LIMB Demonstration Project Extension and Coolside Demonstration

Project completed

Participant

The Babcock & Wilcox Company

Additional Team Members

Ohio Coal Development Office—cofunder

Consolidation Coal Company—cofunder and technology supplier

Ohio Edison Company—host

Location

Lorain, Lorain County, OH (Ohio Edison's Edgewater Station, Unit No. 4)

Technology

The Babcock & Wilcox Company's (B&W) limestone injection multistage burner (LIMB) system; Babcock & Wilcox DRB-XCL® low-NO_x burners; Consolidation Coal Company's Coolside duct injection of lime sorbents

Plant Capacity/Production

105 MWe

Coal

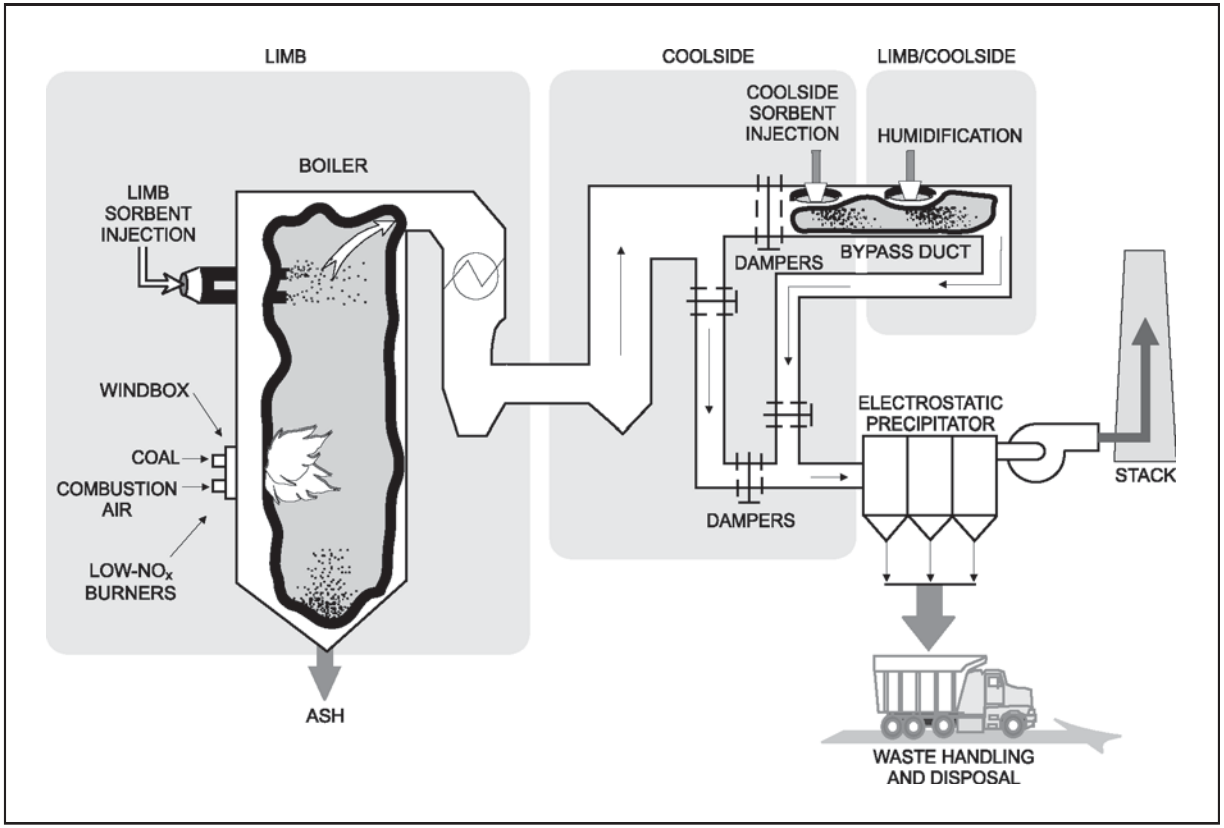
Ohio bituminous, 1.6, 3.0, and 3.8% sulfur

Project Funding

Total	$19,311,033	100%
DOE	7,591,655	39
Participant	11,719,378	61

Project Objective

To demonstrate, with a variety of coals and sorbents, that the LIMB process can achieve up to 50% NO_x and SO_2 reductions, and to demonstrate that the Coolside process can achieve SO_2 removal of up to 70%.

