Externally Co-Firing Existing Boilers with the Products of Combustion of Various Solid Wastes

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Introduction

The term "co-firing", when used by members of the biomass or utility communities, has come to mean mixing a modest amount of clean, dry sawdust with coal and burning the sawdust coal mixture in the existing coal firing equipment of a large, coal-burning, utility boiler. The sawdust typically supplies between 1.5% and 8.5% of the total heat input to the boiler. Boiler steam flows are generally upwards of 1,000,000 lb/h. The power generated is 150 MW_e and more.

The advantages of co-firing include displacing coal and lowering utility carbon dioxide emissions from fossil fuels. Emissions from fossil fuels are considered to be greenhouse gases (GHG). GHG's contribute to global warming. Carbon dioxide emissions from wood waste, agricultural waste, municipal solid waste, etc, i.e., from fuels comprised mostly of cellulose, hemicellulose, etc., are not considered to be GHG's. The argument made is that trees and plants inhale this CO_2 and recycle it as plant matter. In the process tress and plants exhale oxygen. In the present, post-Kyoto era, CO_2 emissions from fossil fuels displaced by CO_2 emissions from wood waste earn the utility CO_2 "offsets". The exact nature of these "offsets" is not known at the present time

This article uses the phrase "external co-firing" to describe a system in which a solid waste (such as wood waste) is burned in an external combustor that has been built alongside, or in close proximity to, an existing boiler. The products of combustion from the external combustor are ducted to the boiler furnace at temperatures between 1,800^{o}F and 2,200^{o}F (982^{o}C to 1204^{o}C). The moisture content of the solid waste can be as high as 65% on a wet basis (186% on a dry basis).

Two "externally co-fired" boiler examples are described in this article. The first example deals with externally co-firing an existing pulp mill power boiler with wood waste which is too wet and/or too dirty to burn on the boiler's grates. The second example involves externally co-firing an existing, coal-fired, utility boiler with hog fuel or other suitable types of biomass waste. The term "hog fuel" refers to wood waste processed by a "hog", i.e., a shredder, hammer or knife hog. The hog reduces the size of the largest dimension of the bark, log ends, slabs, etc., down to 3" minus, typically.

Hog Fuel Power Boilers in Pulp Mills

Externally Co-fired Hog Fuel Burning Power Boiler; Typical Example

The typical example of an externally co-fired hog fuel boiler involves a pulp mill with wood waste, sludge or clarifier dregs too dirty and/or too wet to be burned in its existing power boiler. The mill

practice has been to landfill this material. The provincial/state environmental authorities notify the mill that it can no longer landfill this waste.

The solution for the pulp mill is to install a "clean burning" external combustor within 50 to 100 feet of the hog fuel boiler as well as a breeching - a horizontal, refractory-lined duct - between the combustor's discharge and the boiler's furnace. The dirty/wet waste is disposed in the external combustor. The external combustor's nominal 1,800^{o}F to 2,200^{o}F (depending upon fuel moisture content) "clean" products of combustion are routed to the boiler through the breeching. The "dirt" in the solid waste stays in the external combustor and is removed by its built-in ash removal system.

An external combustor which can process the pulp mill's dirty, wet waste, and whose products of combustion meet the particulate limit of the BC Ministry of Environment, Land and Parks' (MELP) of 120 mg/Nm^3 (milligrams per normal cubic metre) at 8% oxygen by volume - straight out of its nominal 2,000^{o}F stack - is the two-stage Heuristic EnvirOcycler. This particulate loading is approximately 0.05 gr/dscf (grains per dry standard cubic foot) at 12% carbon dioxide by volume.

The EnvirOcycler gasifies wet wood waste in its very large first stage of gentle updraft gasification. It then burns the first stage producer gas in a second stage of vigorous cyclonic combustion; the second stage is located immediately above the first stage.

The US Environmental Protection Agency specifies a particulate limit of 0.08 gr/dscf at 12% CO_2 in ' 60.52 "Standard for particulate matter" in Subpart E "Standards of Performance of Incinerators", Title 40, Part 60 of the Code of Federal Regulations, Revised as of July 1, 1995. Regional US pollution control agencies can, of course, set tighter standards.

Earlier versions of the EnvirOcycler, developed by the author in the late 1970's at the height of the oil crisis, have been in continuous service in the North American forest products industry for over 19 years. March 1999 tests on one of these units showed less than 2 ppmv for CO and 20 ppmv for NOx, corrected to 12% carbon dioxide by volume, when burning typical sawmill wood residue.

