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THE ROCKWELL LOW NO_x/SO_x BURNER DEVELOPMENT

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Combustion and Carbonization Research Laboratory

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ABSTRACT

A slagging combustor for burning pulverized coal with low NO_x/SO_x emissions has been developed by Rockwell International. In pilot plant trials with low-sulphur coals, SO₂ emissions have been reduced by 65% with NO_x emissions ranging from 80 to 150 ppm; carbon carryover has been typically less than 1% in ash.

Design criteria for a 29.2 MWt demonstration-scale burner scheduled for installation on Unit No. 2 at Wabamun Generating Station in 1987 are being developed from the pilot plant data.

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MISE AU POINT DU BRÔLEUR ROCKWELL À FAIBLES ÉMISSIONS DE NO_x/SO_x

par

G.K. Lee

RÉSUMÉ

La Rockwell International a mis au point une installation de combustion à faibles émissions de NO_x/SO_x pour brûler le charbon pulvérisé. Lors d'essais en usine-pilote avec des charbons à faible teneur en soufre, les émissions de SO_x ont été réduites de 65 % alors que les émissions de NO_x variaient de 80 à 150 ppm; de façon caractéristique, le carbone résiduel a produit moins de 1 % de cendre.

On est à élaborer les critères relatifs à la conception d'un brûleur expérimental devant être utilisé à des fins de démonstration et que l'on prévoit installer dans l'unité n° 2 de la Wabamum Generating Station en 1987.

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INTRODUCTION

Canadian guidelines for SO_x and NO_x emissions from new fossil fuel-fired utility boilers are currently set at 258 ng/J ($0.6 \text{ lb}/10^6 \text{ Btu}$) based on a 720-h rolling average. These limits will require the installation of acid gas abatement technology on most new coal fired sources including those to be fuelled with relatively low-sulphur, low-rank coals of Western Canada.

The use of stack gas scrubbers to control SO_x and NO_x emissions is reported to decrease thermal efficiencies from 4 to 7%; to increase the capital cost of new plant from 25 to 30%; to increase plant labour costs by a factor of two; and to be a probable source of water pollution. One potentially, low cost alternative to stack gas scrubbers for pulverized coal-fired boilers involves simultaneously inhibiting the formation of NO_x and enhancing the capture of SO_x during combustion using either dry ash or wet ash (slagging) burner systems.

The dry ash systems include the following generic concepts:

- (a) staged-air burners with sorbent addition to the coal;
- (b) staged-air burners with sorbent injection around the flame;
- (c) staged-air burners with sorbent injection in the upper furnace;
- (d) fuel reburning with sorbent injection in the upper furnace.

The wet ash or slagging systems, being proprietary concepts, are referred to by their corporate names. They include:

- (a) A cyclone-type combustor developed by TRW with bare, water-cooled walls coated with an active slag layer. Research has been completed on a $1 \times 10^6 \text{ Btu/h}$ boiler test simulator shown in Fig. 1.
- (b) A toroidal-vortex flow combustor developed by AVCO with bare, water-cooled walls coated with an active slag layer shown in Fig. 2. Little information is available on its status.
- (c) A design by Coal Tech, based on the GE $1 \times 10^6 \text{ Btu/h}$ ceramic-lined, air-cooled combustor, in which highly-swirled air throws coal to the walls of the chamber. A $100 \times 10^6 \text{ Btu/h}$ combustor design has been completed.
- (d) The Rockwell burner is essentially a refractory-lined, entrained-flow reactor; the non-proprietary aspects of the burner are described below.

COMBUSTOR CONCEPT

The Rockwell combustor shown schematically in Fig. 3 comprises a cylindrical chamber that provides for close control over air/fuel stoichiometries using a multi-stage combustion process.

The primary stages, which operate under fuel-rich conditions, maximize the reaction of fuel sulphur with calcium compounds that are either in the coal ash or added with the coal feed and minimize the conversion of fuel nitrogen to NO_x .

The secondary stages operate under fuel-lean conditions and exhaust combustion gases to the radiant furnace between 1500°C and 1750°C when using normal utility boiler air preheat temperatures. Char burnout is completed in the furnace.

Initial research and development based on a 4.7-MWt burner led to the design of a 7.3-MWt pilot plant and to the experimental confirmation of theoretical considerations which indicated that NO_x emissions from coal could be controlled below 100 ppm (Fig. 4) and that SO_x emissions from coal containing from 0.5 to 4.0% sulphur could be reduced by about 70% (Fig. 5).

This combustor is intended for new boiler designs, as a retrofit to existing pulverized-fired boilers and as a retrofit to oil- and gas-fired boilers as illustrated in Fig. 6. If retrofitted to boilers designed for very low or zero ash fuels, the combustor would be equipped with a slag screen to remove up to 80% of the ash as slag prior to the final air injection stage.

PROJECT FUNDING AND ORGANIZATION

After an initial research investment of about \$5 million US, Rockwell sought and received over \$2 million US in financial assistance, as well as substantive technical guidance from industry to modify the 7.3-MWt pilot plant and to conduct further research with this facility. The industry input is provided through a consortium formed in 1982. Each participant exercises voting rights proportional to their financial contribution through representation on a steering committee. Fig. 7 shows the consortium participants; the voting strength as of December 1985 was roughly 20% per participant.

PILOT PLANT FACILITY

The 7.3-MWt pilot plant, illustrated in Fig. 8, is designed to duplicate the time/temperature history and the chemical transformation that would occur in an operational, coal-fired, slagging combustor installed on a utility boiler.

TEST RESULTS

Prior to formation of the consortium, Rockwell conducted 15 combustion tests, from 1979 to 1981, using the 4.7-MW combustor to verify the theoretical concept for simultaneous NO_x/SO_x suppression under slagging conditions. Three coals - Kentucky No. 9, Illinois No. 6, and Montana Rosebud - were burned without a slag separator. A fourth coal, Utah Kaiparowits, was burned with and without a slag separator.

In 1982 the 7.3-MW combustor with a boiler simulator section was designed and commissioned without a slag separator. This pilot plant was tested by Rockwell on Kentucky No. 9, Gauley Eagle and Black Mesa coals. Since formation of the consortium in late 1982, the pilot plant has been operated using Black Mesa as the reference coal and a series of coals, shown in Fig. 9, nominated by the consortium members. As of January 31, 1986, 20 tests have been conducted under consortium sponsorship and are summarized in Fig. 10.