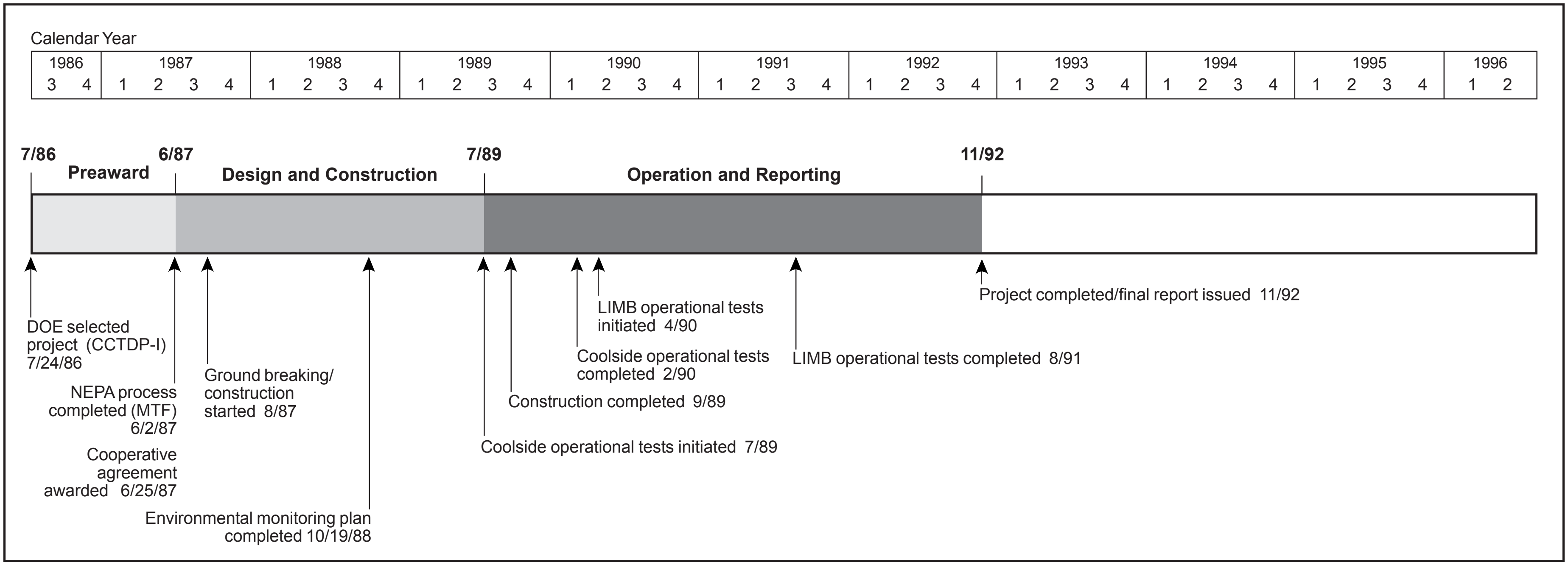


Technology/Project Description

The LIMB process reduces SO_2 by injecting dry sorbent into the boiler at a point above the burners. The sorbent then travels through the boiler and is removed along with fly ash in an electrostatic precipitator (ESP) or baghouse. Humidification of the flue gas before it enters an ESP is necessary to maintain normal ESP operation and to enhance SO_2 removal. Combinations of three bituminous coals (1.6, 3.0, and 3.8% sulfur) and four sorbents were tested. Other variables examined were stoichiometry, humidifier outlet temperature, and injection elevation level in the boiler.

In the Coolside process, dry sorbent is injected into the flue gas downstream of the air preheater, followed by flue gas humidification. Humidification enhances ESP performance and SO_2 absorption. SO_2 absorption is improved by dissolving sodium hydroxide (NaOH) or sodium carbonate (Na_2CO_3) in the humidification water. The spent sorbent is collected with the fly ash, as in the LIMB process. Bituminous coal with 3.0% sulfur was used in testing.

Babcock & Wilcox DRB-XCL® low-NO_x burners, which control NO_x through staged combustion, were used in demonstrating both LIMB and Coolside technologies.



Results Summary

Environmental

- LIMB SO_2 removal efficiencies at a calcium-to-sulfur (Ca/S) molar ratio of 2.0, and minimal humidification across the range of coal sulfur contents were 53–61% for ligno lime, 51–58% for calcitic lime, 45–52% for dolomitic lime, and 22–25% for limestone ground to 80% less than 44 microns (325 mesh).
- LIMB SO_2 removal efficiency increased from 22–25% to 32% using limestone ground to 100% less than 44 microns, and increased an additional 5–7% when ground to 100% less than 10 microns.
- LIMB SO_2 removal efficiencies were enhanced by about 10% with humidification at a 20 ºF approach-to-saturation temperature.
- LIMB, which incorporated Babcock & Wilcox DRB-XCL® low-NO_x burners, achieved 40–50% NO_x reduction.
- Coolside SO_2 removal efficiency was 70% at a Ca/S molar ratio of 2.0, a sodium-to-calcium (Na/Ca) ratio of 0.2, and a 20 ºF approach-to-saturation temperature using commercial hydrated lime and 2.8–3.0% sulfur coal.
- Sorbent recycle tests demonstrated the potential to improve sorbent utilization.

