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DEVELOPMENT OF A VOID FRACTION METER FOR MEASUREMENT OF GAS HOLDUP AT HIGH TEMPERATURE AND PRESSURES

(part of the Program of the Federal Panel on Energy Research and Development----PERD)

Final Report by: ARJAY Engineering Ltd.
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Work on the project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy Mines and Resources Canada

SSC FILE No. 06SQ.23440-9-9155
Contract File No. 23440-9-9155/01-SQ

Canmet Scientific Authority: C. M. Hogan

Dated: November 5, 1993

ARJAY

October 12, 1993

Canmet
555 Booth Street
Ottawa, Ontario K1A 0G1

Attn: Ms. Charlene Hogan

Re: File# 06SQ-23440-0-9155

Dear Charlene:

We are pleased to include the compiled final report consisting of all progress reports referenced to the above file.

We advise that this completes the project as described in the "Statement of Work".

Should you have any further questions or concerns, please do not hesitate to call.

Yours truly,

Greg Reeves.

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Executive Summary

The following is, in part, from the "Statement of Work" as provided in the original contract by CANMET.

The program is to further test and optimize the very preliminary design and construct and test a prototype for operation at hydrocracking conditions. The program was divided into tasks.

A brief summary by Task Number is recorded as follows.

Task 1. A cradle system of multiple sensors attached to a bubbler column initiated this project. The ARJAY Capacitance level monitor (Model 8370) was used to retrieve various readings from the sensors. Results were positive in finding a relationship between gas hold up and capacitance.

Task 2. A multiple sensor probe was designed by ARJAY to allow complete submersion into the bubble column. Under these physical conditions, the ARJAY capacitance monitor was able to record linear relationships between gas hold up and capacitance.

Task 3 & 4. Continued tests by the University of Waterloo using Varsol and air provided data on various correlations that confirmed the potential benefits a completed model would have.

Task 5. Various considerations of the actual end use of a Void Fraction Meter altered the original probe design significantly during this stage. Since the probe was to be used in a small autoclave, space restrictions and probe sizes reduced the physical design ability and output strength of the sensor.

It was determined that a two probe system would be used.

One probe would be used for gas hold up measurement and the second probe would monitor actual level. The reading strength was increased, however, the physical demands of space, temperature, and pressure required the sensor fittings to be mounted remote from the autoclave cap using a pipe extension. Water cooling of the pipe and fittings will allow the fittings to maintain the pressure rating.

Although the sensor design went through several design changes, it is felt that the final model will serve the original parameters of providing a usable reading of gas hold up within a high pressure/high temperature autoclave.

Eventual refinements to the model would make this a commercially viable Void Fraction Meter.

The probe and electronics are now with Canmet for design refinements and testing under actual autoclave operating conditions.

The research and development portion of this contract by ARJAY Engineering Ltd. is complete. This report describes the physical and operational aspects of the Void Fraction Monitor provided to CANMET.

Development of Void Fraction Meter for Measuring of Gas Hold up at High Temperature and Pressure

(Part of the Program of the Federal Panel on Energy Research & Development [PERD])

Final Report by:
ARJAY ENGINEERING LTD.

Work on the project was conducted under the Auspicies of the Canada Centre for Mineral & Energy Technology, Energy, Mines & Resources Canada

SSC FILE NO.: 06SQ-23440-9-9155
CONTRACT FILE NO.: 23440-9-9155/01-SQ
Canmet Scientific Authority: TJW de Bruijn

SUBMISSION DATE: May 31, 1993

COMPTE RENDU EXECUTIVE

Le texte suivant est partiellement repris de l'original "contrat de travail" établit par CANMET.

Le vut du programme est de mettre a l'épreuve le dessein original et de perfectioner ce premier dessin afin de construire et faire fonctionner un prototype pour utilisation dans des circonstances ou il y a "Hydrocracking". Ce programme est divise en taches spécifiques.

Voici l'ennumeration de ces taches et un bref compte rendu de chaqu'une.

Tache No. 1

Le projet a commence a cause du système berceau de multiples sensors attaches a une "tube a bulles". Le sonde de capacitance d'Arjay (modelé 8370) a récupéré de multiples informations récoltes par les sensors. L'enquête a été positif car les résultats sont établis un lien entre la capacité de contenir du gaz et la capacitance.

Tache No. 2

Une probe a multiples sensors a été conçu par Arjay afin de per mettre la submersion totale dans la "tube a bulles". Soumit a ses contraintes physiques le sonde de capacitance d'Arjay a fait preuve de sa capacité d'enregistrer de façon linéaire la relation entre la capacité de contenir du gaz et la capacitance.

Tache No. 3 et 4

Le data qui montre des corrélations diverses a été assemble par l'Université de Waterloo en utilisant varsol et de l'air, ce qui confirme les avantages éventuels qu'aurait l'ultime modelé.

Tache 5

A ce stade, de multiples considérations concernant l'emploie final de "void fraction meter" ont emmené des transformations signifiants de l'original dessein de la probe.

La descision d'utiliser un système a deux probes a été prise.

