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Underground Coal Gasification in the North Muara Tiga Besar Utara Area, East Merapi District, Lahat Regency, South Sumatera

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Abstract

The location of research is located in the North Muara Tiga Besar Area, East Merapi Sub-District, Lahat Regency, South Sumatera. The Geological setting of the North Muara Tiga Besar Area in the South Sumatra Basin is included in the Muara Enim Formation the age is Late Miocene.Coal in the Muara Tiga Besar Utara Area, has a calorific value of 5101-6399 Kcal / kg and is rank High in Bituminous Volatile C-High Volatile Bituminous B according to the ASTM classification. Average quality (proximate test) of Muara Enim Formation coal: sulfur 0.3-1.5% (adb); 1.3-2% ash (adb); inherent moisture 10-12% (adb); volatile matter 40.7-43.4% (adb); fixed carbon 44.5-44.9% (adb), total moisture 29.1-29.8% (Ar); relative density 1.29. Tanjung Enim South Sumatera coal average vitrinite content is (91,4% vol.); liptinite (3.9% vol.); inertinite (4,7% vol.). Eachmaceral or group maceralhas different physical and chemical properties. The variation of composition microscopy showed the changes ofplant communities or coal facies leading to varies of coal quality, with a average vitrinite reflectance value 0.47-0.84, generally the coal rank is subbituminous-bituminous Coal gasification is the process of converting coal into synthesis gas. One of the gas produced is a flammable methane gas. The process of coal gasification can be done by drilling at 2 (two) drill holes toward the coal seam which is the target of gasification coal seam at depth more than 100 meter. The first drill to inject oxygen (O_2) is pressurized like air or water, so it will burn in coal layer, while the second drill serves as a production well to drain raw gas to the gasification reactor for binds CO_2 and eventually methane gas (CH_4) will be flowed to a power plant

Keywords: *coal, gasification, synthesisgas, oxygen, CO_2, CH_4.*

Introduction

The availability of natural gas supply is a key factor in driving Industrial manufacturing operations. The potential of domestic natural gas is very large, however, Indonesia is expected to experience a natural gas deficit in 2022 if it does not find a new natural gas source, because the calculation of demand will increase compared to supply, whereas as with coal most of the natural gas is allocated to export. As is known that natural gas consumption in Indonesia as the final energy is the third largest after fuel oil and coal. The increase in the amount of natural gas needs is positively correlated with the wider use of natural gas for energy and industrial raw materials, as well as for household needs. With these conditions, the coal gasification technology has come to be developed especially for the interests of domestic industries, both as energy and raw materials.

In accordance with the National Coal Policy strategic program that for 2005-2010 are: Integrated Infrastructure, Underground Mining, Human Resources; The years 2010-2015 are: Coal Liquefaction, Increased Use of Domestic Coal, UBC (Upgrading Brown Coal), Coke; 2015-2020 are: Clean Coal Technology, Increased Use of LRC (Low Rank Coal). To support the National Coal Policy Strategic Program, as well as to reduce the rate of coal exploitation that is so fast, it is necessary to immediately undertake optimal and planned coal management efforts. One of the programs being carried out is the Underground Coal Gasification (UCG) system. There are 3 (three) types of processes that can produce gas from coal, namely ground coal gasification (conventional gasification), underground coal gasification (UCG) and coalbed methane (CBM).

Coal Gasification is the conversion of coal into a gas product in a reactor on the surface, with or without the use of reactants in the form of air, a mixture of air / steam (steam) or a mixture of oxygen / water vapor. The air needed is lower than the air used for the combustion process. During the gasification process the main chemical reaction that occurs is endotherm (requires external heat during the process). The gas produced from gasification using air has a lower heating value but on the other hand the operation process becomes simpler.

Underground coal gasification UCG is the conversion of coal into gas products directly below the surface (without carrying out coal mining activities), using reactors in the form of air, a mixture of air / steam or a mixture of oxygen / water vapor. The underground coal gasification process begins by drilling to reach the coal seam and carrying out a link / link followed by the gasification process. This is done by injecting an oxidant (usually air), identifying the coal seams and taking the gas products it produces to the surface of the earth through drill holes made from the surface so that it can eliminate the costs of mining and reclamation. The resulting gas can be used for electricity generation, industrial heat sources or chemical feedstock (Harijanto Soetjijo, 2006) Whereas coalbed methane (CBM) is methane gas trapped inside the coal seams at the time of the coalification process, its nature is similar to natural gas where coal functions as gas source rock so that it can be used for both fuel and raw materials chemical industry.

