste heat is thought by some to add to the urban heat island impact. The greatest point sources of waste heat start from machines and loss of heat through building envelopes. The burning of transport fuels is a noteworthy commitment to waste heat.

Waste Heat Sources: In most of the applications of energy, it is needed in various forms. Typically these energy forms include some combination of: conditioning, mechanical and electric power. By running on source of heat with high temperature, regularly these additional forms of energy are generated by a heat engine. According to the Second law of thermodynamics, a heat engine can never have perfect efficiency, therefore it always generates an additional heat with low-temperature which is frequentlyknownas "waste heat" or "Secondary heat" or "low grade heat". In major applications of heating, this heat is very much useful even it cannot be transported over long distances just like electricity or fuel energy. Power stations and vehicle engines are the major sources of total waste heat. The largest single sources are power stations and industrial plants such as oil refineries and steel making plants.

2. ORGANIC RANKINE CYCLE

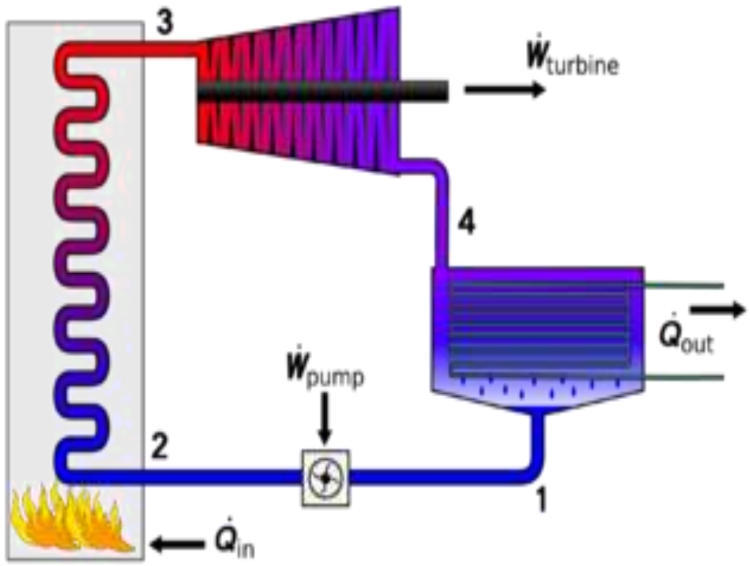

FIGURE 1. Rankine Cycle

The Rankine cycle is named after William John MacquornRankine (July 5, 1820 - December 24, 1872), a Scottish engineer and physicist. Rankine developed a complete theory of the steam engine and indeed of all heat engines. The organic Rankine cycle (ORC) uses an organic fluid such as n-pentane or toluene in place of water and steam. This allows use of lower-temperature heat sources, such as solar ponds, which typically operate at around 70–90 °C. The Organic Rankine cycle (ORC) is named for its use of an organic, high molecular mass fluid with a liquid-vapor phase change, or boiling point, occurring at a lower temperature than the water-steam phase change. The fluid allows Rankine cycle heat recovery from lower temperature sources such as biomass combustion, industrial waste heat, geothermal heat, solar ponds etc. The low-temperature heat is converted into useful work that can itself be converted into electricity. Organic Rankine Cycle (ORC) is a technology that can convert thermal energy at relative low temperatures in the range of 80 to 350 °C to electricity. It can play an important role to improve the energy efficiency of new or existing energy-intensive applications. Organic Rankine Cycle is a well-known and widely spread form of energy production, mostly in biomass and geothermal applications. *Working principle of ORC:* The Organic Rankine Cycle is a Rankine Power Cycle that uses an organic fluid, such as a refrigerant, as the working fluid. Waste heat is used to vaporize the fluid in a heat exchanger. The high temperature and pressure vapor is then expanded through a turbine which drives an electrical generator thus produces power that can be transmitted to the grid. After the energy is extracted from the fluid, it is condensed to a liquid state in a condenser (usually air cooled) then pressurized by a pump to once again enter the heat exchanger and continue the cycle. The working principle of the organic Rankine cycle is the same as that of the Rankine cycle: the working fluid is pumped to a boiler where it is evaporated, passed through an expansion device (turbine or other expander), and then through a condenser heat exchanger where it is finally re-condensed.