These tests evaluated the influence of coal type, residence time, first-stage stoichiometry, coal fineness, sorbent type, Ca/S ratio, first-stage heat extraction, slag removal and carbon burnout efficiency with respect to SO_x and NO_x reductions.

FUTURE RESEARCH

The 7.3-MWt pilot plant program is scheduled for completion by August 31, 1986. However, five additional tasks, involving both pilot plant experiments and laboratory analyses, are considered essential in order to reduce the technology risk associated with the implementation of the proposed Wabamum Demonstration Program. The five tasks, with their approximate cost in US dollars, are listed below in perceived order of technical priority:

1. Laboratory studies on the retention of sulphur in discharged slag (\$37K).
2. Modelling of particle and combustion behaviour in the proposed 30-MW combustor for Wabamum (\$32K).
3. Evaluation of materials for construction of the proposed Wabamum combustor (\$23K).
4. Pilot plant trials on three low-sulphur coals including Whitewood (\$108K).
5. Final report on the pilot plant program (\$47K).

Completion of tasks 1 to 3 and the Whitewood trial in task 4 will reduce significantly the technology risk associated with the Wabamum Demonstration Program.

THE WABAMUM DEMONSTRATION PROGRAM

The extrapolation of the pilot scale research effort and the application of the burner technology to an operational utility boiler are to be implemented through a demonstration program managed by TransAlta Utilities Corp. Following a technical review of boilers within the consortium that would be suitable and available for the demonstration program, the steering committee unanimously agreed to conduct the first field trials of the Rockwell burner on Unit No. 2 at the Wabamum Generating Station near Edmonton, Alberta. This unit, rated at 60 MWe, is front-wall fired with a 3 x 3 burner array. Although the unit was commissioned with natural gas burners, the furnace which was designed to fire subbituminous coal is now retrofitted to burn coal using one pulverizer per horizontal row of three burners.

The Wabamum Demonstration Program contains two phases and will be managed by TransAlta with technical guidance from the consortium steering committee. Phase A involves the design, construction and combustion evaluation of a single combustor with a slag screen at Rockwell (Fig. 11), followed by its installation, shown schematically in Fig. 12, and a 6-month

field trial at Wabamum. Phase B, which would be conditional on the success of Phase A, involves the installation of two additional combustors with no slag screens for a 6-12 month reliability study at Wabamum. Each phase is estimated to cost about \$6000K US for a total program cost of about \$12000K US. The scheduled tasks and the cost breakdown for the Wabamum Demonstration Program are shown in Fig. 13 and 14 respectively.

An engineering feasibility study of the modifications required to install the Rockwell burner on Unit No. 2 has been completed by Monenco on behalf of TransAlta and a submission, made to Energy, Mines and Resources Canada for shared-cost funding to design and build the first full-scale prototype burner with a multi-element injector rated at 29 MJ/s, has been approved.

TransAlta is now negotiating the funding for Phase 1, which will be initiated when the total \$6000K to complete the work, has been secured. The earliest date envisaged for starting Phase 1 is August 1, 1986.