Externally Co-fired, Hog Fuel Burning, Power Boiler; Special Case

This "special" case involves a BC pulp mill which has accumulated a very large pile of hog fuel on its mill site over the last 30 years. MELP is very concerned about leachate from the pile affecting fish habitat in nearby streams. Disposing of the hog fuel in the existing 625 psi/750^{o}F 200,000 lb/h power boiler would create problems. Burning old, high moisture content, low Btu, hog fuel on the boiler's pin hole grate would seriously affect the boiler's ability to satisfy the steam load. At a minimum, the higher ash content would require more frequent grate cleaning.

A solution is to dispose of the old hog in a total of three 90 Million Btu/h Heuristic EnvirOcyclers each with its own built-in, automatic, ash removal system. The 1,800^{o}F products of combustion from each EnvirOcycler are routed to a common stack. A breeching extends from the stack to the front wall of the boiler. The products of combustion can either be dumped up the stack to atmosphere, all the while complying with MELP's 120 mg/Nm^3 particulate limit or, under the

action of the boiler's induced draft fan, be drawn into the boiler furnace through openings in the furnace wall.

Figures 1 and 2 are elevation and plan views of a 625 psi/750^{o}F, 200,000 lb/h hog fuel power boiler at this particular BC pulp mill. Also shown are three, 90 Million Btu/h Heuristic EnvirOcyclers, each firing a common stack.

Each of the three EnvirOcyclers shown is sized to burn 20 wet tonnes/h of 65% (wet basis) hog fuel. The figures show the breeching, which conveys the 1,800^{o}F products of combustion running from the stack to the boiler furnace. Holes are cut in the furnace wall, and the appropriate boiler tubes are bent, to allow entry of the 1,800^{o}F "flue gas" to the boiler furnace. The 1,800^{o}F temperature corresponds to burning 65% moisture content BC coastal hog fuel at an excess air of 18.8% (2.6% oxygen by weight, 2.2% by volume).

Assuming all three EnvirOcyclers are operational 85% of the time, the system shown disposes of just over 150,000 units (200 ft^{3} "units") of hog annually. About 219 tonnes/h, or 111,000 scfm, of products of combustion are discharged to atmosphere. Some, or even the major portion, of these can be induced through the breeching into the boiler and used to displace a significant amount of the imported fresh hog fuel and the natural gas regularly consumed.

Coal Burning Utility Boilers

Problems with Simple Co-firing of Coal Burning Utility Boilers

Simple co-firing of coal-fired utility boilers, as described at the beginning of this article, has not always worked out as planned. The reason this is so is related to the high percentage of coal-fired boilers being fueled by pulverized coal. Co-firing to date has involved mixing wood waste with coal, pulverizing the coal/wood mixture and then burning the mixture in the existing tangentially fired, pulverized coal burners.

Problems have arisen in pulverizing the coal/wood mixture. The moisture content of the "white" wood waste - typically sawdust (i.e., no bark) - must be less than 20% and the maximum dimensions of the wood particles before admission to the coal pulverizers must be kept below 1/4". 3% blends (3% wood, 97% coal) are reported to behave in a similar manner to "wet coal". Output has been reduced by as much as 8%. Emissions have increased.

The presence of potash and soda in wood ash has led to alkali deposits fouling boiler tubes. The fouling problem is worsened when agricultural waste is co-fired because of its higher alkali and its heavy silica (for example: rice hulls) content. In addition, because of the presence of alkalis in the boiler ash its market value to the cement industry is decreased.

Installing a separate wood feed system, independent of the coal feeding system, can reduce the pulverizing and feeding problems. However, separate feed systems do not solve the alkali problem. That problem can be quite severe in boilers designed to operate under supercritical steam conditions.

Externally Co-fired Coal Burning Utility Boilers; Advantages

There are a number of advantages to externally co-fire a large, coal burning, utility boiler with the products of combustion from an external, wood burning, two-stage combustor which meets particulate levels of 0.05 gr/dscf straight out of its stack, such as the EnvirOcycler.

The first obvious advantage is that, because of the very low level of particulate in its products of combustion emission, 99% "plus" of the wood ash stays in the EnvirOcycler's first stage from which it is removed by the first stage's built-in ash removal system. As a result the load on the existing boiler stack clean up system actually decreases.