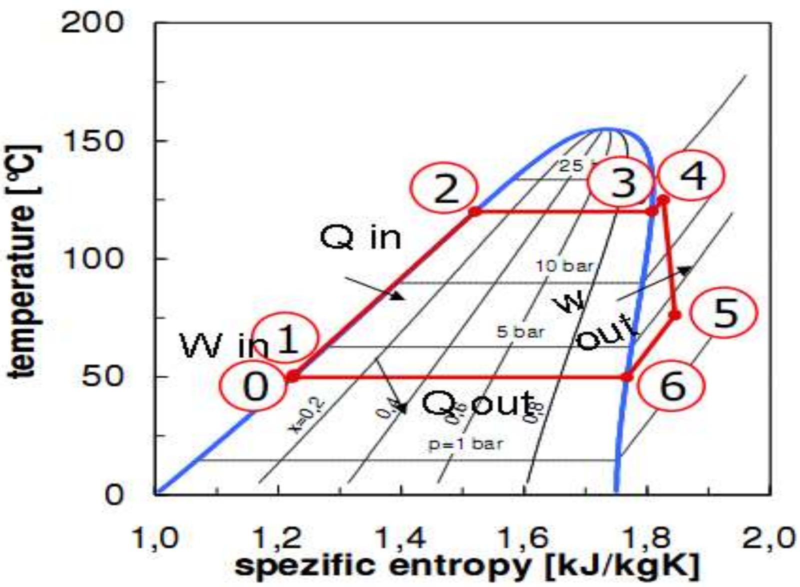

FIGURE 2.

There are four processes in a Rankine cycle. These are identified by numbers in the graph No: 1

- PROCESS 0-1: The working fluid is pumped from low to high pressure from condenser to vaporizer. As the fluid is a liquid at this stage, the pump requires little input energy. This process is reversible adiabatic.
- PROCESS 1-3: The high pressure liquid enters into the vaporizer where it is heated at constant pressure by an external heat source to become a dry saturated vapors. The input energy required can be easily calculated graphically, using an enthalpy-entropy chart till2 and superheated at constant pressure till 3.
- PROCESS 3-6: The dry saturated vapor enters the turbine generating power. This decreases the temperature and pressure of the vapors, and some condensation may occur and expands reversibly and adiabatically.
- PROCESS 6-1: The wet vapor then enters the condenser and is cooled at constant pressure to become a saturated liquid.

PROPERTIES OF PENTANE: **Here (in A.P.C.W) Pentane is used as motive or working fluid.**

- Chemical Name: N Pentane
- Common Name: Amyl Hydride
- Formula: C_2H_5
- Color: Colorless
- Odor: Paraffinic odor
- Physical state: liquid
- Vapor pressure at 100 degrees Celsius 15 Pisa
- Boiling point: 36 degrees Celsius

3. POWERGENERATION USING WHRPP

The generator can generate 4.0MW Power Gross with an alternating voltage 6600V and frequency 50Hz under the given turbine operating conditions with which the generator is connected to the turbine in a modular assembly. A conventional synchronous generator which is used is synchronized with the main supply. The switching on and off of large drive is based on the starting up and stopping of the plant. About 665 kW is taken by drives for the pentane pump, the fans of the air condensers and the thermal oil pump. So overall net power generation of about 3335 MW can be assumed.

FIGURE 3. WHRPP at APCW in Tadipatri

The Waste Heat Power Generation Plant in Cement industry is a facility to generate power by recovering heat from waste gas discharged from a cement plant. This is an energy saving. consumption of a cement plant. Depending on the system used 30–45 kWh/c_{linker} can be generated, which is up to 30 % of the electrical power requirement of a cement plant. The benefits of this technology are clear, as electricity and cost of energy increase, the plants become more and more cost-effective and the situation of emission of CO_2 provides additional motivation. This project, presents an overview of the technology and system vendors, indicates the reference systems and describes the market expectations.