La mesure de la capacité de contenir du gaz serait le travail d'une première probe et une deuxième surveillerait le niveau actuel. Bien que la capacité de relever cette information ce soit amélioré, des exigences physiques d'espace, de température, et de pression ont suite d'installation de monteurs pour les sensors éloigné du four a l'aide d'un rallonge au tuyaux. Le refroidissement d'eau dans le tuyaux et les monture permetterons les montures de maintenir le niveau de pression.

Bien que le dessein du sensor est passe par plusieurs changements, le modelé finale semble être capable de remplir les paramètres originaux qui consiste a fournir une lecture utile de la capacité de contenir du gaz a l'intérieur d'un four a haute pression et température.

Des modifications éventuelles du modelé renderait le "void fraction meter" prêt pour commercialisation.

La probe et les électroniques sont chez Canmet ou ils seront perfectionnés et mis a l'épreuve dans des véritables conditions qu'imposerait le four.

Ceci termine la partie recherche et development d'Arjay Engineering Ltd.. dans ce contrat.

Ce rapport décrit les aspects physiques et fonctioneles du "void fraction meter" fournit a Canmet.

INTRODUCTION

BACKGROUND

CANMET is a world leader in the upgrading of heavy oils, bitumen and coal/oil slurries (coprocessing). Most of these processes use a bubble column reactor, which is the heart of the process. The hydrodynamics inside such a reactor can make or break the process, and gas holdup is the major variable. For example, it determines to a large extent the maximum conversion to distillates that can be obtained. Gas holdup in tubular reactors can be estimated from literature correlations, but some recent publications have shown that at high pressures and temperatures the gas holdups can be markedly different than predicted. Also gas holdup in CSTR's can be a mystery, moreover because the interface can change here because of the vortex created by the stirrer. Gas holdup values must be known if any serious modelling of the kinetics in the (commercial scale or pilot bench scale) reactor is going to be attempted. The measurement of gas holdup is therefore an important step in the design and development of a new process. However, measurement of gas holdup at the high pressures and temperature at which the above mentioned processes operate, is difficult and expensive.

STATE OF THE ART

Some methods that are currently available are:
a) "Shut off" method; is impractical and impossible at commercial scale; in addition it is risky at hydrocracking conditions since the reactor can easily "coke up" during the experiment.
b) Differential pressure measurements; are not easy to do with accuracy, lines can get plugged, and data needed to convert the pressure data to gas holdup are not always available
c) Gamma ray or neutron attenuation measurements; are complex, expensive, need radioactive source, and give fairly localized readings.

THE NEW METER

The University of Waterloo, in cooperation with Arjay Engineering Ltd. has designed, built and tested a capacitance type meter that promises to provide a relatively easy and more economical way to measure gas holdups at these severe conditions. The general design criteria that this meter has the potential to meet are:

1) A response which is linear in void fraction.
2) The ability to give void fraction values for slurries if additional information is available.
3) A void fraction valid for a reasonable volume so that a good average can be obtained for the sometimes rather heterogeneous flow patterns which occur.
4) The potential to give readings for the void fraction at several axial portions (from one meter)
5) A meter unaffected by the colour, viscosity or surface tension of the liquid, or by the gas composition.
6) The ability to measure void fraction at 450 C and 20 MPa.
7) The capability to be used in organic (oil) or aqueous systems. Because of the high dielectric constant of many aqueous solutions, good performance may be more difficult to achieve in these systems.

Some initial tests in a 15 cm diameter acrylic column have been performed at the University of Waterloo that confirmed the potential of this meter. A five sensor probe was tested in varsol/air at a low gas rate to generate a foam layer in the column with a distinct interface. The response was found to be highly linear in void fraction. The intermediate reading for sensor 4 could be interpreted as containing an interface located between a region with a low void fraction and one with a void fraction of 0.9 (foam layer). Using the linear response characteristic, the interface location at x in section 4 was found to be at 72.4 cm from the top. The experimentally observed interface location was at 71 cm.

THE DEVELOPMENT PROGRAM

A two part program is suggested to further test and optimize the very preliminary design and construct and test a prototype for operation at hydrocracking conditions. The first part of the research program will be performed by Arjay Engineering and the University of Waterloo. A second phase to test a developed prototype at high pressure and temperature conditions, will be performed by Arjay Engineering and CANMET/ERL.

Arjay Engineering will provide the design and fabrication of the probes and will lend the electronics required to perform the measurements. Some of CANMET's cold model equipment at the University of Waterloo will be used in testing of the probe at the University. A second phase will take place at the ERL laboratories under a separate agreement.

The work shall be carried out in accordance with the following:

Task 1

Install and test the multi-sensor probe in the 15 cm acrylic bubble column, using the varsol/air system, at several gas rates and two liquid rates.

Task 2

Redesign the probe based on the results from Task 1 and construct a new more unitized version

Task 3

Test new probe design in Varsol/air at several gas velocities and a minimum of two liquid velocities in 15 cm acrylic column. test probe on the inside and outside of draft tube in 30 cm glass column. Development of correlations to describe operating characteristics.

Task 4

Tests with solids present. Glass beads and (if possible) an iron containing solid will be tested at several gas velocities.

Task 5

Design and construct a probe for application at high pressures and high temperatures.