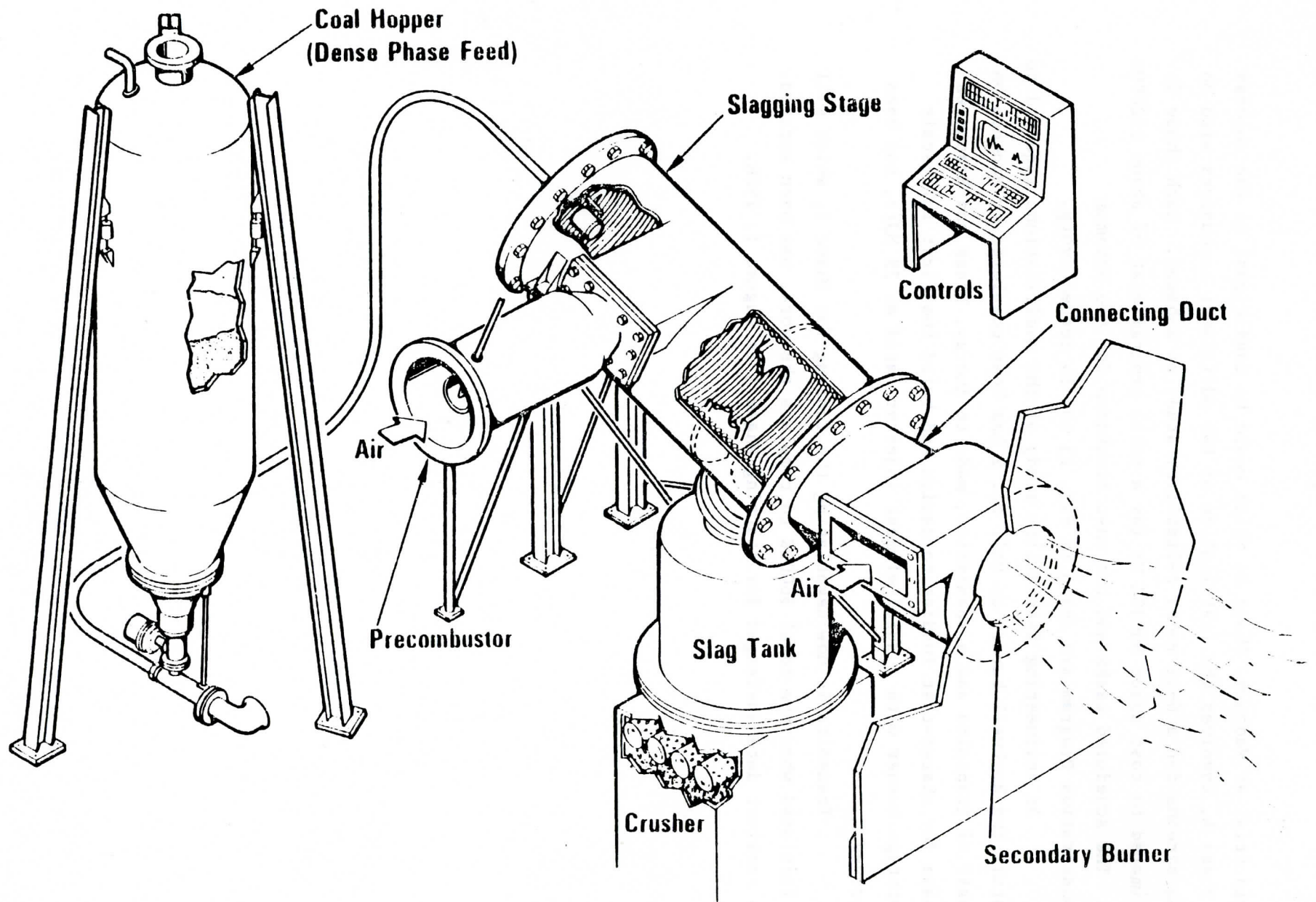


Fig. 1 - TRW slagging coal combustor system

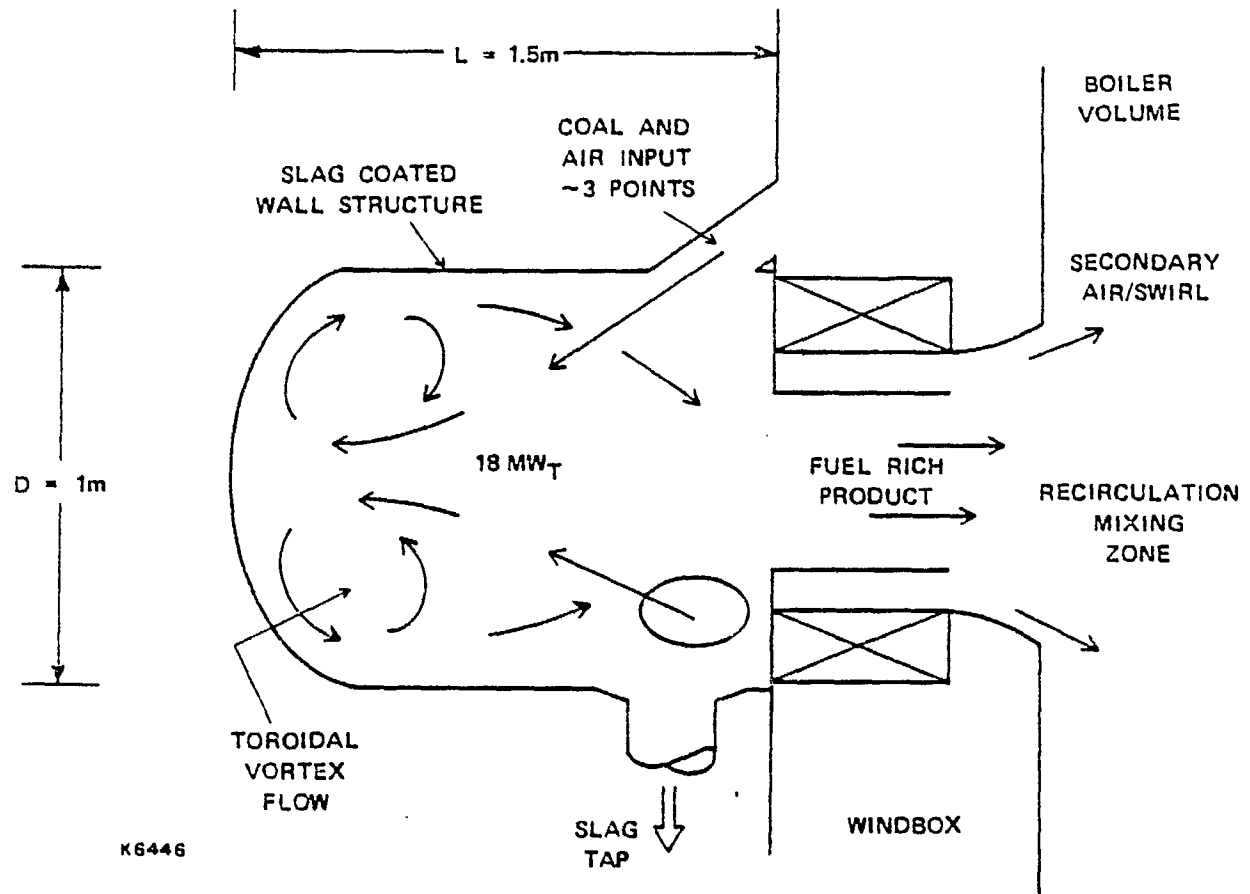


Fig. 2 - AVCO Everett slagging combustor concept

