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COAL_WATER MIXTURE PREPARATION AND COMBUSTION TECHNOLOGY
DG/CPR/85/031/ 11-01

Republic of China

Prepared for the Government of China
by the United Nations Industrial Development Organization
acting as executing agency for the United Nations Development Programme

Based on the work of Mr. R. Manfred
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Vienna

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Activities

March 12-13	Travel
14	Initial technical discussions with Institute Visit and discussions with UNDP representative Visit and discussions with Ministry of Coal
15	Tour of papermill station and review of combustion tests performed in industrial boilers
16	Laboratory visit and discussion of the future project
17	Lecture on state of art technology needs and technology of the utility industry
18	Discussions and preparation of draft Terms of Reference
19	Travel

Summary of Findings

The development of coal-water slurry (CWM) preparation and quality control methods, as well as analytical techniques, in China has taken the same route and has arrived at the same results as earlier work in the U.S., Canada, Sweden and Italy. The Institute has been able to prepare pilot plant quantities of slurry, sufficient for test burns in 20- and 60-ton/hr steam industrial boilers. The slurry, qualitatively, has familiar viscosity and storage stability properties. Brief comparisons of rheological properties, in general, also show conformity. The four selected parent coals in China are of high quality and high volatiles content and should burn most satisfactorily in larger boilers.

The combustion (atomization) burners used in the pilot plant tests are basic and simple. They were designed to fire heavy oil and no modifications have been made to adjust to firing slurry. The increased need for better atomization and the erosion propeties of the coal wil make a fundamental redesign necessary. This specific technology has already been developed and successfully demonstrated. Ample technology is available from Combustion engineering and Bacock & Wilcox (US), Carbogel (Sweden), Fluidcarbon (Sweden), ENEL (Italy), Department ofEnergy, Minerals, Resources (Canada). Use of the already developed equipment and operations would accelerate the project by two years.

I was told that during the next phase of the project both CWM preparation and combustion testing would be scaled up. The Chinese scientific and technical ability is very high, but again, considerable time and funding can be saved by obtaining demonstrated capability:

- power plant pumps; most firms have used Moyno pumps. Piston pumps and low-shear centrifugal pumps have also been used with success. The specifications for these pumps and procurement instructions can be obtained through engineering services by companies such as Stone & Webster, Burns & Roe or Ebasco.

- storage tank configurations; all of the countries listed above and their espective engineering departments/firms have designed and built satisfactory storage facilities. However in this area the schematic design shown me in China look totally acceptable and I believe that a good engineering effort in china would produce adequate storage capability without recourse to foreign firms.

- procurement of instruments and equipment as listed in project document DP/CPR/85/031/A/01/99-Appendix 1; specifications for procurement of the equipment and identification of international procurement sources for such equipment would best be done under a service contract to an engineering firm.

Although this was not identified as a need in the above referenced document, I would strongly recommend that an engineering firm, such as Burns & Roe, Stone & Webster orEbasco be engaged to analyze the prospective three 50 MW boiler test site designs to determine the need and extent of modifications necessary to safely and effectively convert these boilers from firing heavy oil to firing CWM. This analysis should also include an estimate of the time required for such modifications, lay out a commissioning test plan and provide a cost estimate for the commissioning effort (including modifications).

Although not discussed in any detail, I believe that the eventual best benefit for conversion of boilers and increasing coal export, is envisioned to reside in a long distance pipeline which could transport large quantities of fine ground or coarse-ground coal in water for distances as far as 1000 kilometers. Once more, considerable progress has already been made in this field by companies such as Bechtel, Texas Eastern and Snamprogetti.

In summaryI recommend that a single contract be awarded to a competent engineering firm with subcontracts to specific expert firms for the selection and procurement of pumps, analytical equipment and combustion designs. The prime contractor would be responsible for the analysis of the candidate boilers to be converted.

It is probable that the allocated $155,000 will be inadequate for this effort, even excluding the actual purchase of pumps and burners. 1 a more realistic level of effort would be $300,000 and the cost of hardware would add several millions of dolalrs to this project cost. I would also recommend that the cover letter of the prospective request for proposal identify the funding available for the scope to permit bidders to offer the best package within funding limits.

Terms of Reference

Coal Water Mixture Project Support

1. OVERVIEW

The People's Republic of China (PRC) and the United Nations Development Programme (UNDP) are conducting a project aimed at replacing heavy fuel oil in industrial and utility boilers with coal water mixture (CWM) fuel. More background in this project is shown in Attachment A and typical coals and slurry properties are shown in Attachment B. The CWM nominally contains 70% coal ground to a fine consistency in water with about 1% additive to stabilize the mixture and provide suitable rheological properties.