The development of underground coal gasification (UCG) in Indonesia is hampered by three things, there is still a lack of understanding of underground coal gasification (UCG) technology, unclear regulations and the potential to reduce the possibility of reservoir leakage if the reservoir is not suitable. The basic regulation of underground coal gasification (UCG) currently still refers to the Minerba Act and PP 77 of 2014 concerning the third amendment to government regulation No. 23 of 2010 concerning the Implementation of Mineral and Coal Mining Business Activities which states that one of the coal processing activities is coal gasification (coal gasification). Meanwhile, products from underground coal gasification (UCG) are gas which in fact fall into the category of oil and gas regime, so that mapping and determination of regulations need to be more clearly related to underground coal gasification (UCG).

According to the underground gasification (UCG) association there are around 350 m3 of gas that can be produced from 1 ton of coal with the production cost of UCG energy resources is less than US $ 1.0 - 1.5 per MMBTU (standard measurement unit for natural gas and is a standard to compare the energy content of various classes of natural gas and other fuels, MMBTU = 293.08kWh); (Sawhney, 2006 in Harijanto Soetjijo, 2006) The research location located in the Bitahan area, Rantau, South Kalimantan, is an active open mining area up to now. The area is very potential to be developed as an underground coal gasification field, considering that the open mining process is getting deeper and deeper, so it needs to be continued to develop subsurface coal gasification. Seam-A is an active seam that is currently being mined with a thickness of 15 meters, and is also a seam target for the development of underground gasification. Currently coal gasification technology is one of the right choices to convert coal into gas because gas products can be further processed to become various end products such as synthetic natural gas (SNG), ethanol, methanol, BBM, petrochemical, urea and electricity through integrated technology gasification combined cycle (IGCC) which is very environmentally friendly.

Geological Setting

According to Van Bemmelen (1949), the South Sumatra Basin is physiographically a Northwest-southeast Tertiary Basin, which is bounded by the Semangko Fault and Bukit Barisan in the southwest, the Sunda Shelf in the northeast, Lampung highland in the southeast which separates the basin from the Sunda Basin and the Twelve Mountains and Thirty Mountains in the northwest that separate the South Sumatra Basin from the Central Sumatra Basin. The South Sumatra Basin is a Tertiary old arc basin formed as a result of interaction between the Sunda Exposure (as part of the Asian continental plate) and the Indian Ocean plate. This basin area covers an area of 330 x 510 km^2, of which the southwest is bordered by the Pre-Tertiary outcrop of Barisan Hill, to the east by the Sunda Shelf (Sunda Shield), to the west bordered by the Tiga Puluh Mountains and to the southeast by Lampung highland (Barber et al, 2005); (Figure 1).

The South Sumatra Basin is influenced by 3 tectonic phases, namely the Syn-Rift Megasequence phase which lasted 45-29 million years ago, Post-Rift Megasequence at 29-5 million years ago and which lasted 5 million years ago (Ginger and Fielding, 2005). The research area (Lahat area) is included in the Syn Orogenic / Inversion Megasequence tectonic phase, which in this phase according to Ginger and Fielding (2005) has formed many structural traps for hydrocarbons in the South Sumatra Basin. The major structure that develops in the Muara Tiga Besar area is an anticline that has an East-West directed axis. The research area is in the northern wing of the anticline and has a relatively similar position (homocline) with the slope of the layer to the north. The research area is included in the Muara Enim Formation which is one of the infill formation of the South Sumatra Basin. According to Sosroamidjojo (2009) the Muara Enim Formation is composed of sandstones, claystone, with coal inserts. According to Ginger and Fielding (2005), the Muara Enim Formation is Late Miocene. At the time of the Late Miocene, there was an increase in volcanic activity in the Bukit Barisan Mountains. Most of the formation sediment material is deposited in the fluvio-deltaic environment.

Coal in the study area belongs to the High Volatile Bituminous rating according to the ASTM classification.
Stratigraphy of the South Sumatra Basin can generally be known as one megacycle (large cycle) consisting of a transgression and followed by regression. Formations formed during the transgression phase are grouped into Telisa Group (Talang Akar Formation, Baturaja Formation, and Gumai Formation). The Palembang group was deposited

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during the regression phase (Air Benakat Formation, Muara Enim Formation, and Kasai Formation), while the Lemat and older Lemat Formations were deposited before the main transgression phase (Figure 2).