Operational

- Humidification enhanced ESP performance, which enabled opacity levels to be kept well within limits.
- LIMB availability was 95%. Coolside did not undergo testing of sufficient length to establish availability.
- Humidifier performance indicated that operation in a vertical rather than horizontal mode would be better.

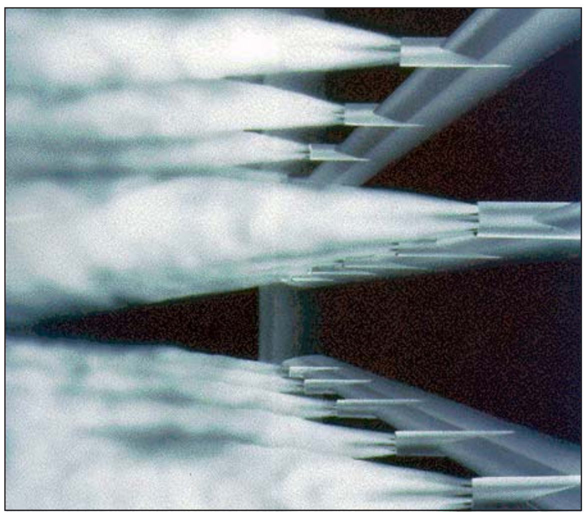
Economic

- LIMB capital costs were $31–102/kW (1992$) for plants ranging from 100–500 MWe and coals with 1.5–3.5% sulfur, with a target SO_2 reduction of 60%. Annual levelized costs (15-year) for this range of conditions were $392–791/ton of SO_2 removed.
- Coolside capital costs were $69–160/kW (1992$) for plants ranging from 100–500 MWe and coals with 1.5–3.5% sulfur, with a target SO_2 reduction of 70%. Annualized levelized costs (15-year) for this range of conditions were $482–943/ton of SO_2 removed.

Project Summary

The initial expectation with LIMB technology was that limestone calcined by injection into the furnace would achieve adequate SO_2 capture. Use of limestone in lieu of the significantly more expensive lime would keep operating costs relatively low. However, the demonstration showed that, even with fine grinding of the limestone and deep humidification, performance with limestone was marginal. As a result, a variety of hydrated limes were evaluated in the LIMB configuration, demonstrating enhanced performance. Although LIMB performance was enhanced by applying humidification to the point of approaching adiabatic saturation temperatures, performance did not rely on this deep humidification.

Coolside design was dependent upon deep humidification to improve sorbent reactivity and the use of hydrated lime. Sorbent injection was downstream of the furnace. In addition, sorbent activity was enhanced by dissolving sodium hydroxide (NaOH) or sodium carbonate (Na_2CO_3) in the humidification water.



Water mist, sprayed into the flue gas, enhanced sulfur capture by the sorbent by approximately 10% in the LIMB process when 20 °F approach-to-saturation was used.

Environmental Performance (LIMB)

LIMB tests were conducted over a range of Ca/S molar ratios and humidification conditions while burning Ohio coals with nominal sulfur contents of 1.6, 3.0, and 3.8% by weight. Each of four different sorbents was injected while burning each of the three different coals with one exception. Other variables examined were stoichiometry, humidifier outlet temperature, and injection elevation level in the boiler. Exhibit 3-37 summarizes SO_2 removal efficiencies for the range of sorbents and coals tested.

While injecting commercial limestone with 80% of the particles less than 44 microns in size (minus 325 mesh), removal efficiencies of about 22% were obtained at a stoichiometry of 2.0 while burning 1.6% sulfur coal. However, removal efficiencies of about 32% were achieved at a stoichiometry of 2.0 when using a limestone with a smaller particle size (*i.e.*, all particles were less than 44 microns). A third limestone with essentially all particles less than 10 microns was used to determine the removal efficiency limit. The removal efficiency for this very fine limestone was approximately 5–7% higher than that obtained under similar conditions for limestone with particles all sized less than 44 microns.