Toward this purpose the PRC has conducted successful laboratory studies and pilot application projects to demonstrate the ability to prepare practical slurries with at least four representative bituminous coals and fire these, for extended time periods, in 40 ton/hour industrial boilers. Both the scale of slurry preparation and combustion are being scaled up. However, before the CWM can be fully commercialized, additional problems need to be studied and solved. Most of these will be addressed by Chinese engineers, but engineering services are solicited to take advantage of worldwide technology developments on related projects.

2. BACKGROUND AND JUSTIFICATION

At present, China produce annually more than 100 million tons of petroleum, of which 25 percent is used as fuel oil for boielrs and kilns. The petroleum output will increase with each passing year, but not rapidly enough; the increments cannot meet the increasing demand from various industries, especially from aviation, communication and chemical industry. China has about 770 billion tons of proven coal reserves to be relied upon as the prime energy resources. In 1985, the coal output of the country amounted to 870 million tons which, by the end of this century, will increase to 1.2 billion tons. Therefore, China has been stressing on coal utilization in its energy development, and has put out an energy policy of replacing fuel oil with coal, which will not be influenced by the oil price fluctuation in the international market.

To change oil-firing facilities into coal-firing, major efforts in research, development and equipment design need to be undertaken, covering complete conversion of boilers, construction of coal storage, coal pulverization, ash-dumping and railway transportation facilities, all of which are usually unavailable in existing power plants. Considering all the tasks above, especially the investment and the time lost, it becomes unpractical and unfeasible. so, when fuel oil is lacking, many power plant boilers actually prefer to shut down partially or completely. In the late 1970s, there came into being the technology of CWM, which behaves similarly as heavy fuel oil in storage and combustion, and soon rose to be a potential ompetitor of oil. In recent years its rapid development has brought it near to commercialization. China has favourable conditions for the introduction and development of CWM technology because:

- China has rich coal resources suitable for CWM preparation.

- After the low-ash and low-sulfur coals are separated from raw coals for CWM preparation, middling and refuses of different qualities can also find their consumers, which is concordant with the coal-saving policy of multipurpose coal utilization to meet different demands.

- The Chinese Government encourages the conversion from oil to coal so that it will guarantee the capital outlays in accordance with economic policy.

Owing to the above reasons, the project of research and development on CWM technology is considered by the Government as a key task in China. At present, seven institutions and five coal mines and coming CWM consumers are involved in this project. They work as a consortium and cooperate with each other under a joint programme to scale up in time the techniques developed into industrial application. As the research work proceeds, personnel involved are expanding. Work so far accomplished include:

- Preparation processes and additives formulations for several Chinese coals has been developed and experiment facilities with capacity from 0.5 to 1 ton/hour have been set up.

- An oil-fired industrial boiler with a capacity of 20 tons of steam per hour has been converted into CWM-fueling; this steam is utilized for regular process heating in a paper mill.

- Long duration application trial had been successfully demonstrated. The demonstration system consisted of CWM preparation in continuous base, long duration storage and unloading, re-storage and combustion at end user. Total CWM consumed amounted to about 3,000 tons and combustion time, 800 hours.

Objectives:

1. To identify the conversion requirements of existing utility plants from firing heavy oil to firing CWM.

2. To prepare procurement specifications for components which can currently be obtained only from international sources.

3. To identify multiple, worldwide sources for these components and support the subsequent procurement effort by expert consultancy.

Scope of Work:

The project will include:

1. Analysis of three small (about 50 MW) utlity plants to determine the extent of modifications needed to receive, store, handle and fire CWM. Typical CWM properties are

given in Appendix 1. Plant lay-outs and boiler schematics for this plants will be provided after contract award. This analysis will include identification of the physical changes and additions required, the rpedicted effect of these changes on plant performance and estimated cost of conversion. The analysis should also contain a commioning plan and test schedule for the three boiler systems showing ramp-up condition, milestones and schedules.

2. An identification of optional choices and recommend choices for -

   - CWM pumps for various plant needs

   - boiler front end CWM pipeline systems including valves, filters, flow meters, temperature controls and atomization system.

   - combustion monitoring system including instrumentation for feeding, scanning, controlling and recording combustion data.

3. Consultations with the Chinese and UNDP project management to select that equipment which needs to be procured from non-Chinese sources.

4. The preparation of specifications for the equipment thus identified and preparation of international bidder's lists for each item.

