Reducing Operating Costs in Stoker Boilers With Natural Gas Cofiring

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Natural gas cofiring in stoker boilers is now coming of age and maturing as an off-the-shelf tool to improve the economics of stoker boiler firing. This article seeks to review the five most popular economic drivers related to operating cost reductions available through natural gas cofiring.

BACKGROUND

Natural gas cofiring is a technology that blends the most desirable characteristics and capabilities of natural gas with more difficult and problematic solid fuels like coal and wood wastes. Natural gas cofiring involves the use of a very small amount of natural gas, typically less than 10%, firing over stoker grates through special burners. The cofiring burners that have been developed are of a high pressure drop, very turbulent design. The effect of the gas firing zone is to burn out carbon particulate, lower excess air requirements, and smooth out solid fuel variabilities and excursions. This translates into lower operating costs and improved stoker operations even with natural gas fuel costs being two times the cost of coal on a Btu basis.

Burner companies throughout the world and especially in the United States have installed natural gas burners into solid fuel fired boilers for more than 50 years. This, however, is not cofiring. Cofiring is the special systems, equipment, and operational techniques that allow for natural gas to be burned simultaneously with other fuels.

Starting in the mid 1980's, the gas industry began exploring whether auxiliary gas burners could offer significant benefits to boiler operators when used for sustained gas cofiring rather than solely for warm-up or standby duty. Consolidated Natural Gas Company (CNG) through East Ohio Gas evaluated cofiring at Kent State University and a power plant in Painseville, Ohio, chain grate and spreader stokers, respectively, both equipped with single COEN COFYR burners. The Gas Research Institute (GRI) evaluated cofiring at a Vanderbilt University spreader stoker equipped with dual COEN COFYR burners.

The process of cofiring has come through a learning curve and progression just like a number of other technologies. These early projects used off-the-shelf single gas burners designed for 100% firing. At the required cofiring turndown rate the burner's large throats produced a lazy flame that did not penetrate the furnace. These burners did displace some coal Btu input with natural gas and showed marginal additional benefits of improved operational flexibility, increased efficiency, and reduced NO_x emissions and opacity. However, the systems as evaluated were not optimized and did not show nearly the kinds of benefits that today's specialty burners provide.

Additional work was needed in both market development and burner/boiler engineering to deliver the full potential of cofiring benefits. To further develop cofiring practices, GRI initiated a series of demonstration projects with a team comprised of East Ohio Gas, Columbia Gas Cos., Acurex Environmental, and COEN Company to optimize cofiring equipment and practices, and to verify performance and economic benefits.

Cofiring today typically means two burners arranged for tangential firing to maximize turbulence. The design of these burners create a spinning flame as the burner fires over the grate. This turbulence makes for an incineration zone over the grate. At the time this article was written, 12 stoker cofiring projects were either in an operating, installation, or procurement phase. These projects are listed as follows:

Site	Status
Vanderbilt University, TN	Operational
Kent State University, OH	Operational
Dover Municipal, OH	Operational
Hoover, OH	Operational
Oberlin University, OH	Operational

Ford Motor, OH	Operational
Notre Dame University, IN	Operational
Boise Cascade, WA	Procurement
Eli Lilly, IN	Procurement
D.B. Johnson, WA	Procurement
Anon. Site #1, VA	Procurement
City of Manitowach Public Utility	Procurement

The most prominent economic drivers for cofiring projects have traditionally been environmentally based. Cofiring is one of the most cost effective means to avoid air pollution compliance upgrades with stoker boilers when using solid fuels. Cofiring's ability to reduce particulate is well documented through extensive testing at a number of the operational sites. The five most popular operating cost reduction drivers that have been experienced with cofiring include the following:

1. Efficiency Improvements
2. Relaxed Coal Specifications
3. Opportunity Fuels
4. Summer Loads/Turndown
5. Derate Recovery

EXAMPLES OF COFIRING OPERATING COST REDUCTION SCENARIOS

The growing population of successful natural gas/coal cofiring projects has yielded important information on operating cost savings. The information presented below is for a fictitious site created for example purposes. However, the information used has been obtained or inferred to be reasonably based on actual site performance data.

EXAMPLE —COAL STOKER SITE INFORMATION

1. Fired output needed = 90,000 MBtu's
2. Efficiency = 72%
3. Gas cost = $3.00/MMBtu
4. Coal cost = $2.00/MMBtu ($50/ton @ 12, 500 Btu/pound)
5. Operating hours (8,000 per year)
   65% full load
   35% @ 15,000 MBtu's (Summer)

OPERATING COST REDUCTION DRIVERS

1. Efficiency Improvements

Cofiring with natural gas in stoker boilers has been shown to improve efficiency (heat rate) by 2.6% at Dover, Ohio, and 7.0% at Oberlin, Ohio. Three phenomena contribute the most to this. They are carbon burnout, excess air reduction, and firebox heat transfer improvements.