Technical details of whrpp

- Thermic Fluid Oil Inlet Temperature: 270 deg. Celsius
- Thermic Fluid Oil Outlet Temperature: 120 deg. Celsius
- Pentane inlet temperature from vaporizer107 deg. Celsius
- Pentane outlet temperature from vaporizer: 204 deg. Celsius
- Pentane inlet temperature into turbine: 204 deg. Celsius
- Pentane outlet temperature from turbine: 147.3 deg. Celsius
- Pentane inlet pressure into turbine: 22.9 bar
- Pentane outlet pressure into turbine: 2.03 bar
- Pentane inlet temperature into recuperate: 147.3 deg. Celsius
- Pentane outlet temperature from recuperate: 83 deg. Celsius
- Pentane inlet temperature into condenser: 83 deg. Celsius
- Pentane outlet temperature from condenser: 58 deg. Celsius

Power parameters of whrpp

- **Power parameters**
- Gross Output: 4000 kW
- Net output (Organic energy converter): 3400 kW
- Annual Power Generation: 251 Lac. KWh
- *Assumptions*
- Load Factor: 98%
- Run Factor (Kiln 330 days / year): 330 days
- Availability (Outage 3%) : 97%
- Clinker cooler exhaust heat conditions:

- Flow rate, average : 375,500 Nm3/HrTemperature,average320 °C
- Ambient air, design : 35 °C
- Clinker cooler air velocity : 12 Met / Sec

Electrical details of the generator:

The synchronous generator driven is by ORMAT turbine through flexible coupling. The specifications of generator are 4800kW, 6000kVA, AC brushless, two bearings and single shaft extension. The generator will be connected to a 50 Hz system.

Ratings:
Type: Brush less, revolving field
Rated Voltage: 6,600/3810 ± 10 % volt, 3-phase,6- wire
Rated Output 4,800 kW, 6,000 kVA
Power factor range 0.8 lagging
Rated speed 1500 p.m.
Rated frequency 50Hz
Rated current 524.8Amp
Rotation counter clock wise (looking from exciter side.
Efficiency 96.5% minimum guaranteed at full load Over Speed Generator shall be capable of withstanding without adverse effects, over speed of 1875(+25%) rpm for the duration of 2 minutes.

Applications:

- Traditionally, waste heat of low temperature range (0-120 °C, or typically under 100 °C) has not been used for electricity generation despite efforts by ORC companies, mainly because the Carnot efficiency is rather low (max. 18% for 90 °C heating and 20 °C cooling, minus losses, typically ending up with 5-7% net electricity). In general, waste heat below 100 °C could be used for the production of bio fuel by growing of algae farms or could be used in green houses or even used in eco industrial parks
- Waste Heat of medium (120-650 °C) and high (>650 °C) temperature could be used for the generation of electricity or mechanical work via different capturing processes.
- Waste heat recovery system can also be used to fulfill refrigeration requirements of a trailer (for example). The configuration is easy as only a waste heat recovery boiler and absorption cooler is required. Furthermore, only low pressures and temperatures needed to be handled.

4. CONCLUSION

In this project, a large quantity of flue gases at high temperatures is produced by the kiln of the cement plant in to the atmosphere and that waste heat is also recovered at high efficiency.

- Amount of heat carried by exhaust air Q = 23979.2 kW.
- Heat carried by Thermic Fluid Q (waste heat recovered) = 22990 kW.
- Efficiency of the waste heat recovery = 95.8%.
- Efficiency of Format Energy Converter = 19 %.

In this study, it is concluded, that the Waste Heat Recovery Power Plant project generates electricity by deriving from the organic Rankine process, makes the recovery plant most efficient and clean over conventional plant for same power rating. This project can be treated as the efficient method of utilization of waste gases for the production of electrical energy and one can hope that the “Waste Heat Recovery “will play a significant role in the industrial development of 21stcentury.

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