Proposal Requirements:

The proposal(s) prepared in response to the solicitations should contain:

1. Resume showing prior, specific experience by the bidder with CWM conversion analyses.

2. Availability of engineering personnel to this project who are experienced in CWM technology and are familiar with the work already performed in the USA, Canada, Italy, Japan and other sites.

3. A list of subcontractors to be engaged to prepare designs and procurement plant for specific components such as pumps, burners, etc.

4. A detailed description of the project approach and plan.

5. A time schedule for the conduct of this project.

6. A list of the deliverables such as reports, designs and specifications resulting from this project.

CANDIDATE

RFP Recipients

Mr. J.W. Ackerman (Fossil Fuels only)
Contract Research Division
BABCOCK & WILCOX
1562 Beeson Street
Alliance, OH 44601

Mr. Ronald R. McKinsey
EPRI Coordinator
BECHTEL GROUP, INC.
50 Beale Street (50/150/A70)
P.O. Box 3965
San Francisco, CA 94119

Dr. J.C. Grosskreutz
Manager, Advanced Technology Projects
BLACK & VEATCH
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P.O. Box 8405
Kansas City, MO 64114

Mr. John Philipp, P.E.
Vice President
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BURNS AND ROE, INC.
800 Kinderkamack Road
Oradell, NJ 07649

Mr. Dennis H. Burr, P.E.
Product Manager - Fossil R&D
C-E Power Systems
COMBUSTION ENGINEERING, INC.
1000 Prospect Hill Road
P.O. Box 500
Windsor, CT 06095-0500

Mr. John A. Marino
Vice President, Fuel Utilization
OTISCA INDUSTRIES LIMITED
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Syracuse, NY 13208

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Principal Engineer & Partner
PIPELINE SYSTEMS INCORPORATED
San Francisco Office
61 Avenida de Orinda
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SARGENT & LUNDY ENGINEERS
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San Francisco, CA 94101

Mr. George O. Buffington
Regional Manager, Bus. Devel.
STONE & WEBSTER ENGINEERING CORPORATION
245 Summer Street
P.O. Box 2325
Boston, MA 02107

Dr. Anton Roeger, III
Program Manager-Energy Utilization
TEXAS EASTERN TRANSMISSION CORPORATION
P.O. Box 2521
Houston, TX 77252-2521

Mr. E.W. Stenby
STEARNS-ROGER DIVISION
United Engineers & Constructors, Inc.
P.O. Box 5888
Denver, CO 80217

Mr. A.J. Karalis, P.E.
Advanced Engineering
UNITED ENGINEERS & CONSTRUCTORS
30 South 17th Street, 11U4
P.O. Box 8223
Philadelphia, PA 19101

APPENDIX

REPORT ON

INITIAL COAL SLURRY CHARATERIZATION TESTS

(CONTENTS)

I. SCOPE

ACCODING TO THE CONTRACT SIGNED BY CHINESE GOVERNMENT AND UNDP, THE GRADUATE SCHOOL OF CHINA INSTITUTE OF MINING AND TECHNOLOGY UNDER COAL MINISTRY SHOULD MAKE LABORATORY EXPERIMENTS ON SLURRYABILITY OF THE SELECTED FOUR COALS. ONCE THE CONTRACT WAS SIGNED, WE HAVE STARTED OUR WORK. THE FOLLOWING IS WHAT WE HAVE OBTAINED.

II. SELECTED COALS

1. D-PANG COAL
2. D-TONG COAL
3. B-YI COAL
4. F-SHUN COAL

III. ADDITIVES

ANIONIC SURFACTNTS AND STABILIZERS

IV. TEST RESULTS

1. COAL ANALYSES

SEE TABLE 1

TAB.1 COAL ANALYSES

	B-Y	F-S	D-F	D-P
PROXIMATE ANALYSIS				
MOISTURE,%	1.83	4.74	1.03	0.78
ASH,%	6.93	4.19	4.73	9.56
VOLATILE,%	36.37	39.88	28.70	34.24
FIXED CARBON,%	54.87	51.19	66.48	56.20
HEAT VALUE,KCAL/KG	7567	7438	7881	7370
ULTIMATE ANALYSIS				
CARBON,%	84.99	83.02	82.24	77.66
HYDROGEN,%	5.03	5.50	4.42	4.29
NITROGEN,%	1.54	1.22	0.89	1.38
SULFUR,%	0.56	0.44	0.40	0.30
ASH COMPONENS				
SiO_2	43.04	54.14	57.97	--
Fe_2O_3	9.04	6.53	13.66	--
Al_2O_3	33.03	29.90	18.82	--
CaO	4.76	1.41	2.86	--
MgO	2.22	1.69	--	--
MISCELLANEOUS				
HGI	--	57	58	65
FUSION,T.C	1370	1480	1245	1300