The study area is composed of Muara Enim sandstone units with lithology in the form of flaser structure sandstones, carbon laminated sandstones, glauconitic sandstones, coal interbedded and Muara Enim claystone units with lithology in carbonic claystone, lenticular claystone, laminated claystone, laminated claystone, tuf sandstone, coal interbedded . The Muara Enim sandstone unit contains coal seam C (Petai) and D seam (Merapi), while in the Muara Enim claystone Unit contains A seam (Mangus as the research target) and seam B (Suban); (Figure 3)

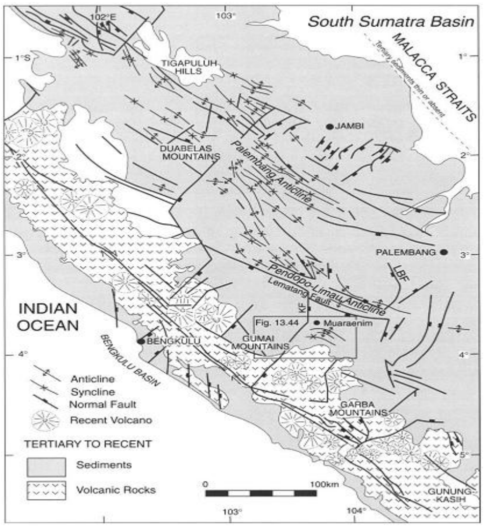

Figure 1. Main structure of the South Sumatra Basin (Barber et al, 2005)

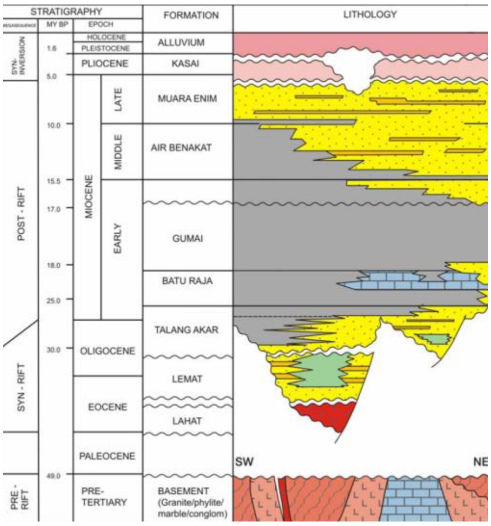

Figure 2. Regional Stratigraphy (Ginger and Fielding, 2005)

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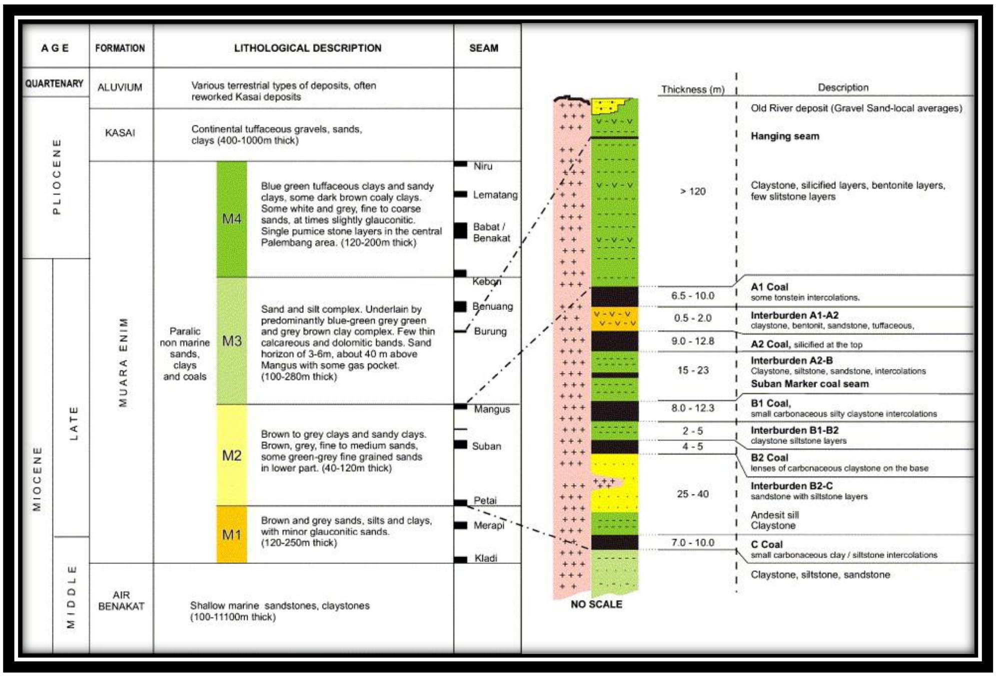