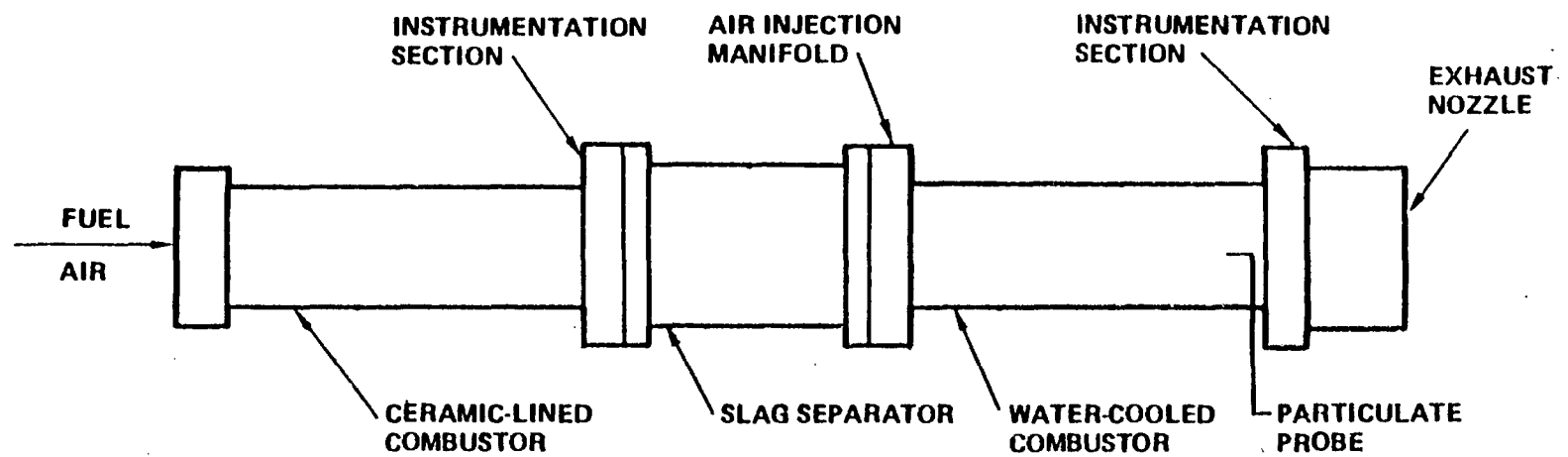


Fig. 3 - Schematic of Rockwell combustor

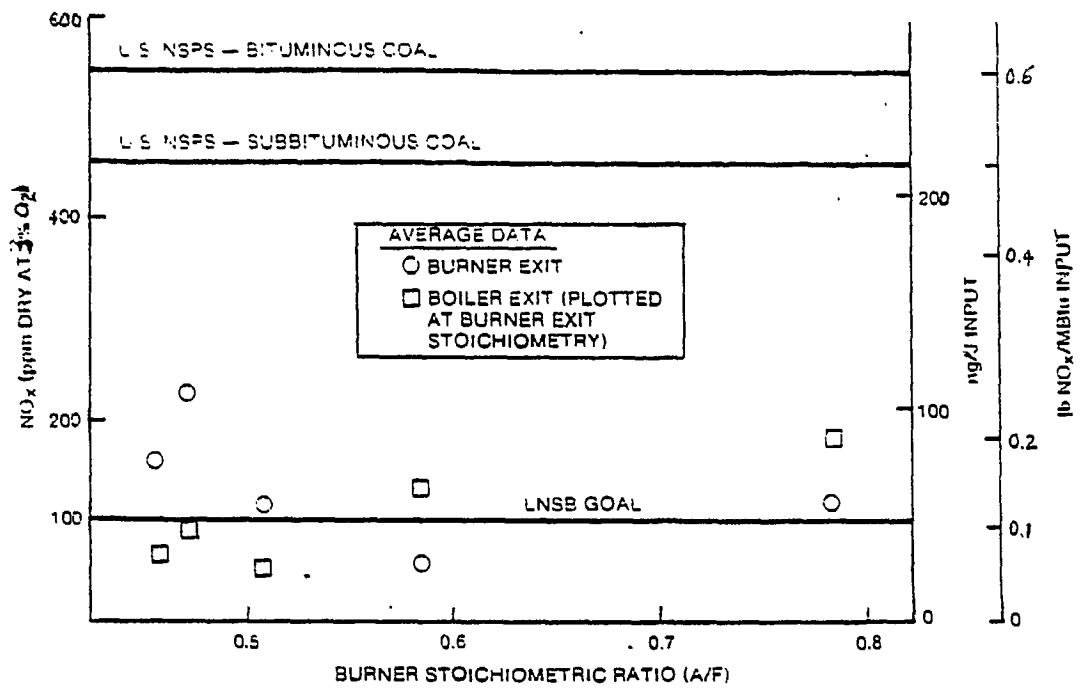
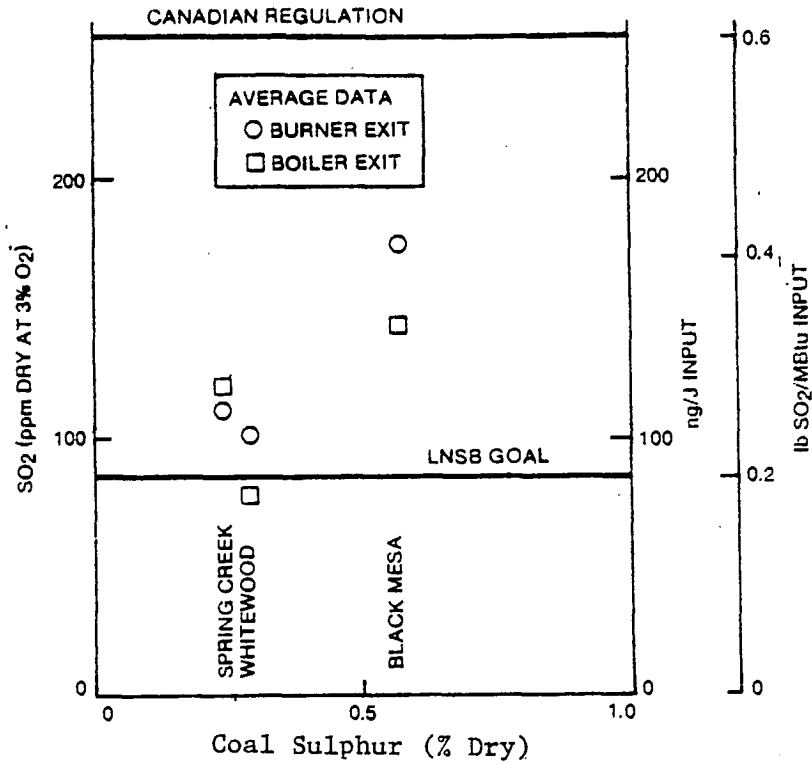
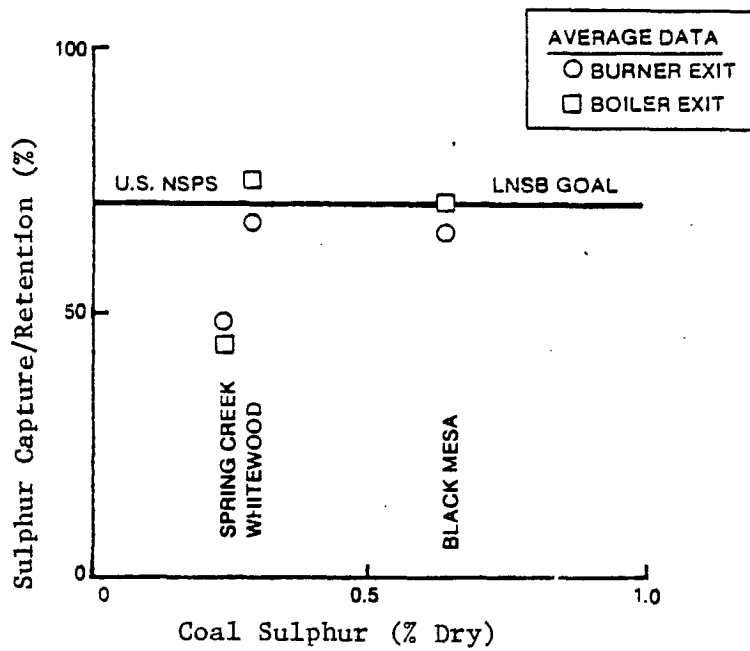


