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EPRI AP-3599
Project 1411-1
Final Report
July 1984

Solid-Liquid Separation for Liquefied Coal Industries

Prepared by
University of Houston
Houston, Texas

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Research Project 1411-1

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Research Category: Coal-derived liquids

NOTICE

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ABSTRACT

This book has been written for engineers concerned with separation processes related to liquefied coal slurries. Difficulties in removing mineral residues and unconverted carbon represent a major obstacle to economic production of liquefied coal products. Reactor slurries in which hydrogenation has been used to upgrade coal generally contain 5-10 weight percents of solids which must be removed. Various kinds of equipment employed for particulate removal include rotary drum pressure, candle, and leaf filters, solid bowl centrifuges, hydrocyclones, and critical solvent de-ashers.

Although emphasis has been given to filtration of solvent refined coal, much of the material is of a fundamental character and is applicable to other fields. Analysis of filtration data requires an understanding of the principles of frictional flow through compressible beds of particulates. Much of the analysis appearing in the literature must be carefully evaluated as errors and misinterpretations abound.

EPRI PERSPECTIVE

PROJECT DESCRIPTION

One of the major problems in coal liquefaction processes is how to separate solids, mineral matter, and unconverted coal from liquefaction products. A study and survey were made of various solid-liquid separation (SLS) schemes used in process development since 1970. A general background to solid separation technology was sought to produce a well-rounded treatise on the technology and to provide a useful guide for the technical community. Filtration of solvent-refined coal (SRC) was emphasized, although much of the research material is of a fundamental character and is applicable to other fields.

PROJECT OBJECTIVES

The primary objective of this project (RP1411-1) was to search for, review, and evaluate SLS technology developments in coal liquefaction processes. A second important objective was to critically analyze selected experimental data, since current methodology is not always applied. Other objectives were to significantly emphasize filtration of SRC liquids and to supply methodology generally applicable to filtration.

PROJECT RESULTS

Most of the significant coal liquefaction process development efforts in the United States, the United Kingdom, and the Federal Republic of Germany are referred to in this work. Many approaches to the solid separation problem were investigated and the results were critically analyzed. A general background to SLS was developed. Solid separation as a division of particle technology and dependence on particle science was discussed. Equipment and processes utilized in pertinent liquefaction applications were discussed in the context of the current technology. Particle-characterization methods and particle-size distributions of liquefied coal slurries were explored. Interfacial phenomena of particles in coal-derived liquids were considered. Flow through porous media related to cake filtration was thoroughly developed. The application of classical filtration behavior analyses and preferred analyses was suggested. Extensive data from the Wilsonville SRC pilot plant were analyzed and interpreted, and application of the Wilsonville experience was projected.

The final report supplies an authoritative treatment of SLS technology as it relates to coal liquefaction. The book contains ample references for each chapter, significant papers, articles, literature reviews, and selected abstracts.

Norman C. Stewart, Project Manager
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SUMMARY

Following an introduction in Chapter 1, a general background to solid-liquid separation (SLS) is developed in Chapter 2. The position of SLS as a division of particle technology is discussed. Particle technology is shown to depend upon particle science which has the major subdivisions of particle categorization and surface chemistry or interfacial phenomena. SLS is divided into four major areas of (1) pretreatment, (2) thickening, (3) separation, and (4) post-treatment. Chemical and physical pretreatment operations are employed to increase particle size and to simplify subsequent operations. Gravity or centrifugal thickening removes a large fraction of the liquid prior to the more expensive filtration and centrifugation. Post-treatment is involved with filtrate clarification and washing and deliquoring of cakes.

Equipment and processes utilized in separation of ash and char from liquefied coal are discussed in Chapter 2.

Particle characterization is the subject of Chapter 3. Coal macerals and asphaltenes are discussed as they relate to liquefaction. Analyses of particle size distribution of liquefied coal slurries using the Coulter Counter, microscreens, sedimentation techniques, and the scanning electron microscope are compared.

Joseph Henry, Jr. contributed Chapter 4 which deals with interfacial phenomena of particles in coal derived liquids.

Basic principles of flow through porous media constitute the subject of Chapter 5. Parameters involved in porous media and Darcy's law provide the background for the chapter. The concept of drag or effective pressure is developed. Drag forces cause rearrangement of

particles in porous beds. Behavior is classified in accord with cake compressibility which is broken down into (1) incompressible, (2) moderately compressible (kaolin, liquefied coal solids), or (3) highly compressible (colloidal silica, flocculated waste water). Concepts of permeability and specific flow resistance are introduced.

In Chapter 6, the principles of Chapter 5 are used to develop formulas for cake filtration. Porosity and liquid pressure variations as a function of distance are derived. Volume vs. time relations for constant pressure, constant rate, and centrifugal pump filtration the heart of this chapter. Classical methods for analyzing filtration behavior are shown to be in error. Preferred methods of analysis are introduced.

Chapter 7 deals with the analysis of data taken during the filtration of liquefied coal. Data coming from the Wilsonville SRC plant indicate that clogging of both cake and medium by fine migrating particles is of major importance. Chapter 8 deals with continuous, rotary drum filtration. Cycle analysis is the subject of Chapter 9. Experimental equipment used for laboratory studies of filtration characteristics of liquefied coal slurries is covered in Chapter 10. The appendix is devoted to summaries and comments on representative articles which have appeared in the literature.

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