Figure 3. Stratigraphy and Coal Formations of Muara Enim (Shell Mijnbouw, 1978)

Methods

This research was conducted in the coal mining in Lahat area and its surroundings. The research methods carried out in the field are coal observation and sampling and infrastructure data collection for gasification development planning. The main target of coal seam is Seam Mangus Seam A-1 in Muara Enim Formation (Figure 4). The method for taking coal samples is carried out directly in the outcrop of coal mine walls at seam-A by the ply by ply method, based on the appearance of the lithotype macroscopically. Then each sample is reduced in size, and a composite is then divided into two for archives and laboratory analysis.

Figure 4. Outcrop of Mangus Coal Seam A-1

Laboratory analysis work includes:

a. Proximate analysis of coal

b. Microscopic analysis of coal to identify mineral composition, minerals and vitrinite reflectance values. Coal samples taken from the core are in the form of drill then prepared for polishing incisions. In sample preparation several tools and materials are needed such as:

   1. Coal samples
   2. Resin powder (transoptic powder)
   3. Pounder Tool

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4. Sizes 16, 20 and 65 mesh sizes
5. Print polished briquette, heaters, thermometers, and presses
6. Grinder-polisher
7. Silicon carbide sizes 800 and 1000 mesh and alumina oxide size 0.3; 0.05; and 0.01 microns
8. Glass preparations and night candles

Coal samples obtained from the drill core are reduced by coning and quartering to obtain the appropriate number of samples for analysis needs. Next, the coal samples were crushed manually and sifted using 16 mesh and 20 mesh sieves, the coal grain size fraction -16 mesh +20 mesh obtained was used for coal petrographic analysis.
The coal fraction size -16 mesh +20 mesh is then mixed with resin powder (transoptic powder) with a ratio of 1: 1. The mixture is then put into the mold and heated to 200^{o}C. After the temperature reaches 200^{o}C the heater is turned off and the mold is pressured to 2000 psi. Briquette can be removed after the temperature reaches room temperature. The next stage is briquette polishing which starts with cutting using a polishing tool (grinder-polisher) then smoothed with silicon carbide size of 800 mesh and 1000 mesh above the glass surface. Next polished using alumina oxide measuring 0.3 microns, 0.05 microns, and finally measuring 0.01 microns on silk or silk cloth. The resulting polishing incision is placed on the preparatory glass with the night candle holder then leveling.

Observation of polishing incisions is done using a reflectance microscope both qualitatively and quantitatively to determine the mineral content and minerals in coal. Microscopic research using reflected light with 200 times magnification with observation of 500 points.

The analysis process was carried out at the Coal Petrographic Laboratory, TekMIRA Research Center, Bandung. Coal Mining Classification uses Australian standards (AS 2856, 1986) and the microscope used is Microscope Spectrophotometer Polarization with Fluorescence, type: MPM 100, brand: Zeiss.

Microscopis Characteristics of Mangus Coal Seam A-1

The results of the microscopic analysis of Muara Enim Formation Coal, Lahat District, South Sumatra, all samples were taken from coal outcrop data on the coal mine wall (Figure 4). Microscopic (maseral) composition of Mangus Seam A-1 Muara Enim Formation is divided into Vitrinite, Liptinite and Inertinite maceral groups. The average percentage of the vitrinite maceral groups in the Muara Enim Formation is 91.4%, the average Rv (random) ranges from 0.47 – 0.84% (rank: sub-bituminous-bituminous).
Vitrinite maceral group consists of subgroups:

a. Telovitrinite for the Muara Enim Formation, Lahat Region, Maseral Telovitrinite consists of telocolinite. Telocolinite under a microscope shows gray to dark gray, forming bright layers
b. Detrovitrinite (Muara Enim Formation), consists of maceral densinite and desmocolinite. Desmocolinite in the form of fragments that are surrounded in inertinite, liptinite or can be in other mineral materials. Maseral densinite is the result of gelification of attrinite maceral with a low level of gelification. The detrovitrinite maceral group is a component that forms (detrital) fragments of vitrinite masses (Stach, 1982). Maseral detrovitrinite can function as a gas storage which is a component formed from detrital from vitrinite maceral originating from shrubs or from woody plants with high bacterial activity. Shrub plants are easily reconfigured during the humification stage so that they form a detrital component. High bacterial activity will be able to turn wood plant cells into detrital maseral. This detrital component has more cell fragments and large porosity so that the gas absorbed in the internal mineral maseral coal will increase along with the increase in the mineral mass derived from this shrub (Stach, 1982).
c. Gelovitrinite for the Muara Enim Formation, consists of metallurgical maceral. Microscopically, corpogelinite maceral seems homogeneous, round to oval, usually isolated in desmocolinite.

Coal mineral as a representation of components of plant species from which coal is formed greatly determines the characteristics of coal, especially the quality of coal. The composition of coal microscopy, especially coal mineral components shows the basic ingredients of coal constituents. Each coal maceral group has different physical properties and chemical composition (Figure 5). Vitrinite is a result of the process of pembatubaraan humic material derived from cellulose ($C_6H_{10}O_5$) and lignin plant cell walls containing wood fibers such as stems, roots, leaves, and roots. Most of the vitrinite macral group originates from the acid-humic fraction of the humic core, in the form of dark compounds from complex compositions.The compound contains elements of carbon, oxygen, hydrogen and nitrogen. Vitrinite has a variety of heavy and soluble molecules, has an aromatic nucleus and contains functional groups of hydroxyl (-OH) and carboxyl (-COOH). The compound is formed during peatification and mouldering, even partially in the brown coal stage, mainly from plant cell walls in the form of lignin and cellulose. In addition to the original material, the formation and characteristics of humic acid are dependent on environmental conditions related to the redox potential value (eH) and pH.

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Plant core is easier to hydrolyze, such as: disaccharides, starch, cellulose, hemicellulose, pentosanes, pectins and proteins decomposed without any difficulty by bacteria and fungi, some produce methane gas (CH_4) and fluid (carbon dioxide, ammonia, methane (CH_4) and water, which will come out and remain until it produces solid material (especially humik substances), which participates in coal formation. Relatively stable lignin has a better preserved structure and is concentrated in peat compared to wood residues that are not rich in lignin, for example is cellulose-rich tissue in herbaceous plants, physical properties of maceral groups, such as vitrinite which have an average density of 1.24 and high oxygen content and volatile matter content of around 41.68% which can produce methane (CH_4) or gas prone: The relatively high content of vitrinite in Muara Wahau coal is included in type III kerogen as a characteristic from organic humic matter comes from high-level woody plant tissue (angiosperm). The Vitrinite is a high-density methane (prone gas) maseral.

The average percentage of Liptinite groups for the Lahat Region of Muara Enim Formation is 3.9%, consisting of mineral: sporinite, resinite, cutinite, alginite and suberinite. The liptinite group comes from plant organs (algae / algae, spores, spore boxes, outer skin (cuticles), plant sap (resin) and pollen / pollen). The liptinite group is rich in aliphatic bonds and has the most hydrogen content and the least carbon content compared to other maceral groups (Figure 5). Liptinite has the specific gravity of 1.0 - 1.3 and the highest hydrogen content compared to other maceral, while the volatile matter content is around 66%. Liptinite will produce oil (oil prone).

The average percentage of inertinite maceral groups for the Lahat region of Muara Enim Formation is 4.7%, consisting of maceral subgroups: fusinite, semifusinite, sclerotinite and inertodetrinite. Mineral inertinite group is a mineral which is relatively rich in carbon (C), has the highest reflectivity and low flouresense, has strong aromatic properties due to several causes: charring and oxidation of plant fibers. So inertinite is a component that is oxidized because of reduced peat moisture. The inertinite group is thought to come from plants that have been burned (charcoal) and some are thought to be due to the oxidation process from other maceral or decarboxylation processes caused by fungi or bacteria (biochemical processes). With this process the inertinite group has a relatively high oxygen content, low hydrogen content, and an O/C ratio higher than the vitrinite and liptinite groups.

Inertinite comes from the word "inert" containing basic elements that are not reactive and contribute to the blending of coking coal such as fusinite, semifusinite and sclerotinite maceral. Inertinite comes from cellulose and lignin from plant cell walls. These constituents undergo fucinitization during bonding (Taylor et al., 1998). The characteristic of inertinite is high reflectivity, little or no flouresense, high carbon content and little hydrogen content, strong aromatics due to several causes, such as charring, mouldering and destruction by fungi, biochemical gelification and plant fiber oxidation (Figure 5).