Fig. 4 - NO_x control in pilot-scale burner



a) SO_x emissions



b) Sulphur capture

Fig. 5 - SO_x control in pilot-scale burner

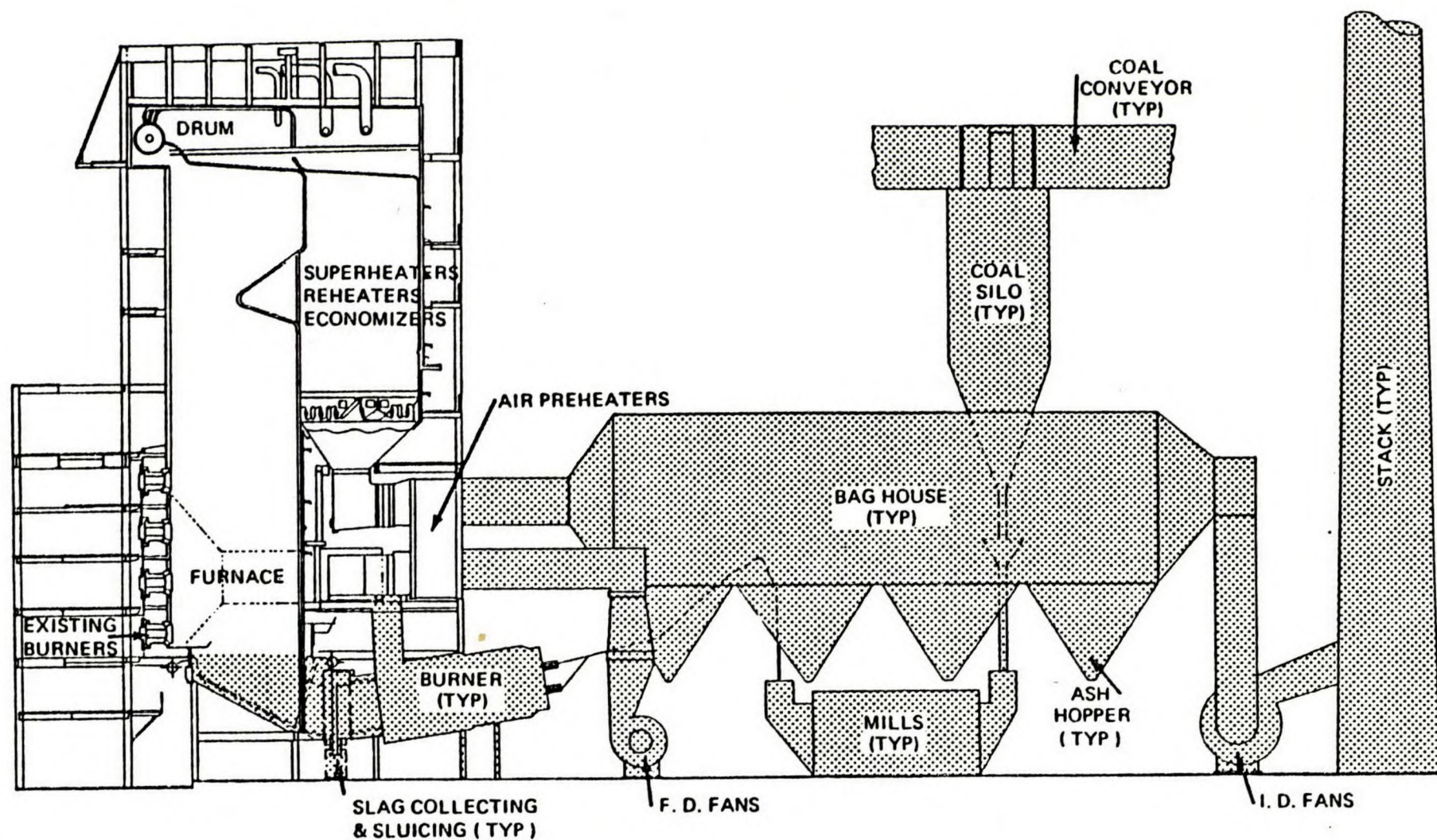


Fig. 6 - Schematic of Rockwell combustor retrofitted to a gas-fired boiler

CONSORTIUM PARTICIPANTS
<ul style="list-style-type: none">• HOUSTON LIGHTING AND POWER CO.• NIAGARA MOHAWK POWER CORP.• SOUTHERN CALIFORNIA EDISON CO.• WISCONSIN PUBLIC SERVICE CORP.• TRANSALTA UTILITIES CORP.
<ul style="list-style-type: none">• VOTING STRENGTHS ARE PROPORTIONAL TO CONTRIBUTIONS.

