Application of the Exergy UCG technology in international UCG projects

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Abstract. Underground Coal Gasification is a subject of continuing global interest in the energy sector. While the international scenario in UCG is promising, it is deeply desirable that advances in this area are seen in India as well. This is particularly so with the Paris Climate Agreement bringing in more stringent challenges for clean energy development. India has many potential coal basins which may be suitable for UCG deployment. India is in dire need of indigenous source of gaseous and liquid hydrocarbons that could compete with imported products. It is also the country with exceptionally large and diverse coal and lignite resources, large part of which could not be mined due to geological complexity and prohibitive cost. Thus, there is a rationale that the εUCG™ technology plays a decisive role in realizing the potential of Indian coal resources for the benefit of Indian industry and population.

1. Background
Underground coal gasification (UCG) can be commercialized only if it demonstrates consistent syngas quality and consistent production output (with a variability of less than 1%) and can be applicable at a commercially significant scale. What is a commercial scale for a UCG plant? We would like to suggest that UCG should operate in a cost-effective and environmentally sustainable way, producing syngas flow rates equivalent to about 1 Mt/year of coal or lignite, with an economic plant life of up to 30 years. (Although in some special circumstances, smaller plants may also prove to be commercially viable). As an example, a 300 MW IGCC power plant running on syngas produced by a εUCG™ plant gasifying typical Gujarat lignite would consume about 1.7 MT of coal per annum. Thus, commercial plant requires large coal reserves of the order of 50 million tons, with extraction efficiency of 90-95%, which has been demonstrated by εUCG™ technology. In terms of stable quality of syngas product, the following process represents an inherent challenge for UCG technologies. The UCG cavity can be considered as a chemical reactor with walls made up of coal. This means that the size of this reactor is continuously changing, as the diameter goes on increasing. This leads to lower gas velocity due to the equation of continuity. A lower gas velocity leads to less turbulence, which leads to a poorer level of heat and mass transfer. This, therefore, leads to lowering gas quality eventually showing increased oxygen content in the production well. At this point of time, the operations need to be stopped and parameters revised. Any successful UCG technology aspiring to achieve commercialization must demonstrated how it overcomes this syngas deterioration phenomenon.

Controlled retracting injection point (CRIP) has been suggested by Hill and Shannon [1] as a solution for syngas deterioration issue. This allows the operator to choose optimal time and distance in movement of the injection point. It is a very popular approach and many simulation studies have been developed to model this process [2]. However, the process has inherent issues as the gas quality

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deteriorated in the same way as conventional UCG processes (even though the quality was slightly better) as evidenced by performance of Rocky Mountain 1 UCG trial (1986-1988). As an alternative to this, parallel CRIP method was suggested. This also presents some in-built challenges as it turns uneconomical with greater width of the channel (the effect of “cannibalizing” the product gas). This problem may be solved by allowing the roof to collapse strategically such that the width of the channel reduces to around 3 metres and improvement of reaction is seen. Therefore, the basic principle here is that the cavity should not be allowed to grow uncontrollably, failing which the reaction process becomes extremely slow. Another issue with CRIP based systems is the mine plan i.e. significant cross-flow and mixing of the gases in the reactors was seen if they were not far apart. With increase in the distance between the two reactors, the extraction efficiency reduces to uneconomic levels.

Similarly, bord and pillar method may also not be used to UCG processes due to risks of spontaneous combustion, uncontrolled overburden deformation and loss of water resources. Thus, there may be a great difficulty in completely rehabilitating the operational site.

2. The εUCG™ technology

The Exergy UCG™ (εUCG™) technology, unlike a conventional UCG processes, is not a two well process. Rather, it is a large scale mining method. It has inbuilt advantages in terms of rock deformation and water influx management. It involves drilling of directional, inclined, vertical and other wells, and has been developed based on 75 years of Soviet UCG experience. The average panel capacity in this technology is about 5 PJ/a, while the mine average coal extraction rate is around 95%. The technology has shown suitability with a wide range of coals as shown in Table 1.

| UCG Plant      | Rank  | Thickness, m | Depth, m | Dip, ° | LHV, MJ/kg |
|----------------|-------|--------------|----------|--------|------------|
| Lisichansk     | Bituminous | 0.44 - 2.0   | 60-250   | 38-60  | 20.1-23.0  |
| Yuzhno-Abinsk  | Bituminous | 2.2-9.0     | 130-380  | 35-58  | 28.9-30.7  |
| Podmoskovnaya  | Lignite  | 2.5         | 30-80     | <1     | 11.8       |
| Angren         | Lignite  | 3.0-24.0    | 110-250  | 7      | 15.3       |
| Shatskaya      | Lignite  | 2.6         | 30-60    | <1     | 11.0       |
| Sinelnikovo    | Lignite  | 3.5-6.0     | 80       | <1     | 8.0        |
| Chinchilla     | Sub-bituminous | 10.0        | 135      | <1     | 21.7       |
| Majuba         | Bituminous | 3.5-4.5    | 285      | 3      | 20.3       |
| Kingaroy       | Sub-bituminous | 17.0       | 200      | 5      | 23.5       |
| Huntly West    | Bituminous | 4.0-22.0   | 220-540  | 0-75   | 24.5       |
| CC Alberta     | Sub-bituminous | 7.0        | 150-260  | 6      | 20.5-23.0  |
| Alaska SHR     | Lignite/Sub-bituminous | 1.0-12.0  | 50-650   | 0-75   | 11.0-16.5  |

