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Environmental Assessment of Dry Coke Quenching Vs. Continuous Wet Quenching

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Environmental Assessment of Dry Coke Quenching Vs. Continuous Wet Quenching

by

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1.0 INTRODUCTION

In the early 1970's the Weirton Steel Division of National Steel Corporation built a new coke plant consisting of a single battery of 87 ovens and complete coal chemical plant and support facilities. The Brown's Island plant featured the most advanced production techniques and air and water pollution control devices. A significant feature of this plant was the development of a new concept in abating air pollution normally associated with the pushing and quenching operations. The system, designed and constructed by Weirton Steel, and the Koppers Company with the support and cooperation of EPA, provided for a totally enclosed coke pushing and a continuous wet quenching system. There have been a number of mechanical and design problems that have prevented the continuous operation of this system.

As a response to energy conservation needs and as a possible solution to environmental problems from coke quenching and pushing, DOE (formerly ERDA) and EPA awarded a contract on August 1, 1977 to National Steel Corporation to perform a feasibility study for the installation of a dry coke quenching facility at their Weirton Steel Division's Brown's Island coke battery. A subcontract was awarded to Pennsylvania Engineering Corporation, the exclusive licensee of the Waagner-Biro dry coke quenching process in the United States, to provide the design engineering and solicitation of the necessary equipment pricing. The project was completed in September 1978.

In addition to the basic engineering and cost data provided by this study, estimates were made for emissions from the dry quenching process. Unfortunately, data were not provided for the potential emissions that might result from transport of the dry quenched coke from the quenching area to the end users of the coke nor for the emission reductions resulting from decreased steam production requirements at the steam generating plant.

Information from project reports, various draft reports, and observations made during a site visit to the National Steel Corporation's Weirton, West Virginia, plant are analyzed in this report to provide a first level assessment of the environmental impact of installing a dry coke quenching process at the Brown's Island coke plant. Information needed to complete an environmental assessment of this process change is identified.

2.0 SUMMARY AND CONCLUSIONS

This report compares the multi-media environmental impact of continuous wet quenching and dry quenching of coke as applicable to National Steel Corporation's Weirton, West Virginia plant. In both cases, only coke produced by the Brown's Island battery is considered. Very limited test data directly applicable to either case are available. The data presented, therefore, are based on design information, test data from related processes, and engineering estimates. Particular notice should be taken that modifications to the continuous wet quenching process have been made, and which are not reflected in the data tabulated, that could measurably affect the comparison, especially for solid and liquid discharges. Table 1 summarizes the various emissions from the processes. It does not include the emissions that might result as the coke is transported from the quenching area to areas of final use (blast furnace, sinter plant, etc.). The comparison includes pushing emission controls, emissions from the coke cooling processes, and emissions from the steam generating boilers. In calculating emissions from the boilers, it was assumed that all particulate and fly ash emissions occurred as a result of coal burning and that coal consumption would decrease in proportion to the amount of steam produced by dry quenching.

It can be seen that dry coke quenching results in substantially lower emissions of particulate matter, less solid waste (calculated on a dry solids basis), and less gas that has been in direct contact with hot coke. There is also a strong probability that less organic material would be emitted by the dry coke quenching process. The dry quenching process, however, has a substantially higher aqueous effluent. A substantial fraction of this effluent is untreated river water used for noncontact cooling of the bunker shell. Effluent from the coke pushing gas cleaning car accounts for 146 ℓ/Mg (this is not counted in the wet quench since the effluent is recycled to the cooled coke). Thus, only 36 ℓ/Mg (from the bunker seal) is a direct dry coke quench process effluent.

TABLE 1. EMISSIONS COMPARISON[a]

Type Emission	Continuous Wet Quenching 154 Mg/hr Design	Continuous Wet Quenching 125 Mg/hr Rate	Dry Quenching 125 Mg/hr Design	Difference[b] at 125 Mg/hr Rate
Particulates	0.484 Kg	0.53 Kg	0.038 Kg	0.492 Kg
Solid Waste	4.28 Kg	4.28 Kg	1.033 Kg	3.25 Kg
Liquids				
Process Related	197 liters	197 liters	379 liters	(182 liters)
Vessel Cooling			269 liters	(269 liters)
Gaseous				
Process Contact	1675 M^3	2090 M^3	291 M^3	1799 M^3
Noncontact	-		203 M^3	(203 M^3)
Organic, Air Emissions				
Polynuclear Aromatic Hydrocarbons	0.42×10^{-3} Kg	0.42×10^{-3} Kg	Unknown but estimated to be much lower than wet quenching.	-
Polar compounds	0.61×10^{-3} Kg	0.61×10^{-3} Kg		-
Benzo(a)pyrene	0.024×10^{-3} Kg	0.024×10^{-3} Kg		-

[a]All data are calculated per megagram (1000 Kg) of coke produced.

[b]Numbers in parentheses indicate areas where emissions from dry quenching exceed those from continuous wet quenching.

Coke transport emissions are not included in Table 1 because there is insufficient data to estimate the magnitude of the emissions. Visual inspection of the transport system when conventionally wet quenched coke was being processed indicated little fugitive emissions from all sources. Emission factor calculations indicate that dust emissions from dry coke transport could be as much as 144 times higher than for wet coke. One Japanese company reports that emissions at the coke screening station are three times as great as experienced when wet coke is processed. However, since the Japanese use enclosed conveyors in addition to the control equipment at the screening station and blast furnace coke storage area, and since there are no emission controls on the Weirton system, one can only say that emissions from dry coke transport should be substantially greater than from wet coke. No accurate statement of the relative magnitude can be made.

The conclusions that can be drawn from the available data are:

1. Substantially less particulate matter should be emitted to the atmosphere from dry coke quenching.
2. Substantially less direct process contact gas should be emitted from dry coke quenching.
3. Substantially less solid waste will be generated by dry coke quenching only if steam produced by the process is accompanied by decreased coal use at the plant steam generating boilers.
4. Substantially more aqueous effluent is generated by the dry quenching process. About 40 percent of this additional water has been in direct contact with process solids.
5. A substantial increase in emissions from coke transport and screening will occur from the dry coke quenching process unless some type of dust control is instituted.
6. Obvious options available for control of transport emissions are: wetting the coke, adding a chemical dust suppressant, or installing dust capture and control equipment.

   With regards to the last conclusion, wetting the coke may eliminate some of the potential advantages of using dry coke in the blast furnace. Chemical dust suppressants are unproven in this application. Installing control equipment is the most expensive but surest way of controlling emissions and retaining the potential advantages of blast furnace usage of dry coke.

7. Engineering assessment indicates less organics, particularly polynuclear aromatic hydrocarbons, will be emitted from the dry coke quenching process.
8. With proper operation of wastewater treatment facilities and control of coke transport emissions, dry coke quenching should have less negative environmental impact than continuous wet quenching.