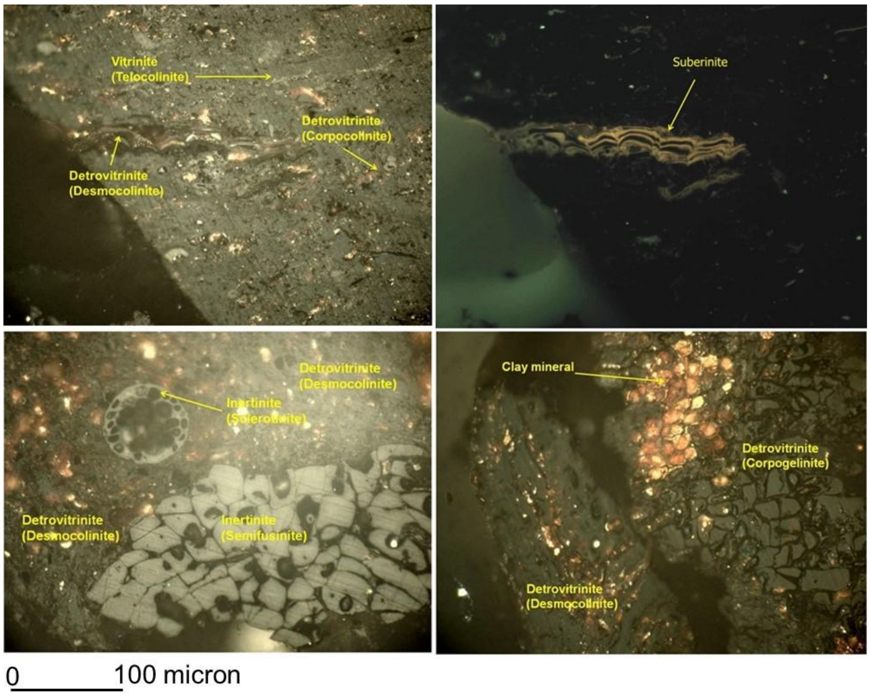

Figure 5. Seam A-1coal microscopic maceral appearance.

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Results and Discussion of Underground Coal Gasification Processes

There are three parameters that must be considered in the implementation of an underground coal gasification process. The first parameter is geological parameters such as layer thickness, type of cover layer, and base layer. The second parameter is coal properties such as water content, ash content, nature of development. The third parameter, is the parameter of gasification operations such as volume, pressure, the distance between the inlet and exit holes or the length of the gasification zone, temperature (Wieber & Sikri, 1978, in Harijanto Soetjijo, 2006). there are many factors that can influence the gasification process, one of the factors that should be considered is the coal gasification zone that is formed or formed during the process.

The basic concept of the UCG process, according to the UCG Association, is to use 2 wells into the coal seam, the first well is used to inject oxidants (*hot steam*), while the second well is used to bring gas to the surface.
Coal seam gasification is the process of converting coal seam into synthesis gas. One of the gases to be produced is methane gas which is flammable. Changes in coal into flammable gas occur through several chemical processes in the gasification reactor.

The initial stage is to develop CO_2 fixation technology on coal seam, where coal seam heaten up to reaction temperature and undergoes pyrolysis or refining. Coal, except impurity minerals, are converted to Hydrogen (H_2), Carbon Monoxide (CO), and Methane (CH_4), with gas reagents mainly oxygen (O_2) and steam.
The process of underground coal seam gasification can be done simply by drilling 2 drill holes in the direction of coal seam at a depth of more than 100 meters, the first drill to inject pressurized oxygen such as air or water, thencoal seam burning occurs, the second drill serves as a well production to flow raw gas to the gasification reactor to bind CO_2 and methane gas (CH_4) is flowed to the power plant (Figures 6 and 7).