2696 2273

NOTE: 1. ALL THE ULTIMATE ANALYSIS DATA IS ON THE DAF BASIS EXCEPT D-P COAL WHICH IS ON DRY BASIS

2. ASH-FUSION TEMPERATURES WERE MEASURED IN A REDUCTION ATMOSPHERE

2. D-FANG COAL SLURRYABILITY

COAL WATER SLURRY CHARACTERISTICS:

- -- SOLID CONTENT, 70.56 % (DRY BASIS)
- -- VISCOSITY, 1052 CP (100 1/S, HAAKE, 298 K)
- -- STABILITY, TO BE TESTED
- -- MEAN SIZE, 36.15 MICRON
- -- PARTICLE SIZE DISTRIBUTION, SEE TAB.2
- -- RHEOLOGY, SEE APPENDIX 1

TAB.2 COAL PARTICLE SIZE DISTRIBUTION IN D-P CWS

SIZE	CUMULATIVE WT. %	WEIGHT %
300	100	0.4
212	99.5	1.5
150	97.9	7.2
106	90.7	7.3
75	83.3	6.4
53	76.9	10.1
38	66.8	7.7
27	59.1	9.3
19	49.8	9.6
13	40.1	8.1
9.4	32.0	6.5
6.6	25.4	5.6
4.7	19.7	6.0
3.3	13.7	5.0
2.4	8.6	3.6

3. D-TONG COAL SLURRYABILITY

CWS CHARACTERISTICS:

-- SOLID COTENT, 70.19 % (DRY BASISI)

-- VISCOSITY, 1200 CP (100 1/S, HAAKE, 298 K)

-- STABILITY, TO BE TESTED

-- MEAN SIZE, 46.14

-- PARTICLE SIZE DISTRIBUTION, SEE TAB.3

-- RHEOLOGY, SEE APPENDIX 2

TAB.3 COAL PARTICLE SIZE DISTRIBUTION IN D-T CWS

SIZE (MICRON)	CUMULATIVE WT. %
280	99.1
180	96.1
154	94.1
125	90.6
110	88.0
90.0	83.2
76.0	78.6
61.5	72.3
30.7	50.6
21.7	40.7
15.3	32.0
12.5	27.7

4. B-YI COAL SLURRYABITY

CWS CHARACTERISTICS:

- -- SOLID CONTENT, 67.0 % (DRY BASIS)
- -- VISCOSITY,
- -- STABILITY, TO BE TESTED
- -- MEAN SIZE, 54.6 MICRON
- -- PARTICLE SIZE DISTRIBUTION, SEE TAB.4
- -- RHEOLOGY, SEE APPENDIX 3

TAB.4 COAL PARTICLE SIZE DISTRIBUTION IN B-Y CWS

SIZE (MICRON)	CUMULATIVE WT. %
280	97.2
180	92.6
154	89.4
125	85.1
110	82.2
90.0	77.1
76.0	72.6
46.6	58.7
31.6	47.9
23.3	40.2
16.5	32.5
13.4	28.5

5. F-SHUN COAL SLURRYABILITY

CWS CHARACTERISTICS:

-- SOLID CONTENT, 65.7 % (DRY BASIS)