3.0 PROCESS DESCRIPTIONS

3.1 CONTINUOUS WET QUENCHING[1]

The process schematic is shown in Figures 1 and 2. The coke oven door machine is of standard design. The coke guide car consists of two connected sections. The first section is the coke guide rack which is similar to standard designs except that it is totally enclosed and fits tightly against the buckstays and against the top of the jamb casting. No smoke should escape from the oven door opening or from the guide during a push.

The second section of the coke guide is the hood. It is a double segmented, quadrant type shroud with a rectangular cross section. The shroud is mounted on the front steelwork of the coke guide frame to totally enclose the push. The movable section pivots to contact the raised section of the hot coke transfer car. The hot coke transfer car is capable of handling (without moving) the coke pushed from one oven. The hopper is totally enclosed even during periods of travel.

A gas cleaning car, composed of two sections, is used to move the coke car. The locomotive and operators cab forms one section and a scrubbing system forms the other. Gases withdrawn from the hot coke car pass through a water quench duct, a high energy variable throat Venturi scrubber, a flooded elbow, cyclonic separator, exhaust fan (400 hp), and out the exhaust stack. Contaminated water is returned to the main recirculation system and periodically replenished. During start up and coke transport the fan louvers are restricted and the Venturi operated at about 18.7 mm of Hg (10 in. w.c.) pressure drop. While receiving or discharging coke, the louvers are open and the pressure drop across the Venturi is about 65.4 mm of Hg (35 in. w.c.).

In Figure 2 the hot coke is shown being unloaded into one of three track receiving hoppers. Each hopper is sized to accept one oven of coke and is equipped with top closure plates to prevent escape of fumes between discharges of coke from the car. This opening is closed as soon as the coke dump is

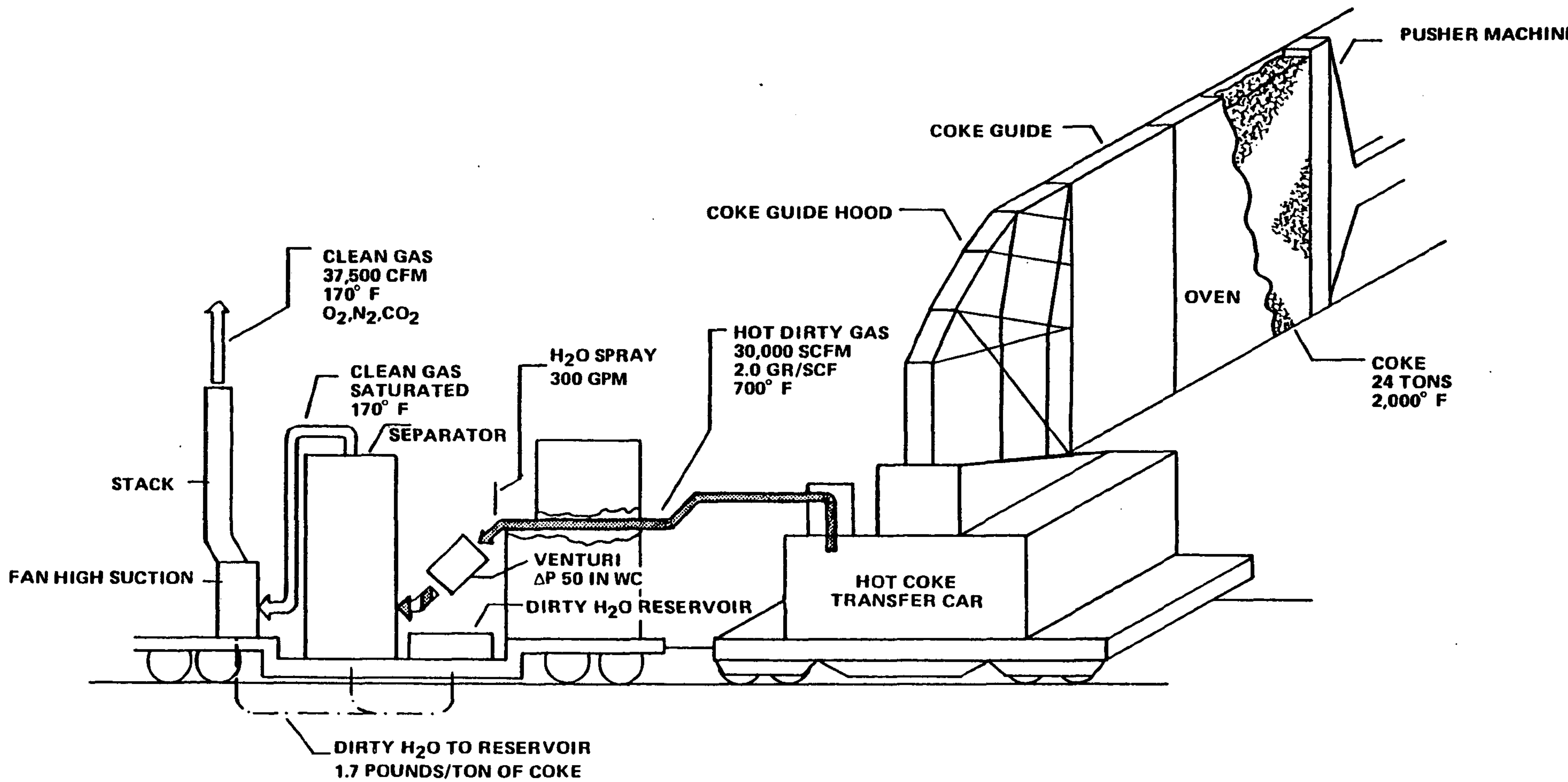

Figure 1. Coke guide and gas cleaning car.[1]