Fig. 7 - Participants in Rockwell burner consortium

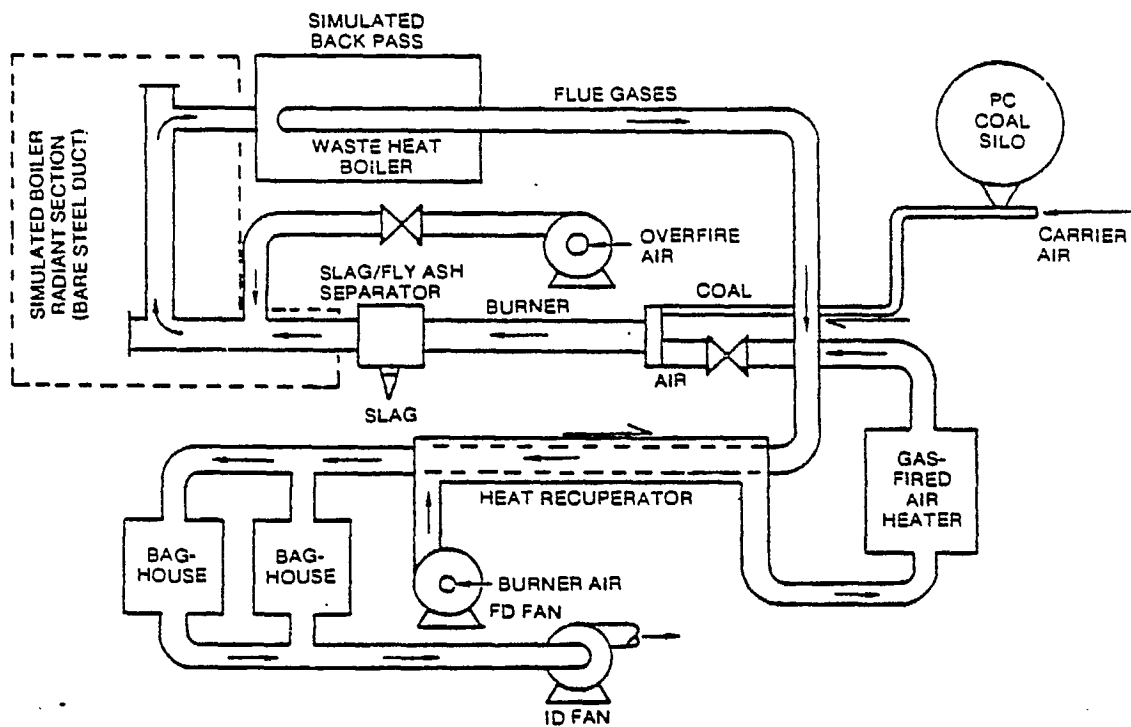
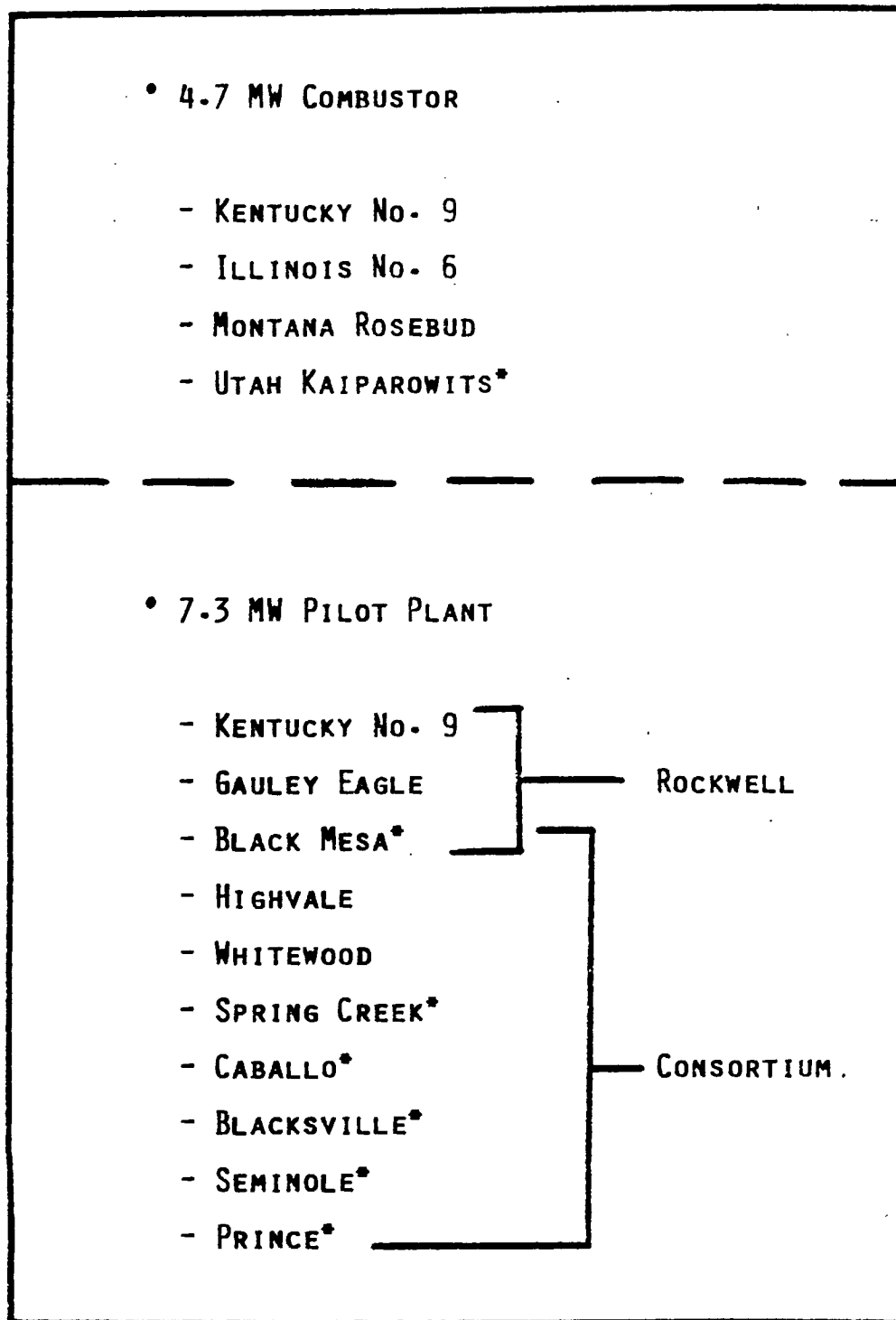


Fig. 8 - Rockwell pilot-scale test facility



* WITH SLAG SCREEN

Fig. 9 - Coals burned in the 7.3 MWt pilot-scale facility

Test No.	Time h	Coal	$\frac{Ca}{S}$	Slag %	Remarks
1		Kentucky No. 9			Combustor, injector, combustion and technology verification by Rockwell.
		Gauly Eagle			
		Black Mesa			
		Rosebud			Burner cooling water removed.
15		Kaiparowits			
16	7.1	Black Mesa	2.0	-	Comparison of lime additives
17	4.7	Black Mesa	2.0		Fine coal + lime additive
18	4.1	Black Mesa	2.0		First stage residence time greater.
19	5.5	Black Mesa	2.0		First stage refractory thickened.
20	2.3	Black Mesa	2.0		
21	1.3	Highvale	3.9		
22	2.9	Highvale	3.4		Flange broke
23	3.0	Whitewood	3.9		Coal weight inaccurate
24	7.0	Black Mesa	2.0		
25	6.0	Whitewood	3.9		
26	1.7	Black Mesa			
27	1.8	Black Mesa			First test with slag screen.
28	8.7	Spring Creek		72	No slag tapped
29	-	Spring Creek	-	-	Duct failure; aborted test
30	4.3	Spring Creek	-	80	First stage refractory thickened.
31	5.5	Caballo		80	Slag buildup below tap hole
32	6.0	Seminole	2.7	72	Strut in slag screen failed
33	6.2	Blacksville	1.5	64	Slag not fluid; tube missing
34	+6.0	Prince	1.4	68	Fluid slag; tube missing
35		Seminole	1.4	68	Fluid slag; tube missing