-- VISCOSITY

-- STABILITY, TO BE TESTED

-- MEAN SIE, 28.64 MICRON

-- PARTICLE SIZE DISTRIBUTION, SEE TAB.5

-- RHEOLOGY, SEE APPENDIX 4

TAB.5 PARTICLE SIZE DISTRIBUTION IN F-S CWS

SIZE (MICRON)	CUMULATIVE WT. %
280	99.8
180	99.0
110	95.4
76.0	90.0
43.0	75.5
30.4	65.1
21.5	54.5
15.2	44.5
12.4	39.2

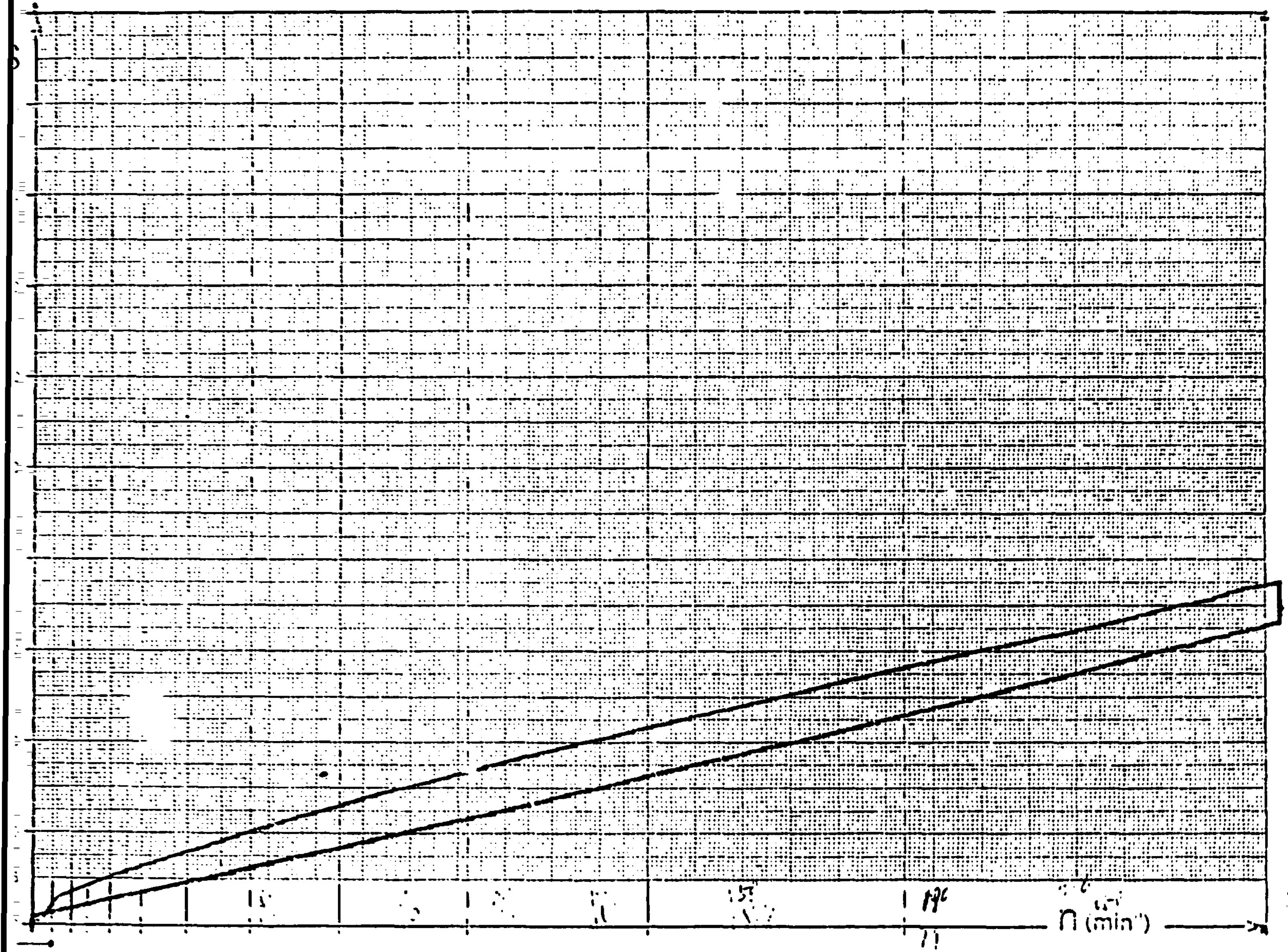
V. SUMMARY

WE HAVE FORMULATED AND PREPARED COAL WATER SLURRIES USING THE COAL MENTIONED ABOVE. SOME OF THE COAL WATER SLURRY PROPERTIES HAVE BEEN MEASURED AND LISTED IN THIS REPORT. BUT STILL WE HAVE A LOT OF WOEK TO DO. FOR EXAMPLE, WE HAVE TO FIND OUT A WAY TO EVLUATE CWS STABILITY IN BOTH STEADE AND KINETIC STATES. WE ARE GOING TO SELECTE CHEAPER AND MORE EFFICIENT ADDITIVES BASED ON MODERN CHEMICAL ANALYSIS TECHNOLOGY.