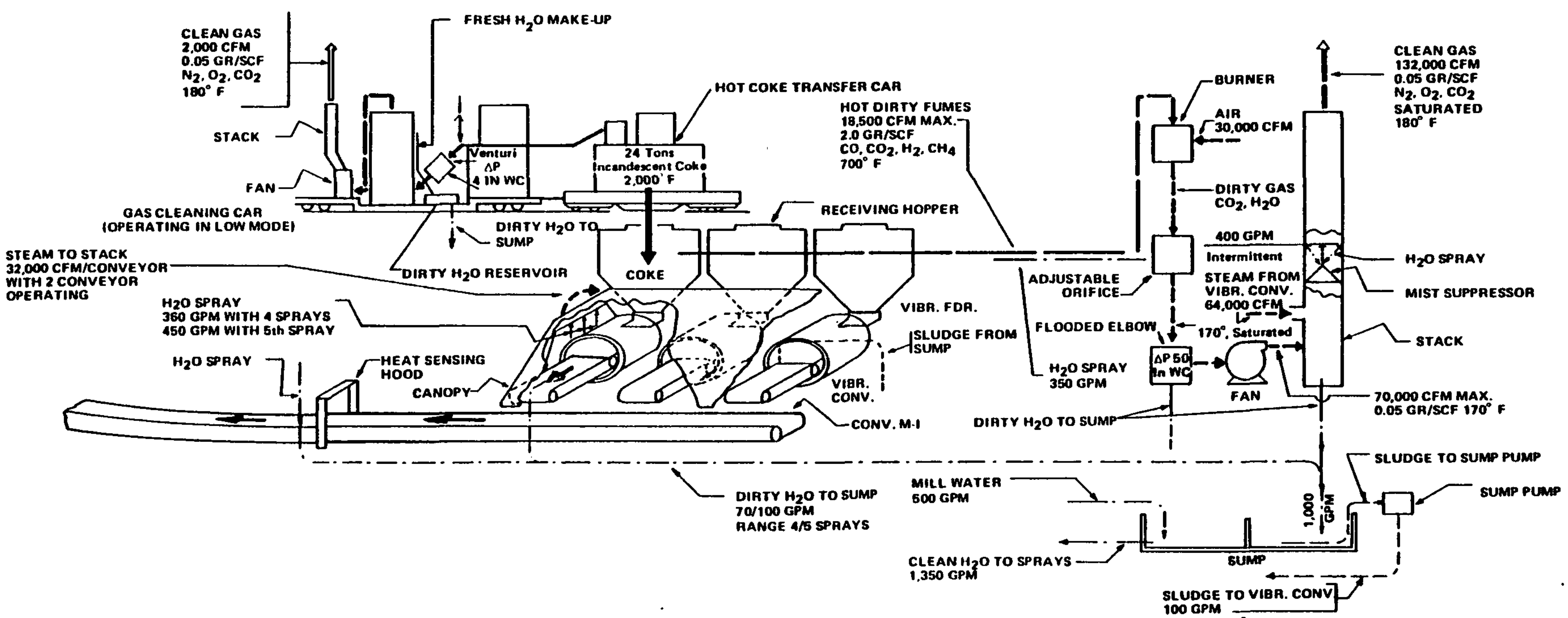

Figure 2. Continuous wet coke quenching schematic.[1]

completed and the fumes in the hopper are exhausted through a duct near the top of the hopper.

This system as originally designed is shown in Figure 2. The hopper fume cleaning system was extensively redesigned after several explosions, caused by combustible gas mixtures in the ducting, occurred. In the current configuration, the hopper fumes are evacuated through a steam ejector powered high energy scrubber during the brief (about 1 minute) coke dump period. For the remainder of the cycle (about 15 minutes) fumes are vented directly to atmosphere. All dirty water flows to a settling basin.

The hot coke from the track receiving hopper originally discharged onto a vibrating conveyor where it was cooled with water sprays. This system has been redesigned because continuing problems with the conveyor could not be solved. The hot coke now discharges into a rotating horizontally mounted drum.[2] Water is sprayed onto the coke through axially mounted spray nozzles in the center of the drum. Coke is moved through the drum by steel plates welded to the drum interior wall (screw conveyor). Excess water is separated from the coke by screens near the discharge end of the drum and flows to the settling basin. Make-up water, to replace steam losses, to the spray system is supplied from the general service source. As designed, all solids captured by the gas cleaning car and coke quenching were to be added to the cool coke conveyor. A second clarifier has since been added and the solids are removed for disposal or use in other plant processes. No water is discharged from the system.

Each drum has a steam exhaust duct at the drum inlet end. At the top of each exhaust duct is an axial type fan for positive steam removal. The steam goes to an exhaust main and is carried to the stack. A mist suppressor is provided in the stack to remove entrained water and particulate matter.

Coke is discharged from the quench drum onto a short, 5 meters ($\sim$15 feet), covered conveyor that has additional water sprays. Coke is transferred onto a second conveyor belt (uncovered) which is equipped with a temperature sensor and a bank of water sprays. The coke is transported via this belt to a junction point just below yard level where it discharges onto a conveyor belt that conveys the coke to the top of the load-out bin.

Coke from the emergency coke wharf also enters the system at the junction point. Coke is loaded into trucks from the bottom drop load-out bin.

The discussion above basically describes the system as it currently exists. There have been a number of changes that could affect emissions from the process relative to the original design. For example, the track receiving hoppers for hot coke are evacuated and cleaned only during periods of coke dumping rather than continuously as originally designed. Also there has been a change in handling procedures for the coke dust captured. Since inadequate data are available to estimate the effect these changes have on emission levels, only original design data are used in this report.

3.2 CONTINUOUS DRY QUENCHING

This description is condensed from Pennsylvania Engineering Company's Phase I Engineering report[3] for installation of a Waagner-Biro dry coke quenching facility (Figure 3) at National Steel's Weirton, West Virginia Brown's Island coke plant. It is possible, therefore, that some changes could occur if a decision to build were made.

The same basic coke pushing system as used in the continuous wet quench will be used. Two options were identified for transferring the hot coke to the dry quench bunkers. If the existing hot coke car is retained, there will be an intermediate transfer, by bottom drop, into a bucket on a shuttle car located beneath the hot coke car rail tracks. The alternative is to replace the hot coke car with a new car and two dismountable buckets that can be hoisted directly to the dry quench bunkers. In either case, the gas cleaning system on the hot coke car will be used to capture emissions during the push and transfer. The bucket is then positioned at the hoist station where the spreader beam and hooks are attached to the bucket. The bucket is raised to the top of the CDQ plant and positioned over the appropriate bunker. The bunker extract damper and cover are opened and the bucket lowered to supports on the bunker opening. Final lowering of the hooks opens the bottom doors and discharges the hot coke into the bunker. The process is repeated in reverse as the bucket is raised.