Carbon burnout occurs as unburned carbon in airborne particulate comes off stoker grates and becomes consumed in the gas cofiring zone. Measured reductions of carbon in fly ash were found to be typically 33-35% (Dover, Ohio, site).

Documented Carbon Burnout—Dover, Ohio, Site (Percent Carbon in Fly Ash)

	Baseline	Cofire
Fly Ash	36	24
Mechanical Collector	67	42
Bottom Ash	16	18

Carbon burnout also helps to reduce quantities of ash that need disposal. Cofiring's more effective burnout of carbon also makes for less sooting and a cleaner fire side. This improves heat transfer between soot blows and also reduces soot blow frequency.

When cofiring burners are deployed they also make for more effective mixing/turbulence in the firebox area. This increases heat transfer in the firebox section of the boiler. Stack temperature reductions of 15-20 degrees Fahrenheit have been experienced with cofiring.

Cofiring burners deliver air and oxygen for combustion (excess air) in a zone where overfire air is typically introduced. This air helps to minimize the need for over-fire air. It also helps to reduce the overall need for excess air.

Sites have experienced an overall reduction in induced draft fan air flow requirements. The reduction in flow requirements and friction losses makes for horsepower savings at the I.D. fan.

Efficiency increases tend to almost offset the increased fuel costs associated with natural gas. These increases alone generally do not offer enough operating cost savings to make cofiring attractive.

Site Impact (Increase Efficiency 3.0% with Cofiring)

A. Previous Fuel Input Cost:
125 MMBtu's ($2) = ... $250/Hour

B. Cofiring Fuel Input Cost (10% Gas Use):
New fuel input = 90/.75 = 120 MMBtu's
Coal Cost = 108 ($2) = ... $216/Hour
Gas Cost = 12 ($3) = ... $36/Hour
Total Cofiring Fuel Cost $252/Hour
Net Deficit ($2/Hour)

2. Relaxed Coal Specifications

Cofiring with natural gas has been documented to give boilers a wider operability range. Operability for a stoker generally means the ability to perform without opacity (smoking) episodes and/or slagging. Cofiring also reduces Sulfur Dioxide, Nitrogen Oxide, and Carbon Monoxide emissions. This increased operability also means that a wider range of fuels can be successfully burned.

Cofiring experiences to date have shown the biggest coal specification change opportunity to be in the area of burning more fines. Coal fines (severely undersized particles) generally blow through stokers and cause back end (flue gas cleanup) problems. Cofired boilers (the Dover, Ohio, case especially) have been able to accept substantially more in the way of fines.

The potential for trying local/lower-priced coals may have merit with a cofired stoker. This is especially helpful in a world in which stoker coal suppliers are becoming scarce.

The following economics apply to our example site for a scenario where coal costs are able to be reduced by only 10%.

Site Impact (Relaxed Coal Specifications—10% Coal Cost Reduction)

A. Previous Fuel Input Cost:
125 MMBtu's ($2) = ... $250/hour

B. Cofiring Fuel Input Cost (10% Gas Use):
New fuel input = 90/.75 = 120 MMBtu's $250/Hour

Coal Cost = 108 ($1.80) = ... $194.40/Hour
Gas Cost = 12 ($3) = ... $36/Hour
Total Cofiring Fuel Cost $230.40/Hour

Net Benefit $19.60/Hour

3. Opportunity Fuels

Cofiring's unique ability to incinerate carbon/volatiles over stoker grates makes for a unique opportunity to utilize waste fuels including biomasses (i.e. opportunity fuels). In cases where waste fuels are used, cofiring may make it unnecessary to do as careful of a job in preparation (sizing/drying). This can especially improve the potential for more biomass use.

In cases where opportunity fuels have been considered but deemed not feasible (manufacturing solid wastes from foods or furniture) because of a need for baghouse upgrades or extensive back end cleanup, times may have just changed. A number of studies have identified cofiring as the lowest first cost way to reduce particulate emissions for many operating/fuel scenarios.

The following economics apply to the example site for cofiring with 10% opportunity fuels. It was assumed for purposes of this article that an opportunity fuel would be available at $.10/MMBtu's. In some cases, off-site disposal cost savings would credit handling/preparation costs for the opportunity fuel.

Site Impact—10% Opportunity Fuels

A. Previous Fuel Input Cost:
125 MMBtu's ($2) = $250/hour $250/Hour

B. Cofiring Opportunity Fuel Cost:
New fuel input = 90/.75 = 120 MMBtu's
Coal Cost = (96 MMBtu's) ($1.80) = $172.80/Hour

Opportunity Fuel Cost =
(12 MMBtu's) ($.10) = $1.20

Gas Cost = 12 ($3.00) = ... $36/Hour

Total Cofiring Fuel Cost $210.00/Hour

Net Benefit $40.00/Hour

4. Summer Loads/Turndown

Cofiring gives you the ability to turn your old minimal turndown boiler into a 10 to 1 or more turndown gas boiler, almost instantaneously, only for as long as you need it to be that way.