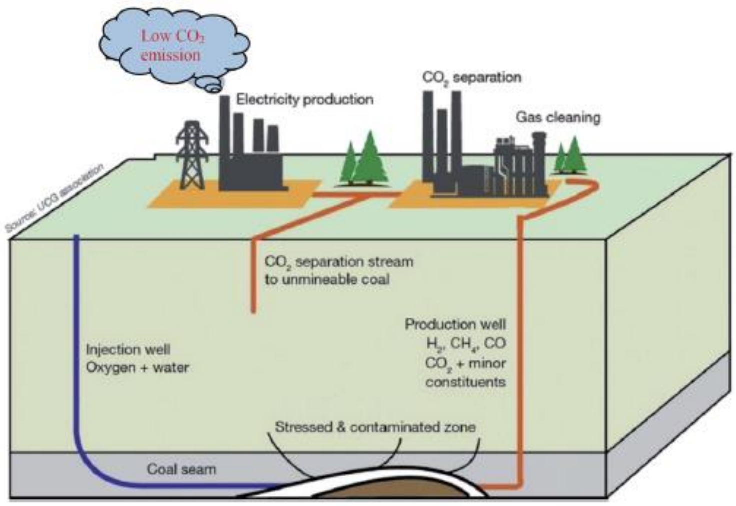

Figure 6. Schematic diagram of an underground coal gasification system (Guo et al., 2016)

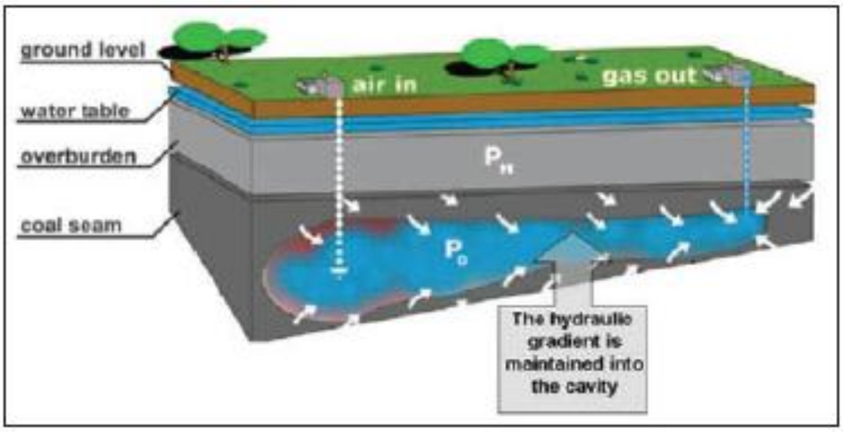

Figure 7. Flow chart of utilization of methane gas from underground coal gasification (Mark et al., 2006)

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The principle of underground coal seam gasification processis same as gasification process on the surface, producing a gas from mixture of hydrogen, carbon monoxide, methane, carbon dioxide and higher hydrocarbons. The gas obtained using air injection has a heating value between 3.5 to 5.0 mJ / m3. Some classifications of heating values are: low-BTU (180-350 BTU / SCF); medium-btu (250-500 btu / scf); high-btu (950-1000 btu / scf). The gasification reactor can be developed by drilling and connecting several injection wells and production wells.There are several coal geological factors such as: coal reserves, coal seam geometry, seam thickness, hydrogeology and lithology types of coal seam seam sediments are determinants of success for making gasification reactors.
The underground coal seam gasification process is more friendly forsuistanable living than coal fired power plants, such as:

a. Reducing the risk of workplace accidents on the surface during operations.
b. Higher worker security.
c. There is no disposal of ash from coal combustion.
d. Easier to rehabilitate the environment.
e. Have possibility to remove CO_2 gas from coal combustion.

Underground gasification is different from other gasification methods because this method is carried out in coal mine far below the ground so that interpretation of subsurface geological conditions must be used in designing and building underground gasification systems as well as selecting operations that guarantee the stability and consistency of gas production (Figure 6).

The parameters of this process, such as pressure, output temperature, and flow are affected by rock and coal types which vary in diffrent location. Information on the condition of the gasification process should always be monitored and updated. Process parameters must be adjusted to accommodate changing conditions from gasification. The advantages of operating extensive underground coal seam gasification, as follows:

a) Unlimited coal supply for gasification because it does not require coal and water supply to continue the reaction.
b) The Gasification Process Underground coal produces a very large underground and heat gas capacity, so the gas supply is very stable and constant.
c) Underground gasification is made of several underground reactors with each large output. Gas flow from several reactors can be mixed as needed to maintain overall gas quality. The reactor output can be designed in such a way as to optimize coal extraction and gas supply from the entire gasifier.
d) There is no ash and crust produced and does not require further handling because it is underground.
e) Groundwater flow in the gasifier produces an effective vapor layer around the reactor so that the heat lost is small.
f) The optimal pressure on the underground gasifier increases the flow of ground water into the cavity holding chemical processes at the gasifier boundary and maintaining contamination in the area.