The coke is cooled by gas circulating through the bunker. Cool gas, 130°C (∿270°F), is blown into the bottom of the bunker. As the gas rises

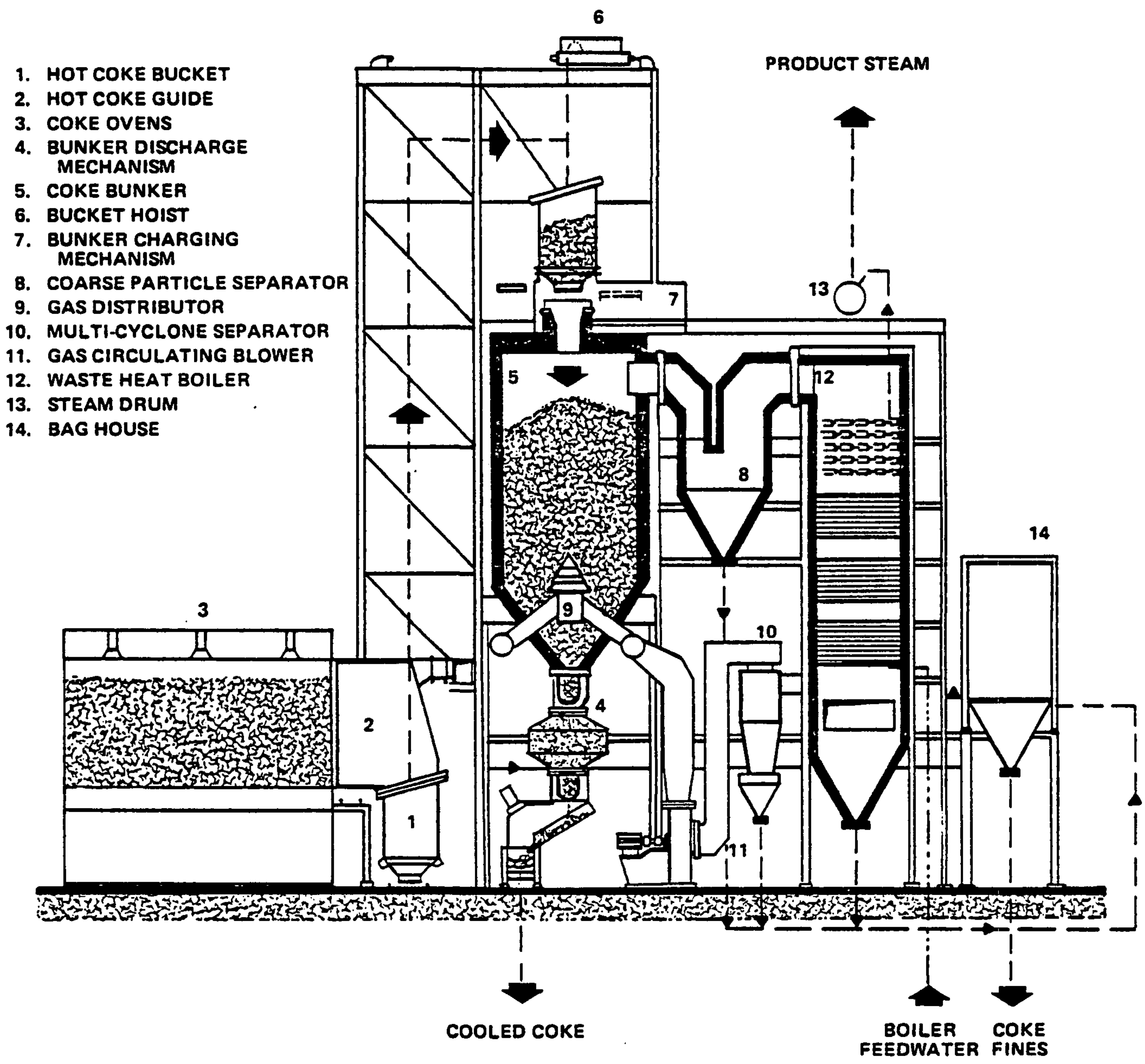

Figure 3. PEC/AWB dry coke quenching system schematic flow sheet.[3]

through the hot coke, it is heated to about 675 - 790°C (1250-1450°F). The hot gas passes through an impingement type coarse separator to remove heavy particles released during the charge, then through a gas mixer, where cool gas bypassing the bunker lowers the temperature to a uniform 675°C (1250°F). The gas then passes through a steam generating waste heat boiler where the temperature is reduced to about 130°C (265°F). After removal of additional fine coke dust by a multiclone separator, the gases are recycled to the bunker. Coke, cooled to 205°C (400°F) or less is removed from the bunker almost continuously through an automatic cutoff gate and double flap valve. Coke charging and discharging are accomplished without escape of circulating gas or inlet of air. The coke is discharged onto a belt conveyor which will convey coke to the belt junction station and to the load-out bin described in the wet quenching section.

Coke fines are removed from the plant at: the bunker charging mechanism, coarse and fine particle separators, and purge gas and coke discharge bag filters. All these points are closed and the fines discharged through slide and double flap valves. All fines collected are conveyed to a bin which discharges to a closed road tank car for removal. The purge gas is burned in a coke oven gas fired incinerator after passing through its bag filter. A gas purge is required by the gas volume increase resulting from the injection of air into the hot gas leaving the bunker. Air is injected to maintain a low level of combustibles.

River water is treated to provide boiler make-up. The water is clarified and filtered to remove suspended solids. The water is then treated in a reverse osmosis unit and softened in a base exchanger. A small stream of this purified water is fully deionized for use in the steam atemperators. Oxygen is removed from the boiler feed water by vacuum deareation and injection of sodium sulfite.

Clarifier underflow, filter backwash, reverse osmosis reject, sodium and calcium chlorides from base exchange regenerator, and spent regenerate (HCl, $NaOH$, and ions removed) from the deionizer are discharged to the wastewater treatment system (contaminated water from the hot coke car scrubbing system will also discharge to this system). Wastewater treatment consists of solids settling (clarifier) and pH adjustment.

3.3 COKE TRANSPORT FACILITIES[2]

In both the previous descriptions, transport of the cooled coke was carried through to the load-out bin. The load-out bin is an elevated structure under which large trucks can pass. Coke is loaded into the trucks via a bottom drop chute in the bin. Drop distance varies from 3 to 6 meters (10 to 20 feet). The coke is transported to the mainland where it is dumped into an underground bunker. The coke is transported via a loosely covered conveyor to the screening station. The coke passes over and through several vibrating steel screens to separate it into different size fractions. The screened coke is conveyed to several discharge points where it is loaded into railcars, a 7 to 9 meter drop (20 to 30 feet). The coke is transported via the railcars to the blast furnace stock house and loaded into bins from the bottom drop railcars. The coke is conveyed to a final screening point and dumped into weigh bins before being dropped into the blast furnace skip car. There are no emission suppression or collection devices in use at any point described in this section.

3.4 STEAM GENERATING BOILERS[4]

Steam produced by dry quenching will replace part of that produced by the boiler house. This should result in reduced emissions at the boiler house.

There are 5 high pressure and 7 low pressure boilers. Three are normally coal fired but can switch to coke oven (COG) or blast furnace (BFG) gas. Fuels used in the boilers are: natural gas, COG, BFG, fuel oil, coal and waste heat. The boilers use the excess gas produced in the plant before switching to alternate fuels (except for two which are always coal fired). Some of the steam is used to produce electricity.