During the design phase, it was expected that injection at the 181-foot plant elevation level inside the boiler would permit the introduction of the limestone at close to the optimum furnace temperature of 2,300 ºF. Testing confirmed that injection at this level, just above the nose of the boiler, yielded the highest SO_2 removal. Injection was also performed at the 187-foot level and similar removals were observed. Removal efficiencies while injecting at these levels were about 5% higher than while injecting sorbent at the 191-foot level.

Removal efficiencies were enhanced by approximately 10% over the range of stoichiometries tested when using humidification down to a 20 ºF approach-to-saturation temperature. The continued use of the low-NO_x burners resulted in an overall average NO_x emissions level of 0.43 lb/10^6 Btu, which is about a 45% reduction.

Exhibit 3-37
LIMB SO_2 Removal Efficiencies
(Percent)

	Nominal Coal Sulfur Content		
Sorbent	**3.8%**	**3.0%**	**1.6%**
Ligno lime	61	63	53
Commercial calcitic lime	58	55	51
Dolomitic lime	52	48	45
Limestone (80% <44 microns)	NT	25	22

NT = Not tested
Test conditions: injection at 181 ft, Ca/S molar ratio of 2.0, minimal humidification.

Operational Performance (LIMB)

Long-term test data showed that the LIMB system was available about 95% of the time it was called upon to operate. Even with minimal humidification, ESP performance was adequately enhanced to keep opacity levels well below the permitted limit. Opacity was generally in the 2–5% range (limit was 20%).

Environmental Performance (Coolside)

The Coolside process was tested while burning compliance (1.2–1.6% sulfur) and noncompliance (2.8–3.2% sulfur) coals. Objectives of the full-scale test program were to verify short-term process operability and to develop a design performance database to establish process economics for Coolside. Key process variables—Ca/S molar ratio, Na/Ca molar ratio, and approach-to-saturation temperatures—were evaluated in short-term (6–8 hours) parametric tests and longer term (1–11 days) process operability tests.

The test program demonstrated that the Coolside process routinely achieved 70% SO_2 removal at design conditions of 2.0 Ca/S molar ratio, 0.2 Na/Ca molar ratio, and 20 ºF approach-to-saturation temperature using commercially available hydrated lime. Coolside SO_2 removal depended

Exhibit 3-38
LIMB Capital Cost Comparison
(1992 $/kW)

Coal (%S)	LIMB	Coolside	LSFO	LIMB	Coolside	LSFO
	100 MWe			150 MWe		
1.5	93	150	413	66	116	312
2.5	95	154	421	71	122	316
3.5	102	160	425	73	127	324
	250 MWe			500 MWe		
1.5	46	96	228	31	69	163
2.5	50	101	235	36	76	169
3.5	54	105	240	40	81	174

Exhibit 3-39
LIMB Annual Levelized Cost Comparison
(1992 $/Ton of SO_2 Removed)

Coal (%S)	LIMB	Coolside	LSFO	LIMB	Coolside	LSFO
	100 MWe			150 MWe		
1.5	791	943	1418	653	797	1098
2.5	595	706	895	520	624	692
3.5	525	629	665	461	570	527
	250 MWe			500 MWe		
1.5	549	704	831	480	589	623
2.5	456	567	539	416	502	411

on Ca/S molar ratio, Na/Ca molar ratio, approach-to-adiabatic-saturation, and the physical properties of the hydrated lime. Sorbent recycle showed significant potential to improve sorbent utilization. The observed SO_2 removal with recycled sorbent alone was 22% at 0.5 available Ca/S molar ratio and 18 ºF approach-to-adiabatic-saturation. The observed SO_2 removal with simultaneous recycle and fresh sorbent feed was 40% at 0.8 fresh Ca/S molar ratio, 0.2 fresh Na/Ca molar ratio, 0.5 available recycle, and 18 ºF approach-to-adiabatic-saturation.

Operational Performance (Coolside)

Floor deposits experienced in the ductwork with the horizontal humidification led designers to consider a vertical unit in a commercial configuration. Short-term testing did not permit evaluation of Coolside system availability.

Economic Performance (LIMB & Coolside)

Economic comparisons were made between LIMB, Coolside, and a wet scrubber with limestone injection and forced oxidation (LSFO). Assumptions on performance were SO_2 removal efficiencies of 60, 70, and 95% for LIMB, Coolside, and LSFO, respectively. The EPRI TAG™ methods were used for the economics, which are summarized in Exhibits 3-38 and 3-39.

Commercial Application

Both LIMB and Coolside technologies are applicable to most utility and industrial coal-fired units, and provide alternatives to conventional wet flue gas desulfurization processes. LIMB and Coolside can be retrofitted with modest capital investment and downtime, and their space requirements are substantially less than for conventional flue gas desulfurization processes.

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