APPENDIX 1

D-PONG SLURRY

ROTOVISCO FLOW CURVE



HAAKE

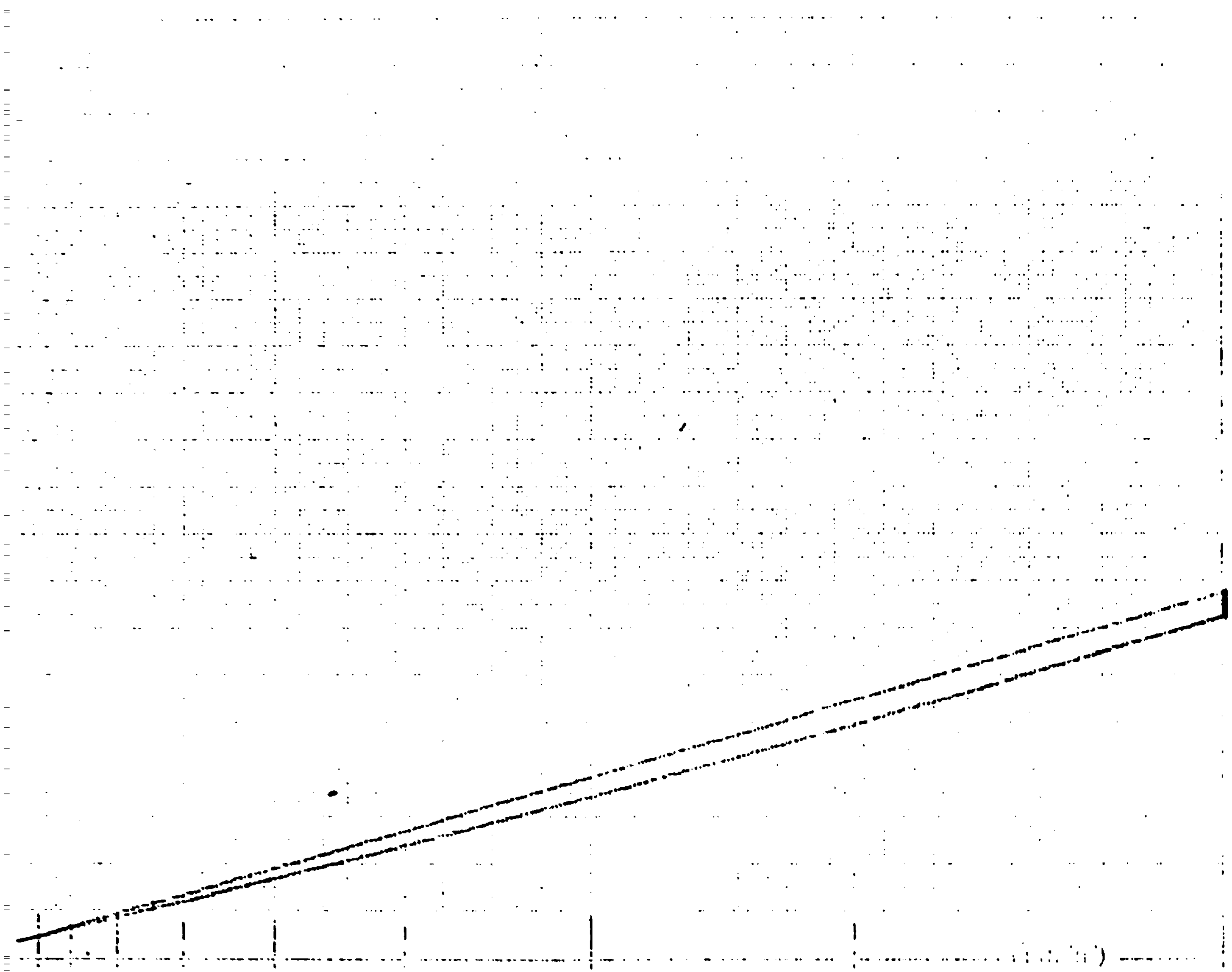
3.75

0.19

4171

APPENDIX 2

D-TONG SLURRY

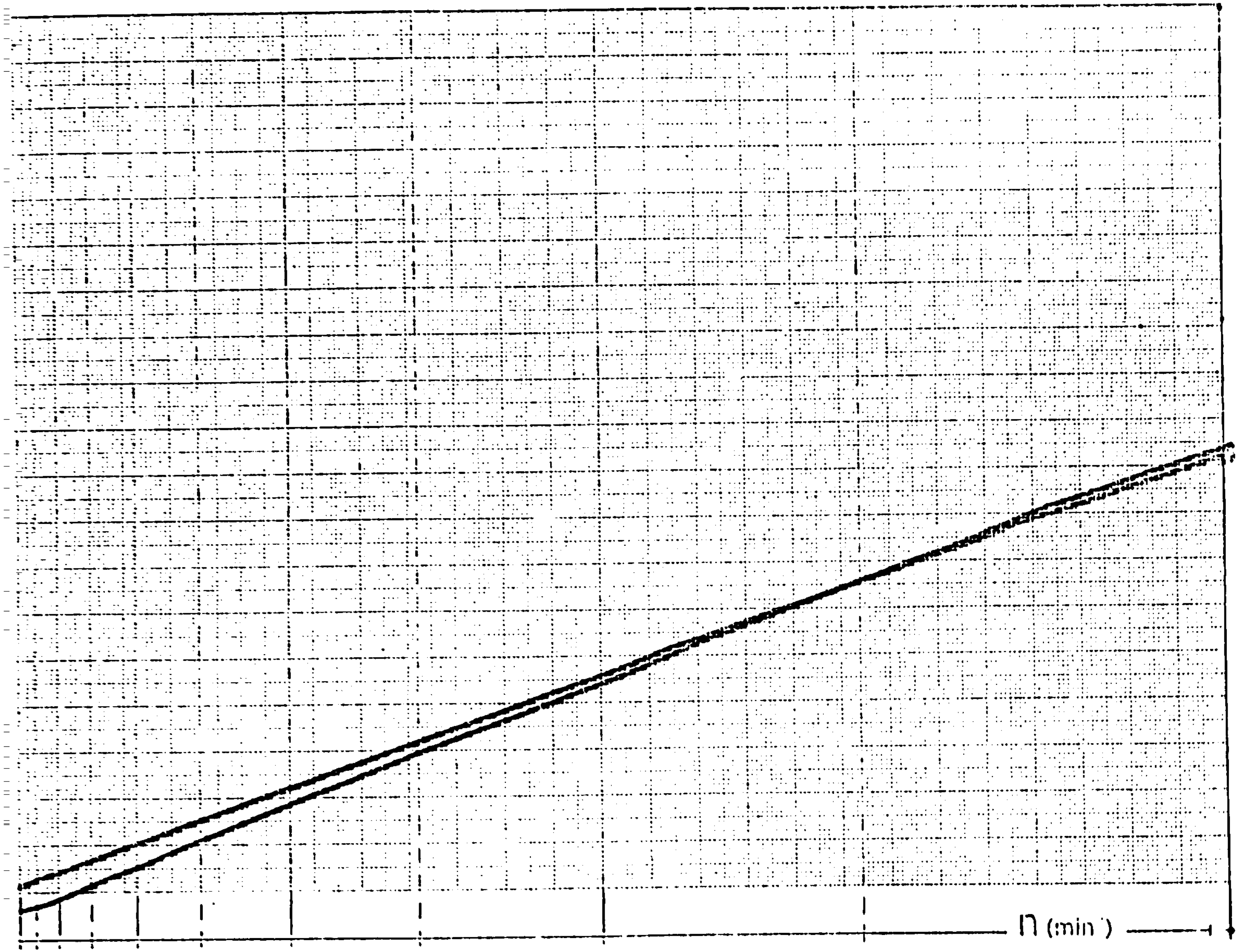


HAAKE, INC. •

ROTOVISCO FLOW CURVE

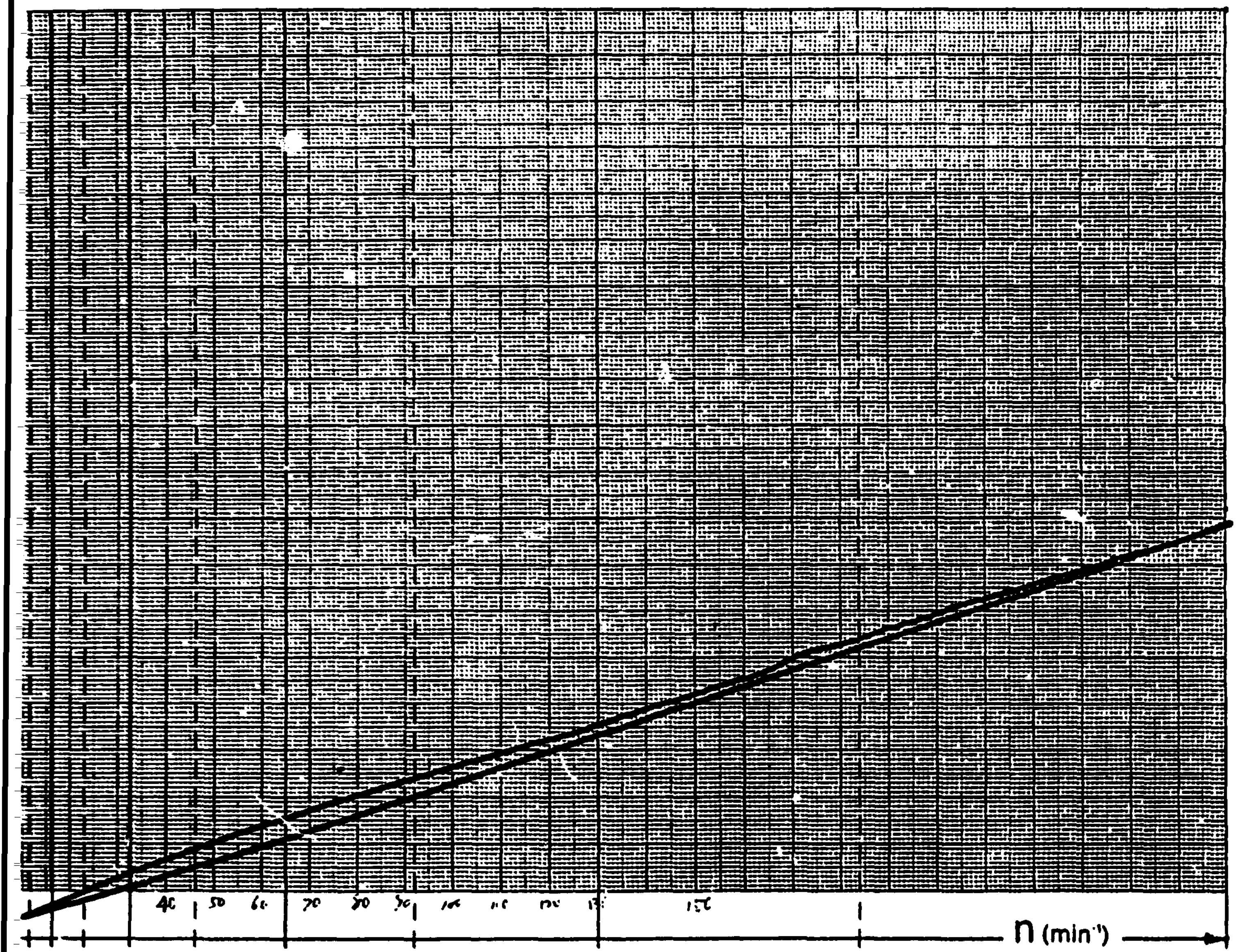
APPENDIX 3

HAAKE



F - SHUN SLURRY

ROTOVISCO FLOW CURVE



HAAKE

Shear stress: $\tau = A \cdot S$ in Pa

Shear rate: $D = M \cdot n$ in s^{-1}

Viscosity: $\eta = \frac{G \cdot S}{n}$ in Pa·s

Date	[illegible]
No.	[illegible]
Substance	[illegible]
Temperature	[illegible]
ROTOVISCO RV	[illegible]
Measuring head	
Sensor system	
Factor A	[illegible]
Factor M	[illegible]