A second advantage is that, because of the EnvirOcycler's large grate surface area, its grate temperatures rarely exceed 1,200^{o}F (649^{o}C) when burning wood waste. This is 200^{o}F lower than the boiling point of potassium (1,400^{o}F) and over 400^{o}F lower than the boiling point of sodium (1,616^{o}F). As a result, the amount of potassium and sodium vapors carried over into the boiler by the EnvirOcycler's products of combustion is quite small. Minimal alkalis means minimal alkali deposits.

A third advantage of external co-firing is the flexibility afforded in the type and moisture content of the biomass co-fired. The EnvirOcycler can dispose of wood waste with moisture contents ranging from 10% to 65% on a wet basis. This includes bark from ocean borne logs which contains sea salt.

Now, it is known that the cellulose molecule in wood and paper can react with elemental chlorine from NaCl (and PVC's, see below) to form dioxins and furans. However, because the EnvirOcycler's second stage is refractory-lined, virtually all the dioxin or furan molecules formed in its first stage are completely destroyed by the 1,800^{o}F to 2,200^{o}F temperatures in its second stage. There are no waterwalls present in the second stage to radiantly suck heat out of the burning "producer gas" according to T^4 - thereby locking in some of the intermediate products of combustion such as dioxins and furans - as happens in large, mass burning boilers in waste-to-energy plants.

Flexibility in the type of fuel consumed extends to agricultural wastes (including rice hulls), refuse derived fuels (RDF), shredded municipal solid waste (MSW), mixtures of shredded MSW and municipal sewage sludge, demolition and construction debris, etc. Dioxins and furans - formed in the EnvirOcycler's first stage when PVC (polyvinylchloride) plastics are incinerated - are essentially destroyed in the EnvirOcycler's second stage.

A fourth advantage is the EnvirOcycler's turndown ratio of at least 5:1. Thus, a 75 Million Btu/h EnvirOcycler, externally co-firing a 1,000,000 lb/h coal burning utility boiler supplying steam to a 150 MW_e generating station can operate at 15 Million Btu/h and still meet all its environmental specifications. Turndown ratios of as high as 9:1 have been observed in these combustors.

A fifth advantage relates to the EnvirOcycler's 15 second response time. In other words, within 15 seconds of a step change to the Set Point of the EnvirOcycler's Btu Demand controller, the Btu Output has changed to 63% of the final value. This is considered quite fast. The quick response time is due to the EnvirOcycler's first stage of updraft gasification and the fact that the

underfire airflow control behaves exactly like a "gas valve". An increase in underfire air generates more producer gas and hence delivers more Btu's to the boiler. A decrease in underfire air results in less Btu's sent to the boiler.

A sixth advantage of co-firing a coal-burning boiler with an external combustor, such as the EnvirOcycler, which has been fitted with a dump stack permits the rapid dumping of the co-fired waste's products of combustion to atmosphere in the event of an emergency. Since the products of combustion meet 0.05 gr/dscf when burning wood waste the amount of stack cleanup required during this emergency procedure would be minimal. Feeding the co-fired waste in with the coal does not afford this flexibility.

Finally, the most significant advantage of all of external co-firing is the possibility of burning wood/coal blends of at least 10% (10% wood, 90% coal). The literature on simple co-firing pulverized coal boilers would indicate that blends of 3% to 4% are all that are practical without pre-drying and, perhaps, pre-hammermilling, the clean, white wood waste. The blend percent it could be higher than 10%. The limit is established by the lower radiant heat transfer to the furnace water walls and the superheater tubes from the external combustor's nominal 2,200^{o}F products of combustion. The temperature of the products of combustion of pulverized coal exceeds 3,000^{o}F.

Externally Co-fired Coal Burning Utility Boilers; Costs

A major US utility studied the possibility of converting a 270 MW_e pulverized coal burning boiler to burn mixtures of 10% wood waste and 90% coal. Preliminary calculations reveal that, assuming "standard" 1970's coal burning, utility, power plant technology, the 2,200^{o}F products of combustion from three, wood burning, 75 Million Btu/h, EnvirOcyclers, each externally co-firing a single 270 MW_e coal-fired boiler, transfer sufficient sensible heat to the boiler to produce enough steam to generate just over 27 MW_e.

The estimated installed cost of the three EnvirOcyclers, the wood waste storage bin, and all conveyors and breechings is about US $8 Million. This works out to about US $300/$kW_e$.