Our firm has known of a number of cases where stokers can not get down to where they need to be for summer loads or during process load reductions (evenings/weekends). The answer for some is to make the minimum steam and just vent it. Still others discontinue stoker operations at the first sign of seasonally lower loads and run gas boilers. Cofiring allows for the turndown conditions to occur in a way that matches and follows loads.

Another issue to consider is the typical degradation of stoker boiler efficiency as loads drop. Operating on gas during these load conditions makes for more efficiency. This also helps to offset the natural gas cost premium. Cost savings can come from eliminating the need to make steam and then vent it. Savings can also come from eliminating the need to operate alternate equipment (standby boilers) just to handle what the stoker cannot.

The potential for cost reductions available from eliminating summer or low load waste for the example site are as follows:

Site Impact—6 to 1 Turndown Versus 4 to 1

Previous Hourly Cost

Input fuel = 22.5/.65 = 34.62 MMBtu's

Cost = 34.62 ($2) = $69.24/hour $69.24

Gas Use Cost (2% Efficiency Increase)

Input fuel = 15/.74 = 20.77 MMBtu's

Cost = 20.27 ($3) = $60.81/hour $60.81

Net Benefit $8.43/Hour*

Firing on gas during low loads and summer conditions also frees up labor and makes for less wear and tear on boiler auxiliaries. Addi-

*Plus water/boiler auxiliaries/labor.

tional electrical savings also occur from reduced coal/ash handling equipment operations. In some cases overtime for coal or ash handling system maintenance can also be minimized.

5. Derate Recovery

Cofiring has been demonstrated to allow stoker boilers to once again operate near design steaming capacity. Steaming capacities can degrade over time for a number of reasons. In some cases, coal conditions from various suppliers have changed from design such that operating at full load makes for severe opacity (smoking).

Recovering this capability with cofiring makes it possible to avoid the use of alternate equipment, (in some cases gas boilers), to regain this load. This means that more load can be provided at lower mixed fuel costs. Derate recovery also helps reduce costs where on site power generation occurs. Our firm has seen a number of cases where aerated stokers leave money on the table by not generating enough steam to meet turbine capacities. Cofiring helped Dover Light & Power achieve a 10% increase in peak steaming capacity. This made for an additional 1.5 MW of capacity.

The potential for cofiring cost reduction related to better use of mixed fuel capacity for the example site are as follows.

Site Impact- 20,000 MMBtu's increased capability

Cost On Gas Boiler

Cost = (20/.74)($3.00) $81.08/Hour

Cost With Cofiring

Cost = (20/.74)($2.33) = ... $62.97/Hour

Net Benefit = $18.11/Hour

CONCLUSIONS

Operating cost benefits for the example site described above, using each of the five largest operating cost savings drivers, make for the following annual benefits: (8,000 hours total, 65% at full load, 35% at 15 MMBtu)

Benefit component	Annual Savings
1. Efficiency	($10,400)
2. Coal Specifications	$101,920
3. Opportunity Fuels	$106,080
4. Summer Loads	$23,604
5. Derate Recovery	$94,172
Total Savings	*$305,376*

It's very rare that all of these benefits would be available to any one site. However, it's also very rare that cofiring is implemented only because of operating cost benefits. In fact, most of the installed site drivers considered environmental and operating benefits as primary motivators.

Site Economics

The cost of cofiring depends on many things. However, installed costs have generally ranged between $180,000 and $400,000 per boiler. Most sites with only one or two of the operating cost drivers identified will find attractive investment returns with cofiring.

The simple paybacks at the example site versus the operating cost drivers identified for a $250,000 installed cost project would be as follows.

Example Site Paybacks

Case	Payback
All Benefits	8 Months
Efficiency/Coal	3.3 Years
Efficiency/Coal/Summer	2.7 Years
Efficiency/Coal/Derate	1.5 Years

All sites present unique and specific circumstances. Careful detailed analyses need to be done before project commitments are made.

Cofiring stoker boilers with natural gas is now becoming a more general tool with substantial operating history. The technology has now evolved and operating practices are well defined. The industry expects the number of project sites to at least double by the end of 1998. Operating cost reductions are now well recognized as an important and growing driver for making this happen.

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Mr. Puskar's firm is contracted with The Industrial Center, Inc., Arlington, VA, to provide technical marketing agent services to the cofiring industry. The Industrial Center's Executive Director, Mr. Bruce Hedman, Ph.D., represents a consortium of natural gas utilities including East Ohio Gas, Indiana Gas, Northern Indiana Public Services, MichCon, Consolidated Natural Gas and Columbia Gas of Ohio in this effort.

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