Total steam capacity of the boiler house is 1,509,000 Kg/hr (3,327,000 lbs/hr) or 13,218,000 Mg/yr (14,570,000 tons/yr). The design heat input is 4.8×10^{12} joules/hr ($4,552 \times 10^{6}$ BTU/hr). The maximum permissible particulate emission from the boilers is 186 Kg/hr (410 lbs/hr) (based on West Virginia regulation of 0.09 lb (0.041 Kg)/MBTU input with which the plant is in compliance) or about 0.13 Kg/Mg (0.25 lb/ton) steam produced. The plant estimates that normally about 29 Mg/hr (32 tons/hr) of coal are burned and 118 Mg/day (130 tons/day) of fly ash is generated (wet basis, $\sim$50 percent solids).

4.0 EMISSIONS

This section provides an estimate of the emissions to the environment from the various processes. The comparisons are based on the original designs with the systems operating at design conditions even though the current configuration of the continuous wet quenching system differs from the original design. Design emissions data[1] are given for the wet continuous process as originally designed since actual test data are not available. Where appropriate, test data from conventional wet quenching processes are included. Design data[3,5] are also used for the dry quenching process. These data, however, should be fairly reliable as they are based on experience gained from other installations.

Since the two systems were designed with different coke throughput rates (154 Mg/hr for continuous wet quench and 125 Mg/hr for the dry quench system), where appropriate, the emissions from wet quenching are also calculated at 125 Mg/hr (by assuming all design values remain the same but less coke is processed) to provide a consistent basis for comparison.

4.1 WET CONTINUOUS QUENCHING

As originally designed, emissions from the process should occur at only two points: the gas cleaning car stack and the process stack (which receives gas from the continuous quenching and from the coke receiving hopper).

The gas cleaning car is designed to operate in two modes. A low gas flow, 56.6 NM^3/min (2000 CFM) is used during start up and coke transport. A gas flow of 1062 NM^3/min (37,500 CFM) is used during coke pushing and discharge. If the assumption is made that the system operates 50 percent of the time in each mode and that the particulate emission concentration equals the design rate in both cases (0.05 grain/SCF-0.11g/NM^3 design, this source contributes 3.69 Kg/hr (8.14 lbs/hr) or 0.024 Kg/Mg (0.048 lb/ton) of coke (154 Mg/hr, 170 tons/hr design coke rate) which is equivalent to 0.030 Kg/Mg (0.06 lb/ton) if 125 Mg/hr of coke is processed. Design data for the process stack shows a gas exhaust of 3,740 M^3/min (132,000 CFM) with a grain loading of 0.11 g/M^3 (0.05 grain/SCF). At the design rate of 154 Mg/hr (170 short tons/hr), the particulate emissions would be 24.68 Kg/hr (54.5 lbs/hr) or 0.16 Kg/MG of coke (0.32 lb/ton) which is equivalent to 0.20 Kg/Mg if 125 Mg/hr of coke is processed.

Solids removed from the recycle water clarifier (which contains solids from the gas cleaning car, from the excess quench water returned to the sump, and from the main system scrubber) are returned (design condition) to the coke conveyor system for separation at the screening station. (Present practice is to route the water to a second clarifier and remove some solids for use at the sinter plant.) An estimate of these solids can be made as follows. The process design is for 0.85 Kg of particulate/Mg of coke (1.7 lbs/ton) to be captured by the gas cleaning car. Conventional wet quenching is estimated[6] to produce 36 Kg of coke breeze per Mg of coke produced. This added to the 0.85 Kg/Mg from the gas cleaning car yields 36.85 Kg/Mg coke (73.7 lbs/ton) of particulate in the clarifier sludge (37.0 Kg/Mg at 125 Mg/hr coke rate).

Organic emissions from the continuous wet quench may be similar to that from a conventional quench tower. The tests at U.S. Steel-Lorain[7] can be used as an indication of possible emissions. The emissions found for clean quench water and non-green coke are: polycyclic aromatic hydrocarbons 0.419×10^{-3} Kg/Mg coke, total polar compounds 0.606×10^{-3} Kg/Mg coke, benzo(a)pyrene 0.024×10^{-3} Kg/Mg coke. These, however, pertain only to emissions from the main stack. No data are available to indicate the magnitude of organic emissions from the gas cleaning car system.

4.2 DRY COKE QUENCHING

The dry coke quenching plant design capacity is 125 Mg coke/hr (138 tons/hr). On this basis the design particulate emissions from the incinerated purge gas is 0.00047 Kg/Mg coke (0.0009 lb/ton). Emissions from the bag filter which collects dust from charging, discharging, fine solids conveying and the fine solids storage bin are estimated to be less than 0.0047 Kg/Mg coke (0.009 lb/ton). Estimated emissions from pressure relief valves, 17 M^3/hr at 22.8g/M^3 (600 CF/hr at 10 grains/CF), gives an additional 0.0031 Kg/Mg (0.006 lb/ton) for a total particulate emission of 0.0083 Kg/Mg coke (0.0166 lb/ton coke).

Design solid emissions from the process are silt from treatment of water for use in the boiler, and coke dust collected in the bunker seal water. Silt amounts to 0.065 Kg/Mg coke (0.13 lb/ton of coke) and coke dust to 0.023 Kg/Mg (0.046 lb/ton) of coke for a design solid emission of 0.088 Kg/Mg (0.18 lb/ton) of coke.

Liquid emissions from the plant are designed for 503 ℓ/Mg (121 gallons/ton) of coke. The design flow rates into the wastewater treatment clarifier are given in Table 2. The last four columns indicate the contribution these streams make to the total dissolved solids (TDS) and suspended solids in the wastewater plant discharge.

TABLE 2. LIQUID EMISSIONS FROM DRY QUENCHING

Effluent	Volume ℓ/Mg Coke	TDS mg/ℓ	TDS gms/Mg Coke	Suspended Solids(3) mg/ℓ	Suspended Solids(3) gms/Mg Coke
Filter Backwash	2.17	350	0.76	50	0.11
Clarifier Underflow	0.79	350	0.28	50	0.04
Bunker Seal Water	35.8	350	12.5	50	1.8
Boiler Blowdown	14.6	1500	21.9	50	0.7
Water Treatment Reject	179	1330	238	5	0.9
Cooling Water(1)	270	350	94	90	24
Water Softener Regenerant	0.5	8000	4.0	-	-
TOTAL(2)	530	740	371	55	27.6

Note: (1) Cooling water enters the system after wastewater treatment. TDS & TSS same as river water.

(2) Total represents mean after mixing and eoualizing all effluents, after solids removed from clarifier and bunker seal water.

(3) With the exception of water softener regenerant, all solids (dissolved and suspended) were present in original river water. Water softener regenerant TDS are sodium, magnesium and calcium carbonates, chlorides and sulfates.

Gaseous emissions occur from the process at two sources--the incinerated purge gas and bunker circulating gas from pressure relief valves. Design data for these emissions (particulates were discussed above) are given in Table 3.

Gaseous emission from the dust collecting bag filter is 204 M^3/Mg. This is air drawn in collecting the dust, not process gas.