Fig. 10 - Summary of pilot-scale burner tests

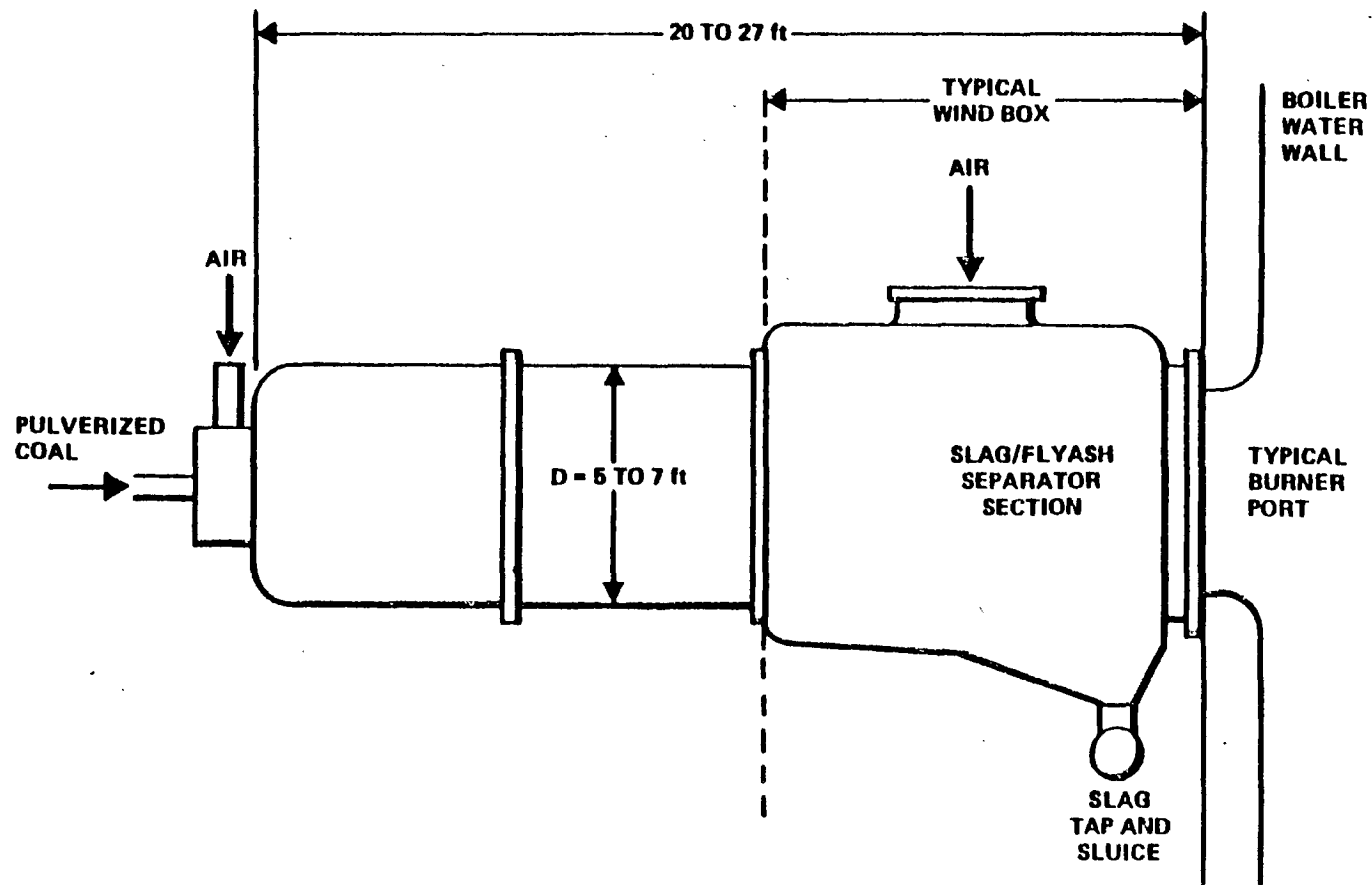
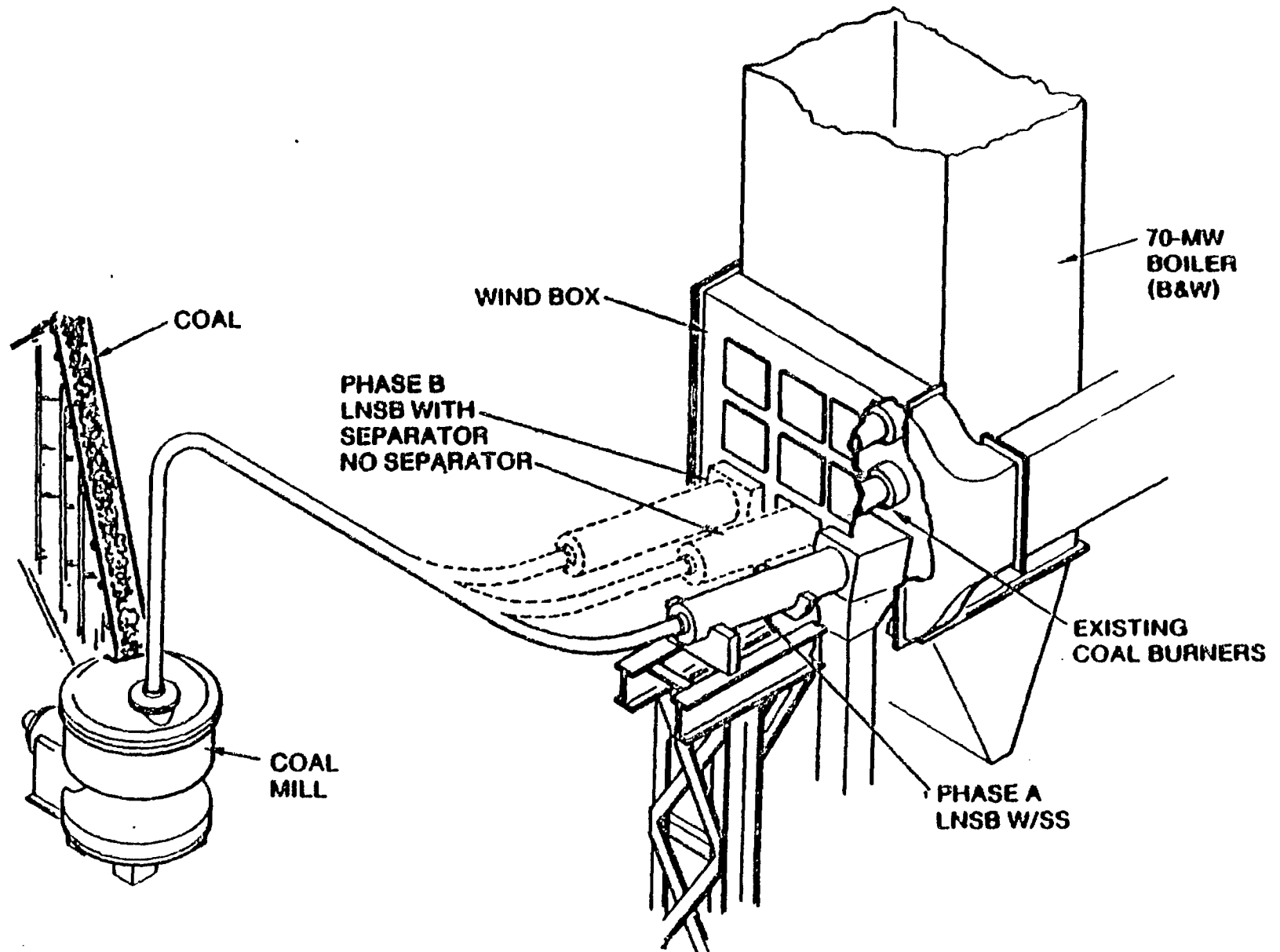
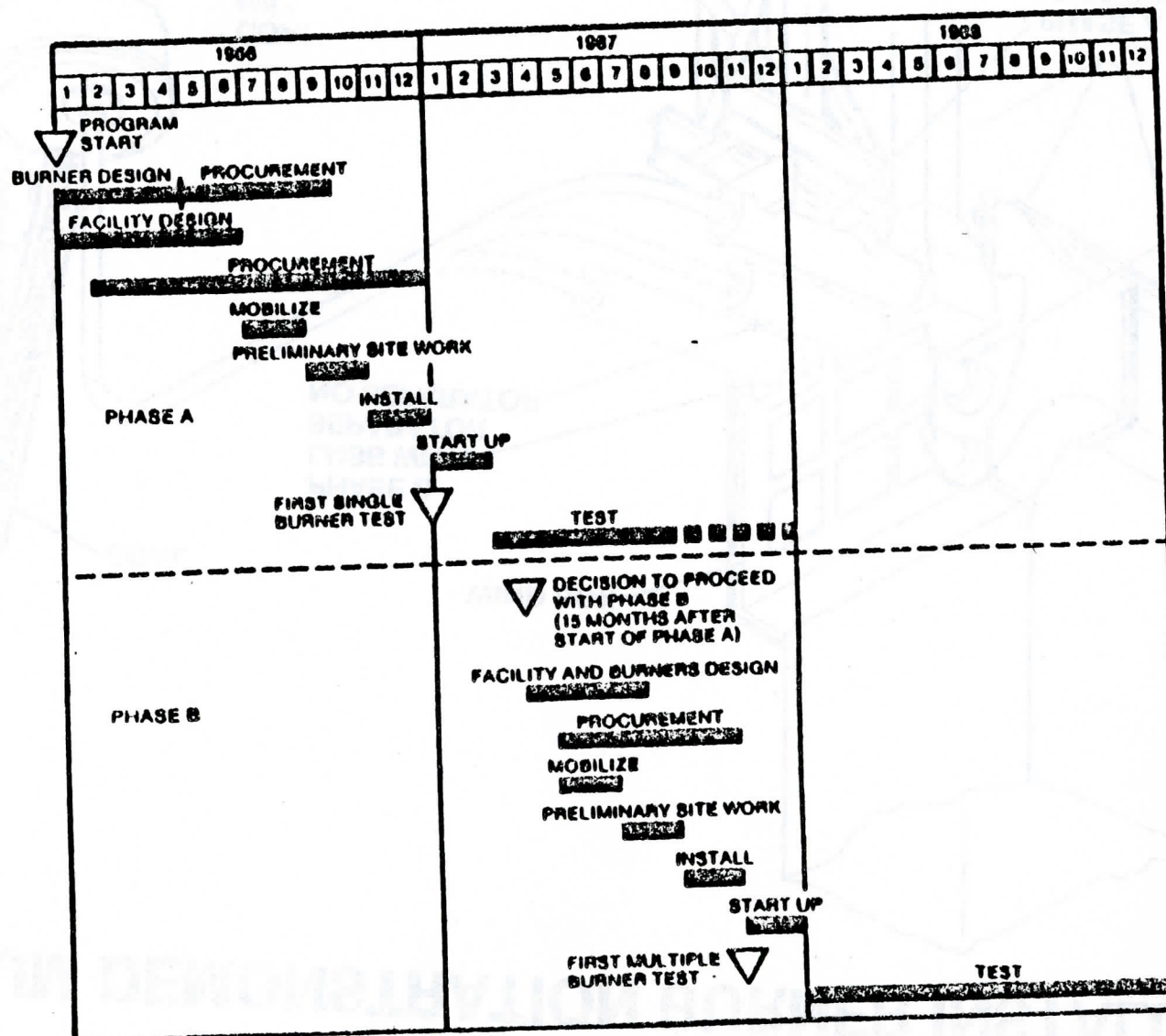


Fig. 11 - Schematic of Rockwell 29 MJ/s commercial-scale slagging combustor

WABAMUM DEMONSTRATION BURNER INSTALLATION



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Rockwell International
Rocketdyne Division

Fig. 13 - Low NO_x/SO_x demonstration program

85-MA23-0-6A

COST BREAKDOWN (\$000 CND)

	PHASE A	PHASE B
BURNER DESIGN	\$ 481	\$ 309
BURNER PROCUREMENT	763	631
FACILITY DESIGN	586	366
FACILITY PROCUREMENT	1734*	943
MOBILIZE	215	323
PRELIMINARY SITE WORK	323	398
INSTALL	323	323
STARTUP	150	150
TEST/OPERATE	430	704
DISMANTLE	—	688
TOTAL	\$5005	\$4835 = \$9840 (\$6888 U.S.)

*WITH PHASE B COMMON REQUIREMENTS

Fig. 14 - Wabamum demonstration cost breakdown