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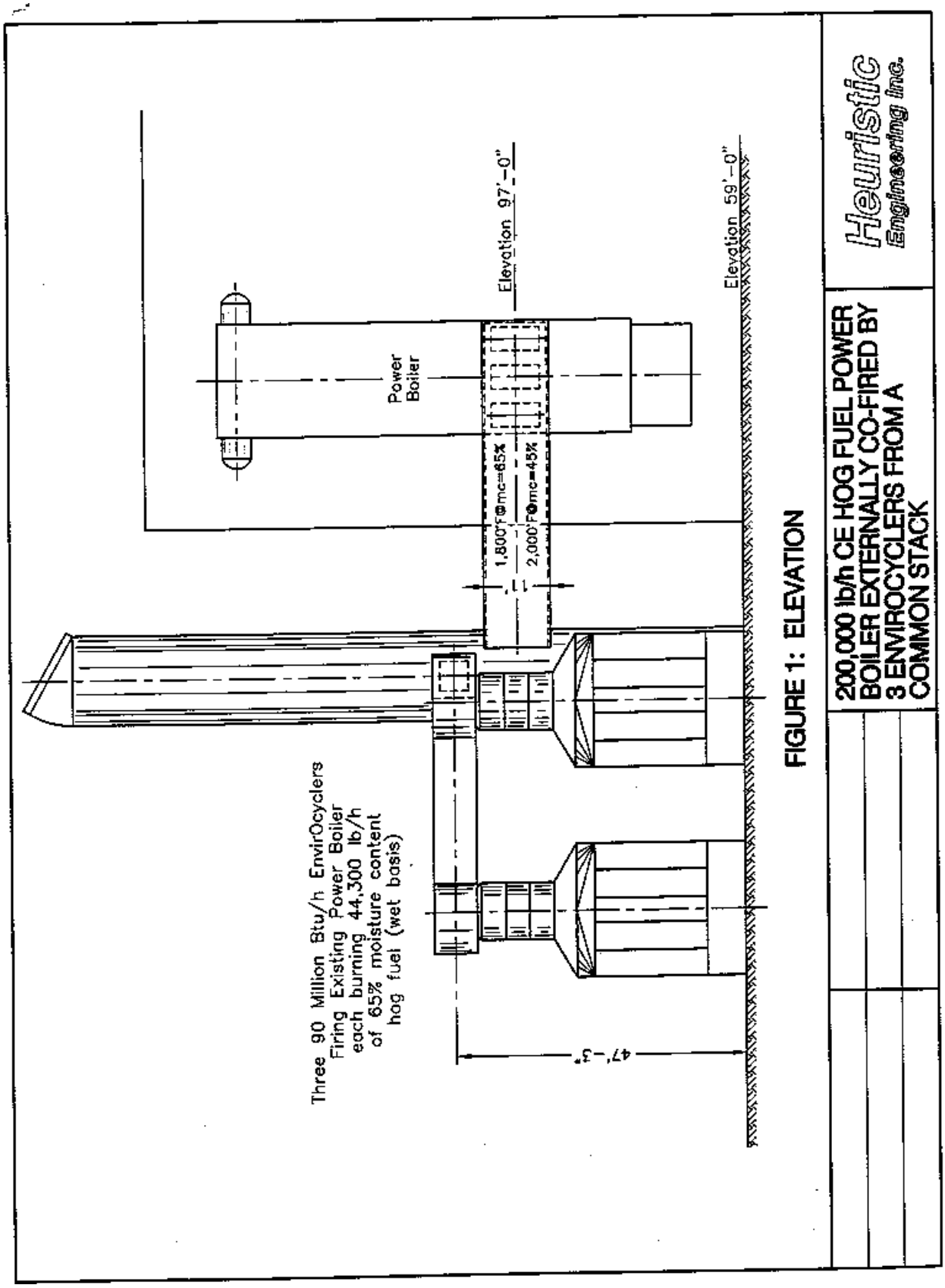
Power Boiler
Elevation 97'-0"
Elevation 59'-0"
1,800°F@mc=65%
2,000°F@mc=45%
47'-3"
Three 90 Million Btu/h EnviroCyclers
Firing Existing Power Boiler
each burning 44,300 lb/h
of 65% moisture content
hog fuel (wet basis)
FIGURE 1: ELEVATION
200,000 lb/h CE HOG FUEL POWER BOILER EXTERNALLY CO-FIRED BY 3 ENVIROCYCLERS FROM A COMMON STACK