The Exergy UCG™ (εUCG™) technology is a technology for extracting the energy and hydrocarbons from underground unminable fossil fuels deposits, such as coal, lignite or shale, by converting them into gaseous and liquid hydrocarbons in a gasification process performed in situ, whereby drilled wells are used for delivering oxidant for gasification process and transporting products to the surface for processing and beneficial use. The εUCG™ technology was developed by Ergo Exergy Technologies Inc and has been applied in multiple international UCG projects.

The εUCG™ technology can help create a large-scale source hydrocarbons from unmineable coal or lignite in the countries and areas where there is no other source of natural gas and petroleum. This source of hydrocarbons is indigenous, safe, environmentally clean and carbon-efficient. Thus produced, the hydrocarbons have highly competitive costs and therefore can be used as fuel for high-efficiency power generation or as raw materials for synthesis of clean fuels and chemicals, including automotive fuels, ammonia-based fertilizers, synthetic methane, DME etc.

The εUCG™ technology is a large-scale mining technology with a typical panel capacity of about 0.3 million metric tonne per annum. The process incorporates controlled rock deformation and ground water influx into underground reactors. Depending on quality of coal and specifications for required
products, the process may include injection of compressed air, oxygen, steam and water, carbon dioxide and other oxidants. Injection of oxidants and production of syngas is effected via drilled boreholes, design of which is suited to geologic condition and includes vertical, inclined and directional wells. In the root of the \( \varepsilon \text{UCG}^{\text{TM}} \) technology lies the stream method of UCG, developed and commercially exploited in the former USSR for more than 70 years. In the last 20 years the \( \varepsilon \text{UCG}^{\text{TM}} \) technology has been applied in the projects developed in Australia, New Zealand, Canada, South Africa and the USA.

In relation to global warming concerns, the gaseous products of \( \varepsilon \text{UCG}^{\text{TM}} \) technology can be used for power generation in a high-efficiency IGCC plants with significant reduction of CO\(_2\) emissions compared to coal-fired plants. Besides, the concentrated gaseous product stream of the \( \varepsilon \text{UCG}^{\text{TM}} \) technology provides an easy and inexpensive opportunity for CO\(_2\) capture and sequestration. The latter is aided by creation of underground cavities in the course of gasification process, which after cooling may be used for storage and sequestration of supercritical carbon dioxide. In this case the carbon footprint of a \( \varepsilon \text{UCG}^{\text{TM}} \) IGCC plant would be lower than that of a natural gas CCGT plant. The typical cost of hydrocarbon products of the \( \varepsilon \text{UCG}^{\text{TM}} \) technology is approximately $1.00 per MMBTU, although the actual cost may vary with the depth and thickness of the coal seam and the coal quality. Specific projects where \( \varepsilon \text{UCG}^{\text{TM}} \) technology has been applied will be considered in this lecture in detail. They took place in greatly varying geologic and hydrogeological conditions and have been very successful in demonstrating capabilities of technology to safely produce low cost hydrocarbons while always protecting the environment, especially the groundwater.

It is expected that this technology will lead to significant cost reductions in Indian conditions (as shown in Table 2).

### Table 2. Costs of various product with \( \varepsilon \text{UCG}^{\text{TM}} \) technology, as against market price

| Parameter                  | \( \varepsilon \text{UCG}^{\text{TM}} \) | Market price |
|---------------------------|------------------------------------------|--------------|
| Cost of Electricity ($/MWh)| 21.79                                    | 48.23        |
| Cost of SNG ($/mmBTU)     | 2.14                                     | 2.72         |
| Cost of Methanol ($/tonne) | 69                                       | 315          |
| Cost of Gasoline ($/Gallon)| 0.66                                     | 3.90         |
| Cost of Methanol ($/Gallon)| 0.94                                     | 3.22         |
| Cost of Urea ($/tonne)    | 106                                      | 413          |

3. Conclusions
There is significant repository of resource, regulations and expertise in terms of UCG deployment in India. The \( \varepsilon \text{UCG}^{\text{TM}} \) is a well-established technology with evident advantages, already shown in the Chinchilla I project and other operations around the world. The technology overcomes several of the shortcomings shown in the CRIP and bord and pillar methods. The cost of various commodities with this technology is well below the market price. The technology has also demonstrated sustainability as no major environmental issues have surfaced in the operations [3]. The writing on the wall is now clear – UCG in India needs to take-off with committed developers and investors. Coalfields in various part of the country may be suitable for UCG and an optimum path may be set for its deployment to generate a clean energy alternative, which also caters to natural gas availability and cheap electricity.

References
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