TABLE 3. GASEOUS EMISSIONS FROM DRY QUENCHING

	Incinerated Purge Gas		Pressure Relief Valve Gases	
Component	Volume %	M^3/Mg Coke	Volume %	M^3/Mg Coke
CO	-		3.0	0.004
CO_2	16	3.3	15.6	0.02
O_2	0.6	0.12	-	
H_2	-		0.9	0.001
H_2O	10	2.0	6.3	0.009
N_2	73.4	15.0	74.2	0.10

The data above are design values for the dry coke quenching facility proper. In practice, the emissions from coke pushing must also be considered. As previously discussed, emissions from the gas cleaning car are (design):

cleaning car stack - 0.030 Kg/Mg (0.06 lb/ton)

scrubber solids - 0.85 Kg/Mg (1.7 lbs/ton)

Estimated scrubber blowdown is 146 ℓ/Mg (35 gallons/ton) of coke (5,800 mg solids/liter blowdown). Blowdown water quality is unknown. The scrubber blowdown water will be treated in dry quench wastewater treatment system.

4.3 EMISSION FROM COKE TRANSPORT

There are no quantitative measurements of the emissions that occur during transport of either wet or dry quenched coke. For rough estimation purposes, however, an equation developed for particulate emission from storage pile formation by means of conveyor stacker[8] can be used.

$$EF = 0.0009\ (S/5)(U/2.2)(H/3)/(M/2)^2\ \text{Kg/Mg}$$

where:

EF = dust emission

S = silt content of aggregate

M = moisture content

U = mean windspeed

H = drop height

If we assume S, U, and H are identical for both types of coke:

$$EF = 0.00011\ SUH/M^2$$

Using typical moisture contents of 6 percent for wet quenched coke and 0.5 percent for dry quenched

$$EF = 0.00011\ SUH/36 \text{ for wet quench}$$

$$EF = 0.00011\ SUH/0.25 \text{ for dry quench}$$

That is, dust emissions from dry quenching would be expected to be 144 times the dust emission from wet quenched coke. For a silt content of 2 percent, wind speed of 1 M/sec and drop distance of 8 meters, the calculated emissions from one drop are 0.000049 Kg/Mg and 0.0070 Kg/Mg for wet and dry quenched coke, respectively. It should be noted that the two cokes differ in ways that could substantially change this comparison. The dry coke is maintained at higher temperatures for several hours longer than wet quenched coke which promotes more complete coking; it is subjected to substantial abrasion in the cooling chamber which removes much of the more easily generated dust; test data indicate that dry quenched coke is substantially stronger (more abrasion resistant) than wet quenched coke.[9] These factors may reduce the estimated difference in emissions. It is known, however, that dust emissions from dry coke handling are significantly higher than for wet quenched. The Kawasaki Steel Company (Chiba Works) in Japan reports[10] that dust emissions triple at the screening station when dry quenched coke is processed. This plant has hoods and dust pickup points on the screening operation, transfer points and in the stock house. Nippon Kokan (NKK)

(Ohgishima Works) has two CDQ plants[10] (a total of 8 chambers each rated at 70 Mg/hr, one chamber maintained as a standby). Dust control at the screening station is by fabric filter (3500 NM^3/min). A 4,000 NM^3/min fabric filter is also used at the blast furnace coke bin. All Japanese plants operating CDQ's transport the cooled coke with covered conveyors and collect emissions at transfer points and the screening station.

Since, as previously described, there are no emission controls on the coke transport system at Weirton, dust emissions from these areas would be substantially greater than are observed with the use of wet quenched coke. It would seem obvious, therefore, that some method of dust control will be required on the coke transport system at Weirton.

5.0 EMISSION COMPARISON - WET VERSUS DRY QUENCHING

5.1 COKE PUSHING

Essentially the same coke pushing system would be used for either quenching method. Thus emissions from the gas cleaning car are unchanged. However, with wet quenching the scrubber blowdown (both solids and liquids) would have been added to the coke. The solids would have been separated at the coke screening station and used as breeze and the aqueous phase (absorbed into the coke), and any contaminants therein, would pass into the blast furnace or other combustion device. With dry coke quenching, the scrubber blowdown would be added to the CDQ wastewater treatment system and be discharged as sludge and aqueous effluent. The emissions are summarized in Table 4.

5.2 QUENCHING EMISSIONS

Direct emissions to the atmosphere should occur only from the main quench stack for the wet quenching process. Design data for production of 154 Mg/hr show gas emissions of 1457 M^3/Mg of coke with particulate emissions of 0.16 Kg/Mg of coke. If organic emissions from the continuous wet quenching are the same as conventional wet quenching, data obtained at U.S. Steel - Lorain would indicate organic emission from continuous wet quenching as: polycyclic aromatic hydrocarbons 0.419×10^{-3} Kg/Mg coke, total polar compounds 0.606×10^{-3} Kg/Mg coke, and benzo(a)pyrene 0.024×10^{-3} Kg/Mg coke.

Design data for the dry quenching process show total gas emissions of 224 M^3/Mg, 90 percent of which is air drawn through the baghouse used to collect fine coke emissions at the various cool coke transfer points. Total estimated particulate emissions are 0.0083 Kg/Mg. No data are available to estimate the potential organic emissions. However, since the purge gas is incinerated and air used for dust collection contacts only cool coke, it is likely that only the gas from pressure relief valve opening could contain organics. This gas is estimated to be only 0.14 M^3/Mg. Thus the overall organic emission to the air should be substantially less than for wet quenching.

TABLE 4. PUSHING EMISSION COMPARISON

Component	(125 Mg/hr Design) Dry Quench	(154 Mg/hr Design) Wet Quench	(125 Mg/hr Coke)[c] Wet Quench
Particulate from gas cleaning	0.030 Kg/Mg	0.024 Kg/Mg	0.030 Kg/Mg
Gas emissions[a]	269 M^3/Mg	218 M^3/Mg	269 M^3/Mg
Scrubber blowdown			
Solids	0.85 Kg/Mg	All	All
Liquid[b]	146 ℓ/Mg	Recycled	Recycled

[a]Gas composition unknown, organic content unknown.

[b]Discharge water quality unknown.

[c]Calculated assuming only 125 Mg/hr coke processed and all emission rates equal to design values at 154 Mg/hr coke rate.

There are no process solid wastes from the continuous wet quenching system. All solids captured by the system (as designed) are added to the quenched coke, separated at the screening station and used in other processes (as breeze). Present practice is to send the slurry to a second clarifier. Solids are removed from the clarifier and used in the sinter plant. Silt removed from river water must, however, be considered a solid waste since the water is consumed (not returned to the river with the silt). Estimated water consumption of the quench process is 600 ℓ/Mg (144 gallons/ton). Silt removed from this volume of water is estimated to be 0.024 Kg/Mg coke.