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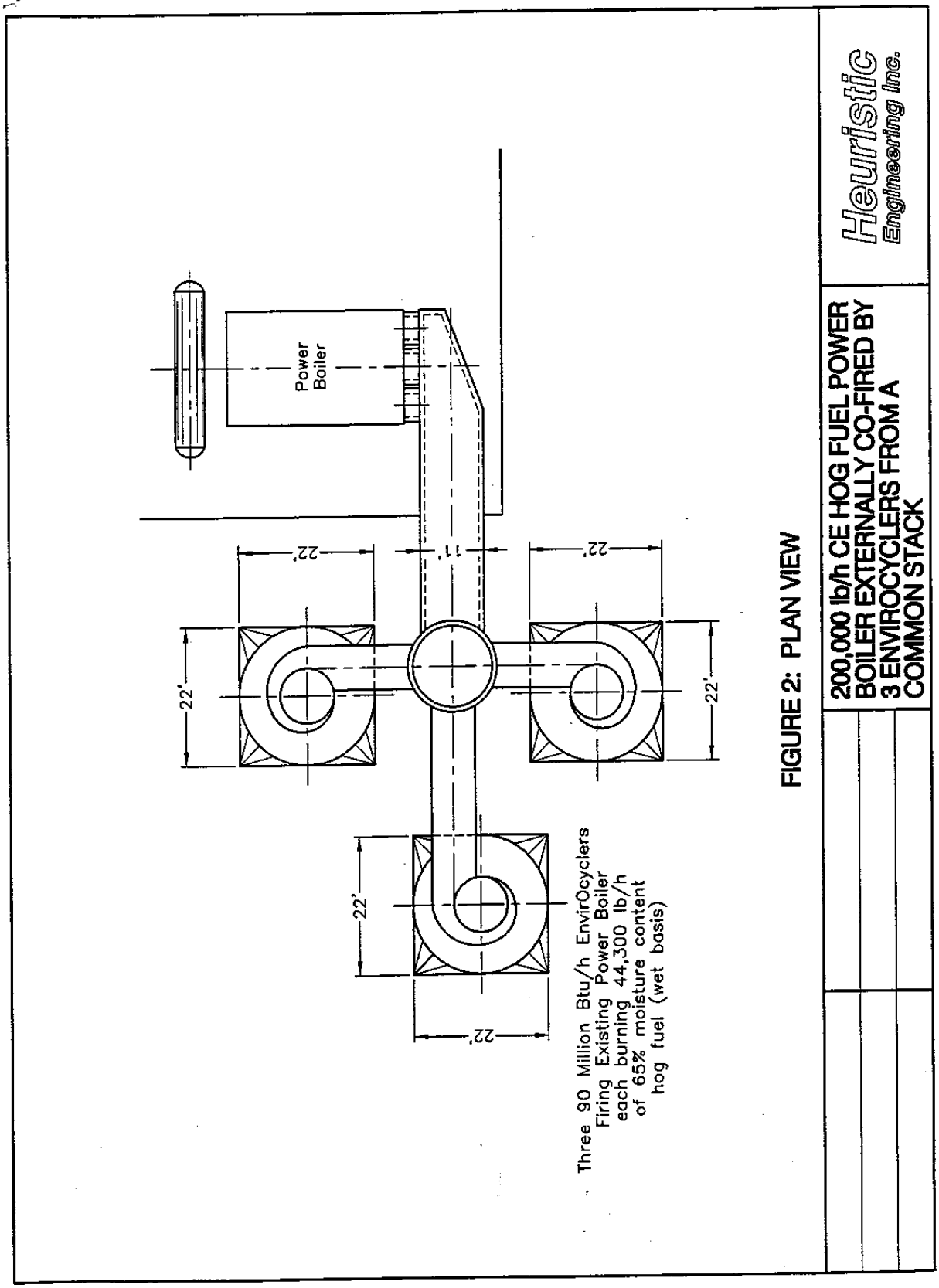
Power Boiler
22'
11'
22'
22'
22'
22'
Three 90 Million Btu/h EnvirOcyclers Firing Existing Power Boiler each burning 44,300 lb/h of 65% moisture content hog fuel (wet basis)
FIGURE 2: PLAN VIEW
200,000 lb/h CE HOG FUEL POWER BOILER EXTERNALLY CO-FIRED BY 3 ENVIROCYCLERS FROM A COMMON STACK
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