Conclusions

Underground Coal Seam Gasification Technology provides a bright opportunity and prospect for the commercialization of the national electricity industry, in order to utilize unused excess coal reserves, especially underground mining.More benefits from Gas and Steam Power Plants with Underground Coal Technology, are as follows:

1. The gas used to generate electricity in the Gas and Steam Power Plant system, comes from the coal gasification process that takes place underground, so that pollution is minimal.
2. The Gas and Steam Power Plant is an application of coal seam utilization technology in Indonesia to meet the electricity supply by utilizing underground coal seams which have not yet carried out their potential value.
3. Does not change the land use system significantly.
4. Suppress the negative impact of electricity generation on the environment.
5. Obtain additional supply of clean water as a by-product of the coal gasification process.

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Lembar Tanya Jawab

Moderator : Soeprijanto (Teknik Kimia, Institut Teknologi Sepuluh Nopember)
Notulen : Heni Anggorowati (UPN "Veteran" Yogyakarta)

1. Penanya : Gyan Prameswara (Teknik Kimia UGM)
   Pertanyaan : Apakah ada dampak dari proses gasifikasi batubara bawah tanah terhadap lapisan tanah diatasnya?
   Bagaiamana cara mengetahui bahwa gas CH_4 dalam tanah tersebut sudah habis?
   Jawaban : Proses gasifikasi batubara bawah tanah ini tidak mempunyai dapak terhadap lapisan tanah di atas nya sehingga lebih aman.
   Prinsip dari rekasi pirolisis adalah gas CH_4 akan mengalir menuju tekanan yang lebih rendah sehingga gas CH_4 yang dihasilkan akan terus mengalir dan tidak akan habis selama masih ada batubara di bawah tanah.

2. Penanya : Reonaldo (Teknik Kimia UPNVY)
   Pertanyaan : Pada penelitian ini proses gasifikasi hanya dilakukan pada seam A-1, apakah memungkinkan untuk dilakukan pada seam A-2 dan seam B?
   Jawaban : Kedepannya akan dilakukan pada ketiga seam tersebut tetapi karena ini untuk tahap awal pada permukaan maka hanya dilakukan pada seam A-1 tetapi untuk kajian selanjutnya juga akan dilakukan pada seam A-2 dan seterusnya. Seam A-2 ke bawah dengan tebal hampir 9 meter akan sangat memungkinkan untuk dilakukannya gasifikasi karena semakin dalam batubara maka potensi gas nya juga akan semakin besar.

3. Penanya : Yusuf Rizky Rahmantria (Teknik Kimia UPNVY)
   Pertanyaan : Apakah proses *underground gasification* ini berdampak terhadap lingkungan sekitar?
   Jawaban : Proses *underground gasification* sangat ramah terhadap lingkungan sekitar. Salah satu keuntungan menggunakan *underground gasification* adalah tidak adanya *fly ash* dari hasil pembakaran batubara. Seperti yang kita ketahui bahwa pada PLTU yang ada saat ini salah satu permasalahan nya adalah polutan berupa *fly ash*.

4. Penanya : Erinda Yuliana (Teknik Kimia UPNVY)
   Pertanyaan : Apakah ada perubahan nilai kalor batubara setelah proses *underground gasification* ?
   Apakah proses gasifikasi ini dapat dilakukan untuk semua jenis batubara?
   Apakah dilakukan disulfurisasi pada proses gasifikasi ini?
   Jawaban : Pada proses *underground gasification* ketika gas diambil, kalori masih tetap ada, bahkan setelah gas tersebut habis, batubara masih bisa ditambang.
   Semua jenis batubara dapat dilakukan proses gasifikasi bawah tanah.
   Disulfurisasi selalu dilakukan di PLTU dan tidak dilakukan pada proses penambangan.

5. Penanya : Violita Indrayani Putri (Teknik Kimia UPNVY)
   Pertanyaan : Apakah gas yang dihasilkan dari proses gasifikasi dalam tanah ini hanya gas CH_4 atau ada gas – gas yang lainnya?
   Jawaban : Batubara mengandung 80% CH_4 sisanya adalah CO_2 dan O_2 dan semua gas tersebut ikut keluar dari hasil gasifikasi bawah tanah.