Solid emissions from the dry quenching process are coke dust collected in the bunker seal water and silt from water treatment. Coke dust from the bunker seal is estimated at 0.023 Kg/Mg. Silt is not removed from the cooling water. Silt removed by feed water treatment (boiler feed water) is estimated at 0.065 Kg/Mg coke. These solids will be disposed of by on-site landfill as a sludge (20 percent solids).

Coke fines collected in the dry quench process can be used as pulverized fuel, possibly returned to the coke breeze system on the coal blending station feeding the ovens, or used at the sinter plant.

There are no liquid emissions from the continuous wet quenching system. The blowdown slurry from the clarifier is added to the coke on the conveyor belt or sent to the sinter plant. Water retained by the coke either passes into the blast furnace or other combustion equipment. Effluent from the dry coke quenching wastewater treatment plant is estimated to be 503 ℓ/Mg coke containing 0.37 Kg/Mg coke of dissolved solids and 0.028 Kg/Mg coke of suspended solids. All of this water except the bunker seal water and once through cooling water is associated with steam production which is discussed below. Since the cooling water is not treated prior to or after use, it does not constitute a process effluent (assuming credit is allowed for solids contained in the raw water). Thus only the bunker seal water is a real process effluent. Design data for this stream (36 ℓ/Mg) indicate it should have the same TDS as raw river water (350 mg/ℓ) and only 50 mg/ℓ suspended solids (river water 90 mg/ℓ) after clarification. The assumption apparently was made that the bunker seal water picks up no contaminants by contact with the coke dust.

5.3 EFFECT ON EMISSIONS FROM STEAM GENERATING

The design rate of steam production from the dry quenching process is 1222 Mg/day (1344 tons/day). Wastewater produced from the steam generation system is 197 ℓ/Mg coke or 484 ℓ/Mg steam. This wastewater would contain (obtained from design estimate of the individual stream compositions) 0.26 Kg/Mg coke of TDS (0.64 Kg/Mg steam) and 0.0018 Kg/Mg coke of suspended solids (0.0044 Kg/Mg steam). Silt removed in treatment of water for boiler feed is estimated as 0.065 Kg/Mg coke (0.16 Kg/Mg steam).

Design steam production from the plant steam generating boilers is 36,218 Mg/day (39,924 tons/day). Particulate emissions (maximum permissible by state regulation) are 0.12 Kg/Mg steam (0.25 lb/ton). Data were not available on the water quality.

To estimate the emission change potentially resulting from replacement of steam generated by the boilers with steam from dry quenching, several assumptions will be necessary.

The first assumption is that the same quantity of water for boiler feed is treated and discharged (per Mg steam produced) in both systems. The assumption is equivalent to saying there is no impact on silt removed, TDS and suspended solids discharged, or water intake or discharged per Mg/steam produced for those activities directly related to steam production.

Other assumptions made are that steam reduction at the boilers will be accomplished by reduction in coal burning and that all particulate and fly ash from steam generation come from coal burning.

Coal burned in the boilers releases about 26.7×10^9 joules/Mg (11,500 BTU/lb). Design data supplied by National Steel indicate that 3.18×10^6 joules are required to produce one kilogram of steam (1368 BTU/lb). Therefore, the amount of coal that must be burned to produce the equivalent amount of steam generated by dry quenching (1222 Mg/day) is:

$$\frac{(1222 \text{ Mg steam/day})(1000 \text{ Kg/Mg})(3.18 \times 10^6 \text{ joules/Kg steam})}{26.7 \times 10^9 \text{ joules/Mg coal}}$$

= 145.4 Mg coal/day

= 160.3 tons coal/day

= 6.06 Mg coal/hr (6.68 tons coal/hr).

National Steel estimates they burn about 29 Mg (32 tons) of coal/hr. Dry coke quenching can reduce this consumption by 20.9 percent ((6.06/29) x 100). From our assumption that all boiler produced particulate emissions and fly ash are produced by coal burning, a reduction (maximum) of 38.9 Kg/hr (85.69 lbs/hr) of particulate (from 186 Kg/hr (410 lbs/hr) maximum), and a reduction of 12.32 Mg/day (13.59 tons/day) of fly ash (dry basis) from the current estimate of 59 Mg/day (65 tons/day) - dry basis - would be obtained by dry coke quenching steam generation.

These potential emission reductions translate into a net credit for emission from dry coke quenching of 0.3 Kg/Mg coke for particulate emissions and 4.1 Kg/Mg for solid emissions. Energy consumption at the boiler house is also reduced by 3.68×10^9 BTU's/day.

5.4 SUMMARY OF EMISSION COMPARISON

Table 5 gives the emissions estimates from the two quenching processes.

TABLE 5. OVERALL EMISSION SUMMARY[a]

Process Area	Continuous Wet Quench 154 Mg/hr Design	125 Mg/hr Rate	Dry Quench 125 Mg/hr Design
<u>Coke Pushing, Gas Cleaning Car</u>			
Particulates, air	0.024 Kg	0.030 Kg	0.030 Kg
Gas emissions	218 M^3	269 M^3	269 M^3
Scrubber blowdown			
Solids	All recycled	All recycled	0.85 Kg
Liquids	All recycled	All recycled	146 liters
<u>Quenching</u>			
Particulates, air	0.16 Kg	0.20 Kg	0.0083 Kg
Gas, process contact	1457 M^3	1821 M^3	22 M^3
Gas, noncontact			203 M^3
Organics			Unknown but
PAH	0.419×10^{-3} Kg	0.419×10^{-3} Kg	estimated much
Polar compounds	0.606×10^{-3} Kg	0.606×10^{-3} Kg	lower than wet
BAP	0.024×10^{-3} Kg	0.024×10^{-3} Kg	quench.
Solids	0.024 Kg	0.024 Kg	0.023 Kg
Liquids	None	None	
Cooling water			269 liters
Bunker seal water			36 liters

(Continued)

TABLE 5. (Continued)

Process Area	Continuous Wet Quench 154 Mg/hr Design	Continuous Wet Quench 125 Mg/hr Rate	Dry Quench 125 Mg/hr Design
Steam Generation[b]			
Particulate, air	0.3 Kg	0.3 Kg	0
Solids	4.26 Kg	4.26 Kg	0.16 Kg
Liquids	197 liters	197 liters	197 liters
Gaseous pollutants	Not determined	Not determined	Not determined
Cool Coke Transport			
Particulate	No data. Visual observations indicate little emission at all points.		No data. Visual observations and other information indicate a significant problem unless dust suppression or collection used all points.

[a]All data are per Mg coke produced.

[b]Calculated basic production of 1222 Mg/day of steam.