Factor G	[illegible]
Program	
Signature	

HAAKE, INC. • 244 Saddle River Road • P.O. Box 549 • Saddle Brook, N.J 07662 • (201) 843-2320

APPENDIX 2

Instruments and Equipment ~~to be supplied under UNDP Contrubution~~

	Item	Set
1.	Ion Chromatograph	1
2.	Atomic Absorption Spectrophtometer	1
3.	Gas Chromatograph	1
4.	Image Scanning and Analysis System, Magisianor Quantimet	1
5.	Liquid Chromatograph	1
6.	FTIR Spectrometer	1
7.	Heatflux Calorimeter	1
8.	Precision Surface-Tension Meter	1
9.	Precision Contact-Angle Meter	1
10.	PHW Apparatus (for measurement of wettability)	1
11.	Automatic Moisture Meter for Slurry	1
12.	Accessories for Quantasorb (Flow Controller)	1
13.	Accessories for Robot Sifter (Standard Seives)	1
14.	Accessories for RV 12 Rotoviscosimeter	1
15.	Standard Sphereical Particles for Calibration	1
16.	Laser Anemometry System	1
17.	Heat Flowmeter	1
18.	Portable Digital Pyrometer	1
19.	Monitoring System for Flue Gas Analysis	1
20.	Portable Carbon Dioxide Analyzer	1
21.	Portable Sulfur Dioxide Analyzer	1
22.	Supersonic Thickness Instrument	1
23.	Optical Fibre Pyrometer	1
24.	CWM Burners and Control System	1
25.	Ash Gage, Coalscan	1

~~Total Estimates US$ 710,000~~

~~Freight and Handling Costs 40,000~~

~~Total US$ 750,000~~