6.0 DATA NEEDS FOR COMPLETE LEVEL 1 ASSESSMENT

The preceding sections of this report have presented the data available on the environmental effects of continuous wet and dry coke quenching. In most cases this information is based on design criteria rather than actual test data. This section defines the data needed to allow a complete comparative environmental assessment of the processes to be made.

6.1 COKE PUSHING

Coke pushing emission control in the two processes is virtually identical. Design data have been used to estimate the particulate and gaseous emissions from the gas cleaning car. The data do not provide the following information usually obtained in an environmental assessment (EA).

1. Size classification of the particulate emission.
2. Elemental analysis of the emitted particulate.
3. Analysis of the gas for such components as: H_2S, SO_X, HCN, NO_X, CO, and metals in gaseous form such as Hg, Sb, As.
4. An estimate of organic material in the emission such as phenols, benzene, benzo(a)pyrene and other condensed ring aromatics.

An estimate was made for the total volume and suspended solids in the scrubber blowdown. A good EA would confirm these by actual measurement. Also, since the blowdown will be sent to wastewater treatment in the dry quench process but is recycled in the wet quench process, the blowdown should be tested for organics and metals (by Level 1 procedures) and for pollutants listed on the waste discharge permit, i.e. cyanide, etc.

6.2 CONTINUOUS WET QUENCHING

Emission estimates for particulate and hazardous organics were made for the wet quench process stack emissions. The estimate for organics was based on data from conventional wet quench operations. To produce adequate data for an EA, the stack emissions should be tested for the four items listed for the coke pushing-gas cleaning car.

6.3 DRY COKE QUENCHING

Particulate emissions and some gas composition estimates were made for the dry quench process. These data are probably of fairly good quality. A level 1 EA would, however, normally provide data on the size classification of these particles. These data could be obtained with a cascade impactor. Emissions from the pressure relief valves, purge gas incinerator, and charging emissions should be tested for all four items listed under coke pushing-gas cleaning car. The wastewater treatment plant final effluent (before addition of cooling water) should be tested for dissolved and suspended solids, metals (by Spark Source Mass Spectrometry and Atomic Absorption Spectrometry) and organics, by Level 1 procedures, in addition to criteria pollutants.

6.4 STEAM GENERATING BOILERS

Potential emission reductions achievable at the steam generating plant due to steam production from the dry quench process are variable, depending on which fuel usage is reduced. In this report, it was assumed that the use of coal would decrease. If the plant selects this option, the data provided yield rough emission estimates. The quality of this data could be substantially improved by inspection of the boiler house operating records (tons/hr coal burned, BTU/lb of coal, lbs steam/ton coal burned, tons dry fly ash generated/day, lbs particulate emitted from coal fired boilers/ton coal burned, amount of SO_X and NO_X emitted per ton of coal burned). If the plant should, however, choose to reduce its use of natural gas, oil, or some other relatively clean fuel, the estimated emissions reduction could be substantially reduced or eliminated. Thus, a decision by National Steel personnel is required before the actual emission reduction from the steam generation can be determined.

6.5 COKE TRANSPORT

Emissions from the coke transport system are an area of serious concern and one where little data is available. Visual inspection of the Weirton system indicated only minor fugitive emissions from this source when wet quenched coke is processed. However, all sources contacted indicate that emissions from handling dry coke are substantially greater. To compare the emissions from dry and wet quenched coke transport at Weirton would require extensive sampling for fugitive dust at all the conveyor belts and transfer stations as well as screening operations processing the wet quenched coke. Comparable data from an operating dry quench plant are also needed. Since all transport of dry quenched coke is in covered conveyors and screening emissions are controlled, a measurement of dust captured should provide adequate information. Such an extensive effort would be of limited value since dust control is a virtual necessity in handling dry quenched coke.

The available control options would be wetting the coke so that it is similar to wet quenched coke, adding a chemical dust suppressant, or installing emission control equipment. Adding water would be the cheapest approach for emission control but would eliminate the possibility of obtaining one of the reported benefits of using dry coke in the blast furnace. The effectiveness of chemical dust suppressants is questionable since fresh dust, uncoated by the suppressant, can be generated continuously. Installing control equipment (covered conveyors, and collectors with fabric filters at the screening station) is probably the most capital intensive, but is the surest way of controlling emissions and obtaining the reported benefits of using dry coke in the blast furnace. Of course, an environmental assessment cannot be completed until National Steel choose the control option.

7.0 REFERENCES

1. "Enclosed Coke Pushing and Quenching System Design Manual." Pengidore, D. A., EPA-650/2-73-028, September 1973.

2. RTI site visit, September 6, 1979.

3. "Dry Coke Quenching - Phase 1 Engineering for National Steel Corporation, for Brown's Island Coke Plant, Weirton, W. VA. - Final Project Report, Volume 1." Pennsylvania Engineering Corporation, DOE Contract No. EC-77-C-02-4553, August 1978.

4. Information supplied to RTI by National Steel Corporation, Weirton Steel Division, October 1979.

5. Reference 3, Volume 2.

6. "Environmental and Resource Conservation Considerations of Steel Industry Solid Waste," Baldwin, V. H., M. R. Branscome, C. C. Allen, D. B. Marsland, B. H. Carpenter, and R. Jablin, EPA-600/2-79-074, SW-740, April 1979.

7. "Coke Quench Tower Emission Testing Program." Laube, A. H. and B. A. Drummond. EPA-600/2-79-082, April 1979.

8. "Iron and Steel Plant Open Source Fugitive Emission Evaluation." Cowherd, Chatten, Jr., Russel Bohn, and Thomas Cuscino, Jr. EPA-600/2-79-103, May 1979.

9. Nippon Kokan (NKK) brochure. Cat. No. 165-090.

10. "Trip Report - Visit to Iron and Steel Companies in Japan." Paul Gorman (MRI), October 26, 1979.

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16. ABSTRACT The report gives results of an assessment of the multimedia environmental impacts of continuous wet and dry quenching at National Steel's Weirton, West Virginia, Brown's Island coke plant. The report, based primarily on design data, test data from related processes, and engineering judgement, suffers from the lack of definitive test data. The assessment indicates that dry coke quenching results in less particulate matter emitted, less solid waste generated, less process-related gas emitted, and potentially less emission of polynuclear aromatic hydrocarbons and organics in general, than wet quenching. Dry coke quenching also results in increased aqueous effluents and fugitive emissions from coke transport and screening. The assessment concludes that, with proper wastewater treatment and control of coke transport emissions, the dry quench process should have less negative environmental impact than continuous wet quenching. The report identifies areas where data are insufficient for Level 1 assessment and indicates the testing required for a complete Level 1 assessment.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Aerosols	Pollution Control	13B	07D
Assessments	Waste Water	Stationary Sources	14B	
Coking	Water Treatment	Environmental Assessment	13H	
Quenching (Cooling)				
Iron and Steel Industry		Coke Quenching	11F	
Dust		Particulate	11G	

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